UNIVERSITY OF TURKU

ABSTRACT

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Author	Hassan Merghani	Student number	511239
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Supervisor	Dr.Sc. Hannu Salmela		

Abstract

The emergence of blockchain technology in the past few years has prompted a considerable amount of speculation about its impact on areas such as economies, governance, and business operations. One such area of interest is supply chain management software (SCMS) used by enterprises. There are a couple of studies that have examined the phenomenon of blockchain integration in SCMS from a theoretical as well as practical point of view. However, the current state of literature demands for more in-depth research that identifies the challenges facing blockchain integration in SCMS in order for technology suppliers to be able to develop and deliver solutions that meet the needs of their enterprise customers.

This research was designed to collect the required empirical data through semi-structured interviews with senior decision makers in organisations that represent two categories in terms of blockchain involvement: technology users and technology suppliers. The collected data included the interviewees' opinions on the challenges that prevent or slow down the adoption of blockchain technology in SCMS within their organisations. A customised theoretical framework was used to analyse the empirical data and a scoring system was developed to rank all recorded challenges based on perceived severity. The results revealed that the perceived return on investment (ROI) topped the list as the most critical challenge preventing adoption, followed by stakeholder readiness and management support. A list of other challenges is also presented and discussed in the results.

The outcome of this research puts forward several recommendations for technology suppliers to consider regarding the issues they need to address to increase the adoption rate of their blockchain-based SCMS among enterprise customers. Additionally, this research contributes to the scientific literature with new findings on some nuances of blockchain adoption in SCMS that were not fully examined by extant literature. Moreover, this research further validates the applicability of the used theoretical framework by adding an evidence-based empirical study to the pool of real-world cases that were tested with the same framework.

Keywords	blockchain, supply chain management, enterprise software, IT adoption
Further information	

UNIVERSITY OF TURKU
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INTEGRATING BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT SOFTWARE

Key adoption challenges for enterprises

Master's Thesis
in Information Systems Science

Author:
Hassan Merghani

Supervisor:
Dr.Sc. Hannu Salmela

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List of acronyms and abbreviations

API:	Application Programming Interface
B2B:	Business-to-Business
CTO:	Chief Technical Officer
DAO:	Decentralised Autonomous Organisation
DoI:	Diffusion of Innovations
DSC:	Digital Supply Chain
ERP:	Enterprise Resource Planning
ICO:	Initial Coin Offering
IoT:	Internet of Things
IT:	Information Technology
MNC:	Multinational Corporation
RFID:	Radio-frequency Identification
ROI:	Return on Investment
SaaS:	Software as a Service
SCM:	Supply Chain Management
SCMS:	Supply Chain Management Software
TAM:	Technology Acceptance Model
TOE:	Technology-Organisation-Environment
TPB:	Theory of Planned Behaviour
TRA:	Theory of Reasoned Action
UTAUT:	Unified Theory of Acceptance and Use of Technology

1 INTRODUCTION

1.1 Research area

About a decade ago, in October 2008, an internet user (or users) going by the pseudonym Satoshi Nakamoto published a nine-page white paper describing a new concept for an electronic cash system that is powered by a distributed ledger technology. The author(s) called the cryptography-based currency of this system *bitcoin* and labelled its underlying ledger technology as *blockchain.* (Nakamoto, 2008). Soon after, and due to growing coverage and reports by an abundant of media outlets including Forbes Magazine and Business Insider, public awareness about blockchain increased exponentially and its advocates started promoting it widely as a revolutionary technology and likening it to the internet in its early years, arguing that blockchain promises radical transformations to how business is currently being conducted (Marr, 2016; Peterson, 2019).

To date, bitcoin remains the most recognised application that uses blockchain as its infrastructure. However, blockchain technology is separate from bitcoin and can be adapted to various use cases. One of the key features of blockchain is its ability to eliminate the reliance on intermediaries and third parties to conduct business transactions, which in theory could be applied in any area where more than two parties are involved—notably, supply chains. Most of the current supply chain management software (SCMS) depend on traditional intermediaries to carry out certain processes (e.g. financial institutions for finance trade services), which brings additional costs and slows down the pace of operations (Korpela, Hallikas, & Dahlberg, 2017, p. 4182).

By design, supply chains involve multiple parties to help deliver goods from their origins to the beneficiaries. That is why the field of supply chain management (SCM) has rapidly emerged as one of the most promising areas where blockchain could deliver value. Multiple publications and media reports started endorsing the blockchain promise, and some large companies (e.g. IBM and SAP) as well as numerous startup companies are currently trying to capitalise on the opportunities that blockchain brings by offering blockchain-based solutions to assist with SCM and other business-to-business (B2B) processes. For example, the world's largest retailer, Walmart Inc., recently announced that it was planning to require providers of fresh green vegetables to start using a blockchain solution developed jointly with IBM to improve the traceability of their green produce (Kharif, 2018). Additionally, major cloud computing platforms such as Microsoft Azure and Amazon's AWS are now offering *Blockchain as a Service* as part of their products due to increasing interest among their target users who are software developers and solution architects (Gray, 2015; Lardinois, 2018).

As a result of this growing curiosity in blockchain's impact on SCM, many business hypotheses and potential use cases present themselves to be examined, hence the decision to choose the interdisciplinary field of SCMS as the focus of this research. The aim is to contribute to the current literature on blockchain applications as well as on SCM.

1.2 Research gap and question

This research explores the intersection of two topics related to information systems science: SCMS and blockchain technology. There is a good amount of literature available on SCM since researchers have been studying this discipline for many years. In contrast, the field of blockchain is relatively new when compared to SCM. Nevertheless, one can still find a decent amount of scientific work on blockchain, where authors point out the limitations of their findings and call for further research.

A visible shortcoming in extant literature is that it fails to concretely identify the issues preventing the adoption of blockchain solutions by enterprises that make use of SCMS. When reading through current scientific work, one can see that many publications list and discuss the probable benefits of blending blockchain and SCMS (Abeyratne & Monfared, 2016; Kim & Laskowski, 2018; Thiruchelvam, Mughisha, Shahpasand, & Bamiah, 2018). Yet, adoption by companies in the real world is still not momentous and is far from mainstream. A recent study by professional services company Deloitte Consulting surveyed senior executives in large enterprises and found out that while 74% of the respondents believed blockchain would have a "compelling business case", only 34% indicated that their companies have started using the technology (Pawczuk, Massey, & Schatsky, 2018, p. 6). These findings could leave IT suppliers wondering about the main problems in current SCMS that they should focus on solving via blockchain-based solutions.

Some researchers have already listed a few practical issues facing the use of blockchain in SCMS, but these studies have focused more on the technical limitations of blockchain (Jabbari & Kaminsky, 2018; Reyna, Martín, Chen, Soler, & Díaz, 2018) and less on the compatibility (or lack of) between existing blockchain solutions and the business needs of users. As such, this research does not focus exclusively on the technical anatomy of blockchain, but instead it equally explores technical and non-technical issues that prevent large-scale enterprises from adopting blockchain-based SCMS.

Therefore, considering the absence of clear problem definition in present literature about blockchain adoption challenges in SCMS, the research question of this study is:

What are the current key challenges preventing enterprises from adopting blockchain-based software for supply chain management?

1.3 Scope of the study

This research focuses only on investigating the adoption challenges of blockchain in SCMS. As such, finding out the best solutions to solve those challenges is outside the scope of this research. Nonetheless, some brief discussion about tackling those challenges is still presented at the end of the research. By outlining the adoption challenges in concrete form through the compilation of a list of practical issues that are preventing enterprises from adopting blockchain in SCMS, the outcome of this research serves as groundwork for addressing adoption challenges, because the accurate identification of problems is a step closer to solving them.

Data collected for this research was not exclusively gathered from companies in a certain industry that are using or considering using blockchain. Instead, it was collected from companies in different industries and sectors with the common denominator being their involvement with or interest in blockchain integration in SCMS. An initial plan was to focus only on companies that specifically operate in food supply chains, but due to the scarcity of candidates whom were available for access, the decision was made to expand the candidate pool to cover companies in other industries as well. Moreover, the geographical scope of this research covers companies based only in Finland and Switzerland. However, those companies and their involvement with blockchain and supply chain operations span multiple countries where their supply chain parties are based.

The outcome of this research presents a well-defined list of the key challenges that are either preventing or slowing down widespread integration of blockchain in SCMS. That means, the findings presented and discussed at the end of this research were the result of an in-depth investigation (through interviews and secondary data collection methods) of the practical implementation difficulties facing the researched companies. Thus, those challenges were presented from the perspectives of the two interviewed groups, namely: IT users and IT suppliers. The views of the companies building blockchain-based SCMS were weighed against the views of companies running traditional SCMS and have started using or were interested in using a blockchain-based system. Studying and comparing the perceptions of adoption challenges from both sides created a common ground to align the expectations of both groups and help IT suppliers deliver more customer-driven solutions.

Furthermore, the results contribute to the ongoing research on blockchain and its potential use cases, which would advance the development and usefulness of the technology itself in everyday life.

2 LITERATURE REVIEW

To establish a solid framework of reference for this research, a thorough review of extant literature was conducted. The research topic of this thesis is multidisciplinary because it combines two different fields of study and tries to investigate their co-existence. Both blockchain and SCMS are very distinct research areas. Therefore, literature from each field was reviewed separately first to form a comprehensive understanding before studying the meeting points of both fields. Hence, the division of this chapter into three main subchapters (blockchain technology, SCMS, and blockchain integration in SCMS) helps the reader follow the mind journey of how the background research was conceived and executed.

The literature review spanned various sources of scientific content such as peer-reviewed journals, conference papers, books, etc. A breakdown of all types of sources used in this research including amounts of individual works of each source type can be seen in Figure 1. The literature review process focused on studying peer-reviewed articles in acclaimed scientific journals as the primary and most credible form of knowledge acquisition. Nevertheless, other non-scientific sources (or "grey literature") such as white papers, articles in periodicals, and websites were also consulted—mostly to gather facts, definitions, company statistics, and other present information. A detailed explanation of the used sources is discussed in the research methods chapter of this report. The main keywords used to look up literature included, inter alia: *blockchain, supply chain management, enterprise software, IT adoption,* etc. Additionally, a "snowball effect" was followed, i.e. finding linked works from bibliography/reference lists of reviewed literature.

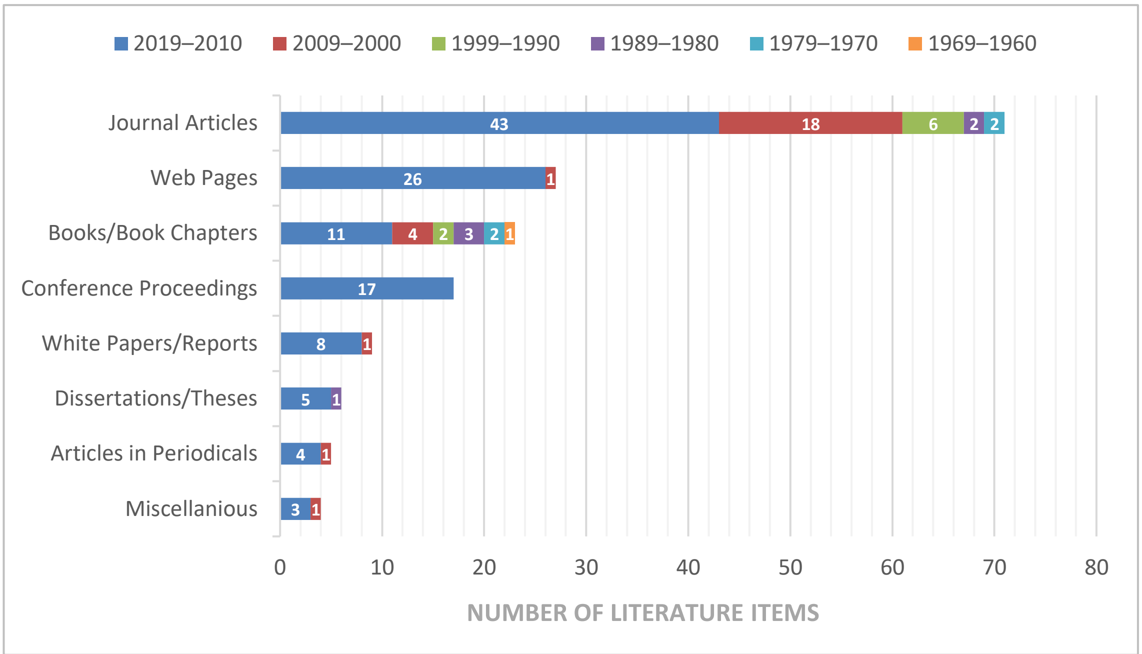

Figure 1 Reviewed literature items by source type and publication year

2.1 Blockchain technology

2.1.1 *Background and evolution*

Akin to most novel technologies, blockchain took some time to attract a larger crowd of users outside its original small circle of enthusiasts and cryptographers. During 2008 and 2009, the term *blockchain* started to spread online in multiple forums and specialist magazines after anonymous author(s) Satoshi Nakamoto published their white paper *Bitcoin: A Peer-To-Peer Electronic Cash System*. The first and original application of blockchain, bitcoin cryptocurrency, was released in early 2009 as an open source project by its creator and that is when more people started to get interested in and involved with blockchain. (Crosby, Nachiappan, Pattanayak, Verma, & Kalyanaraman, 2016, p. 9).

To shed some light on the innerworkings of blockchain, Figure 2 below shows an illustration of how a typical blockchain functions.

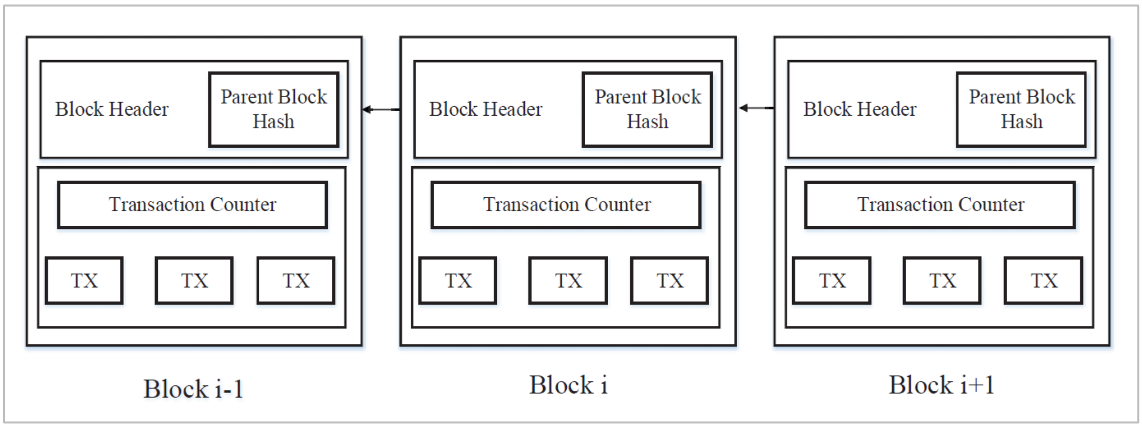

Figure 2 Illustration of a blockchain architecture (Zheng, Xie, Dai, Chen, & Wang, 2017)

As can be seen from the illustration, blockchain is a distributed ledger at its core that records digital transactions and is collaboratively maintained and verified by multiple people (i.e. *nodes*) in the network. Tapscott and Tapscott (2016) define blockchain as a digital ledger technology that can be designed to keep records of economic transactions of virtually anything that has value—not solely of a monetary nature. Every transaction conducted and logged on the ledger is referred to as a *block,* after it has been verified by all the nodes participating in the network. After being verified, the block is added to the list of transactions (i.e. *chain*) effectively making the ledger (i.e. *blockchain*) immutable to alterations without corrupting the whole chain.

The popularity of blockchain increased as the technology evolved over time, aided by the growing interest in bitcoin. For example, the monetary value of bitcoin increased (and dropped) significantly throughout short periods of time (crossing a value of US$17 000 in December 2017 up from around just US$750 at the beginning of the same year), which led more observers to investigate blockchain in depth. (Kelly, 2017). This resulted in bitcoin sometimes being confused or mistakenly used interchangeably with blockchain, despite the latter being merely the underlying technology/infrastructure for bitcoin.

To visualise this interest in blockchain, Figure 3 below shows a graph of online search trends of the term *blockchain* as recorded by Google Trends (a tool that tracks online search trends for different topics over time and across geographic boundaries). The graph in Figure 3 is not representing a specific country or region—it displays the world-wide search trend.

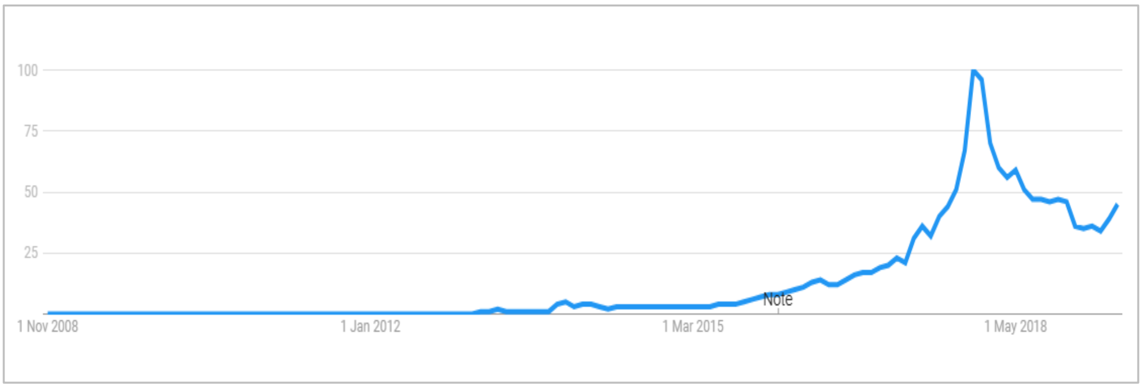

Figure 3 Online search trend of the term *blockchain*, 2008–2018 (Google Trends, 2019)

It becomes clear after examining the search trend as seen above that blockchain has soared in popularity particularly in 2017 and beyond after the sudden hike in bitcoin's value. By that time, blockchain had already reached a level of relative matureness that allowed it to be piloted in several business cases in different industries as examined later in this chapter.

Likewise, the amount of research and academic papers published in the scientific community about blockchain has increased significantly compared to the early years of blockchain inception. Using online search tools from one of the largest scientific citation indexing services—Web of Science—one can clearly notice the surge in publications across the scientific domain that include at least one mention of blockchain in its content. Figure 4 displays a graph illustrating the accumulated number of these publications between 2008 and 2018, which has grown from only two in 2013 to a total of 2 359 in 2018 (inclusive of previous years)—a growth uptick translating to an increase of about 117 850% in five years.

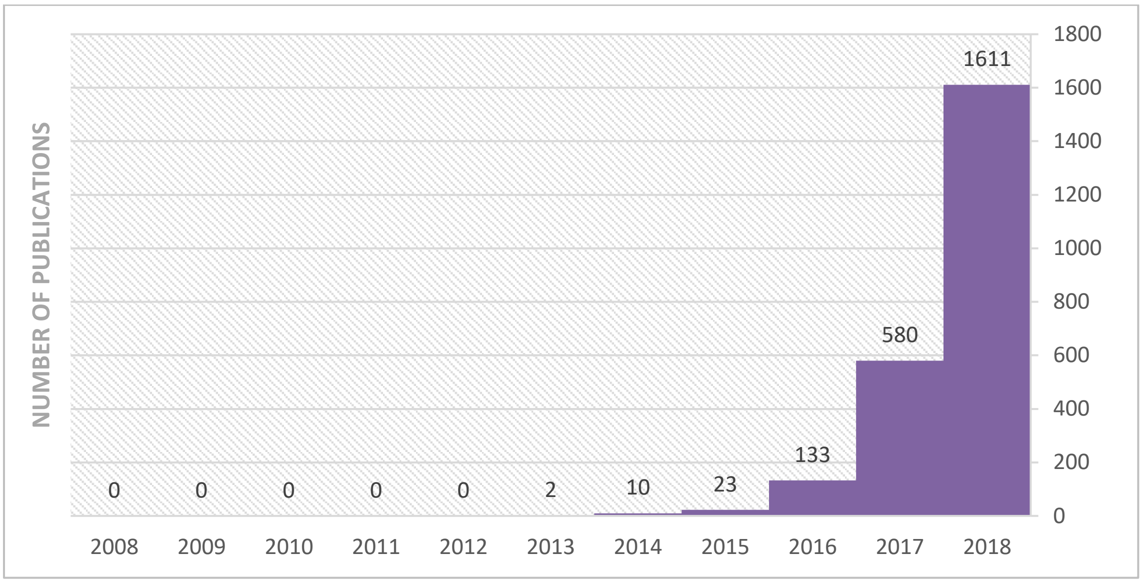

Figure 4 Scientific publications that mention blockchain, 2008–2018 (Data source: Web of Science database, 2019)

This growing interest in blockchain did not manifest only in search queries and published papers: There was also a noticeable increase in the number of newly founded startups that specialise in blockchain development, infrastructure, and services. Crunchbase—a company that offers data and market insights on businesses—lists a total number of 4 619 companies tagged with *blockchain* in its database. Figure 5 below is an illustration using public data from Crunchbase to visualise the number of registered companies in Crunchbase's database that were founded between 2010 and 2018.

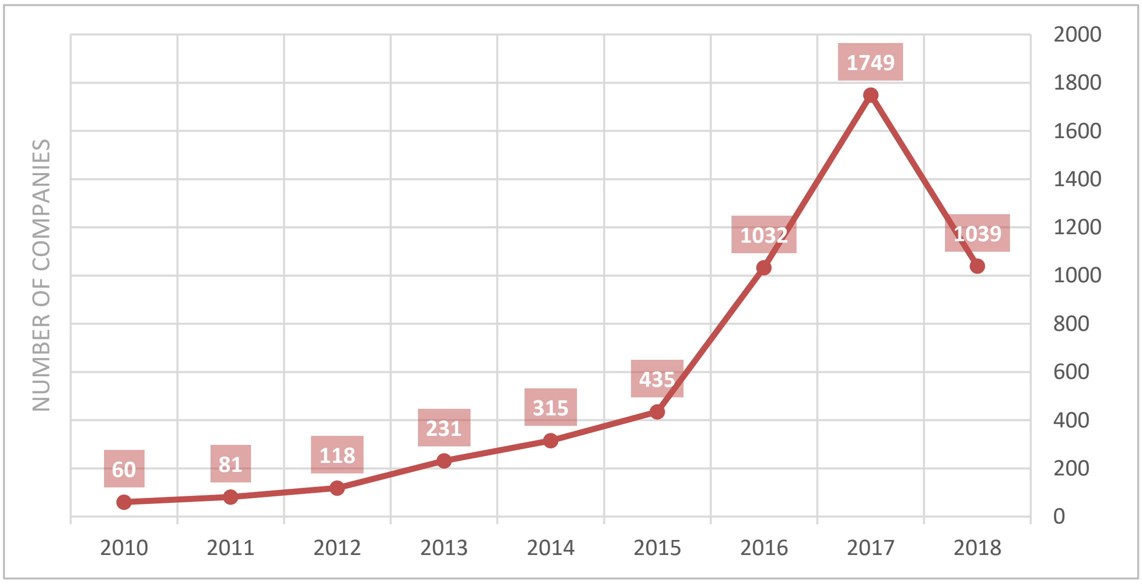

Figure 5 Newly founded blockchain-related companies, 2010–2018 (Data source: Crunchbase.com, 2019)

It is evident from the various statistics and graphs presented above that blockchain has gained a lot of momentum during the past few years, and this momentum continues to grow as more people become aware of its impact. Majority of the available use cases of blockchain, whether in scientific papers or companies, revolve around the use of blockchain in financial services, since it is one of the most promising application fields. However, there is a growing amount of research being conducted in fields other than the financial industry as observers start to understand the full potential of blockchain and all the possibilities and business scenarios it can affect. The next subchapter in this literature review examines a few prominent cases of blockchain adoption in several industries to form a better understanding of the reach and impact of blockchain.

2.1.2 *Blockchain in different industries: Usage and reception*

2.1.2.1 ***Banking and financial services***

Financial services form a vast and influential industry that is prevalent in many facets of business and people's lives. Financial services include any product or service of a financial or monetary nature that is traded in financial markets and is poised to bring financial value to the parties transacting it (Meidan, 1996, p. 7). The market size of financial services is projected to reach a value of around US$26 521.67 billion by 2022. This increase is attributed to global economic growth and more demand for financing and loans from large markets such as Asia-Pacific. (The Business Research Company, 2019). Parties typically involved in the financial services industry include, but not limited to:

- Banks
- Stock exchanges
- Investment funds
- Venture capital firms
- Payment service providers
- Money transfer companies

The most-known implementation of blockchain in the financial services industry is cryptocurrencies, with bitcoin being the prime example. The application of bitcoin (and other cryptocurrencies such as ether and litecoin) is a model manifestation of how blockchain can transform financial transactions in the real world. As touched upon earlier, bitcoin's value has fluctuated exponentially within a brief time, prompting many speculators to perceive it as a financial bubble while others invested heavily in it. Figure 6 below, taken from a currency exchange market of bitcoin, shows the rapid surge in bitcoin's value in US dollars between 2015 and 2019, starting from around US$314 in January 2015 and reaching a peak value of over US$18 000 in December 2017.

