CHALLENGES IN USING BLOCKCHAIN FOR SUPPLY CHAIN MANAGEMENT INFORMATION SYSTEMS

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Abstract

Blockchain has been the hype in technology lately and supply chain management is often mentioned as one of its applications. However, it is unwise to just eat the hype. Blockchain does have weaknesses; some of its natures considered as strengths might be weaknesses or problems in some cases. There are many things to be considered and among them are the challenges. This paper presents a systematic literature review of challenges in using blockchain for supply chain management information systems. This paper aims to help stakeholders and top management of supply chains when considering on adopting blockchain. The literatures were gathered from open-access papers found on Google Scholar. A total of 76 unique papers were found and then 29 were selected. The findings were classified into 12 categories. The top three category of challenges are development and implementation, performance and efficiency, and sustainability and scalability. Apparently, although blockchain in cryptocurrency is pretty solid, there are many challenges in its usage for supply chain.

Keywords: *blockchain; smart contract; challenge; difficulties; supply chain; information systems*

1. Introduction

Lately, cryptocurrency has become a trend, especially Bitcoin. Until the end of May 2019, 1 bitcoin can value up to IDR 117 millions (Coinbase, 2019) – a really huge amount. Aside from trading like stocks or Forex, many earns from Bitcoin by mining. Mining is actually what runs Bitcoin (Zheng et al., 2017). The miners run Bitcoin and they're getting paid for it, in Bitcoins (Udokwu et al., 2018; Yaga et al., 2018). The need for miners is caused by how blockchain on which Bitcoin runs works. Blockchain is often regarded as a very secure technology due to its heavy use of cryptography. How bitcoin runs well despite booming worldwide while having no central authority proves its security. Some even say that it has never been hacked (Trummer, 2019).

Blockchain is a digital ledger technology which transactions are immutable (can't be altered), is distributed in the network without the need for trust, and keep growing as transactions keep getting recorded. Just like a real ledger, blockchain keeps a complete record of every transactions ever happened there. There is no central server in blockchain; every node works together to run the system with (ideally) equal standing. Because there's no central server, every node keeps a copy of the ledger. This is part of how blockchain keeps the system secure despite having it run by mutually distrusting nodes. (Nakamoto, 2008; Yaga et al., 2018; Zheng et al., 2017)

Blockchain was meant to be a publicly distributed ledger, but there are also other types of blockchain. In private blockchain, there are certain level of trust on some nodes. This makes the blockchain kind of centralized, so the key to security is held by those trusted nodes. Private blockchain is usually used for internal organization system. In private blockchain, new participants needs to be accepted by the manager, the trusted nodes. Private blockchain can also restrict participants privileges. Consortium blockchain is a private blockchain with larger scale. Consortium blockchain is usually used for a system that includes many organizations, for example, supply chain management information system. (Zheng et al., 2017)

Supply chain is a sequence of processes and flows that aim to fulfill end customer requirements and take place between companies involved. Supply chain doesn't only include manufacturers and suppliers but also logistic entities, retailers, and end customers themselves. Traditional supply chains suffer from bullwhip effect, causing overestimations over demand spikes that grows bigger as it goes uphill the supply chain. That effect is caused by limited knowledge of the actual demand and requirements, limited view of the customer end of the chain. This is the main reason of

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why supply chain management is needed. (Van Der Vorst, 2004)

Van Der Vorst defined supply chain management (SCM) as “the integrated planning, coordination, and control of business processes and activities in the supply chain to deliver superior consumer value at less cost to the supply chain as a whole whilst still satisfying requirements of other stakeholders in the supply chain”. With supply chain management, supply chains can increase profitability by reducing costs and providing better delivery performance and product quality thanks to better information availability and collaboration. (Van Der Vorst, 2004)

SCM relies heavily on information, so it also relies on ICT and information systems. Supply chain management information system (SCMIS/SCIS) is important for sustainable SCM because it benefits organization, suppliers, and customers (de Camargo Fiorini & Jabbour, 2017). SCMIS’ main purpose is to provide information and information capability to support strategy, operations, management, and decision making in supply chain (Daneshvar Kakhki & Gargeya, 2019). SCMIS is a distributed system; it integrates the supply chain members’ existing information systems. The higher the integration, the easier the cooperation becomes, and consequently, the better the firm performance will be (Budiarto et al., 2017). However, SCMIS is hard to implement due to the complexity of integrating many existing information system from many firms which have differing objectives (Denolf et al., 2018).

How blockchain enables secure, immutable, transparent, and often cheaper transactions makes many businesses and platforms adopt it, including supply chain and logistics (Pereira et al., 2019). Blockchain can help reduce bullwhip effect more thanks to its information transparency and integrity (Babich et al., 2019). Mitch, a supply chain researcher and lecturer, said (in Fleischmann and Ivens, 2019) that supply chain today is executed by an intermediary which became the one bonding the trust between parties. Even with SCMIS, there has to be an entity managing it (Yuan et al., 2019). This can be solved by the trust established by blockchain the execution enforcement of smart contracts, which can be regarded as blockchain 2.0 (Hasanova et al., 2019). Supply chains can use smart contracts to automate the steps to be executed for certain events, such as item shipping, arrival, etc (Abou Jaoude & George Saade, 2019).