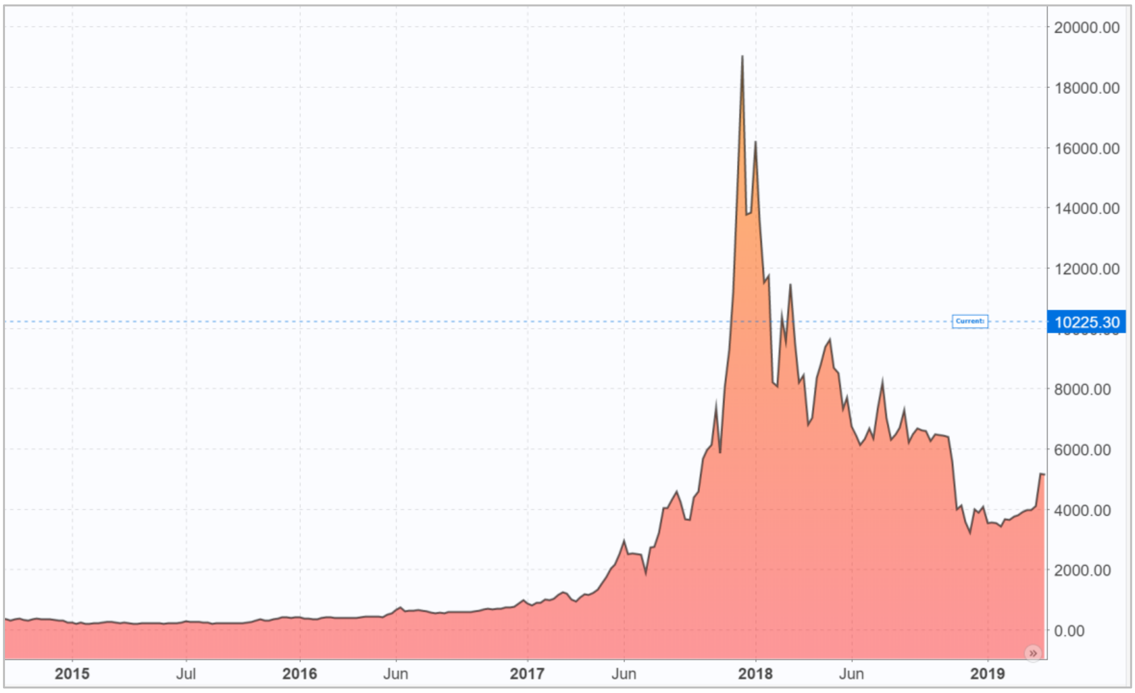

Figure 6 Monetary value of bitcoin in US dollars, 2015–2019 (Data source: Bitcoin.com, 2019)

On another note, one of the latest trends affecting the financial services industry is the rise of the financial technology sector (colloquially called "fintech"). Fintech refers to new product and service innovations often driven by startups developing software solutions that attempt to disrupt offerings of traditional financial service providers, such as banks (Menat, 2016, p. 10). Fintech startups have offered a diverse portfolio of solutions ranging from products that focus on certain functions such as wealth management to full banking services through mobile-only platforms. Combined, these startups have received funding of over US$19 billion (Mead, Pollari, Fortnum, Hughes, & Speier, 2016, p. 11).

Blockchain is no stranger to many of these fintech innovations since it is closely tied (and often confused) with the bitcoin cryptocurrency. Nguyen (2016, pp. 51–52) posits several advantages of why blockchain is set to bring vast improvements to financial services and the reasons behind the growing number of companies that have started to adopt blockchain and integrate it within their existing business operations. Some of the mentioned reasons include:

- Reduction in transaction costs
- Faster and more efficient operations
- Improved transparency of transactions

One example of organisations investing in blockchain-based financial services solutions is traditional banks (which might seem like a paradoxical example since traditional banking institutions are the very target of disruption often pursued by fintech startups). A prominent case is the Bank of China, which has reportedly invested in and financially supported the development and implementation of a blockchain-based platform for home-buyers that is developed jointly by Hong Kong Applied Science and Technology Research Institute and the real estate firm New World Development (Alexandre, 2019).

When it comes to people's reception of blockchain adoption in financial services, the general impression seems to be more on the positive, but slightly cautious side. Deloitte's 2018 global blockchain survey asked respondents whether they agree or disagree with the statement that blockchain will disrupt the industries that their own organisations operate in, and 64% of those working in financial services said they "somewhat agree" or "strongly agree" (Pawczuk, Massey, & Schatsky, 2018, p. 20).

2.1.2.2 ***Healthcare industry***

Medical and healthcare services are among the fields where blockchain has recently demonstrated a potential impact that started to become visible, albeit still not as momentous compared to financial services. By definition, the healthcare industry is a set of several fields including but not limited to: public health management, medical research, pharmaceutical products, medical records software, medical insurance, and many others (Mettler, 2016, pp. 1–2). The market size of the healthcare industry is significant and global spending on healthcare between 2017 and 2021 is projected to increase at an annual rate of 4.4%, with pharmaceutical annual spending in particular rising by an average of 4.9% (The Economist Intelligence Unit, 2016, p. 3).

Due to the sensitive nature of the healthcare industry and its direct impact on human lives, it is typically heavily regulated by governments. Thus, the healthcare industry tends to be more risk averse. However, that did not stop the industry from experimenting with and adopting new technological innovations—whether blockchain related or something else. Mettler (2016) as well as Khezr, Moniruzzaman, Yassine, and Benlamri (2019) discuss several example scenarios in the healthcare industry where blockchain could provide value, such as:

- Smart healthcare record management
- Reducing medical billing costs
- Tackling counterfeit pharmaceutical products
- Improving data management for wearable medical devices

The integration and usage rates of blockchain in the healthcare industry are growing as a response to the unparalleled need for safeguarding patients' personal data resulting from the rise in services that collect and process this data (Khezr, Moniruzzaman, Yassine, & Benlamri, 2019, p. 1). An example use case is a blockchain solution developed by American healthcare technology company Change Healthcare. According to its website, Change Healthcare processes claims worth over US$2 trillion per year and the company says its blockchain-based enterprise-scale application offers improved claims management transparency, auditability, traceability, and trust. (Change Healthcare, 2018).

Another example of a blockchain-based healthcare product is from the American company Hashed Health, which has developed a system to track and verify credentials of healthcare professionals and practitioners. The system attempts to make it more transparent for users to check the professional credentials of a medical expert and easily access information such as their verified occupation records. The company also offers a diverse portfolio of other health-focused blockchain solutions. (Hashed Health, 2018). Since its founding in 2016, Hashed Health has received over US$1,8 million in funding according to the company's public profile on Crunchbase.com[1]. This gives more credibility to the claim that the positive reception of blockchain-based healthcare systems is growing.

2.1.2.3 ***Legal industry***

Since blockchain is primarily centred around removing the dependence on trusted intermediaries (which are integral components of the legal industry, e.g. clearing houses, mediators, etc.), it was inevitable that the effect of blockchain would impact various legal tasks and functions. Filippi and Wright (2018) argue that due to the nature of blockchain as a decentralised ledger that supports transactions between multiple parties, it is foreseeable that blockchain's impact would extend to the creation and development of digital smart contracts to enhance and regulate the transactions that blockchain logs. Therefore, processing and provisioning cryptocurrency transactions (which are entirely digital procedures based on computer code) meant that digital contracts (whether for commercial agreements or otherwise) would also become code based, making them vital modules of blockchains.

As such, a prominent example of blockchain usage in legal functions is the introduction of smart contracts. A smart contract is an executable piece of code that is digitally signed by two or more entities entering into an agreement and is run on a blockchain-based protocol. Smart contracts are code based by design, which essentially means that once a smart contract's code has begun executing, it is only possible to halt, modify, or

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[1] Public company profile available at https://www.crunchbase.com/organization/hashed-health

terminate the contract by having the undersigned parties agree to reflect such changes in the underlying code that powers the smart contact. (Filippi & Wright, 2018). Therefore, traditional legal tasks such as ratifying a contract become integrated in blockchain-based agreements.

Delmolino, Arnett, Kosba, Miller, and Shi (2016, p. 81) illustrate the innerworkings of a smart contract in Figure 7 below. The figure depicts the roles of different entities that take part in executing a cryptocurrency smart contract, including the contract parties, the miners, and the public blockchain itself where the contract's status is stored. The smart contract can be figuratively likened to a trusted third party that ensures the availability and accuracy of the contract, but not its privacy.

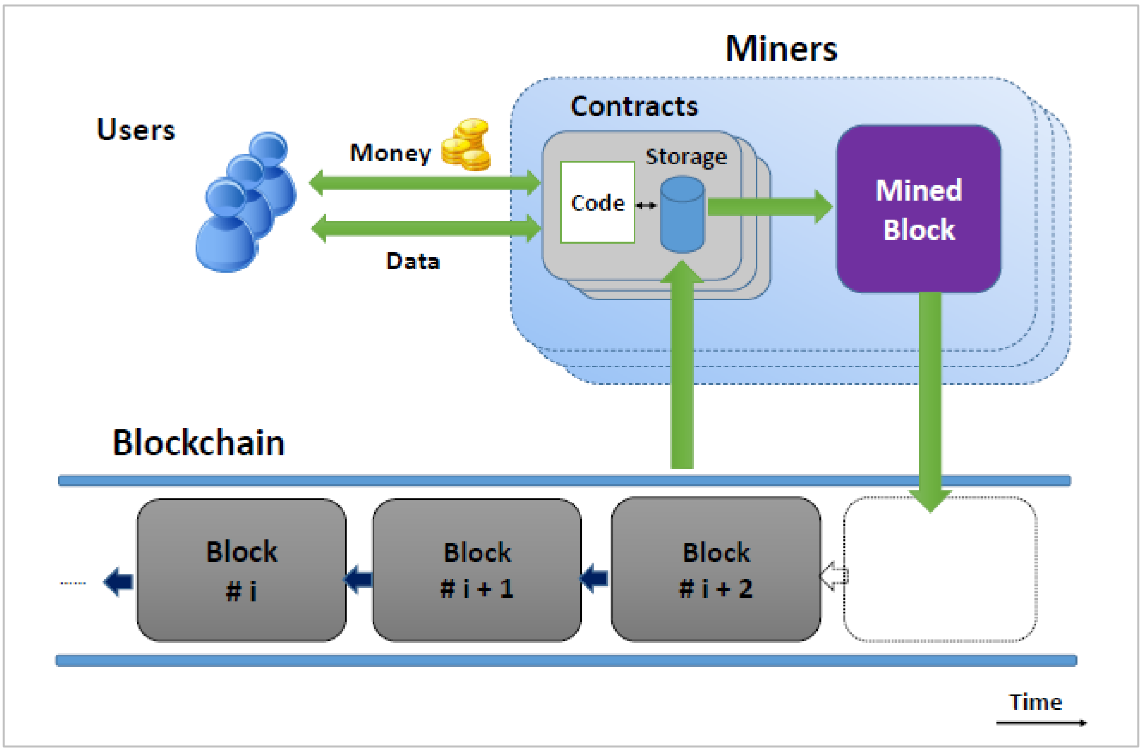

Figure 7 Illustration of a decentralised smart contract system for cryptocurrencies (Delmolino, Arnett, Kosba, Miller, & Shi, 2016)

Additionally, there are many examples in history of novel technologies disrupting traditional industries (or a function of an industry) mostly when such industries had areas of weakness or suffered from specific issues that these novel technologies promised to fix. One such example of an imperfect legal area that can be considered ripe for blockchain adoption is the monitoring and enforcement of copyright and intellectual property laws. Summarised in the list below are some of the existing challenges in digital copyright law that blockchain attempts to solve (Savelyev, 2018, pp. 552–553):

- *Piracy:* One of the most common copyright-related misconducts is the replication and misuse of copyrighted material without their owners' permission. Digital assets can be nearly cost-free to acquire and easy to reproduce, making virtually anyone with internet access able to obtain such material without the owners' knowledge. Pursuing legal action against those copyright infringements is a challenging task to carry out online due to the sheer number of replicas of copyrighted material and the number of people who might have obtained them. By using cryptographic hash functions, it is possible to use blockchain to create unique, time-stamped copies of digital assets that can be tracked and given select rights such as e.g. restriction of unlimited digital copying.
- *Transparency of ownership legal status:* The fragmentation of databases and sources of information regarding copyrighted material on the internet has made it difficult to identify which works have copyright restrictions and who are the owners of those copyrights. This is partly due the decrease of entry requirements that an individual must possess to claim copyright ownership over their creative works on the internet. Blockchain's hashing and timestamping features can provide a solution to this problem given that a timestamped transaction on a blockchain is, by design, an immutable record proving that a specific event took place at a specific time. Therefore, creators can make use of blockchain to hash their work and verify their ownership of it, which can replace traditional methods such as having to register the work with a patent registration office. There are already blockchain-based solutions currently online, such as Bernstein.io, that are attempting to solve the online challenges of intellectual property rights.
- *Fair compensation for asset owners:* The issue of unfair rewarding/payment of copyright owners and original content creators has long been a debated topic in the digital age. Large distributors such as publishing houses, record labels, etc. usually take considerable amount of commission money in return for disseminating creative works of artists and other creators, which in turn reduces the pay-out amount that these creators eventually receive. The more intermediaries and third parties get involved between the content creator and the end consumer, the higher the costs become and the less compensation the creator receives. The introduction of cryptocurrencies such as bitcoin provides a promising solution to the issue of fair compensation by enabling automatic payments through smart contracts that execute based on, for example, users' consumption frequency.

2.1.3 ***Blockchain adoption in enterprise software***

Before attempting to investigate the current adoption rate of blockchain solutions in enterprise business processes, it is worth understanding what value can blockchain bring to companies that are considering it. Tapscott and Tapscott (2016) list a slew of areas where blockchain promises transformative impact: From financial services to enterprise architecture to more economic inclusion and invention of completely new business models. The potential of blockchain to affect various business processes and challenge existing operational models is becoming clear. In practice however, capitalising on these possibilities and translating them into actual working solutions is not happening at a pace that most companies can easily accommodate (Pawczuk, Massey, & Schatsky, 2018, p. 11).

Nonetheless, the increasing interest in blockchain is pushing more enterprises to explore the technology and the ways it can affect their businesses, either with fully functioning blockchain solutions that integrate into core business areas or with experimental pilot projects that serve as prototypes to demonstrate the impact of blockchain. Forbes Magazine mentions that at least 50 of the largest public companies, including all top 10, currently have at least one project or application related to blockchain. One of the examples mentioned in this list is the Industrial and Commercial Bank of China, which is experimenting with a blockchain-based solution to authenticate digital certificates instead of using a trusted third party. Another example is Berkshire Hathaway, which is exploring the use of blockchain to track provenance of high-value items such as precious stones. Moreover, Apple Inc. is reportedly attempting to use blockchain to power an innovative technology that timestamps data. (Castillo, 2018).

These few examples about which enterprises are currently using blockchain and for what type of projects reveal that despite the growing attention towards blockchain and the eagerness to capitalise on it, hard facts tell us that broad adoption is yet to happen and various reasons can be attributed to this situation. Supply chain is one of the areas where the previous revelations apply, that is why this research attempts to find out the key adoption challenges for blockchain-based SCMS and the causes behind them.

2.1.4 *Prospects and outlook of blockchain*

2.1.4.1 ***Fields of opportunity***

Even though blockchain is still in its infancy, one cannot neglect that it is rapidly gaining ground in the business world and other areas as was apparent from the points and examples discussed previously in this chapter. The promising changes that blockchain is supposed to bring and its areas of application are diverse, thereby laying the foundation for many researchers and enthusiasts to speculate and try to predict the fields that would be the next target for blockchain integration. A few of the most prominent examples of these fields, compiled from multiple sources as cited below, include:

- *Voting:* As it matures, blockchain promises to fill the void in the current electronic voting solutions that people are sceptical about. A few blockchain-based systems and protocols have been proposed by several researchers to prove that blockchain can deliver a reliable platform for voting that ensures voter privacy and validity without reliance on trusted third parties, whether for decision-making in organisations or public voting for political elections. For example, Zhang et al. (2018) have proposed a voting protocol based on blockchain that guarantees end-to-end voter privacy and protection against fraud. The authors demonstrate the implementation of their protocol on the Hyperledger Fabric (a blockchain framework developed by an industry consortium that includes Linux Foundation and IBM). Another patented invention by Spanos, Martin, and Dixon (United States Patent No. US 9,836,908 B2, 2015) presents a practical prototype of holding votes on a blockchain through a distributed network of connected voting devices that securely record voting data and continuously update the tally, which should prevent fraud or errors in the voting process. These examples demonstrate that there are tangible attempts at applying blockchain in voting systems, although many cybersecurity experts oppose electronic voting solutions in general because they believe those systems to be fundamentally insecure (Orcutt, 2018). That is why it would need a cultural and mindset shift for such solutions to be accepted and adopted widely.
- *Food and agriculture:* Another major opportunity for blockchain is likely to be in the food industry, evident by the growing number of food safety, food tracking, and food distribution solutions being developed on blockchain by both startups as well as established enterprises. There are several use cases and research results for blockchain use in the food and beverages industry. One such example is a Swiss-based startup called Ambrosus, which has developed a blockchain platform to track food products from origins to distribution points and until products reach end consumers covering all parties along the food supply chain: Farmers, production factories, distributors, and retailers. Ambrosus has published a paper highlighting an example case of its product being implemented for the olive oil market, where it helps in strengthening the safety and origin traceability of oil to ensure its adherence to quality standards. (Ambrosus, 2017). Another example is from Tian (2016), who presents the perceived advantages of a blockchain-based information system for the traceability of agri-food supply chains. This proposed system promises to reduce the amount of damaged and lost food produce in underdeveloped logistics systems. The system in question relies on Radio-frequency Identification (RFID) technology and Internet of Things (IoT) devices to monitor and track the movement, quality, and weight of produce as it moves from point A to point B in the supply chain. However, Tian (2016) also notes that such new system would likely incur high costs if it is deployed because it is still a rather immature technology according to current business standards—especially for larger enterprises. The

system also presumes that all supply chain stakeholders are using the same technology platform and infrastructure for the system to deliver value, which can be difficult to fulfil. One more example is specifically intended for coffee supply chains: There seems to be growing interest for the integration of blockchain-based systems in this industry, since coffee is one of the largest traded commodities in the world. One can find several use cases of companies that use blockchain for coffee supply chains such as Bext360, Crypto N' Kafe, Starbucks, etc. (Thiruchelvam, Mughisha, Shahpasand, & Bamiah, 2018, pp. 122–123). Thus, due to the amount of published research papers and reported use cases related to blockchain in the food industry, it can be argued that blockchain has the potential to improve food safety (Ahmed & Broek, 2017; Hua, Wang, Kang, Wang, & Wang, 2018; Kamath, 2018).

- *Distributed cloud storage:* Ever since the emergence of cloud computing and the growing availability and usage of cloud computing platforms, the popularity of using a centralised cloud service as a storage for digital assets has increased. However, the typical issues that come with using a centralised third party for any service (such as trust and security issues) were also present with cloud storage services. (Xue, Xu, Zhang, & Bai, 2018, pp. 385–386). Occasionally, those issues manifest themselves as incidents of breaches, data leaks, and hacking attempts. Hence, the idea of creating distributed cloud storage systems surfaced, encouraged by the introduction and continuous development of blockchain. Xue, Xu, Zhang, and Bai (2018) have proposed and detailed a new encrypted distributed data storage system labelled DStore that uses Ethereum (a blockchain-based distributed computing platform) and smart contracts to store users' files on different physical disks located across the globe.
- *Decentralised Autonomous Organisation (DAO):* The concept of a DAO has been brought up recently in the scientific and academic communities as it is closely tied with the previously discussed point about the potential of blockchain in voting systems. Kraus, Obrist, and Hari (2019) explain the concept of a DAO as a form of immutable governance rules for groups of people working together towards a shared objective or goal. A DAO is decentralised since the laws that govern the organisation are stored in the form of code on the blockchain, and it is autonomous because it executes the rules automatically according to the smart contract it is incorporated in—effectively eliminating human intervention. That means any community or group of people can opt to create an "organisation" using blockchain and smart contracts as governance tools to enforce their organisation's statutes and bylaws programmatically. With this model of governance, voting rights can be allocated automatically to holders and implemented whenever the need arises in accordance with the DAO's rules. In a commercial setting, a DAO has the potential to generate revenue for its owners and shareholders by programmatically creating and delivering value that DAO's customers pay

for. The revenue generated by the DAO would then be distributed among the beneficiaries as described in the smart contract's code when the DAO was established. Additionally, since a DAO's code and programmed logic are immutable, that would always require the majority of shareholders to reach a consensus before any proposed changes get approved. That means, even original owners and creators of a DAO would not be able to change its code single-handedly. (Kypriotaki, Zamani, & Giaglis, 2015). This new form of organisations made possible by blockchain has potential to transform and automate the way businesses have been conducting their work. However, it has yet to prove feasible on a large scale because no big-name DAOs are currently present. The concept of a DAO also introduces several legal challenges for businesses and lawmakers since the current regulations and national laws are lagging because many governments do not currently recognise such distributed, independent organisations as accountable legal entities (Kypriotaki, Zamani, & Giaglis, 2015).

2.1.4.2 ***Obstacles and barriers***

Despite the growing interest and increasing amount of promising opportunities for blockchain, this new technology still faces various challenges (Zheng, Xie, Dai, Chen, & Wang, 2017, p. 561). As is the case with most novel changes, whether technological or non-technological, there will always be resistance against adoption—especially during the early phases of change. Blockchain brings along with it several obstacles that slow down its acceptance and adoption by the wider public, including individuals and businesses.

For instance, Dhaou, Zalan, and Toufaily (2017) have presented some adoption challenges that are facing blockchain and categorised them as technological, regulatory, social, etc. One of the most pressing and persistent adoption obstacles that blockchain would need to overcome is to shift the culture of its potential users towards acceptance, which would encourage its usage as a practical and reliable technology. The culture shift is also affected by the lack of sufficient human labour that is skilled in blockchain, which causes the awareness of blockchain applications to be limited as a result (Dhaou, Zalan, & Toufaily, 2017).

Moreover, as blockchain usage increases, its ability to handle projects of larger scales is being inspected. Scalability (or lack of) is another barrier that affects the adoption of blockchain by larger enterprises with bigger systems. Scalability here refers mainly to storage capacity and performance, in addition to latency and transaction speed (Zheng, Xie, Dai, Chen, & Wang, 2017, pp. 561–562). To put this scalability issue into perspective, blockchain's rate when it processes transactions is currently limited to seven transactions per second. When compared to, for instance, rates of payment systems such as PayPal (115 transactions per second) or the Visa network (up to 56 000 transactions per second), it becomes clear that they are higher than blockchain's rate (Gao & Nobuhara, 2017, p. 13). Researchers are already discussing the need for a faster and more scalable blockchain infrastructure and a few of them have proposed some solutions, which attests to the rapid ongoing progress to increase the matureness of blockchain. For example, Eyal, Gencer, Sirer, & Renesse (2016) have proposed a redesigned blockchain protocol (labelled Bitcoin-NG) that promises to be more scalable after they have conducted large-scale experiments of about 15% the size of bitcoin's blockchain. Furthermore, other scalable consensus protocols that attempt to address this seven-transactions-per-second limitation of blockchain have been proposed by Gao and Nobuhara (2017); Cong, Ren, and Pouwelse (2018); and Ehmke, Wessling, and Friedrich (2018).

One can also find several other barriers of different magnitudes that slow down the adoption of blockchain, some of which are technical such as usability, throughput, security, and privacy (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016, pp. 3–4), while others are more general such as lack of regulations and standards (Wang, et al., 2019, p. 7).

2.1.4.3 ***Future trends***

The growing amount of research in academia that has been presented earlier and the several implementation examples in companies that are discussed throughout this research demonstrate the increasing interest in blockchain and provide clues to predict its future direction and trends. To illustrate, development-wise, Wang, et al. (2019) have discussed several trends that specifically relate to smart contracts. One example is formal verification, which ensures that a system is running according to its formal behaviour specifications. Another example is the trend to extend the concept of DAO to apply to societal management beyond the boundaries of a traditional organisation. In addition, Yang, Garg, Raza, Herbert, and Kang (2018) have reviewed other trends such as those concerning blockchain's consensus protocol and how an increasing number of solutions are being developed to make the protocol more scalable and to push scalability initiatives forward.

Another trend is the surge of the initial coin offering (ICO) phenomenon, which is another domain that is gaining popularity and momentum as an alternative form of fundraising—especially for startups. ICOs are a method of funding typically used by entrepreneurs and startups to raise funds by offering certain amounts of cryptocurrencies for purchase by interested investors, which they can later sell or exchange for some products and services. ICOs have managed to secure more than US$5.3 billion in funding for numerous startups around the world in 2017, including US$150 million for The DAO project, which was one of the first large ICOs to take place. (Adhami, Giudici, & Martinazzi, 2018, pp. 64, 66). All of this proves the trendiness and growing adoption of ICOs within the startup and venture capital communities. Despite the risks that come with ICOs (such as being decentralised and not supervised by a single trusted authority, which increases the contributors' exposure to possible fraud), this has not prevented their amounts to increase and their success rate to reach 81%. However, in 2017 ICOs have been banned in China and South Korea. (Adhami, Giudici, & Martinazzi, 2018, p. 65. 67).

2.2 Supply Chain Management Software (SCMS)

2.2.1 ***Brief history of modern SCMS***

Supply chains are essential systems that facilitate the provision of goods from producers to consumers. As these supply chains become larger and start to assimilate more members, the need arises to efficiently manage their complexities to ensure the continuity of a smooth flow of goods. Thus, SCM emerged as a prominent concept and field of study. Handfield and Nichols (2003) mention that the terms *supply chain* and *supply chain management* were first coined by British logistician and consultant Keith Oliver in 1982 in an interview for the Financial Times newspaper. Since then, and throughout the 1990s, the terms have gained popularity and their usage has become more visible in both academia and industry. This meant the emergence of a plethora of scientific articles published in the SCM field and a surge in practitioners who are increasingly incorporating the terms in their professional titles (Handfield & Nichols, 2003; Sees, 2013).

The development and rapid matureness of SCM as a field of study and a business function led to the introduction of a category of software systems designed to manage the increasing complexity and sophistication of global supply chains, for both small and medium-sized enterprises (SMEs) and multinational corporations (MNCs). As such, an increase of SCMS usage started to become visible in the enterprise software scene. SCMS can be defined as the software tools and modules that organisations use to execute and manage different activities of supply chains, including transactions, business processes, supplier relationships, etc. (Kolenko, 2014). Throughout this research, the term SCMS is used exclusively to denote such software systems as defined above and the use of *systems* in SCMS will not refer to the set of non-technical managerial rules and practices put in place to organise and supervise a supply chain.

Several IT suppliers and software developers have started developing SCMS to meet the demands of enterprises and the need for technological solutions to streamline the process of managing complex supply chains. Software systems that were developed in the early days of digitalisation were mainly in-house or premises-based solutions, while the more recent ones tend to be cloud based because of the growing popularity of cloud computing and the shift towards Software as a Service (SaaS) models. Statistics show that more companies are becoming accustomed to cloud-based software, which contributed to having more IT suppliers use cloud-first or cloud-only delivery models for their software. That is why research and advisory company Gartner predicts that SaaS solutions will account for over 35% of total SCM spending by 2021. (Gartner, 2017).

Throughout the late 1990s and early 2000s, most major companies with supply chain operations managed to deploy software systems to manage their supply chains, mainly as a result of growing adoption of centralised enterprise resource planning (ERP) systems, which significantly enhanced the handling and processing of supply chain–related data (Robinson, 2015). Additionally, the emergence of advanced planning systems (APS), which are software solutions that help with managing different types of operations planning (e.g. planning of demand, production, transport, purchasing, etc.), has advanced the progress in developing software to handle different supply chain planning tasks and wide-ranging supply chain operations (Meyr, Rohde, Wagner, & Wetterauer, 2005). For instance, SAP, founded in Germany in 1972, is one of the leading IT suppliers of SCMS and its enterprise software solutions are widely used across several industries. As an example, one of SAP's solutions, Advanced Planner and Optimizer (APO), is a fully integrated APS that is comprised of multiple modules as illustrated in Figure 8 below.

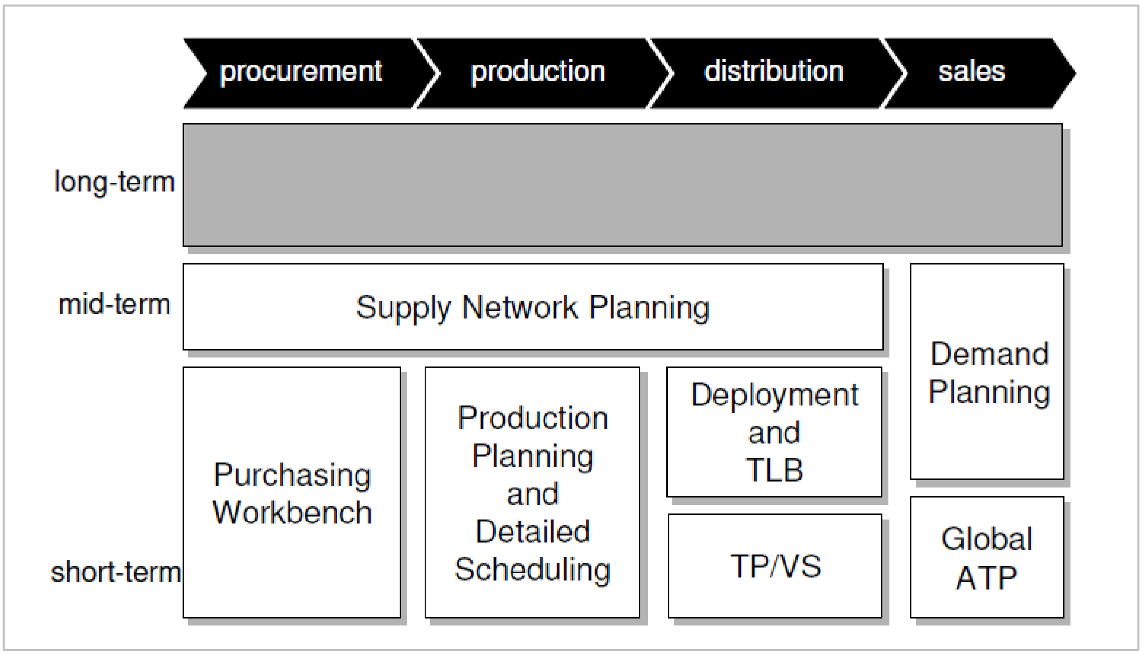

Figure 8 SAP APO modules (Meyr, Rohde, Wagner, & Wetterauer, 2005)

As can be seen from the figure above, this integrated SAP software solution attempts to cover various SCM tasks: From initial demand and procurement planning to sales operations where products and goods reach end users. Moreover, the system allows for collaboration between many users and stakeholders in the planning and processing of shared tasks at any predefined point throughout the supply chain. This is accomplished by giving authorised online access to designated users, thus allowing for cross-company collaboration and easier off-premises usage. (Meyr, Rohde, Wagner, & Wetterauer, 2005, p. 353). Nevertheless, even though software systems like these provide flexibility when it comes to collaboration among supply chain stakeholders, one of their key limitations is that most of them require the participating parties to be using the same software system to reap the promised benefits. Given the increasing complexity of supply chains and the possibility of having additional intermediaries and service providers joining the chain, it becomes a challenge to provide a complete and fully integrated SCMS that caters for the needs of every stakeholder in the supply chain. Modern SCMS—especially blockchain-based ones—are currently trying to address this very issue as presented later in this research.

2.2.2 *Current issues in supply chain management (SCM)*

The discipline of SCM has been studied extensively within both the academic and managerial communities ever since the first emergence of the term *supply chain management* in the early 1980s (Lambert & Cooper, 2000, p. 66). That means, many organisations already have SCMS set up in place with related procedures to efficiently oversee them. Meanwhile, the increasing sophistication of business operations has caused SCMS to become more advanced, which means that there are more chances that newer SCMS solutions end up being unable to meet every need of an organisation despite coming equipped with multiple features. As such, it is more relevant for this study to investigate modern, up-to-date issues of SCM that can theoretically be solved with blockchain, instead of addressing issues from older literature.

Based on this, a 2010 survey of over 600 senior executives conducted by management consultancy firm McKinsey & Company has listed some of the most feared issues affecting supply chains as reported by the companies participating in the survey. The top five of those issues were (Gyorey, Jochim, & Norton, 2010):

- Increasing volatility in customer demand
- Increasing consumer expectations about customer service/product quality
- Increasing cost pressure on logistics/transportation
- Increasing pressure from global competition
- Increasing volatility of commodity prices

The above issues reveal that current supply chains have inherent challenges that are constantly growing as can be noticed from the repetition of the word *increasing*. Even with the current IT systems that organisations already use to manage their supply chains, the issues listed above indicate that they stem from the supply chain operations themselves and not necessarily from the IT systems that support them. This implies that IT systems are not always successful in providing technological solutions to business problems. The reasons for that can sometimes be attributed to technology limitations (Jabbari & Kaminsky, 2018), which paves the way for new technology advancements (e.g. blockchain) to drastically reduce the effects of those problems, or better yet—anticipate and prevent them before they occur.

2.2.3 *Impact of information technology on SCM*

Around the late 1990s and early 2000s, the term *supply chain* was only recently starting to become mainstream as an all-inclusive replacement to the term *logistics*, which was more commonly used (Handfield & Nichols, 2003). That became even more evident in 2005 when the professional association *Council of Logistics Management* officially changed its name to the *Council of Supply Chain Management* in order to adapt to the changing perception and usage of the term (Robinson, 2015). During that era, more companies were paying close attention to the emergence of internet usage in IT systems and what it meant for their businesses. Since the internet technology was still relatively immature when it comes to wide-spread adoption and people's attitudes towards it, several articles and research papers have been published predicting different scenarios of how B2B operations would be affected (or not) by the rise of the internet. SCM was one of the industries where researchers have started studying the impact of internet on it. Some authors such as Lancioni, Smith, and Oliva (2000) have researched the impact that internet would bring to SCM and provided several reasons why enterprises should adopt internet-enabled IT systems to improve their SCM. Despite the underlying challenges that came with the internet at that time, Lancioni, Smith, and Oliva (2000) have concluded that integrating internet across IT systems would bring more opportunities and growth for the companies involved. Additionally, their paper listed the results of a questionnaire that covered over 100 respondents and it showed a total of 90.1% respondents confirming that they were using the internet to conduct some of their supply chain tasks, which was a high percentage considering the relative novelty of internet technology during that period (Lancioni, Smith, & Oliva, 2000, p. 49).

Over the years, a number of authors including Lancioni, Smith, and Oliva (2000); Akkermans, Bogerd, Yücesan, and Wassenhove (2003); and Huang and Handfield (2015) have all discussed the impact of IT applications in general, including internet and ERP systems, on SCM. Their findings can be summarised in the following points:

- *Faster communication, operation, and decision-making:* A range of factors affect the rate of success in managing a supply chain effectively, one of which is the instant availability of crucial information about any element in the supply chain in a timely manner. Fast access to supply chain data can determine, inter alia, whether to proceed with a certain business operation; whether to complete, cancel, or delay some orders due to unforeseen changes; whether management can take certain decisions instead of others; etc. In addition, faster retrieval of information allows for faster reaction to customer requests, which in turn increases the company's efficiency. Technology, including the internet, has provided supply chain operation managers with the luxury of having information at their fingertips, giving them the opportunity to avoid unnecessary costs and increase the profits of their businesses. (Lancioni, Smith, & Oliva, 2000). Moreover, it is widely accepted that digitalisation improves companies' efficiency in conducting their work (see, for example, Lancioni, Smith, & Oliva 2000; Degryse 2016; Bechtsis, Tsolakis, Vlachos, & Iakovou 2017) because IT systems have proved their ability to transform previously manual, mundane tasks to much faster activities and to automate routine chores to help companies thrive in a fast-paced environment.

- *Cost-saving opportunities:* In supply chain operations, costs can increase for several reasons as the supply chain network is usually complex and involves several members with differing tasks and responsibilities. For instance, keeping unnecessary inventory results in extra administrative costs that could be easily avoided if the company used IT systems to manage its inventory and balance the supply–demand in the market. Brody (2017, p. 4) has reported that it usually costs a company on average 20–40 cents annually to keep every US$1 worth of inventory. Maintaining a low inventory amount reduces the burden that comes with monitoring and transporting products across the supply chain, thus effectively cutting down the amount of fees that the company would incur if its inventory was not in check. (Lancioni, Smith, & Oliva, 2000). Additionally, the availability and exchange of vital data among all parties in the supply chain increases the level of knowledge of the company's operation managers about state of orders; purchase cost and details; shipment tracking and whereabouts; billing and invoicing; etc. This data can be shared by all supply chain parties including retailers, suppliers, manufacturers, etc., which results in lower customer support costs (and enquiries) due to availability of all vital information within the IT systems in use.
- *Less-interrupted availability of customer service:* Communication and customer service are vital components in conducting any type of business, and the supply chain industry is not an exception. Lancioni, Smith, and Oliva (2000, p. 52) have noted that the delivery of 24/7 customer service helps companies remain competitive within their industries, thus suggesting that an always-available customer service is becoming less of an extra amenity and more of a standard as customers are beginning to take it for granted. With the adoption of advanced, internet-enabled IT systems to run supply chain operations, the days of predefined daily working hours and limited availability of customer service are slowly becoming less predominant. This proves true especially for global enterprises with cross-border operations in multiple markets where time

zones vary, which signals the necessity for 24/7 availability of customer service. (Gupta, Seshasai, Mukherji, & Ganguly, 2007). On the one hand, this provides customers with higher service quality and shorter support waiting time. On the other hand, it serves as grounds for the company to reduce possible losses by fusing customer service costs in their price calculations. However, companies need to find a good balance and a sustainable way to provide this round-the-clock customer service while ensuring that it would not lead to unnecessary overhead cost for their businesses. On a parallel note, Love (1997) also concurs that IT is an important enabler in facilitating communications and cooperation, which are crucial elements in all supply chain operations. Smooth flow of communication within the same organisation as well as across multiple parties in the supply chain ensures that every contact point in the supply chain is equally updated about the state of any operation, which in turn results in better and more useful fulfilment of customer support requests. In addition, it allows multiple contact points in the supply chain—instead of only one—to gain access to the information required for serving customers.

- *Unlocking new markets:* Globalisation is widely perceived to have been made possible due to advances in IT and the adoption of internet in conducting business operations between countries (see, for example, Freund & Weinhold 2002; Intriligator 2004). Nowadays, many MNCs are headquartered in one country while several parts of their supply chains are spread across multiple countries. The effect of this geographic dispersion on countries has affected areas such as employment of labour and creation of new economic opportunities. That is because companies constantly seek, inter alia, affordable alternatives to conduct business; efficient and high-quality manufacturing; experienced suppliers and vendors; etc. Altogether, these new opportunities equip companies with more competitive advantages to succeed across markets. (Intriligator, 2004). One prominent example is the way China’s economy has significantly boomed during the 1990s and 2000s due to the increasing reliance on the expertise and affordability of Chinese manufacturing and production by companies seeking to boost the competence of their supply chains.

Since blockchain advocates often make the case for its future impact on business operations by comparing it in its current state to the state of the internet during the 1990s, it is possible to make a similar comparison here, taking into account the findings from the literature above, about the impact of internet and IT on SCM. That is to say, the natural progression of technology poses itself as a realistic explanation to why blockchain could very well be “the next big thing” in SCMS, therefore justifying a need to thoroughly study this technology and its integration with SCMS. As such, more research regarding blockchain integration in SCMS is required to lay the ground for decision makers to gain a mature and in-depth understanding of its impact on their businesses.

2.2.4 ***Digital supply chain (DSC)***

2.2.4.1 ***Concept and implementation***

The definition of what a supply chain encompasses has evolved over time due to, for example, modern technologies penetrating different areas of work and affecting all parts of an industry's value chain. As a result, terms such as *industry 4.0* and *digital supply chain (DSC)* emerged to reflect the rapid shift towards applying new technological innovations in business and production. (Szozda, 2017, p. 401). DSC essentially refers to the idea of a supply chain network that is based on a digital/IT foundation and uses technology tools to conduct its operations, as opposed to a traditional network of parties that mostly rely on paper and manual methods of doing business (Rouse, 2016).

Despite the presence of digitalisation initiatives in many organisations and the transformation of many labour-intensive business processes towards usage of digital technologies, most supply chain networks have not achieved full technological integration. That is, a typical supply chain consists of multiple stakeholders, both internal and external, and aligning all their processes under one streamlined IT platform is not an easy task to achieve. (Jabbari & Kaminsky, 2018, pp. 10–11). Current literature has been studying the digitalisation of SCM for the past two decades and to this day there still appears to be challenges with full technological assimilation of supply chains. Korpela, Hallikas, and Dahlberg (2017, p. 4190) concluded that, among the companies they studied, there exists a significant gap in alignment of business processes and the readiness of an organisation to increase its reliance on DSCs.

The above findings are noteworthy since the original premise of introducing such technological inventions is to solve the problems that supply chains suffer from. Yet, the proposed solutions prove to be difficult to implement in full alignment with the rest of the supply chain network. Therefore, this situation produces an outcome where: 1) a DSC is only half functional, thus not achieving its full potential and 2) the speed of technology innovation stagnates because of slow adoption of modern technology by supply chain members. The introduction of blockchain-based systems to manage supply chains is no exception: It also promises better performance and improved efficiency, yet the adoption by organisations is slow. An example of such situation can be seen in a research report released by Gartner, which has revealed that managers were generally aware that their industries will be greatly affected by digital transformations, but have indicated that their organisations were not prepared to adapt quickly to these transformations (White, 2016).

2.2.4.2 DSC as an element of industry 4.0

The term *industry 4.0* (or *fourth industrial revolution*) has emerged as a reference to the changing landscape of the manufacturing industry. It follows a similar theme to the early mechanisation and automation of manufacturing processes throughout the 18^{th} and 19^{th} centuries, which have become known as the industrial revolution (and later as the *first* industrial revolutions, after people started numbering consequent industrial shifts similarly). Likewise, as the first industrial revolution was characterised by incorporating mechanical abilities in manufacturing processes, the second industrial revolution's theme carried a shift towards usage of electricity and electrical energy rather than mechanical. More recently, the third industrial revolution was linked with the growing trend of digitalisation in industrial processes of organisations. Fast forward to today's world, and the fourth industrial revolution revolves around the advanced digitalisation and use of intelligent software and hardware to automate and improve various manufacturing processes. (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). Therefore, it includes, inter alia, emergent fields such as artificial intelligence, machine learning, robotics, big data, IoT, cyber-physical systems, autonomous vehicles, etc. (Schwab, 2015). Industry 4.0 (the *4.0* being a reference to the widespread naming convention of software versions) has several alternative names adopted in different regions—although all refer to similar concepts—such as smart factories, advanced manufacturing, or industrial internet of things (Tjahjono, Esplugues, Ares, & Pelaez, 2017, p. 1176).

Therefore, the digitalisation of SCM proves to be an integral component of the upcoming iteration of industrial revolutions considering the vital role that supply chains play in the manufacturing industry. In fact, the impact of industry 4.0 on supply chains can already be seen in the next generation of advanced SCMS powered by several industry 4.0 technologies. Tjahjono, Esplugues, Ares, and Pelaez (2017) have analysed various types of literature (including scientific articles, newspapers, government reports, as well as several internet sources and videos) in order to develop a holistic understanding of the possible impact that industry 4.0 would bring on supply chains. The authors have designed their research by first studying the scope of SCM to classify its key underlying components. Afterwards, they have assigned key performance indicators (KPIs) to every component to evaluate the impact of industry 4.0 technologies on each one. Their research has revealed that the top two functions of supply chains that would be affected the most by industry 4.0 were *order fulfilment* and *transport logistics*. Lastly, they have concluded that the most relevant benefits of industry 4.0 for supply chains were the increase of quality, flexibility, efficiency, and productivity.

Regarding implementation, there are a number of companies that have already applied one or more industry 4.0 technologies to some aspects of their supply chains, but not necessarily on the whole supply chain network—mainly because industry 4.0 is still in an early stage and would take several years to manifest at a larger scale. According to Szozda (2017), some of the notable case studies of such companies with practical examples of industry 4.0 implementations include:

- *BMW:* This German automaker's factory in Leipzig is renowned as one of the most automated factories (Kochan, 2006, p. 111). One specific industry 4.0 technology that is prevalent in this factory is RFID, which allows employees to track product components such as raw material and parts across the whole supply chain. In addition, many of the factory's manufacturing processes are automated and performed by robots.
- *Bosch:* This engineering and technology MNC is implementing a slew of technologies related to the fourth industrial revolution (Gerbert, et al., 2015). For example, the company uses a central database that is fed with data from 11 integrated factories as well as 5 000 machines, which includes data about the flow of goods as collected via RFID technology, similar to BMW's case above. This allows multiple employees with differing functions the possibility to gain instant access to data about a machine's situation or availability at every stage in the production line, thus increasing the efficiency of operations in the factory.

2.3 Blockchain integration in SCMS

2.3.1 *Identifying the impact of blockchain on SCM*

Given the perceived benefits of blockchain and the potential impact it could bring to SCM as covered in previous subchapters, it is foreseeable that more researchers and SCM practitioners would start experimenting with this new technology to form a clearer picture of the outcome it can deliver. More scientific and academic literature is becoming available on the topic of blockchain integration in SCM, where authors have studied different areas of implementation or have dived into niche scenarios to better understand the phenomenon. Likewise, multiple sources (as shown in the following subchapter) have reported that a growing number of enterprises are beginning to adopt blockchain-based SCMS to varying degrees based on factors such as company size, supply chain complexity, profitability, etc. As such, identifying the impact of blockchain on SCM first would help at a later stage as it would allow for the comparison of perceived benefits vs. perceived challenges, thus consequently providing a new angle to understand adoption challenges.

Numerous publications have listed a variety of potential benefits that can be achieved in SCM if blockchain adoption becomes more prevalent in the industry, and many of these predictions are overlapping or complementing each other. However, before looking at the impact of blockchain on SCM, one must be familiar with the key blockchain features that are responsible for creating such impact. Therefore, a short list explaining some of the key features of blockchain as extracted from existing literature is assembled below (Dobrovnik, Herold, Fürst, & Kummer, 2018; Kim & Laskowski, 2018; Kamble, Gunasekaran, & Arha, 2019):

- *Distributed ledgers:* A key characteristic of blockchain that replaces the centralisation of public and private ledgers among third parties with a decentralised alternative where all participants in the blockchain own the same ledger. Thus, what this feature does is that it introduces a new "trustless" model for approving transactions instead of establishing trust through intermediaries.
- *Immutability:* Due to the secure hashing algorithms built into blockchain's architecture, all transactions are chronologically verified. Thus, attempted modifications are visible to the whole network, which makes the entire blockchain immutable to alteration—assuming no single entity controls >50% of the network.
- *Cryptocurrencies:* The first mainstream application of blockchain—cryptocurrencies (such as bitcoin) are tokens that act as digital money. Cryptocurrencies are built on top of blockchain, which makes the process of sending and receiving transactions and compensations across the blockchain an integrated experience.
- *Smart contracts:* A programme of self-executing code that contains terms, rules, and regulations pre-agreed upon by members of the blockchain network. Once deployed on the blockchain, smart contracts automate the workflow and fulfil their entrusted terms without human intervention.
- *Consensus algorithms:* An electronic voting system for blockchain-based applications where decisions are automatically taken based on predefined algorithms. These algorithms follow the agreements reached by the majority population of members participating in the network.

Building on the above definitions, Table 1 below categorises the main perceived benefits under four unified areas: 1) improved provenance verification and traceability of goods; 2) reduced number of intermediaries and third parties; 3) lower transaction costs; and 4) increased efficiency through data sharing and automation. Afterwards, these benefits are linked to the corresponding features of blockchain that make them achievable. Additionally, any publication from the examined literature that have discussed one or more of the perceived impacts is listed in a parallel column in the table.

Table 1 Perceived impacts of blockchain on SCM from existing literature

Perceived Blockchain Impact on SCM	Author(s)
Improved provenance verification and traceability of goods: In most current enterprise SCM solutions, up-to-date data about the status of goods is available from a single stakeholder (e.g. the transporter during the distribution stage or the warehouse for inventory amounts). Additionally, it is typically difficult for retailers and consumers alike to verify the origin of products or their ingredients. Blockchain-based SCMS can potentially reduce the fragmentation of this data and break their silos by providing the technical infrastructure needed to achieve universal access to live shipment tracking data and data about product origins at any given time by every member in the supply chain (including end users), thus greatly improving the traceability of goods. *Blockchain feature(s) in use:* Distributed ledgers; immutability	(Abeyratne & Monfared, 2016) (Tian, 2016) (Lützenburg, 2017) (Omran, Henke, Heines, & Hofmann, 2017) (Toyoda, Mathiopoulos, Sasase, & Ohtsuki, 2017) (Wu, et al., 2017) (Barghuthi, Mohamed, & Said, 2018) (Dobrovnik, Herold, Fürst, & Kummer, 2018) (Francisco & Swanson, 2018) (Hatiskar & Archana, 2018) (Kim & Laskowski, 2018) (Petersson & Baur, 2018) (Tian, 2018) (Verhoeven, Sinn, & Herden, 2018) (Chang, Chen, & Lu, 2019) (Kamble, Gunasekaran, & Arha, 2019) (Montecchi, Plangger, & Etter, 2019) (Olsen, Borit, & Syed, 2019) (Queiroz & Wamba, 2019) (Saberi, Kouhizadeh, Sarkis, & Shen, 2019)
Reduced number of intermediaries and third parties: One of the key motives behind the invention of blockchain was to eliminate the "middlemen" and trusted authorities that are required in many business operations (e.g. trade finance). The decentralised nature of blockchain provides grounds for replacing trusted intermediaries with a "trustless" model where, e.g. one party is able to use a distributed ledger to verify and transfer ownership of assets to another	(Abeyratne & Monfared, 2016) (Apte & Petrovsky, 2016) (Tian, 2016) (Gregorio & Nustad, 2017) (Nakasumi, 2017) (Omran, Henke, Heines, & Hofmann, 2017) (Casado-Vara, Prieto, Prieta, & Corchado, 2018) (Dobrovnik, Herold, Fürst, & Kummer, 2018)

Perceived Blockchain Impact on SCM	Author(s)
party that has access to an update-to-date replica of the same ledger. This reduces friction across business processes by removing the need for a central intermediary to maintain the ledger, register transaction data, and guarantee and settle the transaction. Moreover, if participating members choose to handle payments via blockchain-based cryptocurrencies, then they can also bypass the need to route payments through traditional third parties, i.e. banks. *Blockchain feature(s) in use:* Distributed ledgers; immutability; smart contracts	(Petersson & Baur, 2018) (Kamble, Gunasekaran, & Arha, 2019) (Queiroz & Wamba, 2019)
Lower transaction costs: The higher the number of intermediaries in a supply chain, the higher the cost of conducting business operations becomes. Moreover, when supply chain parties transact in different currencies, it leads to increases in transaction costs due to currency exchange fees levied by clearing houses. With blockchain, those additional costs can be lowered or eliminated due to reliance on a decentralised system with a distributed ledger instead of a single authority. Likewise, trade finance costs collected by banks can be reduced if transacting parties use cryptocurrencies to pay each other rather than fiat money. Lastly, costs of maintaining inventory could be reduced if distributed ledgers are used as the “single source of truth” when, e.g. assessing the need for more stock. *Blockchain feature(s) in use:* Distributed ledgers; smart contracts; cryptocurrencies	(Abeyratne & Monfared, 2016) (Gregorio & Nustad, 2017) (Omran, Henke, Heines, & Hofmann, 2017) (Barghuthi, Mohamed, & Said, 2018) (Dobrovnik, Herold, Fürst, & Kummer, 2018) (Jabbari & Kaminsky, 2018) (Petersson & Baur, 2018) (Chang, Chen, & Lu, 2019) (Mavale & Bhosale, 2019) (Min, 2019) (Olsen, Borit, & Syed, 2019) (Queiroz & Wamba, 2019) (Saberi, Kouhizadeh, Sarkis, & Shen, 2019)

Perceived Blockchain Impact on SCM	Author(s)
Increased efficiency through data sharing and automation: By automating routine tasks that are usually done by humans, blockchain can make organisations with supply chain operations more efficient by reducing their administrative workload and allowing them to focus on their core business functions. As an example, distributed ledgers can reduce the amount of back-and-forth communication that happens between supply chain parties to enquire about the status of shipments, inventory, etc. That is because all supply chain data would be stored in a ledger that all parties have access to and where all data is always up to date and immutable to modifications. Moreover, by using smart contracts, all terms and conditions of a contract are automatically executed, thus removing a good chunk of the manual work that is usually carried out to uphold a contract's rules. *Blockchain feature(s) in use:* Distributed ledgers; smart contracts; consensus algorithms	(Tian, 2016) (Chen, et al., 2017) (Lützenburg, 2017) (Nakasumi, 2017) (Omran, Henke, Heines, & Hofmann, 2017) (Barghuthi, Mohamed, & Said, 2018) (Casado-Vara, Prieto, Prieta, & Corchado, 2018) (Dobrovnik, Herold, Fürst, & Kummer, 2018) (Hatiskar & Archana, 2018) (Jabbari & Kaminsky, 2018) (Petersson & Baur, 2018) (Tian, 2018) (Kamble, Gunasekaran, & Arha, 2019) (Mavale & Bhosale, 2019) (Min, 2019) (Queiroz & Wamba, 2019) (Saberi, Kouhizadeh, Sarkis, & Shen, 2019)

2.3.2 *Existing blockchain uses in SCM*

Despite the new and developing state of blockchain, that did not prevent some companies from embracing it in their supply chain activities. In addition to the case mentioned in the introduction chapter about the Walmart–IBM collaboration, a research conducted by Verhoeven, Sinn, and Herden (2018) has listed several company cases that use blockchain in SCM. One such example is China-based company 300Cubits, which uses smart contracts to tokenise shipping agreements between customers and container lines to reduce the amount of container booking cancellations. Another example is Bext360, which is developing a blockchain-based system to trace and monitor the supply chains of coffee beans with a focus on improving the conditions for farmers to ensure fair compensations.