There are many examples of blockchain usage in supply chains. Maersk, the global shipping company, and IBM are collaborating the provide end-to-end supply chain solution with blockchain to track shipping containers (Johnson, 2018). Provenance use blockchain to promote trust in supply chain by providing transparency (Kshetri, 2017). Walmart, which uses blockchain to track shipping of mangoes from Mexico to the US and its supply chain in China, said that it shortened the time needed to track produce from six days to two seconds (Felin & Wilson, 2018). FarmaTrust made a blockchain system for pharmaceutical supply chain (Dasgupta et al., 2019).

There is only one question that forms the base of this paper: is it wise to use blockchain for a supply chain? Despite being seen as a technology with high security, there are weaknesses in blockchain. Blockchain that keeps growing will be storage demanding, especially in systems that uses huge amount of data, such as supply chains (Saad et al., 2019). Smart contract may seem like a useful feature, but it is very complex and just like other applications, there may be bugs (Babich et al., 2019). However, unlike normal codes, those bugs and problems caused by them might be way harder to fix due to the distributed and immutable nature of the blockchain and the complexity of the smart contract. Lastly, organizations might not be willing to reveal their data to the system (Babich et al., 2019). This is a common issue in supply chain management, but this wastes one of the strengths and reasons to use blockchain; its transparency. That transparency itself might even be the cause of the unwillingness, because organizations might lose its bargaining power as information are revealed (Van Der Vorst, 2004).

Zhang et al. (C. Zhang et al., 2019) in his literature review on blockchain application in food SCM mentioned the following challenges: scalability, adaptation (persuasion and regulations), and outside-of-blockchain issues. Mohan (Mohan, 2018) in his research to improve food traceability with blockchain adds availability of experts to the list of challenges. Saberi et al. (Saberi et al., 2019) in his research on relationship of blockchain to sustainable SCM presents many challenges grouped into the following barriers: intra-organizational barriers, inter-organizational barriers, system related barriers, and external barriers. Although Zhang et al. mentioned system integration as one of blockchain’s benefits, Baruffaldi and Sternberg (Baruffaldi & Sternberg, 2018) mentioned system integration as one of the challenges. In addition to that, privacy issues also need to be addressed (Baruffaldi & Sternberg, 2018; Rabah, 2017).

This paper will discuss the challenges in using blockchain for supply chain management information system. This paper is hoped to be a help when considering to use blockchain for supply chain management and a base for further research. This paper was done with systematic literature review which will be explained later.

2. Methods

This research was done with systematic literature review. It is a systematic method to identify, evaluate, and synthesize completed works produced by researchers, scholars, and practitioners (Okoli, 2015). This systematic literature review was done with simplified steps inspired by (Okoli, 2015; Torres-Carrion et al., 2018; Xiao & Watson, 2019). Graphic representation of the methodology is shown in Figure 1.

Figure 1. Systematic Literature Review Phases

The methodology used consists of four phases: planning, searching and filtering, review and analysis, and reporting. In the planning phase, the research question and the review protocol were defined. The review protocol consists of the paper sources, the search queries, and the inclusion and exclusion criteria. In the searching and filtering phase, the papers are searched from the source using the queries and then filtered with the criteria. In the review and analysis phase, the review is done for each paper, reading the paper and taking note of anything relevant to the research question, and then the results are grouped into categories and combined. In the reporting phase, the final results are reported; this paper is written.

The papers were gathered from Google Scholar. Papers were taken from papers from first three pages of search or at least 10 first papers from 2019, 2018, and 2015 which fulfills inclusion criteria 1 to 4 and does not fulfill the exclusion criteria 1 and 2. Papers were further filtered by the exclusion criteria, mainly the fourth criterion for the content.

The following research question were formulated and used: “What are the challenges in using blockchain for supply chain management information systems?” There are 3 versions of the search query, but they’re basically the same. First, a query was derived from the research question. The original query were then split into three: one mentioning information system and SCM, one only mentioning SCM, and one only mentioning information system. This was done because papers often don’t mention the “information system” part of SCMIS and only mention SCM. Those papers might be excluded if the query includes “information system”. Below are the final queries:

1. (“blockchain” OR “smart contract”) (“weakness” OR “difficulties” OR “challenges” OR “difficult”) (“supply chain” OR “SCM”)
2. (“blockchain” OR “smart contract”) (“weakness” OR “difficulties” OR “challenges” OR “difficult”) (“supply chain” OR “SCM”) (“information system” OR “SCMIS” OR “SMIS”)
3. (“blockchain” OR “smart contract”) (“weakness” OR “difficulties” OR “challenges” OR “difficult”) “information system”

The following inclusion criteria were used:

1. The paper was dated 2015 or later.
2. The paper is written in English or Bahasa Indonesia.
3. The title is related to blockchain and blockchain challenges or/and its usage in supply chain or information systems.
4. The paper’s full text is accessible freely, even if it’s the author’s version.