In the following subchapters, two selected use cases are examined in detail to look at existing examples of blockchain integration in SCMS that are moderately mature. The main sources from which the information about Case I and Case II were collected are Verhoeven, Sinn, and Herden (2018); Heutger and Kückelhaus (2018); and Mavale and Bhosale (2019). Additionally, official websites of both projects and other online sources, press releases, and media reports were used and are cited accordingly.

2.3.2.1 ***Case I: SmartLog by Kouvola Innovation***

According to the project's official website, SmartLog is a proof-of-concept platform built on blockchain that aims to facilitate and improve the reliability and speed of information flow among members of the same supply chain. This is done to increase the efficiency of supply chain operations and to reduce the amount of time it takes to transport goods from point A to point B. The SmartLog project is a collaboration between several industry partners, with the project lead being Kouvola Innovation—an agency owned by the Finnish government. Other partners of the project include (SmartLog, 2016):

- Region Örebro county, Sweden
- Transport and Telecommunication Institute, Latvia
- Valga County Development Agency, Estonia
- Sensei LCC, Estonia
- Tallinn University of Technology, Estonia

Additionally, Kouvola Innovation is collaborating with IBM on grounds of mutual interest to further develop the SmartLog project while IBM benefits by improving its products due to the onboarding of larger users on its blockchain platform (Naumoff, 2017). The main focus of SmartLog is to reduce cargo transport times in two European transport network "corridors" as identified by the European Commission: The Scandinavian–Mediterranean corridor, and the North Sea–Baltic corridor (Holmström, 2018). The European Union has funded the SmartLog project with a €2,4m grant over a three-year period starting from 2016 until 2019 (Castillo, 2016).

SmartLog attempts to address a central problem of supply chains, i.e. the lack of efficient communication and data flow between supply chain members. The creators of SmartLog describe the current situation of communication channels in supply chains as fragmented in silos within each organisation, thereby preventing partner organisations from accessing the same info. In addition, information is often times fragmented inside the same organisation, i.e. communication taking place over a multitude of tools (emails, phone calls, text messages, internal ERP systems, etc.) which creates redundancies and further separates supply chain partners from having access to a shared, unified source for all the relevant information they need. (Lammi, 2018).

The creators of SmartLog are aiming to make their solution an open industry standard rather than being a proprietary product for commercial gains. The underlying technology of SmartLog is set to be developed as a unified communication platform that connects to the companies' ERP systems to collect information and status updates about in-transit cargo shipments and store them into a blockchain, effectively making live data accessible to all authorised companies. The process of data gathering is done by the participating companies as well as via the blockchain itself.

SmartLog uses the open source framework Hyperledger Fabric as its blockchain technical infrastructure. Hyperledger Fabric helps SmartLog allow participating companies to connect their existing enterprise software to the platform and gain access to relevant information, assuming their software supports the Universal Business Language (UBL) standard (Sutton, 2018). Figure 9 below illustrates the concept of SmartLog.

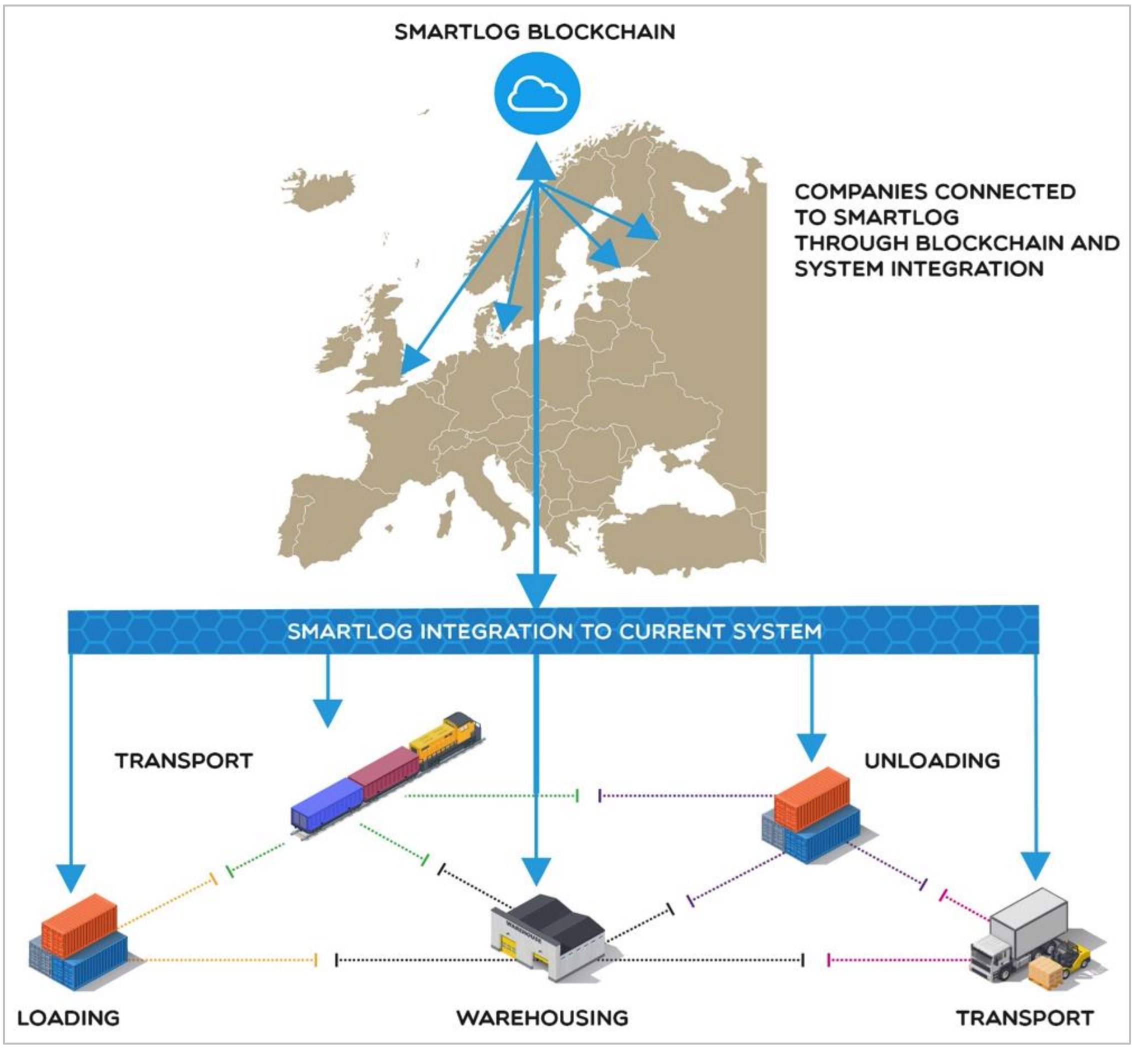

Figure 9 Concept of SmartLog project (Lammi, 2018)

As for the challenges of SmartLog, Verhoeven, Sinn, and Herden (2018, pp. 13–14) have posited a couple of shortcomings of the project after studying it. One shortcoming was an apparent inconsistency when it comes to applying SmartLog as a global standard when its current focus is primarily regional. Additionally, the authors have discussed the disconnect between the aim to consolidate all important supply chain information in one place and the project's reliance on voluntary participation of companies as the primary source of data. This means that companies would eventually need to actively use SmartLog as their go-to solution for supply chain communication, yet the project does not currently offer or describe any incentive for companies to take this decision. Moreover, the authors have noted that the need to use a blockchain distributed ledger instead of a traditional database was not directly justified by the available information about SmartLog. From Kouvola Innovation's point of view, one of the biggest implementation challenges for SmartLog is ensuring that the exact information is securely delivered to participants that need it without creating a mess of information flow due to data being fed to the system from multiple sources (Naumoff, 2017).

2.3.2.2 ***Case II: TradeLens by Maersk and IBM***

According to its official website, TradeLens is an open and neutral platform that aims to digitalise the global trade industry by removing inefficiencies and connecting all ecosystem partners of global supply chains. The project is developed by American IT firm IBM and Danish shipping and logistics giant Maersk. Previously known as Global Trade Digitization, the project first started development in 2016 and was officially launched as TradeLens two years later in August 2018 as a joint endeavour by the two companies to "help set trade free". Users of TradeLens represent shipping companies, customs authorities, inland carriers, port operators, and other members of the shipping and logistics business. TradeLens claims to have over 100 members across six continents on its platform. (TradeLens, 2019). According to a company presentation, TradeLens has the following partners on the platform as of November 2018 (World Trade Organization, 2018):

- 43 ports, terminals, and operators
- 4 shipping lines
- 8 government authorities
- 3 inland providers

Legally speaking, TradeLens is set up as a joint venture where Maersk owns 51% of the company while IBM owns the remaining 49% (Hackett, 2018). When TradeLens was first conceived, IBM and Maersk identified a set of problems in the supply chain industry that were the backbone of what the joint project was trying to solve, namely:

- Fragmentation of data
- Time-consuming processes
- Delays in customs clearance
- Complexity and cost of operations

All the above challenges were experienced by various companies that engage in one or more activity related to SCM, which drove the idea behind the TradeLens platform to mature. When it first launched, TradeLens introduced its proposed solution to those problems by promising to connect all ecosystem partners, facilitate information sharing, and foster collaboration and trust through, e.g., digitising customs declaration forms—which is believed to cut down approximately US$1,8 trillion in global costs annually (Hardjono, 2018, p. 34). In Figure 10 below, there is an example screenshot of one part of TradeLens' user interface where users can manage all forms related to a single shipment in one place, which is one of TradeLens' key features.

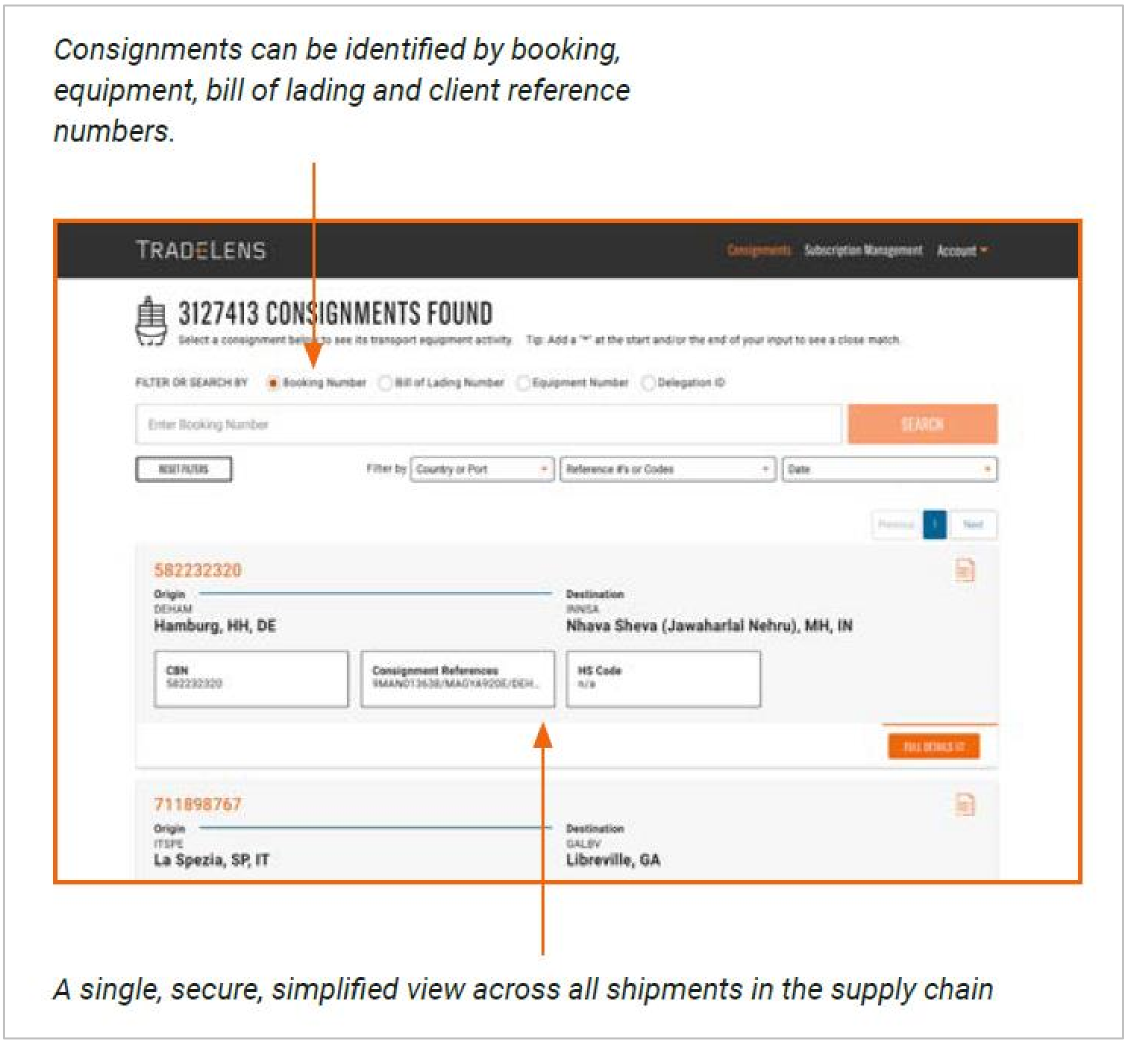

Figure 10 Screenshot of Shipment Manager screen in TradeLens

Technically speaking, TradeLens can be described as having three components: 1) the blockchain where all transactions and shipment activities are recorded; 2) the application programming interface (API) that companies can use to connect to the platform and build new applications on top of it; and 3) the set of standards that enable the sharing of information among partners (Miller, 2018). In parallel, on most of its official marketing material and communication channels, TradeLens presents itself as a solution that is built around three primary pillars (World Trade Organization, 2018; TradeLens, 2019):

- *Ecosystem:* The diverse network of partners that feed data into the platform by sharing relevant information about shipments throughout the whole supply chain journey. This includes shippers, authorities, terminals, etc.
- *Platform:* The technology that brings the solution into existence. The platform is built on the Hyperledger Fabric framework and is powered by IBM's cloud computing capabilities. Partners can access the platform via open APIs.
- *Application and Services Marketplace:* To create more value and advance innovation, third-party IT suppliers can build and publish extra components atop the TradeLens platform that other users can benefit from.

Even though TradeLens as a product is fairly mature and well-polished compared to other blockchain solutions, most of the available information about TradeLens was only found through the project's official channels or via news reports (which are prone to bias and exaggerations). Therefore, there is no sufficient impartial data to verify the feasibility of implementing TradeLens and the extent to which it benefited (or not) its users. Since the system is still new, it is likely that it would take a few more years before it becomes clearer whether it has provided tangible benefits for its users.

3 RESEARCH DESIGN AND METHODOLOGY

3.1 Approach to designing the study

Research design can be defined as a set of techniques and methods used to conduct a certain research by combining all parts of the research work and analysing them in a way that efficiently addresses the research topic and attempts to answer the research question(s) (Creswell, 2014). In other words, it is a complete roadmap of how the research project is conducted from start to finish, including collecting and analysing data, drawing conclusions, and discussing the findings at the end. In addition, research design addresses the approach used for the application of chosen theoretical frameworks in the research process. The planning and preparation of such roadmap prior to executing the research helps in evaluating the feasibility and applicability of different parts of the research before the work starts, thus giving the researchers useful insight to make more informed decisions regarding the selection of research methods, theoretical frameworks, amount of data needed, and other research aspects.

This research is exploratory in nature and its purpose is to develop a more comprehensive understanding of the major challenges that face enterprises regarding the adoption of blockchain in SCMS. Saunders, Lewis, and Thornhill (2009), based on the work of Robson[1], consider exploratory research as a useful way to find out "what is happening; to seek new insights; to ask questions and to assess phenomena in a new light" (p. 139). Exploratory research—especially in the form of open-ended interviews—allows for more flexibility to form conclusions based on findings from new empirical data, which means less reliance on extracting new findings from existing literature that deal with the same research problem (Fisher & Buglear, 2010, pp. 182–183). Moreover, to realise this exploratory collection of empirical data, this research relied on semi-structured interviews as a primary method for data collection, since they offered flexibility and balance between sticking to the boundaries of the thematic questions while at the same time giving interviewees the possibility to expand on their answers and share as much information as they want without diverging from the main topic (Saunders, Lewis, & Thornhill, 2009, p. 320).

Conducting exploratory research can be accomplished through either: 1) a literature review; 2) interviews with experts on the topic; or 3) using focus groups (Saunders, Lewis, & Thornhill, 2009). This research makes use of the first two methods as they are the most suitable in terms of applicability and resource efficiency. Carrying out focus group was unfitting in this case considering the limited amount of time reserved for this

[1] Robson, C. (2002). *Real world research: A resource for social scientists and practitioner-researchers* (2nd ed.). Oxford, UK: Blackwell Publishing.

research in addition to the difficulty of coordinating a focus group with all subjects of interest in a timely and efficient manner.

Building upon existing and prior work, this research considered recommendations for further research that were put forward by preceding authors regarding which areas should future researchers improve and focus on. For example, Petersson and Baur (2018) have concluded their research by recommending that more focus be put into interviewing IT consultancy firms to know their perspectives on the perceived challenges of blockchain adoption in SCM. This is because the authors have argued that input from IT consultancy firms would be of noteworthy value since these firms are consulted by many organisations of different sizes, thus giving consultancy firms a more comprehensive understanding of the difficulties surrounding blockchain adoption from the standpoints of multiple and diverse companies rather than a one-sided view.

To design this research accordingly, the type of data that was prioritised during the collection phase was the thoughts expressed by the representatives of interviewed companies about: a) the reasons and concerns, if any, that make their organisations sceptical of adopting blockchain in SCMS; and b) any practical implementation issues their organisations might have faced when/if they have attempted to integrate blockchain solutions in their supply chain workflow. Accordingly, the combination of the perceived vs. actual challenges painted a contrasting picture and allowed for better matching of hypothetical concerns with substantiated problems. Afterwards, the data collected from interviews was analysed to identify patterns then classified under thematic categories to combine an inclusive list of the most prominent adoption challenges of blockchain-based SCMS. The analytical approach to achieve this outcome was deductive because the empirical data was analysed using a theoretical framework that was developed for this study based on and influenced by other recognised theoretical frameworks. This theoretical framework allowed data collection to commence with a fixed set of classifications and it guided the data analysis process to determine which empirical data was assigned under each classification. The conceptualisation and breakdown of this theoretical framework is further elaborated in the following subchapters.

3.2 Research methods

Prior to initiating a research project on any given topic, researchers need to decide on a feasible strategy and to choose the most suitable methods to conduct their research based on the objectives as well as the question of the research (Saunders, Lewis, & Thornhill, 2009, p. 137). Researchers usually base their decisions on which research methods to select for their projects according to a range of criteria such as the research theme, timeline restrictions, type of empirical data needed, available resources, etc. According to

Björklund and Paulsson (2014), a researcher's available resources should be maximised in a way that guarantees the creation of as much knowledge as possible when choosing which research method to apply. There are two approaches to conducting research: Either in an open, exploratory way; or in a pre-coded, structured way. All available research methods can be used to carry out either of these two approaches. For example, interviews can be unstructured and open-ended, or they can be scripted and follow a predefined list of questions. That is also true for other methods such as surveys, panels, observation, etc. (Fisher & Buglear, 2010, pp. 174–175).

There are multiple scientific methods of conducting research, the two most common of which being qualitative and quantitative. The biggest difference between the two methods is that a quantitative approach is mostly used for statistical or computational results while a qualitative one deals with non-measured data (Fisher & Buglear, 2010, pp. 71–72). Since this research on blockchain adoption challenges in SCMS aims to identify said challenges and present them together in a descriptive list, it hardly relies on any numerical input. Thus, a qualitative approach to data collection was the most appropriate choice in this case.

Because they are a prominent method of qualitative research (Kvale, 2008), interviews were the main source of data collection for this research, which is explained in more detail in the next chapter. Conducting interviews would be a proper course of action when attempting to classify problems that are vaguely defined and would help with understanding them better (Saunders, Lewis, & Thornhill, 2009, p. 318). Thus, interviews would help with collecting crucial empirical data from primary sources and documenting this data for future reference. Other reasons for choosing interviews to gather empirical data were that they provide a chance for deeper discussions on any given topic with participants, which consequently allows for extracting more meaningful data to analyse. Additionally, interviews are most helpful when there is a general lack of documented literature available on the research topic that studies the concepts and issues in depth, which is the case for the adoption of blockchain in SCMS considering the novelty of the topic.

3.3 Validity and reliability of the study

It is widely accepted that humans have intrinsic biases that are shaped by the environments they live in, the sources from which they consume information, the people they often interact with, among other factors (see, for example, Hammersley & Gomm, 1997; Saunders, Lewis, & Thornhill, 2009). Those biases are likely to manifest themselves in researchers' work when they collect data, interpret results, and draw conclusions. Thus, it is necessary for researchers to acknowledge this vulnerability and to employ measures in their research that aim at reducing the effects of personal preconceptions to a minimum and to critique their own interpretations and accounts of the results. Authors such as Creswell (2014), Fisher and Buglear (2010), and Björklund and Paulsson (2014) have all addressed several areas where researchers must work to ensure the validity, reliability, credibility, and applicability of different parts of their research, including during tasks such as reviewing previous literature, collecting the needed data. analysing and presenting the findings, etc. In the following subchapters, there is a detailed explanation of how this research was designed to account for validity by drawing on ideas and recommendations from the above-mentioned authors throughout three main research phases: 1) reviewing the literature; 2) collecting empirical data; and 3) analysing and presenting the findings.

3.3.1 *Selecting literature sources*

To supplement the empirical data that was collected, a good amount of literature from all interdisciplinary topics of this research was sourced, studied, analysed, and summarised in the literature review chapter. The literary work was obtained through several channels, both online and offline. Major scientific search engines and academic databases were used to look up credible papers that were relevant for this research. Some of these services included the likes of Web of Science, ResearchGate, EBSCO, Google Scholar, Microsoft Academic, and ScienceDirect. The form of acquired literature ranged from journal articles and conference proceedings to articles in periodicals and other publications.

However, even though the emphasis for the literature research was on finding quality scientific/academic peer-reviewed papers, in some situations it was inevitable to resort to material from the so-called “grey literature” such as white papers, industry reports, etc. to find the needed information. This was mainly due to the novelty and contemporary relevance of the research in addition to the rapid development of a field such as blockchain, which renders some academic sources (e.g. journal articles) a bit outdated by the time they get published. Nevertheless, those less-scientific sources were used primarily to present facts and information such as their authors’ opinions, dates, numbers, statistics, etc. whenever they were deemed relevant.

3.3.2 *Collecting empirical data*

In this research, several measures were implemented to guarantee a reliable and credible outcome as much as scientifically possible within the available resources. Firstly, when it comes to external validity, the sample of selected interviewees, despite not being a big one, was chosen from among varying industries to produce output that is as generalisable as possible for different sectors. Interviewing companies that work in a similar industry or ones that are similar to each other would limit the generalisability of the results in several ways, since the research is intended to be industry-agnostic and applicable for any enterprise that participates in a supply chain. Moreover, the interviewed companies represented different profiles in terms of size, age, and level of involvement with blockchain, in addition to interviewees being from two distinct groups in terms of relationship to blockchain: IT users and IT suppliers. An acknowledgment to be made here is that the interviewee sample is still not as comprehensively representative as it could have ideally been. Due to a small sample, companies with much diverse backgrounds were not accounted for including ones with diverse industries, geographical locations, etc.

3.3.3 *Analysing and presenting findings*

Triangulating research results and findings means that a researcher can adopt several methods to confirm that their research outcome is credible. For instance, by conducting a survey then after a certain period of time following up with interviews with the same respondents to assess whether the accounts that were formed in the first round (i.e. the surveys) corroborate with the revelations from the second round (i.e. the interviews). Such validity checks would span several angles of the research, from internal credibility assessment to external testing that assures the research outcome is applicable across diverse population segments and not only for the researcher's own selected sample. (Fisher & Buglear, 2010)

The full range of findings from this research were disclosed in the analysis part, including unfavourable outcome or results that do not match the expectations, as recommended by Creswell (2014). Furthermore, while presenting the findings of this research, my own interpretations from the data were made visible as such wherever possible, in order to allow the reader to draw their own conclusions and to independently understand the presented material without the assumption that the results are the definitive truth. This self-reflective critique approach attempts to uphold ethical aspects of research by giving other researchers the tools to replicate the study on their own and the possibility to arrive at different interpreted end results. However, it should be noted that due to the noticeable speed at which research on blockchain applications is progressing, it could prove unreasonable for researchers to reproduce this study within a short period of time (e.g. nine months) because many parts of this research had to be updated multiple times throughout the study duration owing to rapid changes in the industry.

3.4 Theoretical background and frameworks

To determine the most suitable theoretical framework that can be applied in this research, a background study was conducted on several theories and frameworks that deal with adoption within the field of information systems and related disciplines. There are several theoretical frameworks that have been developed over the years by different authors, many of which share a common ground in trying to understand the factors that affect the adoption and diffusion of technological innovations among people and organisations, which is the thematic focus of this study. The most prominent of these theories and frameworks, in chronological order starting from first inception, include:

- 1962, Diffusion of Innovations (DoI)
- 1976, Theory of Reasoned Action (TRA)
- 1986, Technology Acceptance Model (TAM)
- 1990, Technology-Organisation-Environment (TOE)
- 1991, Theory of Planned Behaviour (TPB)
- 2003, Unified Theory of Acceptance and Use of Technology (UTAUT)

In the following subchapters, the top three theoretical frameworks that proved most relevant for this research (TAM, DoI, and TOE) are examined in more detail. Table 2 lists some of the basic facts of each theoretical framework and their focus domains of applicability, i.e. whether the theoretical framework can be applied to understand adoption determinants among individuals, organisations, or both. As this research has a clear focus on organisational adoption of technology, DoI and TOE theories had a leading advantage for selection and TOE was eventually used as a foundation for constructing an adapted theoretical framework, which is explained further in this chapter.

Table 2 Comparison of prominent adoption theories and frameworks

Theory	Discipline	Scope of Applicability		Author(s)
		Individuals	Firms	
DoI	Sociology	✓	✓	(Rogers, 1962; 1983)
TRA	Social Psychology	✓		(Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980)
TAM	Information Systems	✓		(Davis, 1986; 1989; Davis, Bagozzi, & Warshaw, 1989)
TOE	Information Systems		✓	(Tornatzky, Fleischer, & Chakrabarti, 1990)
TPB	Psychosociology	✓		(Ajzen, 1985; 1991)
UTAUT	Information Systems	✓		(Venkatesh, Morris, Davis, & Davis, 2003)

3.4.1 *TAM: Technology Acceptance Model*

Perhaps one of the most studied and applied theoretical frameworks in information systems research is the TAM, first introduced by Davis (1986), which itself is adapted from the TRA. The TAM has received several core updates in the years that followed in the form of a second revision (TAM2); as the unified theory of acceptance and use of technology (UTAUT); and as a third revision (TAM3); all of which were published by Venkatesh and Davis (2000); Venkatesh, Morris, Davis, and Davis (2003); and Venkatesh and Bala (2008) respectively.

The original TAM, as seen in Figure 11, defines a couple of key constructs that contribute to the adoption of innovative technologies by users, i.e. the perceived ease of use and the perceived usefulness of a technology. According to Davis, Bagozzi, and Warshaw (1989), these two constructs indicate whether a user is willing to use a new system, which is largely based on whether said user perceives the system as being easy to use and useful. TAM has been widely applied to study and understand the adoption of technological innovations by users in a variety of consumer products because the model looks at adoption from an individual's point of view, as opposed to from an organisational level.

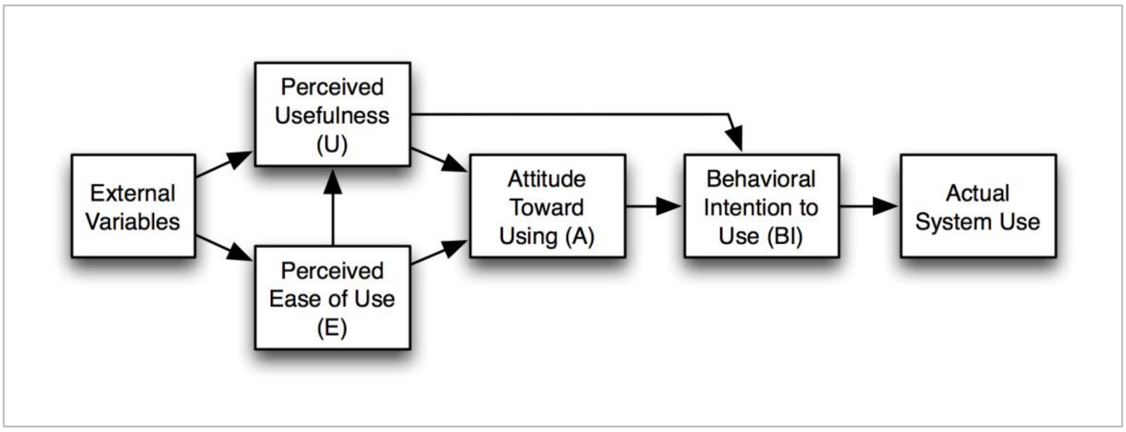

Figure 11 TAM, first version (Davis, Bagozzi, & Warshaw, 1989)

TAM has received some criticism from different researchers, such as Bashange (2015) who argues that the model does not cater for user demographics such as age, education level, etc. In addition, Maruping, Bala, Venkatesh, and Brown (2017) made a case that the use of the behavioural intention construct should be replaced with behavioural expectation, arguing that users can usually be influenced by colleagues, friends, and family to adopt new systems. Moreover, Ajibade (2018) presents a modified version of TAM, labelled Technology Acceptance and Use Model (TAUM), arguing that the original model was not created with the organisational use in mind, thus possibly resulting in misleading findings if applied to study organisational adoption of new technology.

TAM is therefore deemed to be useful to a good extent in understanding some aspects of this research, but is not the best model to apply because this research is studying the adoption of a new technology (blockchain) in an organisational context, rather than solely among individual users.

3.4.2 ***DoI: Diffusion of Innovations theory and model***

The DoI theory first emerged in the early 1960s when Everett Rogers posited it in his book of the same name *Diffusion of Innovation.* The motive behind the creation of the theory was to study and understand the process of acceptance and adoption of new innovations among diverse groups of people within different fields including, inter alia, technology. In his book, Rogers (1962) defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (p. 5). This definition lays out the four core elements of diffusion as explained by Rogers, namely: 1) innovation; 2) communication channels; 3) time; and 4) social system. That means the DoI theory can be applied to understand innovation adoption in areas that are not exclusively related to technological inventions and can encompass wider ranges of diffusion of innovative ideas in societies. (Rogers, 1962).

One of the fundamental concepts of DoI theory is the adopters, who are grouped under distinct categories pertaining to their speed of adoption of an innovation. The illustration of the DoI theory as presented in Figure 12 shows these adopter groups and their percentages of the total population throughout the diffusion timeline of an innovation.

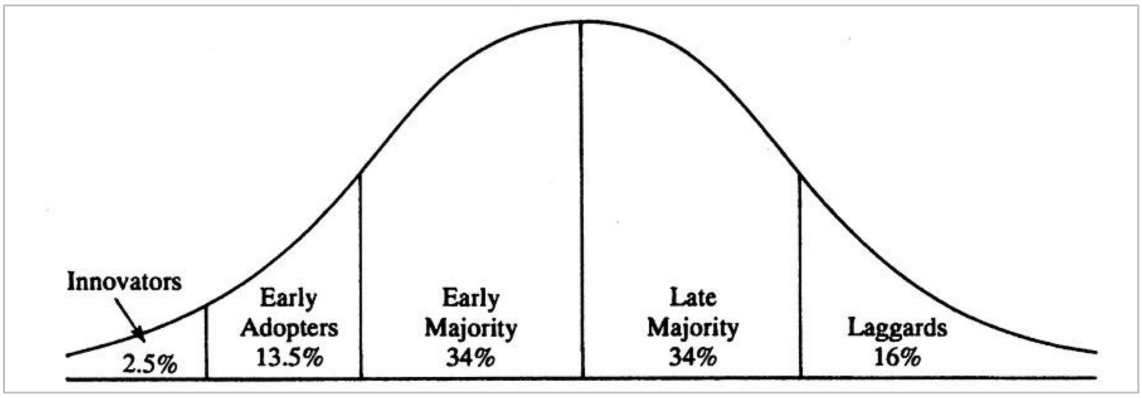

Figure 12 DoI theory's adopter groups (Rogers, 1962)

In brief, Rogers (1962) describes adopter groups as follows: The first and most eager group of people to adopt an innovation are labelled *innovators* (2.5% of total population), i.e. the people who are willing to take risks and test new innovations regardless of the success prospects of said innovations. These *innovators* typically possess financial capacity to alleviate the risks that might come from adoption of an innovation that ends up failing. Second in line are the *early adopters* (13.5% of total population), who are slightly reserved in adopting innovation when compared to *innovators* but are more open to adoption than the rest of the groups described in this theory. They are perceived to have higher social status and financial stability in addition to advanced education, which altogether allow them to choose more freely which innovation to adopt. Thirdly, the *early majority* (34% of total population) come after the *early adopters* in accepting an innovation, with their adoption phase taking place over a period that varies in length. The *early majority* are thought to be of a social status that is above average and some of them hold positions of opinion leadership. Afterwards, there are the *late majority* (34% of total population) who are more sceptical of innovation than the three groups before them. They tend to have below average social status and limited financial resources, and they often adopt innovations only after most of the society has adopted them. Together, the *early majority* and *late majority* make up the largest portion of society (68% of total population). Lastly, the so-called *laggards* (16% of total population) are usually the last group to adopt an innovation. They have low social and financial standings and are risk averse. Age-wise, they tend to be the oldest among all the groups and they have small social circles of only close friends and family. (Rogers, 1962).

Even though the DoI theory first became known to the public in the 1960s, several editions of the original DoI book of Rogers have followed over time, building upon and expanding the theory, with the latest edition being the fifth one, published in 2003. However, that did not prevent DoI theory from receiving a fair share of critical reviews by other researchers. For example, despite the second edition of the DoI book by Rogers and Shoemaker (1971) bearing the updated title of *Communication of Innovations: A Cross-Cultural Approach,* Goss (1979) has brought up the debate on cross-cultural consequences that stem from applying DoI theory in different countries, mentioning that the application of DoI theory in underdeveloped nations has received critical views compared to developed nations. As a rule of thumb, cultural differences always need to be accounted for in scientific research, because what proves applicable in one country might not necessarily be possible to replicate with equivalent results in other countries. Additionally, Downs and Mohr (1976) have criticised the categorisation of adopters into the five groups discussed above, arguing that any person has the potential to be an *innovator*, given that innovations are judged within the context of an organisation in which such innovations are supposed to be implemented. However, this argument would be relevant in scenarios of organisations that have mandated innovation; it does not hold much substance in the context of innovation adoption in society.

The DoI theory offers a general, wide-ranging outline "of how individuals, groups or organizations adopt and diffuse technologies" (Miranda, Farias, Schwartz, & Almeida, 2016, p. 48), which gives a decent overview to study how distinct groups of people within an organisation react to the introduction of an innovative technology—in this case, blockchain. Every organisation is made up of people, in addition to other elements that are unique to the organisation such as its geographical location, culture, governing laws and regulations, etc. For this research however, the DoI theory does not cater for all the dynamics and factors that affect the organisation itself as an entity, as opposed to primarily covering the division of adopters into several groups of people. Therefore, this signals the need for a more comprehensive theoretical framework that is adequate for use in this research and that particularly applies to firms.

An extension of DoI theory goes further to address the organisational aspect of innovation adoption, where Rogers (1983) lays out a model (Figure 13) that demonstrates the variables that specifically affect the diffusion at firm level. Some attributes of this model influenced the proposed theoretical framework that was used for this research.

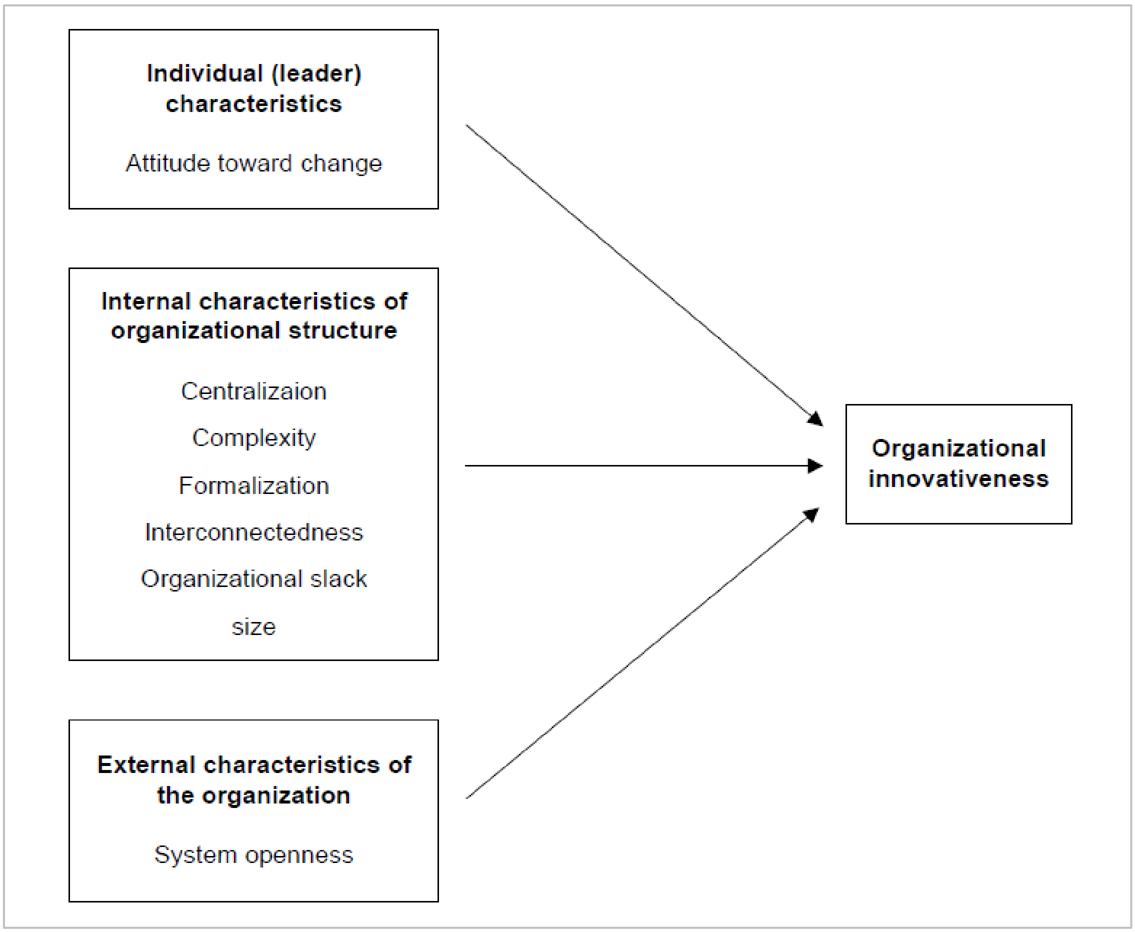

Figure 13 DoI model at firm level (Rogers, 1983)

3.4.3 *TOE: Technology-Organisation-Environment framework*

Since it was first conceived in the 1990's book *The Processes of Technological Innovation* by authors Tornatzky, Fleischer, and Chakrabarti, the TOE framework has been empirically tested and applied in different research papers across various disciplines. Examples include the works of Kuan and Chau (2001) who have investigated electronic data interchange (EDI) adoption in small businesses; Zhu, Kraemer, and Xu (2003) who have explored electronic business adoption; Lin (2014) on the adoption of electronic SCMS; Pan and Jang (2008) who have studied ERP adoption; Wang, Li, Li, and Zhang (2016) who have researched mobile reservation adoption among hotels; etc.

As seen in Figure 14, the TOE framework underpins three fundamental contexts that play an essential role in an organisation's decision-making process when it is adopting modern technologies. These three contexts are *technology*, *organisation*, and *environment*, with each context containing several variables.

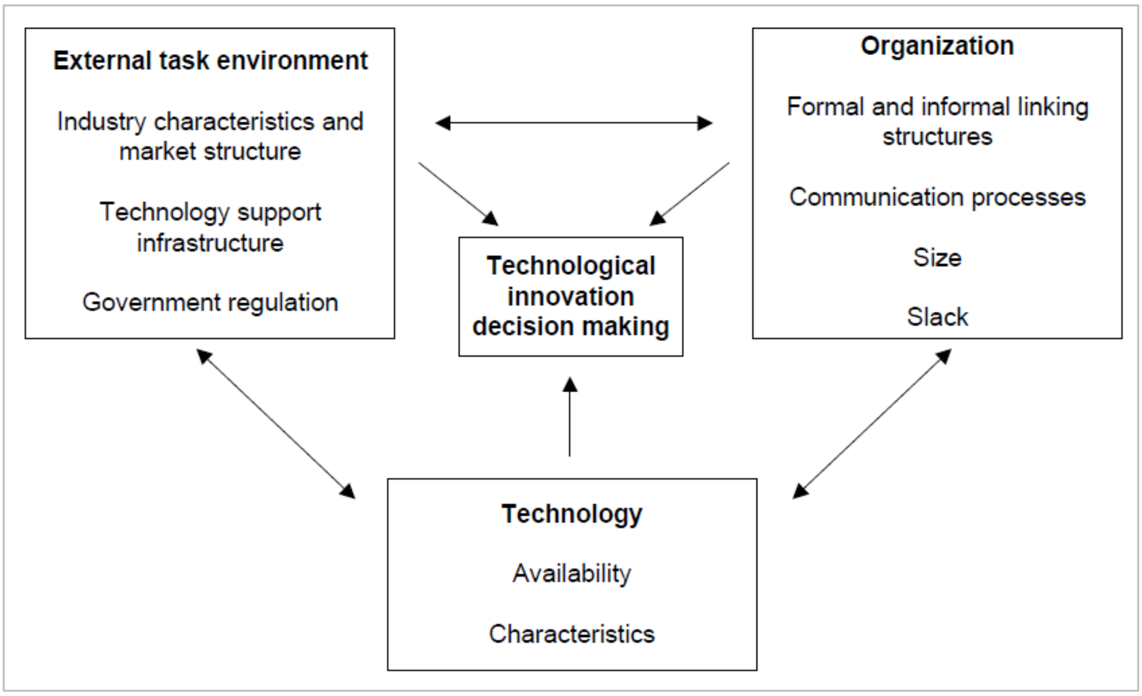

Figure 14 TOE framework (Tornatzky, Fleischer, & Chakrabarti, 1990)

To briefly examine these contexts of TOE framework: Firstly, the *technology* context includes all technologies that are used by the organisation as well as other relevant technologies (e.g. external), whether these others are used or not (Baker, 2012). Variables under this context relate to the technology's features and reception among organisational users such as the technology's compatibility, complexity, etc.

Secondly, the *organisation* context studies the different variables that affect an organisation from within, concerning its structure and composition because a firm's structure is a vital element affecting the likelihood of adopting modern technologies. For instance, Daft and Becker (1978) have noted that decentralised organisations are linked with adoption. As such, the *organisation* context includes variables such as the firm's size, operations, communication, etc. (Baker, 2012).

Lastly, the *environment* context covers all factors external to the firm that directly or indirectly affect its operations, including variables such as regulatory requirements, industry characteristics and competition, the presence (or lack) of technology support, and so forth (Baker, 2012).

These three aforementioned contexts of TOE framework have remained the same over the years and Baker (2012) have noted that the framework has not received major developments since its inception due to several reasons. Some of these reasons may be attributed to observations made by some researchers that TOE framework is comparable in many ways to other prominent models such as DoI. Additionally, as a result of its flexibility in terms of which variables to consider under each of its three contexts, the TOE framework has been considered as "generic" by Zhu and Kraemer (2005, p. 63), therefore not requiring a pressing need for further development since its variables can be freely adapted to each research study that it is being used in.

Compared to TAM and DoI, the TOE framework demonstrates more applicability for adoption scenarios that are specifically addressing organisations rather than individuals. In particular, the organisational context of the TOE framework examines multiple variables that are uniquely tied to the firm as an entity and are flexible enough to be adapted to varying realities of each tested organisation. Therefore, the TOE framework was the primary theoretical framework of choice that guided this research. And as a result, an adapted version of the framework was developed to answer the research question of this study, i.e. challenges of blockchain adoption in SCMS.

3.5 Constructing a theoretical framework

Based on the preceding investigation of major adoption theories and frameworks, both DoI and TOE proved to be viable tools to apply in this research. While the frameworks themselves are fairly established and have been empirically verified by multiple researchers, they are still not a "one-size-fits-all" solution, and in many scenarios there will arise a need for a case-by-case adaptation of each framework to suit the unique requirements of each study. In more advanced cases, it might even be considered critical to adopt more than one theoretical framework to fully address the research questions/hypotheses from all relevant angles. This approach was acknowledged by Oliveira and Martins (2011), who have conducted a comprehensive literature review of technology adoption frameworks that specifically addressed organisational adoption and concluded that: "[…] for more complex new technology adoption it is important to combine more than one theoretical model to achieve a better understanding of the IT adoption phenomenon" (p. 120). Therefore, considering that blockchain is new and complex in structure, in addition to the peculiarities of the SCM field, a theoretical framework (Figure 15) was developed for this research with influence and adaptations from both TOE and DoI frameworks. As illustrated, the proposed theoretical framework attempts to address adoption factors of notable influence that specifically cater for the requirements of this research, which TOE does not account for by default.

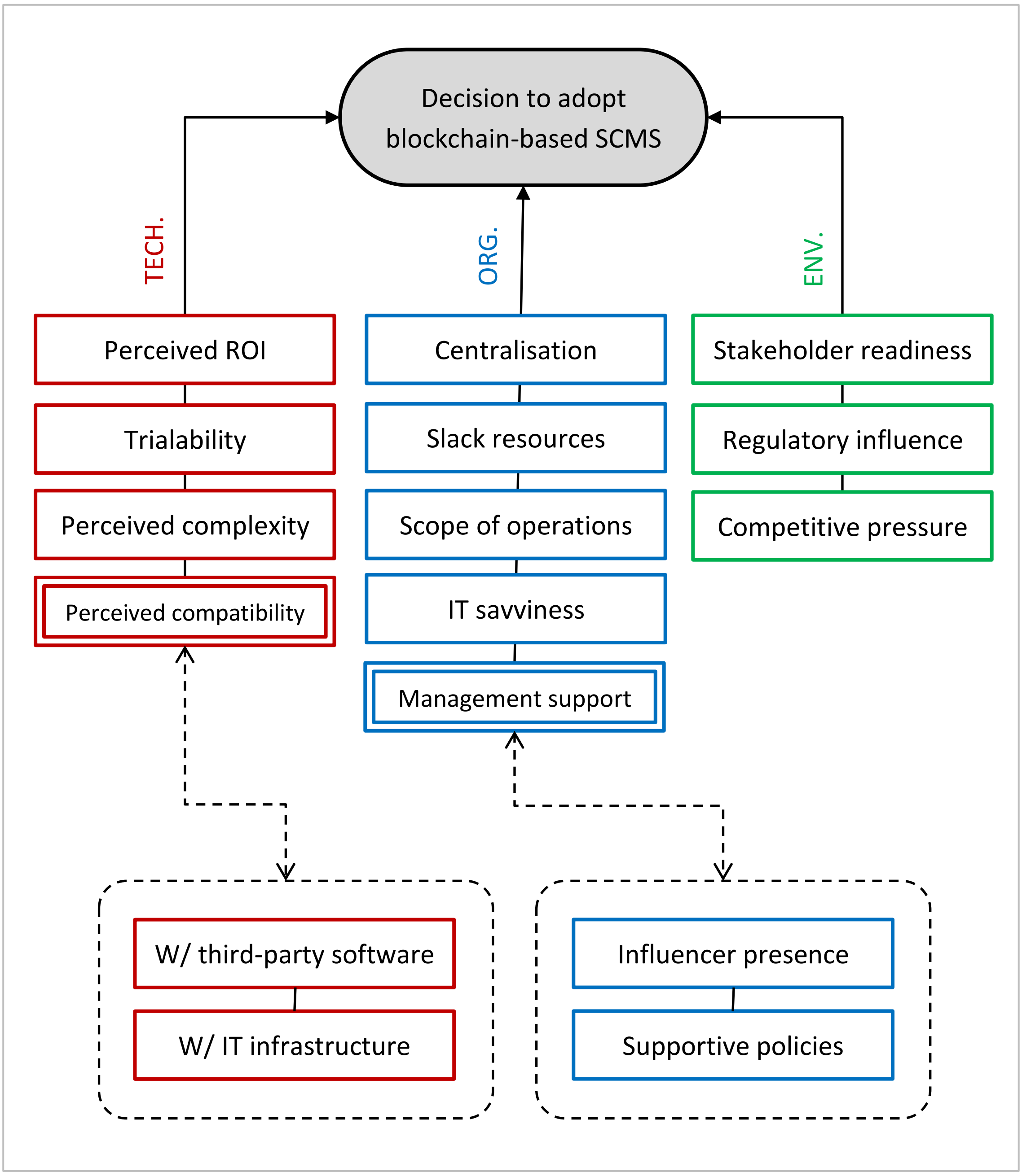

Figure 15 Proposed theoretical framework for blockchain adoption in SCMS

The variables of this theoretical framework were chosen based on findings from previous research that has studied innovation adoption in organisations. Several researchers have explored different sets of variables that affect the business decisions on whether to adopt/not adopt a technology and their discoveries have been empirically tested and challenged in the scientific community through numerous studies. These studies serve as grounds for some of the selection criteria that were used when constructing this proposed theoretical framework, and below are brief descriptions of the framework variables backed by respective studies.

- **Technology context** describes the factors that affect adoption from a technology point of view, including features of the new technology as well as features of existing technologies used in the firm. Variables under this context include:
    - *Perceived ROI:* This variable refers to the return on investment (ROI), i.e. the value and benefits that a company perceives it would gain by adopting a technology when weighed against the cost and resources invested on adopting this technology. Rogers (1983) reports that research has found that perceived advantage of an innovation has big influence on adoption. Likewise, many extant scholarly works have examined similar hypotheses suggesting that a technology's perceived ROI or relative advantage has an impact on adoption rate (Thong, 1999; Lin, 2014; Asare, Brashear-Alejandro, & Kang, 2016; Awa, Ukoha, & Emecheta, 2016; Wang, Li, Li, & Zhang, 2016). Thus, we can theorise that perceived ROI has a positive correlation with adoption likelihood.

      –The higher the perceived ROI of blockchain-based SCMS, the higher the likelihood of an organisation to adopt the technology.

    - *Trialability:* Rogers (1983) defines trialability as "the degree to which an innovation may be experimented with on a limited basis" (p. 243). In the case of SCMS, trialability refers to whether the organisation can test the new system to evaluate its value prior to forming a decision on adopting it. Studies by Al-Gahtani (2003); Ramdani, Kawalek, and Lorenzo (2009); as well as Asare, Brashear-Alejandro, and Kang (2016) have all suggested that the possibility to trial or test a system affects the rate of its adoption. Thus, we can theorise that trialability has a positive correlation with adoption likelihood.

      –The higher the level of trialability of blockchain-based SCMS, the higher the likelihood of an organisation to adopt the technology.

    - *Perceived complexity:* This is a variable that has garnered notable amount of research on its link to adoption. Perceived complexity as described by Rogers (1983) is "the degree to which an innovation is perceived as relatively difficult to understand and use" (p. 242). Researchers have found this variable to have important influence on adoption rates in firms of different sizes as more users tend to adopt technologies that are less complex (Thong, 1999; Al-Gahtani, 2003; Ramdani, Kawalek, & Lorenzo, 2009; Asare, Brashear-Alejandro, & Kang, 2016; Awa, Ukoha, & Emecheta, 2016). Thus, we can theorise that perceived complexity has a negative correlation with adoption likelihood.

      –The higher the perceived complexity of blockchain-based SCMS, the lower the likelihood of an organisation to adopt the technology.

- *Perceived compatibility:* In DoI theory, Rogers (1983) refers to this variable as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (p. 224). Perceived compatibility can cover several categories as described in the definition, and some researchers have further divided it into different variables to study. Within the context of this research, perceived compatibility refers solely to technical aspects and consists of two subfactors that evaluate the technology's compatibility with: 1) *third-party software* that the organisation already uses and 2) the *IT infrastructure* currently used by the organisation. In theory, a new technology might be compatible with the company's infrastructure in a way that makes it easy to deploy, but the same technology could turn out to be incompatible "out of the box" with other organisational software that the company perceive as essential to its operations. In existing literature, researchers have examined the perceived compatibility of a technology as an influencing factor of adoption with consistent affirmation of its influence (Grover, 1993; Thong, 1999; Grandon & Pearson, 2004; Asare, Brashear-Alejandro, & Kang, 2016; Wang, Li, Li, & Zhang, 2016). Thus, we can theorise that perceived compatibility has a positive correlation with adoption likelihood.

  –The higher the perceived compatibility of blockchain-based SCMS, the higher the likelihood of an organisation to adopt the technology.

- **Organisation context** describes the factors that affect adoption based on the unique reality of each organisation in terms of internal structure, employees, and resources, which varies from one organisation to another. Variables under this context include:
  - *Centralisation:* This variable concerns the internal structure of an organisation and the distribution of decision-making power within the firm. It is "the degree to which power and control in a system are concentrated in the hands of a relatively few individuals" (Rogers, 1983, p. 359). Baker (2012) describes decentralised firms as those characterised by having more autonomous teams and by being more fluid compared to centralised firms. Likewise, he notes the findings of researchers who have concluded that decentralised organisations are more likely to adopt innovations. Other studies that have also analysed the role of centralisation on adoption rate include Grover (1993) and Asare, Brashear-Alejandro, and Kang (2016). Thus, we can theorise that centralisation has a negative correlation with adoption likelihood.

    –The lower the level of centralisation in an organisation, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- *Slack resources:* Defined by Rogers (1983) as “the degree to which uncommitted resources are available to an organization” (p. 361), slack resources—especially financial slack—is sometimes mentioned synonymously with organisation size and it can be an indicator of adoption likelihood according to Baker (2012). Yet, Tornatzky, Fleischer, and Chakrabarti (1990) have argued that slack is “neither necessary nor sufficient for innovation to occur” (p. 161). Moreover, the distinction between slack resources and the generic *size* measurement should be emphasised because larger size is not always mutually inclusive with more slack resources. Even though research has demonstrated that larger organisations can be more likely to adopt technology (Zhu, Kraemer, & Xu, 2003), there is no substantial empirical evidence to back the claim that size is linked with innovation adoption (Baker, 2012). Measuring a firm’s size would also imply measuring several subfactors depending on the researcher’s interpretation of size, e.g. number of employees, revenue, geographical presence, etc. which makes the evaluation of slack resources instead of size a more concrete alternative. Thus, we can theorise that the amount of slack resources has a positive correlation with adoption likelihood.

  –The higher the amount of slack resources an organisation has, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- *Scope of operations:* Zhu, Kraemer, and Xu (2003) define the scope of operations as “the horizontal extent of a firm’s operations” (p. 254) and go further to explain the effect of scope of operations from three angles: internal coordination costs, external coordination costs, and synergy of e-business with traditional businesses. Two different studies, one by Zhu, Kraemer, and Xu (2003) and another by Awa, Ukoha, and Emecheta (2016), have both considered organisational scope of operations as a predictor for enterprise technology adoption, positing that firms with greater scope are more prospective adopters. Thus, we can theorise that scope of operations has a positive correlation with adoption likelihood.

  –The greater the scope of operations of an organisation, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- *IT savviness:* This variable can be defined as the degree to which an organisation is comfortable with emerging technologies and its openness to experimenting with such technologies. Based on DoI theory’s adopter groups as explained by Rogers (1962), early adopters of innovations tend to have characteristics that allow them to take risks and test new technologies without much prior regard to its success/failure prospects. Therefore, in the absence of conclusive research on the benefits of blockchain adoption in SCMS, and since blockchain is considered a novel technology and one that is still in early development, it can be argued that firms that adopt blockchain have a higher level of savviness towards IT innovations. Thus, we can theorise that IT savviness has a positive correlation with adoption likelihood.

–The higher the level of IT savviness in an organisation, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- *Management support:* Research has found that support from top management (typically CEOs and other senior decision makers) to be an adoption factor of significance effect in many cases (Ramdani, Kawalek, & Lorenzo, 2009; Grover, 1993; Lin, 2014; Wang, Li, Li, & Zhang, 2016; Asare, Brashear-Alejandro, & Kang, 2016). Furthermore, the advocacy of technology adoption by influencers/thought leaders within the organisation has been viewed as positively affecting adoption rates (Thong, 1999; Valente & Davis, 1999; Baker, 2012). In theory, an organisation can set up supportive policies for adoption to boost its employees' acceptance of modern technologies, but the absence of role models from top management who champion the initiatives and advocate for adoption can render those policies ineffective. Therefore, this variable was further broken down into two subfactors: 1) *influencer presence* and 2) *supportive policies.* That is to signify that management support has wide-reaching effects on adoption and that both subfactors go hand-in-hand regarding their influence on perceived management support. Thus, we can theorise that management support has a positive correlation with adoption likelihood.

–The higher the level of management support in an organisation, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- **Environment context** describes the external factors that affect adoption. These factors are not directly controlled by the organisation itself but are nevertheless influential and cannot be disregarded. Variables under this context include:
  - *Stakeholder readiness:* By design, supply chains involve multiple partners that are indispensable for the functioning of the chain. Within this context, stakeholder readiness can be understood as the degree to which an organisation's trading partners and stakeholders are perceived as ready to adopt a technology. Since the fragmentation of IT systems used by supply chain stakeholders was recognised in a previous chapter as one of SCM's current issues, the premise of onboarding all supply chain parties onto one system would need to presume

the readiness of those parties for adoption. Researchers have acknowledged this factor and several studies have investigated the role of trading partners in an organisation's adoption of technology and the degree to which their influence is critical to adoption decisions (Zhu, Kraemer, & Xu, 2003; Lin, 2014; Awa, Ukoha, & Emecheta, 2016). Thus, we can theorise that stakeholder readiness has a positive correlation with adoption likelihood.

–The higher the level of an organisation's stakeholder readiness, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

- *Regulatory influence:* This is the degree to which supportive government regulations affect the technology adoption process. Baker (2012) has noted that the influence of regulations can either stimulate innovation adoption by mandating firms to adopt technologies to meet set standards, or it can strand adoption when authorities impose strict regulations in highly regulated industries, which can consequently cause adoption costs to increase. For instance, cryptocurrencies have had contrasting reception by governments ranging from supportive regulations in countries like Switzerland (Caytas, 2018), to restrictive ones in countries like South Korea (Adhami, Giudici, & Martinazzi, 2018), which had consequences on their adoption rates. Even though blockchain's implementation in SCMS is a distinct area when compared to cryptocurrencies, it is still reasonable to examine the degree of regulatory influence on the technology. Thus, we can theorise that regulatory influence has a conditional correlation with adoption likelihood: It can be either positive or negative.

–The more regulations push an organisation to adopt blockchain, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

–The more regulations limit an organisation to adopt blockchain, the lower the likelihood of the organisation to adopt blockchain-based SCMS.

- *Competitive pressure:* Research done by Thong (1999); Zhu, Kraemer, and Xu (2003); Grandon and Pearson (2004); Lin (2014); and several others have concluded that pressure to adopt innovations stemming from competition significantly increases an organisation's inclination to adopt. In another study, Chwelos, Benbasat, and Dexter (2001) have found competitive pressure to be the most influential factor on adoption. Thus, we can theorise that competitive pressure has a positive correlation with adoption likelihood.

–The higher the level of competitive pressure on an organisation, the higher the likelihood of the organisation to adopt blockchain-based SCMS.

4 EMPIRICAL ENQUIRY

4.1 Data collection

As this study takes on a qualitative approach, the largest part of empirical data collection during the research process was done via means of semi-structured interviews, totalling to six interviews altogether. The target groups for data collection consisted of executives from companies that are using or considering using SCMS, as well as IT suppliers that are building blockchain-based solutions for the supply chain industry. The qualified interviewees were sourced through professional online communities, personal networks, and direct referrals. In addition, white papers, press releases, newspaper articles, company websites, and social media pages were inspected and used as secondary sources of data collection to complement the empirical data from interviews.

Afterwards, all collected data was prepared for analysis. That is when the raw data was studied to extract patterns then organised under common categories for easier classification. These classifications then served as the basis of the answer to the research question, i.e. the list of key adoption challenges.

4.1.1 *Means of data collection*

4.1.1.1 Interviews as a primary source

Considering the qualitative nature of the research, the most appropriate method of data collection was in-depth, semi-structured interviews with the data providers. In effect, that means one-on-one interview requests were sent to a select number of qualified interviewees to collect the desirable input.

Due to limited mobility resources and given that not all interviewees were geographically situated in proximity to each other, three interviews were conducted electronically via video and voice calls, two took place during face-to-face meetings, and one was carried out in a written format over email.

All interviews started by explaining to the interviewee the background and purpose of this research, then proceeded to explain why the interviewee was selected to provide input. Some interviews were recorded with the interviewee's consent, while others were not. Nevertheless, written transcripts were taken during all interviews to highlight the most prominent parts of the interviewee's answers for later referencing.

The interviewees were fully briefed before the beginning of the interview about the usage policy concerning the data they provide, and they were asked to give their consents before proceeding. Furthermore, personal data of each interviewee (e.g. full name, etc.) were not included in this report and all collected data was kept only on the interviewer's private digital storage for as long as needed until the research was fully finalised. After the research was complete, all unnecessary data—particularly personal data—was deleted. Likewise, the names of the interviewees' organisations were anonymised as per their requests. The final research results were offered to be shared with interviewees who have expressed interest in reading them.

The type of data that was collected from the interviewees included their individual opinions, reflections, as well as any information about the use of blockchain-based systems for SCM. Since the research question to be answered is figuring out the key challenges preventing or slowing down the adoption of blockchain-based SCMS, the data collection process aimed at finding meaningful reasons behind those challenges. Hence, the format of collected data was mostly exploratory and semi-unstructured in nature, after which this data was organised and coded to make the process of extracting meaningful answers and information from it easier. To expand on this, the questions that were asked to the interviewees were mostly open ended, with a few exceptions. The questions focused on the known challenges/obstacles that the interviewees were aware of regarding integration of blockchain in SCMS as experienced from their own work and involvement in their organisations. A sample of these interview questions are attached as an appendix to this document.

4.1.1.2 ***Secondary sources***

Despite the name, secondary data can sometimes be vital to answering a research question, making it of comparable significance to primary data. However, for most research questions (including the one of this study), a combination of both primary and secondary data is needed to answer the question(s) successfully (Saunders, Lewis, & Thornhill, 2009, p. 258). As such, in addition to interviews that were focused on extracting deeper insights from the interviewees about their work on blockchain and SCMS, a few secondary sources (listed in Table 3) were examined as well to complement the empirical data collection. These sources included documentations and observations from several areas where relevant company information can be obtained. For example, public websites of the interviewed companies were inspected to collect background information about each company to save the interviewees' time and avoid asking questions about information that is publicly available. Moreover, some companies have published white papers or commissioned special reports to explain technical aspects of their solutions or to highlight a practical use case by, for instance, conducting market research. These documents were similarly studied, and the information found in them were used to compare the answers obtained from the interviewees to diversify the sources of data. However, as Saunders, Lewis, and Thornhill (2009, p. 272) have noted, secondary data must be approached with the same degree of scrutiny as primary data since it can be prone to bias in certain cases, e.g. company reports deliberately prepared to present a positive image of the organisation. For this research, validity of secondary data sources was measured via cross-checking of secondary and primary data for inconsistencies, then drawing conclusions on whether the results are of reasonable credibility.

Table 3 Overview of secondary data sources

Source Type	Primary Usage	# of Items
Websites & company documents	Collecting background information (facts, business statistics, etc.) about the interviewed companies and analysing documents provided by them	12
White papers	Understanding technical concepts and projects that the interviewed companies are working on/with	10
Video recordings	Watching product demonstrations, explainer videos, and recorded interviews with company executives	4
Social media pages	Observing online user interaction with the interviewed companies and their SCMS solutions, screening public feedback, positive/negative comments, etc.	16
News & media reports	Forming ideas about wider reception (e.g. via media coverage) of SCMS solutions used/developed by the interviewed companies, including critical reviews	21

4.1.2 ***Data collection process***

To maximise the chances of availability of all potential interviewees, a schedule was made to extend the process of interviewing across eight to ten weeks. Nonetheless, to account for unexpected delays or interviewee cancellations and to ensure the completion of this research within the proposed timeline, a deadline was set after which the research work continued with the data at hand. Initially, there was a desire to conduct extensive interviews with close to ten companies that are based in different countries, but at the end the total number of interviewed companies was six and they were based primarily in Finland and Switzerland with their operations spanning other countries as well.

After conducting six interviews, three with IT users and three with IT suppliers, a reasonable level of data saturation seemed to have been reached in accordance with the scope and resources of this research where similar answers and information given by interviewees started to become repetitive. To elaborate on this, O'Reilly and Parker (2013) as well as Fusch and Ness (2015) refer to data saturation, which has its roots in grounded theory, as the point in qualitative research where the chances of producing new information have been reached and no additional new ideas are expected to arise as a result. Unlike quantitative research, a qualitative research does not necessarily need to have a "sufficient" amount of representative sample data because the collected data is not numeric, thus no calculations are needed in most cases. Therefore, every researcher can independently determine whether the goals of their research have been met when/if they see that conducting more interviews would not lead to new insights nor would it provide novel ideas or original input.

4.1.3 ***Interviewee profiles***

The target interviewees for this research were employees in different senior positions within their respective organisations who hold decision-making powers regarding the technologies their organisations use. The reasons for this choice are self-evident since the final say on whether an organisation can/will adopt a blockchain-based system to manage its supply chain usually lies with these decision makers. Thus, they are the ones with the most relevant knowledge on the perceived challenges for adoption. Furthermore, the interviewees were chosen from among organisations that represent two main target groups, namely:

- *Users,* who are companies that currently use (or plan to use) blockchain-based SCMS
- *Suppliers,* who are companies that provide/develop IT systems (including blockchain-based solutions)

All interviewees requested that their organisations' identities be concealed to grant access for this research. As such, and as can be seen in Table 4, pseudonyms were assigned to company names, but their corresponding industries are still included for added context as they are not personal data. Table 4 also provides more information about the backgrounds of interviewed companies, such as founding dates and current number of employees. Additionally, the *Category* column assigns each company under one of the two main target groups, i.e. either a *user* or a *supplier*. Out of the six interviewed companies, three were users and three were suppliers. This was done on purpose to gather a well-balanced amount of data to draw conclusions from since one of the central design choices of this research was to address the research question by examining the adoption challenges as described by both groups of people involved with the technology.

Similarly, all personal data of the interviewees themselves was omitted or anonymised for privacy reasons, but the relevant professional experience and positions of these interviewees were kept—with their consent—to shed light on the backgrounds of individuals providing the data. As such, real names of interviewees were replaced with pseudonyms that share the same initials as the interviewees' actual names for the sake of easier recognition while still maintaining a human image of interviewees in the reader's mind (as opposed to replacing their names with generic identifiers such as *Interviewee 1* or *XN1*). Table 5 below lists detailed professional profiles of all the interviewees who contributed to this research.

Table 4 Interviewees' company profiles

#*	Category	Company	Industry	Size**	Established
U1	User	Qix House	Fashion/Clothing	101–500	1974
U2	User	Aqua Ferry GmbH	Shipping/Cargo	>1000	2005
U3	User	Cheetah Corp.	Retail	501–1000	2001
S1	Supplier	Fast Arrow Ltd.	IT Consultancy	>1000	1989
S2	Supplier	DigiSphere Oy	IT Consultancy	101–500	2008
S3	Supplier	Block16 Solutions	Blockchain	1–100	2015

* *U=User; S=Supplier*
** *Size=Number of employees*

Table 5 Professional profiles of interviewees

#*	Interviewee	Position	Experience
U1	Sara D.	Senior Production Manager	8 yrs.
U2	Mikko T.	CTO	19 yrs.
U3	Fatim G.	Operations Manager	5 yrs.
S1	Rajeev P.	CTO	21 yrs.**
S2	Roberto R.	Technical Account Manager	10 yrs.
S3	Vladimir P.	Product Owner	4.5 yrs.

* *U=User; S=Supplier*
** *Not all 21 years in the same industry; made a career shift after the first 10 years.*

One of the central pieces of information to keep in mind before analysing interview answers was the degree to which each of the interviewees was involved in the process of adoption (for users) or development (for suppliers) of blockchain-based SCMS. This background information gave an indication of the level of experience that interviewees had and helped evaluate how well-informed their answers were in terms of hands-on practice. Table 6 lays out the findings as revealed by the interviews.

Table 6 State of blockchain involvement of interviewed companies

#*	Current Involvement with Blockchain	Since**
U1	The company is aware of the existence and impact of blockchain-based SCMS but so far has not invested heavily on implementation. Current priorities in the company's strategy do not include investing in emerging technologies, but it is still actively interested in studying blockchain's impact on its own business	~11 months
U2	The company is aware of the direct impact of blockchain-based SCMS on its own operations. It has been experimenting with an implementation of a pilot application project throughout the past 10 months developed by a long-time IT partner. This pilot application covers only a limited set of SCM tasks	~20 months
U3	The company has started investing resources into fully understanding the impact of blockchain-based SCMS by e.g. participating in workshops delivered by suppliers. A small pilot project is set to start soon, pending final approval from upper management	~24 months
S1	The company has been working with several enterprise clients on consultation projects related to business applications of blockchain. It employs several full-time experts who work with blockchain conducting market and technical research on the technology	~48 months
S2	Majority of the company's clients seek consultancy in non-blockchain digital transformation projects, but it has recently been involved in two large-scale projects with enterprise clients looking to validate blockchain applicability for their SCM operations	~36 months
S3	The company was founded less than four years ago with a mission to popularise blockchain applications across different industries. It specialises exclusively in blockchain application development, with a separate team focused on building blockchain-based SCMS	~48 months

* *U=User; S=Supplier*
** *Elapsed time since the company first became involved with blockchain (counted from the first time the topic was officially discussed, e.g. in a company meeting)*

4.2 Data classification and analysis procedure

The process of analysis took place simultaneously alongside the data collection phase. Whenever an interview was conducted, it was immediately transcribed and scanned in depth to find major themes/categories in the text and code them accordingly. This initial interview analysis phase was coupled with analysis of secondary sources to increase the validity of data by cross-checking the collected material with independent sources that contain similar ideas. Unlike quantitative research where all numerical data is significant in the analysis, interview transcripts and other secondary data can contain redundant or unnecessary portions that do not contribute to the research (Creswell, 2014), thus an extra step of "skimming the fat" from the qualitative data took place to reduce the volume of overall text and to zoom in on the information that are most relevant for the study.

Interviewees' responses were scanned for potential matches to any variables of the theoretical framework then classified under the most appropriate variable in each context. Similarly, interviewees were asked to go through all variables and identify the ones that had the most influence on their company's adoption decisions. These answers were used to assess the framework's suitability and its ability to cover the major adoption factors.

Furthermore, Saunders, Lewis, & Thornhill (2009) recommend qualitative researchers to make use of computer-aided qualitative data analysis software (CAQDAS) to assist with coding and classification of data, since such software is believed to increase transparency and methodological thoroughness. Several options were considered including ATLAS.ti, MAXQDA, and NVivo. Eventually, NVivo proved to be the most suitable due to its accessibility (licence provided by university), friendlier user interface, and short learning curve. In summary, the data analysis procedure involved four steps (Figure 16).

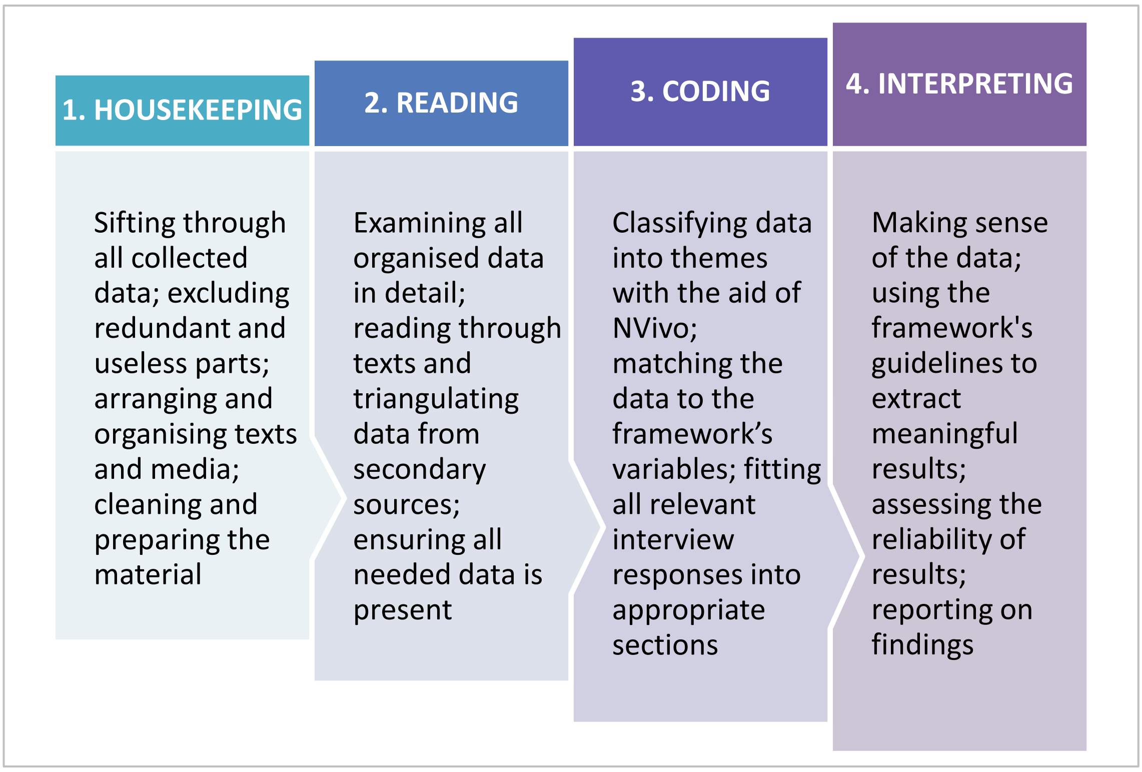

Figure 16 Steps of data analysis procedure

5 FINDINGS AND DISCUSSION

After analysing interview answers and secondary data, a couple of findings emerged. Firstly, interviewees were given the chance to indicate whether each of the presented variables was critical to their decisions on adopting blockchain-based SCMS. As can be seen from the interview guide (attached as appendix 1), interviewees were presented with a list of all variables from the proposed theoretical framework and were asked to mark the ones that they deemed influential on the adoption decision. A brief explanation of each variable was conveyed to the interviewees to ensure that their selections are based on proper understanding of variables' meanings. A summarised result of their answers is presented in Table 7 and Table 8, with the tick sign (✓) indicating that an interviewee identified the corresponding variable as influential, while the absence of a tick indicates the opposite.

Additionally, there were two questions at the end of each interview where interviewees were openly asked to: 1) name some challenges that they believed are preventing or slowing down the adoption of blockchain-based SCMS and 2) identify the challenges that they believed are the most critical or "deal breakers". These open-ended questions were used to analyse the interviewees' answers and to look for mentions of certain challenges that the interviewees voluntarily shared as opposed to being asked to choose from a predefined list. The revelations from these open-ended questions added more weight to some predefined challenges whenever an interviewee mentioned them again to emphasise their influence. Moreover, this approach opened the door for insights about other challenges that were not originally covered by the variables of the proposed theoretical framework.

5.1 Evaluating adoption factors

5.1.1 *User perspective*

Firstly, in the technology context almost all user interviewees mentioned that the listed factors were influential on their companies' adoption decisions. One exception was U2, who did not believe that *perceived complexity* was of influence in his company's case. Secondly, in the organisation context only U1 approved all presented factors as influential. Whereas both U2 and U3 indicated that the factor *IT savviness* was not influential on their adoption decisions, with U3 additionally dismissing *slack resources*. Thirdly, in the environment context all interviewees said that the presented factors were influential except for U1, who chose to express that *competitive pressure* did not have influence on her company's adoption. Therefore, every interviewee excluded at least one factor from the proposed theoretical framework. These findings are presented in Table 7.

Table 7 Significance of adoption factors according to users

Context Variables	Correlation*	Interviewees**		
		U1	U2	U3
Technology				
Perceived ROI	(+)	✓	✓	✓
Trialability	(+)	✓	✓	✓
Perceived complexity	(−)	✓		✓
Perceived compatibility	(+)	✓	✓	✓
Organisation				
Centralisation	(−)	✓	✓	✓
Slack resources	(+)	✓	✓	
Scope of operations	(+)	✓	✓	✓
IT savviness	(+)	✓		
Management support	(+)	✓	✓	✓
Environment				
Stakeholder readiness	(+)	✓	✓	✓
Regulatory influence	(±)	✓	✓	✓
Competitive pressure	(+)		✓	✓

* *(+)=Variable has a positive correlation with adoption likelihood; (−)=Variable has a negative correlation with adoption likelihood; (±)=Variable has a conditional correlation with adoption likelihood*
** *U=User*

5.1.2 ***Supplier perspective***

Firstly, in the technology context all the supplier interviewees unanimously agreed that the listed factors were influential on their companies' adoption decisions without exceptions. Secondly, in the organisation context there were mixed responses: S2 deemed the *centralisation* factor as non-influential; S3 dismissed *scope of operations* as less significant; and both S1 and S2 mentioned that they did not believe *IT savviness* to have influence on their companies' adoption decisions. Thirdly, in the environment context all interviewees unanimously agreed again that the listed factors were influential on their companies' adoption decisions. These findings are presented in Table 8.

Table 8 Significance of adoption factors according to suppliers

Context Variables	Correlation*	Interviewees**		
		S1	S2	S3
Technology				
Perceived ROI	(+)	✓	✓	✓
Trialability	(+)	✓	✓	✓
Perceived complexity	(−)	✓	✓	✓
Perceived compatibility	(+)	✓	✓	✓
Organisation				
Centralisation	(−)	✓		✓
Slack resources	(+)	✓	✓	✓
Scope of operations	(+)	✓	✓	
IT savviness	(+)			✓
Management support	(+)	✓	✓	✓
Environment				
Stakeholder readiness	(+)	✓	✓	✓
Regulatory influence	(±)	✓	✓	✓
Competitive pressure	(+)	✓	✓	✓

* *(+)=Variable has a positive correlation with adoption likelihood; (−)=Variable has a negative correlation with adoption likelihood; (±)=Variable has a conditional correlation with adoption likelihood*
** *S=Supplier*

5.2 Reflecting on interviewee answers to adoption factors

5.2.1 *Technology factors*

5.2.1.1 ***Perceived ROI***

The assumption for this factor is that it positively affects adoption, and all user interviewees acknowledged that it was significant. When asked to elaborate on her choice to designate this factor as having influence on adoption decision, U1 noted her company's relative unfamiliarity with blockchain and emphasised that the company does not usually invest in new technologies until their ROI is proven beyond reasonable doubt. This testimony puts U1's company at the highest level of risk aversion when compared to the other interviewees in the user category. Both U2 and U3 affirmed that a demonstrated ROI of blockchain-based SCMS was an integral factor in their adoption decisions. Nonetheless, despite both representing large organisations, U2 and U3 were not as adamant about the demonstrability of a concrete ROI of blockchain-based SCMS prior to embracing the technology. This was evident by the fact that both U2 and U3 are further ahead in adopting a blockchain-based SCMS than U1 is. This outcome could be partly attributed to the efforts shown by U2 and U3 to determine the ROI of blockchain adoption for their own use cases as opposed to keeping an eye on the industry and observing others' verdicts on the matter and the public's trend towards the technology, which was largely the approach that U1 was following.

Likewise, all supplier interviewees showed their acknowledgment of the importance of demonstrating a technology's ROI on their clients' adoption decisions. Both companies of S1 and S2 have more experience in working with enterprise clients on IT projects compared to S3—whose company is the youngest of the three. This experience allowed S1 and S2 to place emphasis on clear ROI illustration in their sales and marketing efforts to their potential clients. For example, S1 brought up during the interview that his company has several full-time experts solely working on conducting market research on blockchain, which includes the presentation of evidence-based knowledge regarding the potential ROI for each client. As a result, S1 indicated that his company witnessed satisfactory results with clients that requested consultancy services to understand the practical impact of adopting a blockchain-based SCMS. It can be argued that due to its larger business resources, S1's company was able to custom-make ROI demonstrations for individual clients. Unlike S3's company where its limited resources did not allow it to deliver highly personalised ROI demonstrations for each client, but instead relied on generic demonstrations of their solution's ROI.

5.2.1.2 *Trialability*

For this factor, it was assumed that trialability has a positive correlation with adoption, an assumption that all interviewees asserted was accurate. All user interviewees mentioned that their impressions and decisions on adopting blockchain-based SCMS depended on whether the supplier had given them the chance to experiment with the system beforehand. U2 specifically noted that one of the main reasons why his company chose to launch its ongoing, 10-month-old pilot project with its long-time IT partner was the willingness of this partner to offer a trial period of the proposed system with little to no upfront commitment demanded. Even though U2 mentioned that his company was mentally prepared to invest in a blockchain-based SCMS at that stage, it chose this specific partner for the project over another one that asked for higher prerequisites before offering full system trialability. Additionally, U3 (whose company recently pre-approved a pilot project of blockchain-based SCMS but is yet to fully implement it) stated that the supplier's willingness to offer free access to the new system prior to agreeing on the cooperation was a key motivator for decision makers at her company to approve funding the project. In the case of U1 (whose company is in the "considering it" phase and is yet to adopt a blockchain-based SCMS), she mentioned that the ability for her company to extensively test the system is critical for a positive adoption decision. However, she also added that if there were sufficient case studies of similar companies successfully implementing a blockchain-based SCMS and benefiting from it, her company might not necessarily need to request trialability as a pre-condition for potential IT suppliers before deciding to adopt the system.

Similarly, all supplier interviewees who were interviewed for this research acknowledged their understanding of the importance of offering some form of a trial period for their systems that is either functionality- or time-limited. Both S1 and S2 said that their companies' system trialability differs from one client to another based on the unique situation of each client. Conversely, S3's company adopts a different approach and is bundling the same trialability offer with its solution for all potential clients. This difference in approach can be linked to the fact that S3's company is a younger startup that is developing a packaged blockchain-based SCMS as a "one-size-fits-all" product, as opposed to working independently with each client on bespoke systems.

5.2.1.3 *Perceived complexity*

This factor was assumed to have a negative effect on the adoption decision, and almost all user interviewees agreed to this assumption apart from one: U2. During the interviews, both U1 and U3 hinted that a new system that they perceive as complex would result in them not adopting it. U3, whose company pre-approved a pilot project set to start soon, confirmed this by saying that she perceived the system that was offered by the supplier as "wasn't very different from other enterprise software that we already use".

> *Before we agreed to move forward with implementing [the pilot system], we were worried that the learning curve of the new software itself might be too long because our employees' perception of blockchain was that it's a complicated technology. But actually, this turned out to be not entirely true. Because after testing the system, we learned that there is a big difference between the complicated underlying technology of blockchain and the application that runs on it, which wasn't very different from other enterprise software that we already use.*
>
> – U3

The reason for U2's dismissal of perceived complexity as a determining factor in the adoption decision can be attributed to his company's experience and the industry it operates in, i.e. shipping/cargo. When asked to elaborate on his answer, U2 referred to his company's vital role in the supply chain as a shipping company, adding that its position demands it to be at the forefront of pioneering industry trends, including adoption of systems based on emerging technologies such as blockchain. As such, the perceived complexity of the system played little role in the company's adoption decision, with U2 reasoning that if a new technology (e.g. blockchain) shows growing impact on the shipping industry, his company would have to embrace it regardless of the apparent complexity of this technology. U2 then concluded by saying that if a learning curve was inevitable, his company would be comfortable with it if it wanted to maintain its competitive position.

On the supplier side, all the interviewed companies gave similar acknowledgements to the perception of system complexity as a determining factor on the adoption decision. All supplier interviewees said that they place special emphasis on attempting to "conceal" the technical infrastructure of their blockchain-based SCMS to bring the technology closer to human level as much as possible. S3 specifically noted that his company tries to focus its marketing efforts on demonstrating the end value of its product for clients rather than trying to "sell" blockchain to them.

5.2.1.4 ***Perceived compatibility***

The perception of a blockchain-based SCMS to be compatible with a company's existing technology was considered vital by all interviewees—both users and suppliers. This specific factor was broken down into its two subfactors: compatibility with third-party software that the company uses and compatibility with the company's existing IT infrastructure, because they both represent different scenarios for every company. User interviewees stressed the importance of the current software systems they use to manage their supply chain operations, with U2 specifically referencing the fragmented nature of the current systems among the different supply chain members. This situation leaves users reluctant to adopt a blockchain-based SCMS if it does not integrate well with their companies' current technology stacks. Nonetheless, U3 mentioned that even if the new solution was not compatible with the company's IT infrastructure, her company would consider updating its infrastructure to meet the new requirements in case the demonstrated value justifies the investment.

For suppliers, one of the primary development areas they are trying to focus on, according to interview answers, is ensuring that their solutions offer compatibility with software from other vendors. S3 mentioned that it is becoming a widespread practice in software development when a supplier is creating a new product to allocate some resources to make their system integrate with other widely used software. S3 attributes this to the growing number of software solutions in the market and the increasing usage of several independent software products by each user.

> *When we began developing our blockchain solution, we realised from the start that we will have to make it compatible with at least the top third-party software that are most used by potential clients [...] and it was a challenge for us because we knew that there are quite many of them out there and we can't meet every company's needs, so we had to prioritise, but we knew it was important for them.*
> *– S3*

5.2.2 ***Organisation factors***

5.2.2.1 ***Centralisation***

Centralisation was posited as having a negative impact on adoption and all user interviewees considered it significant. U2 and U3 referred to the fact that the decision power to adopt modern technologies within their organisations was—to a certain degree—autonomous, and that is why they manged to start adopting an early-phase blockchain-based SCMS. In the case of U3, she mentioned that while she is still waiting for final approval from upper management to proceed with the pilot project, it was but a mere formality because in these scenarios senior managers usually approve such initiatives as long as they are recommended to them by their direct reports. Therefore, one could argue that this is a decentralised environment since the definition of centralisation as laid out earlier referred to the state of having autonomy to decide on the adoption of technologies.

While all user interviewees acknowledged that the level of centralisation in their companies either have or would affect the adoption of a blockchain-based SCMS, supplier interviewees did not all have the same impression. In particular, S2 considered centralisation a neutral factor from his point of view, mentioning that he believes if a potential adopter company is centralised, it is eventually up to the decision maker(s) to enforce the adoption across the company since they usually have the authority to do so.

5.2.2.2 ***Slack resources***

Even though this factor is expected to have a positive impact on adoption as was theorised in the theoretical framework, some researchers argued that it was neutral and this is backed by one of the user interviewees (U3), whereas all the remaining interviewees considered it to be significant on adoption. Both U1 and U2 said that a moderate abundance of financial resources within their companies contributed strongly to their adoption decisions. Meanwhile, U3 gave the explanation that if she deems a certain innovation as vital to her company's business, she would likely take steps to adopt it regardless of whether her company currently has slack resources available.

> *[…] not always, as I think in most cases whenever we had an opportunity to consider a new innovation or technology for example, we didn't have to see first if we have some excess in the budget. But anyway, we usually only consider innovations when they demonstrate tangible potential according [sic] our research.*
> *– U3*

In contrast, supplier interviewees have all considered slack resources of an organisation to be one of the determining factors that would play a role in the adoption decision of a blockchain-based SCMS. S1 and S2 specifically referenced the cases of two of their clients that were interested in experimenting with a blockchain-based SCMS and indicated that the clients had allocated some of their slack resources (both financial and human resources) to the initiative. Comparatively, S1 brought up a case of a potential client company of theirs that showed interest in adopting a blockchain-based SCMS but was not able to proceed with adoption because this company's management considered the lack of financial slack to be a deterrent. Based on this, S1 added that his company now looks at financial slack when rating the matureness of a potential client.

5.2.2.3 *Scope of operations*

All user interviewees considered this factor to be significant and that it positively affects the likelihood of adoption. Since the factor assumes that the wider the operations of a company are, the more likely this company would adopt a blockchain-based SCMS—all user interviewees who have taken steps in adopting a blockchain-based SCMS perceived that their scope of operations was wide enough to affect the decision-making. U2 in particular referred to his company's large size, which in turn indicates that its operations in the cargo industry are wide-reaching and encompass several levels of activity that might not necessarily be of concern to other smaller companies in the supply chain industry. Additionally, U1 briefly noted that whether her company's operations would expand in the next few years or not would highly likely affect the company's decision in case the topic of adopting a blockchain-based SCMS was on the table at that time.

Supplier interviewees, who all acknowledged the significance of this factor except for S3, added a couple of clarifications to back their answers. S1 agreed that some of his company's clients with limited scope of business operations were the ones that ended up being the least likely to adopt a blockchain-based SCMS. This finding became known after S1's company held workshops on its blockchain-based SCMS for several potential clients and noticed that mostly companies with wider scope pf operations were the ones that eventually moved forward with adoption. On the contrary, S3, whose company exclusively focuses on blockchain development, noted that his company's client portfolio consists of businesses with both large and limited operations, thus prompting S3 to conclude that the scope of operations does not necessarily play a huge role in the adoption decision.

5.2.2.4 *IT savviness*

This factor garnered the least amount of support among interviewees with regards to whether it has influence on the adoption decision. Only two interviewees (U1 and S3) out of six considered that it played a role in their companies' decisions to adopt a blockchain-based SCMS. U1 mentioned that her company's relative unfamiliarity with blockchain and the fact that the company has traditionally not been an early adopter of technology innovations makes it sceptical of trying new technologies. Therefore, the company does not particularly see itself as technology savvy, according to U1. As a result, U1 concluded that if the perception of blockchain among the less technically-oriented workers remains to be viewed as "nerdy", the adoption decision would be negatively affected, thus making this factor a significant one in her company's point of view.

From the supplier side, only S3 was the one that acknowledged IT savviness to be affecting the adoption decision. According to the company's own experience as referenced by S3, it has witnessed that interested clients that end up adopting blockchain applications are more technology savvy. However, S3 followed up and added that since his company is new and very technology savvy, it might have a biased view by instinctively regarding companies that adopt blockchain as being more technology savvy as well. Nonetheless, S3 recounted that his company is actively working to present blockchain as an accessible technology to less-technical audiences.

5.2.2.5 ***Management support***

This factor, along with its two subfactors, was unanimously considered by all user interviewees to affect their adoption decisions. When discussing management support, the focus was that it is an umbrella term for both presence of internal company influencers as well as presence of supportive company policies. Both U2 and U3 said that their fellow employees regard them as the "adoption champions" because they were the ones leading the adoption initiative as part of their job duties. As such, U2 and U3 believed that they have both played a determining role in the adoption process since they were seen as role models and subject matter experts by their colleagues. Additionally, U2 stated that he has already started drafting new company guidelines for adoption of modern technologies based on his ongoing learnings from the partial adoption of a blockchain-based SCMS. U2 described the influencer experience as follows:

> *For the most part, I was the one in charge of overseeing the entire process of making this pilot project see the light. I had to follow up on the progress and report the findings as well as take part in the implementation myself and I don't think the project would have moved forward or been received favourably by employees if there wasn't a person who is a focal point of reference that others follow.*
>
> *– U2*

Likewise, all supplier interviewees concluded that management support was vital for adoption. S1 reflected on some of his company's own experiences with clients that were initially interested due to the presence of one or two technically oriented employees, but eventually ended up not moving forward with adoption because of unsupportive management policies. Moreover, S2 emphasised his findings regarding the importance of management involvement in the adoption of new technology by mentioning that he puts more focus on educating managers about the value of adopting blockchain-based SCMS to increase the likelihood of them passing these learnings on to their organisations by means of better adoption policies and more lenient requirements.

5.2.3 *Environment factors*

*5.2.3.1 **Stakeholder readiness***

All user interviewees agreed on the importance of this factor to the adoption process, mentioning that it is self-evident that it would have an effect since the supply chain industry is very collaborative by design and requires several companies to work together. U2 referred to his company's heavy involvement with third parties in the shipping industry and added that his company is constantly trying to push its partners to accomplish certain tasks, e.g. use a shared system, adopt a new technology, follow specific standards, etc. According to U2, this is being done to reduce the conflicts of having each party working in a distinctly different fashion that could affect another party's way of working. Similarly, when reflecting on the effects of this factor, U3 noted that as part of her company's preparation for implementing the pilot blockchain-based SCMS, it had to conduct a quick survey to understand where its most critical partners are standing in terms of readiness and willingness for adoption. U1 also corroborates this finding by saying that her company would certainly consider whether its partners were adopting a new system before deciding to adopt it itself.

Supplier interviewees were equally on the same page, with S2 acknowledging that in one of the two cases that his company has so far worked on, he had to work with several partners of the client company. He added that the primary motive behind his company taking up the responsibility and initiative of educating its client's partners stemmed from the strong belief that clients are more likely to fully adopt a blockchain-based SCMS if their business partners were using the same system (i.e. as a result of chain reaction). S3 confirmed this narrative by referencing his young company's focus on marketing activities to all parties that typically work together in the same supply chain by offering, e.g. discounts and benefits for successful referrals from existing clients. However, all supplier interviewees still admitted that despite their efforts, stakeholder readiness remains one of the most challenging factors for them to tackle. This is because it involves working with and convincing several independent entities to adopt a new system and those entities want others to demonstrate adoption success first before they can take the step to adopt it themselves.

*5.2.3.2 **Regulatory influence***

The importance of this factor was considered paramount by all user interviewees. Regulatory influence can either be positive or negative for adoption likelihood, as explained in previous chapters. One of the user interviewees, U2, referred to the fact that there were supportive government policies towards adopting blockchain in specific regions around the world, such as in the Zug region of Switzerland where his company operates, which seems to have friendlier blockchain and cryptocurrency policies compared to other places. According to U2, his company has operations in many places around the world, but its Swiss operations see the bulk of the share when it comes to implementation as well as research and development of blockchain. Similarly, other user interviewees considered the regulatory influence to be an important catalyst that could steer the technology and its adoption, arguing that they would have to abide by any potential laws and such laws would affect whether they would heavily invest in—or abandon—the technology.

These views were similarly supported by supplier interviewees who indicated that, in addition to their marketing efforts towards potential clients, they were also working to lobby governments and other legislative bodies to push the technology behind their solutions forward, whether SCMS or other blockchain-based systems. This indicates that there is awareness of the importance and influence of regulations on the wider adoption of blockchain-based SCMS. However, some supplier interviewees (S2 and S3) noted the difficulty in getting some needed regulations in place due to the long times that legislative bodies usually take to introduce changes and new regulations. This proved to be an obstacle in the current pace that blockchain is developing in, as most of the time regulations end up lagging behind the technology. S3 made a peculiar comment regarding the effect of such regulation lag by saying that this situation could disturb the whole industry only when it concerns regulations that affect a large base of the market (e.g. EU-wide regulations) compared to regulations in specific smaller regions, countries, or cities.

5.2.3.3 ***Competitive pressure***

Lastly, the effect of competition on the adoption likelihood of blockchain-based SCMS had positive reception from most user interviewees. The exception was the case of U1, who did not consider the scenario of her company's competitors' adoption of blockchain as a very influential factor on its decision to adopt as well. Given that U1's company can be currently classified as a "non-adopter", this fact sheds some light on its wary approach to adopting blockchain-based SCMS. U1 brought up during the interviewee the stories of two of her company's indirect competitors that have reportedly started experimenting with blockchain-based SCMS with some of their partners. U1 was aware of this news, but mentioned that she has considered the timing, investment, risk, as well as other factors before deciding that it was not the right time for her company to fully adopt a blockchain-based SCMS. Yet, she acknowledged that it will (likely) eventually adopt one.

> *[…] and for example, we know that [competitor 1] and [competitor 2] have announced that they have started to test the use of blockchain SCMS with their partners, but it's still very early in the process and I think they also wanted to get some publicity with this move. We considered several factors and found that we were not yet ready [to adopt a blockchain-based SCMS] even though we think we will adopt it sooner or later, considering the current trend in the industry and pace of development of blockchain.*
> *– U1*

For supplier interviewees, the situation was slightly different. Even though the agreement on the influence of competition was on the same level with user interviewees, the motive of the supplier interviewees was stronger because they are the ones providing the blockchain solutions, which naturally puts them in a state of competition with other suppliers. According to S3, the first mover advantage is considered particularly important in an emerging business area such as blockchain-based SCMS. S3 explains this as one of the main reasons his company was founded a few years ago: To capitalise on this new business opportunity by building a reputation as an influencer and thought leader for potential clients.

5.3 Adoption challenges emerging from analysis

5.3.1 *Scoring system for key challenges*

According to the analysis of interview transcripts—and the interviewees' answers to the last two interview questions in specific—a couple of key challenges emerged. The three scoring criteria used to determine those key challenges were:

1. *Considered Significant:* Number of interviewees who considered this challenge to be significant when asked to rate all variables of the framework. The maximum score for this criterion is 6/6, i.e. all interviewees considered it significant. The weight of this criterion on the final combined score of 10 is 40%, i.e. 4/10.
2. *Deal Breaker:* Number of interviewees who considered the negative effect of this challenge to be a "deal breaker" when asked so at end of the interview. The maximum score for this criterion is 6/6, i.e. all interviewees considered it a deal breaker. The weight of this criterion on the final combined score of 10 is 30%, i.e. 3/10.
3. *Occurrence Count:* Total number of mentions related to this challenge across interview transcripts, analysed using the Word Frequency Query feature of NVivo. The maximum score for this criterion is 47/47 (the highest count recorded for a single

criterion—47—is chosen as the maximum score and the remaining scores are weighed against it). The weight of this criterion on the final combined score of 10 is 30%, i.e. 3/10.

Each of these three criteria was scored separately then added to the scores of the other two criteria to produce a final combined score. Table 9 below illustrates the breakdown of the scoring criteria and their respective weights in the total score of 10/10.

Table 9 Weights of scoring criteria on the final combined score

	Considered Significant	Deal Breaker	Occurrence Count
Maximum Score	6/6	6/6	47/47
	↓	↓	↓
Weight	4	3	3
		↓	
Total		10	

This scoring system was independently developed for this research and the weights were selected based on the perceived effect of each criterion on the adoption decision. For example, *considered significant* has the biggest weight because it is a clear, upfront statement from the interviewee that this challenge has notable significance, which in most cases translated to fewer mentions in consequent answers in the interview. Additionally, both *deal breaker* and *occurrence count* receive equal weights because they complement each other. For instance, an interviewee can identify challenge *x* as a deal breaker then go on to reference the same challenge several times when answering the open-ended questions, thus confirming that he/she did indeed consider it to be a deal breaker by elaborating on his/her decision. Based on this, an initial scoring of all challenges is presented in Table 10. Afterwards, each context's unique challenges are scored separately to determine the key challenges.

Table 10 Initial scoring of all examined challenges

Context Variables	Considered Significant	Deal Breaker	Occurrence Count
Technology			
Perceived ROI	6	6	42
Trialability	6	0	24
Perceived complexity	5	0	19
Perceived compatibility	6	1	28
Organisation			
Centralisation	5	0	18
Slack resources	5	1	24
Scope of operations	5	0	31
IT savviness	2	1	12
Management support	6	5	38
Environment			
Stakeholder readiness	6	5	47
Regulatory influence	6	0	22
Competitive pressure	5	1	30

5.3.2 *Key challenges: Technology*

Not very surprisingly, the *perceived ROI* of blockchain-based SCMS and its direct impact and benefit for companies came at the top place of key technology challenges that affect adoption as expressed by all interviewees. The common denominator among all responses was that, in principle, if a company is unable to articulate and visualise the exact benefit of a new system (particularly in business numbers), then it is highly likely that the company would not adopt such system. For adopter user interviewees, the reason why they went with a pilot project first was because they wanted to test-run the system against a number of KPIs to be able to determine whether the full adoption of the system would prove valuable in the long term. The interviewed companies stated that while they were mostly optimistic about the future of blockchain-based SCMS, the ability to demonstrate its value and translate it into tangible results that users can easily digest is one of the main issues affecting adoption—especially when it comes to convincing decision makers to consider the new system. In addition to perceived ROI, Table 11 below breaks down the scoring of all other challenges in the technology context and Figure 17 illustrates the conclusive results.

Table 11 Calculating scores of technological challenges

Challenge	Considered Significant*	Deal Breaker*	Occurrence Count*	Total
Perceived ROI	6/6 → **4/4** *(100%)*	6/6 → **3/3** *(100%)*	42/47 → **3/3** *(89%)*	**10/10**
Trialability	6/6 → **4/4** *(100%)*	0/6 → **0/3** *(0%)*	24/47 → **2/3** *(51%)*	**6/10**
Perceived complexity	5/6 → **3/4** *(83%)*	0/6 → **0/3** *(0%)*	19/47 → **1/3** *(40%)*	**4/10**
Perceived compatibility	6/6 → **4/4** *(100%)*	1/6 → **1/3** *(17%)*	28/47 → **2/3** *(60%)*	**7/10**

* *All fractions in calculation results were rounded to the nearest whole number*

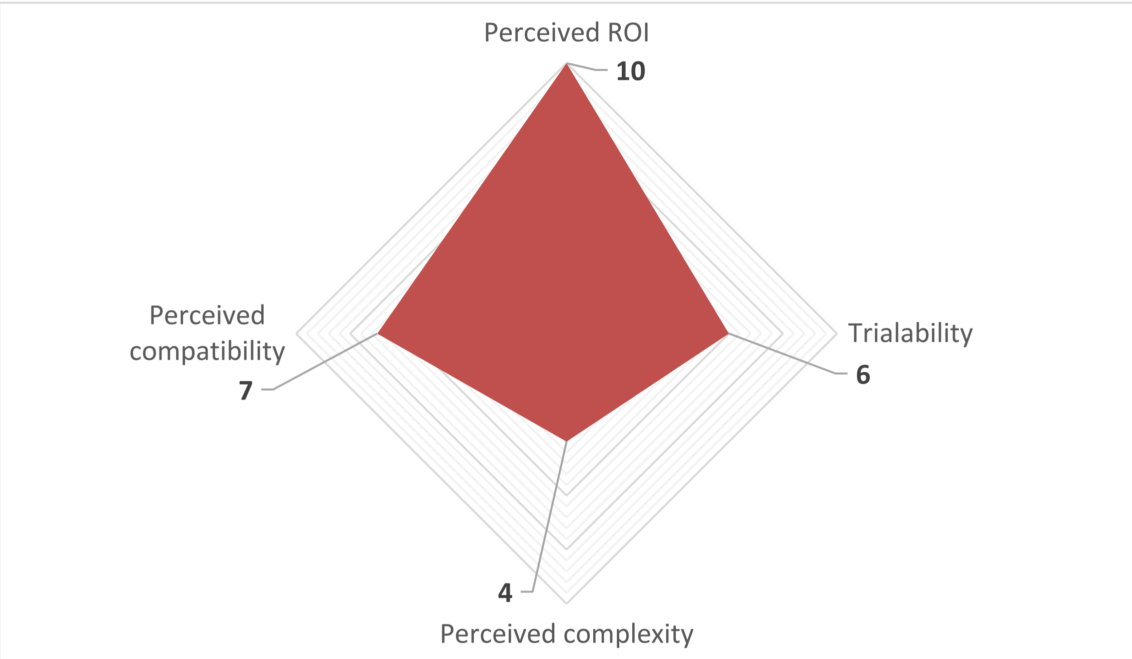

Figure 17 Scores of technological challenges

5.3.3 *Key challenges: Organisation*

After interviewed companies became convinced of the value of adopting a blockchain-based SCMS, the support (or lack of) that their managements gave to the initiative (both tangible and intangible) proved to be of great significance. As such, *management support* came at the top place of key organisation challenges that affect adoption as expressed by all interviewees. As one of the supplier interviewees recalled, one of their potential clients was seemingly impressed by the promised results that blockchain-based SCMS would bring to their business. However, this client had trouble securing strong support from their upper management—mostly because none of the people concerned had the time to "own" the initiative and actively advocate for it across the company, which reinforces the importance of internal adoption influencers. In addition to management support, Table 12 below breaks down the scoring of all other challenges in the organisation context and Figure 18 illustrates the conclusive results.

Table 12 Calculating scores of organisational challenges

Challenge	Considered Significant*	Deal Breaker*	Occurrence Count*	Total
Centralisation	5/6 → **3/4** *(83%)*	0/6 → **0/3** *(0%)*	18/47 → **1/3** *(38%)*	**4/10**
Slack resources	5/6 → **3/4** *(83%)*	1/6 → **1/3** *(17%)*	24/47 → **2/3** *(51%)*	**6/10**
Scope of operations	5/6 → **3/4** *(83%)*	0/6 → **0/3** *(0%)*	31/47 → **2/3** *(66%)*	**5/10**
IT savviness	2/6 → **1/4** *(33%)*	1/6 → **1/3** *(17%)*	12/47 → **1/3** *(25%)*	**3/10**
Management support	6/6 → **4/4** *(100%)*	5/6 → **2/3** *(83%)*	38/47 → **2/3** *(80%)*	**8/10**

* *All fractions in calculation results were rounded to the nearest whole number*

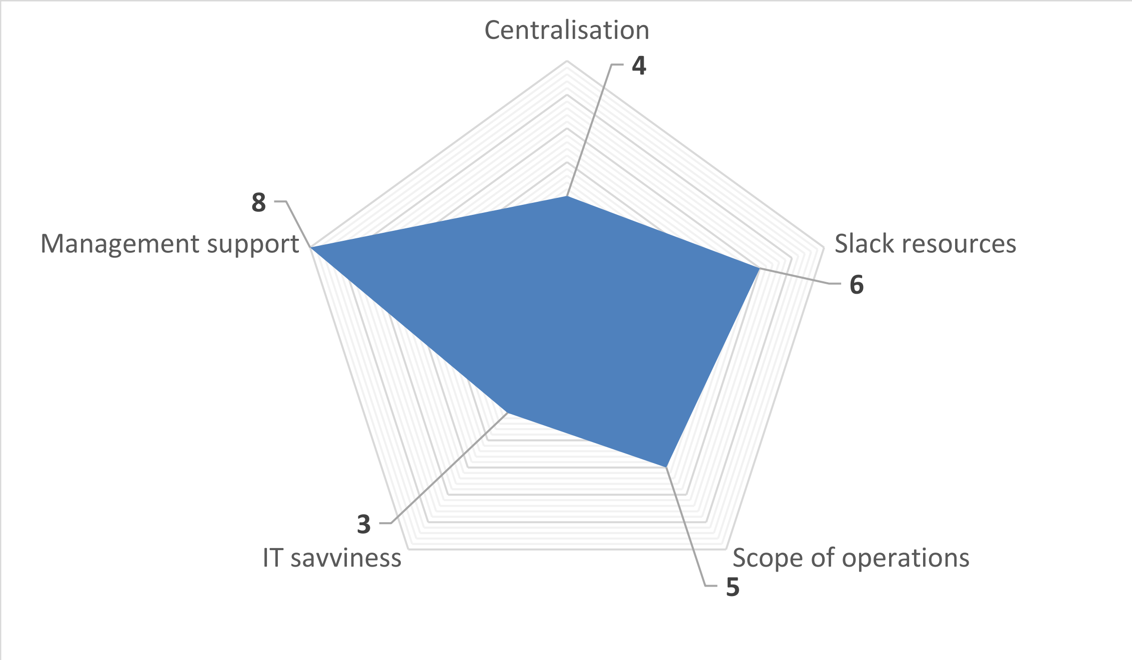

Figure 18 Scores of organisational challenges

5.3.4 ***Key challenges: Environment***

As supply chains are multi-party by design, all interviewees expressed solid recognition of the fact that the success of a novel technology such as blockchain and its integration in SCMS was largely dependent on reaching a positive consensus around adoption among majority of supply chain partners, which was not the case during the time the interviews were carried out. As such, *stakeholder readiness* came at the top place of key environment challenges that affect adoption as expressed by interviewees. Almost all interviewees specifically referred to this factor as a challenge that had (and still has) profound influence on adoption, regardless of whether their own companies were fully invested in adopting a blockchain-based SCMS or not. One interviewer suggested that unless a big, influencing company takes the lead and "forces" other companies to adopt blockchain-based SCMS, the readiness of stakeholders would remain a big obstacle for a long time. In addition to stakeholder readiness, Table 13 below breaks down the scoring of all other challenges in the environment context and Figure 19 illustrates the conclusive results.

Table 13 Calculating scores of environmental challenges

Challenge	Considered Significant*	Deal Breaker*	Occurrence Count*	Total
Stakeholder readiness	6/6 → **4/4** *(100%)*	5/6 → **2/3** *(83%)*	47/47 → **3/3** *(100%)*	**9/10**
Regulatory influence	6/6 → **4/4** *(100%)*	0/6 → **0/3** *(0%)*	22/47 → **1/3** *(47%)*	**5/10**
Competitive pressure	5/6 → **3/4** *(83%)*	1/6 → **1/3** *(17%)*	30/47 → **2/3** *(64%)*	**6/10**

* *All fractions in calculation results were rounded to the nearest whole number*

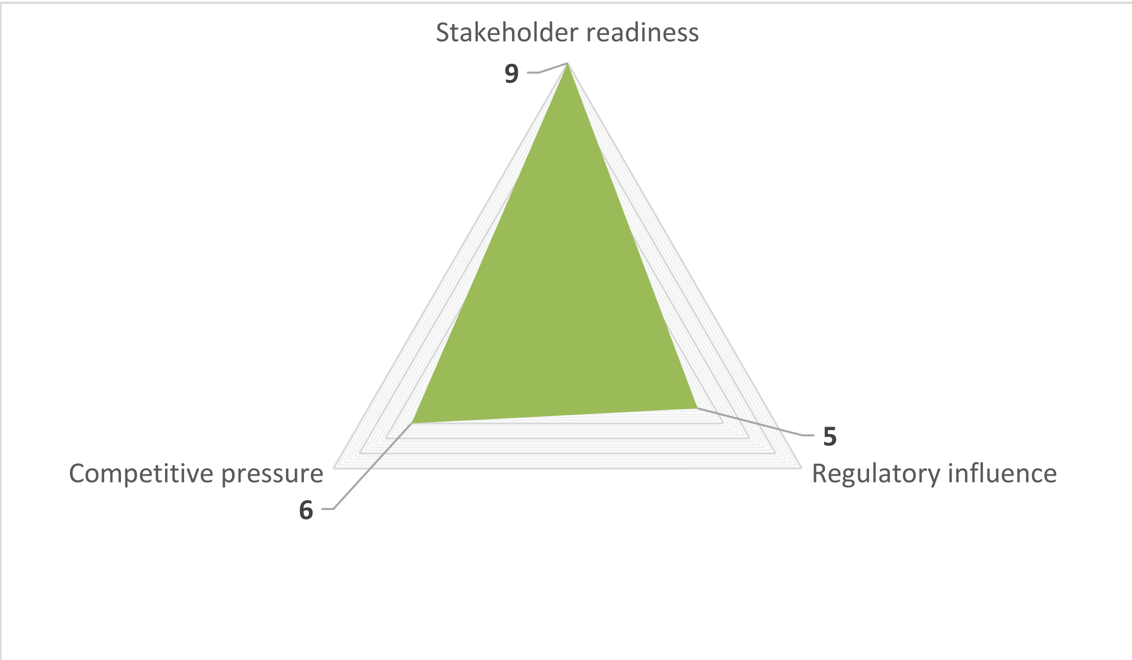

Figure 19 Scores of environmental challenges

5.3.5 *Other challenges*

In addition to the challenges that were assessed via the applied theoretical framework in this research, interviewees talked about a few other issues that similarly affect the adoption of blockchain-based SCMS in enterprises—according to their opinions.

One of those challenges as mentioned by one of the supplier interviewees (S1) is the lack of industry standardisations for such new SCMS. S1 expanded on this issue by assessing the current state of blockchain-based SCMS against other older, more established industrial systems that run major components of supply chain operations. He explains that many of these established systems, which are provided by different vendors, tend to follow a similar approach in handling certain processes because these approaches have been instilled in the industry over time and later on morphed to become standards that most suppliers follow. However, the situation is different in the case of blockchain-based SCMS as each vendor seems to be implementing their own interpretation of how certain processes should be presented for users. S1 recounted that, in his view, the novelty of these solutions was the main reason behind the lack of standardisation. Nonetheless, he added that he believes if the industry was to move forward and fully embrace blockchain in SCMS, suppliers—especially big ones—need to agree on standards and possibly form a consortium among themselves to unify their message to potential clients while still safeguarding their unique know-hows and trade secrets.

Furthermore, another challenge brought up by two user interviewees (U1 and U3) was related to supplier marketing. Both U1 and U3 claimed that the approach that suppliers have taken to showcase and market their blockchain-based SCMS was largely targeted for a technical audience, which alienated the less-technical decision makers and other stakeholders that might have been interested in learning about the solutions. U1 argues that despite being the subject matter expert when it comes to blockchain-based SCMS in her company, she would still be unable to re-explain a technical presentation about blockchain that was held by a supplier to her company's managers or board of directors. While not having a purely technical background herself, U1 stressed that suppliers (at least the ones she had experience with) should adjust their marketing approaches to be less technical and more focused on the business value of their solutions.

Lastly, one supplier interviewee (S3) emphasised on a specific topic that he believed to have notable impact, which is involving users in the development process of blockchain-based SCMS. S3 noted that his company witnessed significant positive reception of its product by one of its clients after this client was involved in the development process and had a say on which features to prioritise, what data should be included in certain reports, etc. According to S3, the client's engagement would have been different in case they were not offered a bespoke system. This sheds light on the challenge facing suppliers of having to allocate resources and assign a dedicated development team for every implementation project to ensure a high degree of personalisation. Nonetheless, S3 acknowledged that there would be a concern of resource sustainability if his company had to commit to similar personalised approaches for each of its future clients, because so far it has implemented this approach with only one client.

5.3.6 *Significance and impact of adoption challenges*

When looking at the analysis results from the previous subchapters and seeing that some of the challenges that were initially put to test scored higher than other challenges, it can be safe to conclude that a certain group of challenges have more overall impact on adoption than the rest of the challenges in the theoretical framework. Based on the completed analysis, Table 14 aggregates all challenges across the three contexts of the theoretical framework that had a score of 6/10 and above.

Table 14 Top-scoring adoption challenges

Challenge	Score	Context*
Perceived ROI	10/10	Tech
Stakeholder readiness	9/10	Env
Management support	8/10	Org
Perceived compatibility	7/10	Tech
Competitive pressure	6/10	Env
Trialability	6/10	Tech
Slack resources	6/10	Org

* *Tech=Technology; Env=Environment; Org=Organisation*

One can rationalise that most of those challenges require financial and human resources to tackle and that both users and suppliers need to take actions to push the adoption further. However, it can be argued that the bulk of the responsibility falls on the suppliers because they are the ones that tend to push users to adopt innovations and focus on making these innovations meet their users' needs.

In addition to improving the technologies and solutions they offer, suppliers also need to work on their marketing efforts by simplifying their message and ensuring that they are communicating the value of their solutions above anything else, which is evident by the fact that perceived ROI scored the highest in the list of challenges.

Moreover, changing users' attitudes towards blockchain-based SCMS is another issue that needs to be attended to. This is strongly tied to perceived ROI since the higher the user perceives the solution as having a good ROI, the more likely the user's attitude towards adopting it would change positively.

6 CONCLUSION

6.1 Implications of the study

6.1.1 *For practice*

One can draw a couple of practical conclusions based on the findings of this study. To begin with, the primary question that guided this research process was to find out the key challenges that prevent companies from adopting blockchain-based SCMS. Naturally, the key beneficiaries from an answer to such question would be the suppliers who are engaged in developing and selling blockchain-based SCMS to business customers, since they would be interested to know why potential customers are not adopting their solutions. The initial assumption was that it is highly probable that suppliers have a different image of what the adoption challenges were compared to the perception of their users. As such, the focus during the research involved both parties of this issue and aimed to understand and interpret their views on the matter to align their concerns more accurately. This resulted in the unveiling of several conclusions that are useful for industry practitioners—especially suppliers—to consider.

Firstly, one can see from the final list of scored challenges that there was no clear dominance of any single context (i.e. technology, organisation, or environment) when looking at the challenges through the proposed theoretical framework (e.g. each one of the top three ranked challenges belonged to a different context). This outcome allows suppliers to focus on addressing every single challenge separately and to not group them under one category. For instance, in the case of perceived ROI, a supplier can direct their efforts towards communicating the value of their solution through different means such as marketing material, product demonstrations, risk-free trials, etc. Having perceived ROI topping the list of challenges means that it was a key factor for the user interviewees to assess whether this new blockchain-based system was worth the investment according to their own criteria. For users who ended up adopting a blockchain-based SCMS, one of their biggest early hurdles was becoming convinced themselves—as well as being able to convince their colleagues—about the ROI of such system. For users who have not adopted a blockchain-based SCMS, regardless of how other adoption challenges fared in comparison, the lack of a perceived ROI was enough to deter them.

Secondly, the research outcome makes it clear that partners and stakeholders play a substantial role on overall adoption rates. Since many of the interviewed users noted that their stakeholders are holding them back from adopting new systems such as a blockchain-based SCMS, suppliers would need to work with all, or at least majority of, stakeholders in any given supply chain to increase chances of adoption. That means focusing on selling only to end customers who represent a single element in the chain would not yield the desired results. Therefore, suppliers should think of ways to address the whole value chain and influence all supply chain stakeholders to achieve better results. This can be done by, inter alia, employing customised and targeted marketing for every stakeholders in addition to targeting influencer companies that can create a chain reaction and pave the way for other companies to follow—whether because of the influencer's direct effect on other companies businesses or because of it setting a tried-and-true, less-risky model for other companies to replicate.

Thirdly, the level of management support within a potential adopter company is vital as it turned out from the research outcome. Thus, suppliers can take several hints as to what constitutes an effective strategy to catalyse management support. For starters, suppliers should attempt to educate and empower decision makers within potential adopter organisations to become advocates for the technology themselves. Research has revealed that internal company influencers are regarded as subject matter experts and are usually considered the ones with the most knowledge about the new system. As such, if suppliers target their marketing efforts towards key decision makers in a company and made sure that these decision makers are fully informed and convinced about the benefits of the blockchain-based solution, then that can effectively turn these decision makers into evangelists and extensions of the supplier's marketing team. An important emphasis here should be placed on the content of marketing: U1 revealed in more than one occasion that the technically-oriented approach that one supplier has used proved to be less effective, which means that it can be off-putting for potential adopters in some situations. This discovery must be acknowledged by suppliers and should push them to adjust their marketing strategies to be more value oriented rather than technology oriented. In other words, the marketing message should be clear on what benefits the potential customer would get if they were to adopt the new system. After this, every other detail is supplementary.

Lastly, one of the remarks that some interviewees made regarding the lack of standardisations in the blockchain-based SCMS market must also be kept in mind when looking to address adoption challenges. The idea of forming industry consortiums or certain clusters of companies to advance the industry's interests and lobby for change has merit to it. It is commonly agreed that when several people or entities organise themselves and work together towards a common goal, they would experience a better outcome compared to when they work separately. Moreover, another way for suppliers to reduce the probability of business users rejecting blockchain-based SCMS is to involve them as much as possible in the development process of the system as opposed to only trying to sell them a "one-size-fits-all" version. Even though involving potential clients in the development process can be risky and resource intensive for suppliers, it can increase the clients' rates of adoption if executed correctly. Thus, suppliers need to find a balance between the two.

6.1.2 *For research*

The findings of this research contribute to the collective literary work of the scientific community in a couple of ways. For starters, it further validates the applicability of the TOE framework and its suitability for multiple scenarios, which in turn adds another evidence-based empirical study to the pool of real-world cases that were tested using this framework. The TOE framework proved to be flexible enough to adapt to different variables without the need for major readjustment to the core construction of the framework. Moreover, the topic of technology adoption in the SCM industry has been studied by several researchers and the particular case of blockchain adoption has also received some attention, although not as much as other areas, which is mostly due to the novelty of the technology. Therefore, this research contributes with new input and empirical findings to some nuances of blockchain adoption in SCMS that were not fully examined by existing works of literature.

Additionally, the approach undertaken by this research compares the findings of two distinct subgroups of companies, i.e. users and suppliers. Such distinction has not received notable consideration in existing research studies, which have either focused on a single category of companies or have researched both categories but have not designed the research in such way that it compares the outcomes of both sides. As such, the analysis of data from this research showed that while there were certain adoption factors that both users and suppliers agreed to, there were other factors where visible differences existed among both categories of interviewees. These comparisons helped with the formation of an inclusive list of adoption challenges that are mutually relevant for both users and suppliers. At the same time, the outcome focused on formulating a defined set of challenges and possible recommendations that are specifically aimed for suppliers to assist them with developing and delivering blockchain solutions that their potential clients would be more likely to adopt.

6.2 Limitations and further research opportunities

Like any other scientific research, this study has its limitations as well, both in terms of data collection and analysis. One of the most notable limitations is the relatively small size of data sample (i.e. number of interviewees who contributed to the study). Even though the selection process of interviewees focused on securing a group of professionals who have diverse backgrounds in different industries, positions, and years of experience, having more than six interviewees would have added additional contrasting data to analyse and compare.

Furthermore, the division of interviewees into two categories (users and suppliers) was a positive consideration to include in the research design. However, this might paint an over-simplified image of reality. For example, putting all users under one “user” umbrella holds the presumption that all these interviewed companies have similar factors affecting their adoption, which is not representative. Each potential company that intends to adopt a blockchain-based SCMS is different from other companies with several factors at play—especially organisational and environmental factors that can prove to have major impact on adoption decisions. As such, a recommendation for any future researcher is to attempt to divide the pool of user companies into subcategories and analyse their attitudes to determine whether any significant trends can be noticed in their approaches to adoption and their perceptions of challenges.

Another observation to be noted is that the data sample in this research was collected from interviewed companies that were based in either Finland or Switzerland. Nevertheless, these companies had intercontinental operations because they were active in several countries and engaged in global supply chain projects to source material, ship products, transport freight, etc. The biggest difference when it comes to the geographical location where the company is headquartered manifests itself in the form of laws and regulations that affect the company. In most cases, as seen from the interviews, the status quo of regulations was neither a major obstacle nor a catalyst for adoption of blockchain-based SCMS. However, user interviewees acknowledged the fact that they would have to respect any changes in regulations that might affect their adoption of blockchain-based SCMS. Based on this, one can recommend that future researchers should explore the regulatory situations in other countries and regions to add more depth and variety to the empirical data.

Furthermore, the theoretical framework used in this research was largely based on an adaptation of the TOE framework by Tornatzky, Fleischer, & Chakrabarti (1990), and despite the fact that the original framework itself has been empirically tested and verified through an abundance of studies, the specific set of context variables that were used for this research are open for debate. That means the collective applicability of all variables has not been empirically tested before, thus making it vulnerable to researcher bias. One recommendation for future researchers is to re-examine whether certain variables in the theoretical framework would still have significant merit to be included in newer studies. For example, one of the organisational variables originally included in the theoretical framework (IT savviness) turned out to be of less significance than what it was thought to be when drafting the framework.

On a final note, in order to calculate the final scores for each of the challenges and rank them in order of severity, a method was used that included counting the number of interviewees who considered a certain challenge to be significant. In addition to that, an extra criterion was used that counted the mentions of each challenge in interview transcripts. One limitation with the latter criterion is that it might not produce results that are reliable every time. That is because the more instances a challenge is mentioned by an interviewee does not automatically mean that such challenge does indeed have major effect on adoption, which could eventually lead to misleading outcome. Future researchers are therefore recommended to create more rigorous, scientifically backed methodologies to rank the significance of adoption challenges and generate reliable results.

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APPENDIX 1 INTERVIEW GUIDE

The interview guide below, which was used to steer the questions and the interview process, contains four sections with several questions under each. Some of the questions that were asked to *user* interviewees differ from the ones asked to *supplier* interviewees. However, the remaining questions were similar for every interviewee.

Interview Questions

- Background questions *[aimed for all interviewees]*
    - Briefly describe your current position within your organisation.
    - What is your background/experience towards your position?
    - How long have you been working in your current organisation?
    - How long have you been working in the same field/industry?
- Questions aimed for users
    - Briefly describe the current software system(s) in use within your organisation for managing supply chain operations.
    - For how long has your organisation been using the current system(s)?
    - What in your opinion are the most useful features in the current system(s)?
    - What in your opinion are the most coveted features that are missing from the current system(s)?
    - Are you, or anyone else in your organisation, aware of blockchain-based solutions available for SCM?
    - If your organisation is already using some blockchain-based SCMS, how would you describe the value that the system provides? Could you elaborate with an example?
    - Do you personally believe that your organisation sees benefits in blockchain for its business and would invest in it?
- Questions aimed for suppliers
    - Briefly describe the current services offered by your organisation that include blockchain use in SCM.
    - How do you view the current adoption rate of blockchain-based SCMS by your target customers?
    - Which market gap(s) would you say your organisation is trying to fill with blockchain-based SCMS?
    - How many clients does your company currently work with on projects related to blockchain-based SCMS?
    - From the data available to you, what would you say are the top in-demand features that current blockchain-based SCMS are not (yet) able to offer?
- Questions on blockchain integration in SCMS *[aimed for all interviewees]*
    - Could you describe examples of practical issues, if applicable, that your organisation faced with blockchain integration in SCMS.
    - How would you personally rate the matureness/readiness of blockchain for enterprise applications in general?

- Based on your company's experience, which factors in the table below you believe influence(ed) the decision of adopting/not adopting blockchain-based SCMS:

Presence of internal influencer(s)	System trialability
Regulatory/governmental influence	Stakeholder readiness
Supportive management policies	Compatibility w/ IT infrastructure
Perceived system ROI	Scope of firm operations
Compatibility w/ third-party software	Firm's slack resources
Centralisation of the firm	Perceived system complexity
Pressure from competition	IT savviness of the firm

- Could you elaborate on your choices from the previous question?
- What do you believe are some of the challenges preventing or slowing down the adoption of blockchain-based SCMS?
- Which adoption challenges of blockchain-based SCMS do you consider as the most critical, i.e. you regard as "deal breakers"?