In addition to the opposite of inclusion criteria, the following exclusion criteria were used:

1. The paper was unpublished (author’s version of published paper doesn’t fall in this criteria).
2. The paper is not a journal paper, a book or book section, or a conference paper.
3. The paper is a duplicate.
4. The paper doesn’t explain challenges of using blockchain in general, supply chains, or information systems (just mentioning doesn’t count as explaining).

3. Results and Discussions

The search result from each search queries in each year range is shown in Table 1. The papers were then merged and duplicates were removed resulting in 74 papers. Those papers were then filtered with the exclusion criteria by skimming, resulting in 29 papers. The selection is presented in detail on Table 1.

Table 1. Paper Selection Process.

Query	Since	Inclusion	Merge	Exclusion
1	2015	21	76	29
	2018	17		
	2019	15		
2	2015	20		
	2018	18		
	2019	19		
3	2015	20		
	2018	19		
	2019	22		

There are 7 papers explaining only blockchain in general, 18 explaining blockchain in relation to supply chain, and 4 explaining blockchain in relation to information systems (Figure 2). There are 18 journal articles, 8 proceedings, and 3 thesis (Figure 3). There are 2 papers from 2017, 10 from 2018, 18 from 2019, and 1 scheduled to be printed in 2020 but is already accepted and published online (Figure 4).

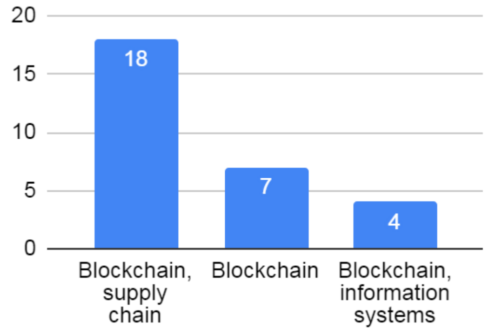

Figure 2. Paper Tags

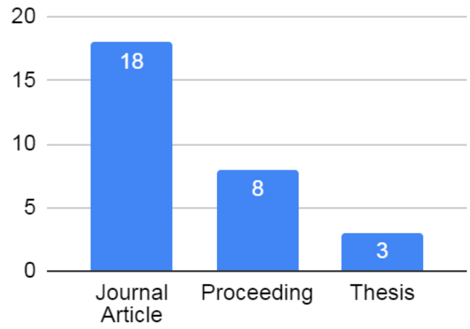

Figure 3. Paper Types

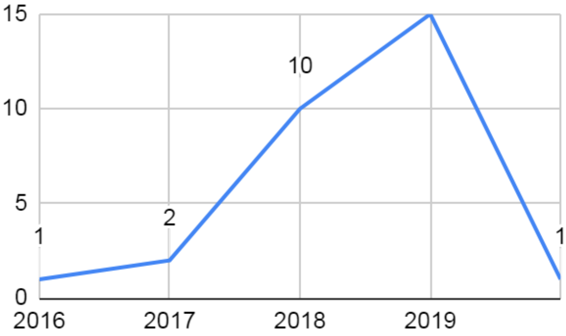

Figure 4. Paper Publication Years

Challenges were searched from the paper and put into categories. The categories used were primarily selected and combined from several papers (Lu, 2019; Meng & Qian, 2018; Mohsin et al., 2019; Yadlapalli et al., 2019). In addition to those selected categories, some categories were added because some challenges didn't quite fit into any of the selected categories or were judged better to be in a more specific category. The challenge categories and count of paper explaining them are shown in Figure 5. The top three most discussed challenges were development and implementation, performance and efficiency, and sustainability and scalability.

3.1. Development and Implementation

The hype around blockchain may make stakeholders want to apply it blindly, anywhere and everywhere. Blockchain is at inflated expectations on Gartner's hype cycle, so cautiousness is advised. Global supply chains are specially complicated because they need to follow various laws and regulations in multiple jurisdictions. (Ahlstrand, 2018)

The blockchain has to align with the supply chain standards used. The standard would first have to be mapped into the solution. Next, the data governance model has to be set up with that standard to ensure data integrity. It is also important to determine which data to share, when, and why. The platform also has to be ready for future applications such as IoT, AI, and big-data analysis, since the natural adaptability and extensibility of blockchain is low. Also, it is hard to extend the platform to third parties such as logistics providers. Implementing smart contracts and splitting the blockchain into one that stores data and one that executes contracts may be a solution. (Fosso Wamba et al., 2018)

Blockchain is resource demanding, specially computational resources for blockchains with proof-of-work validation method. Alternative methods have been developed to solve this issue, but they often introduce new problems (Mendling et al., 2018). Finding the best validation method for the system being

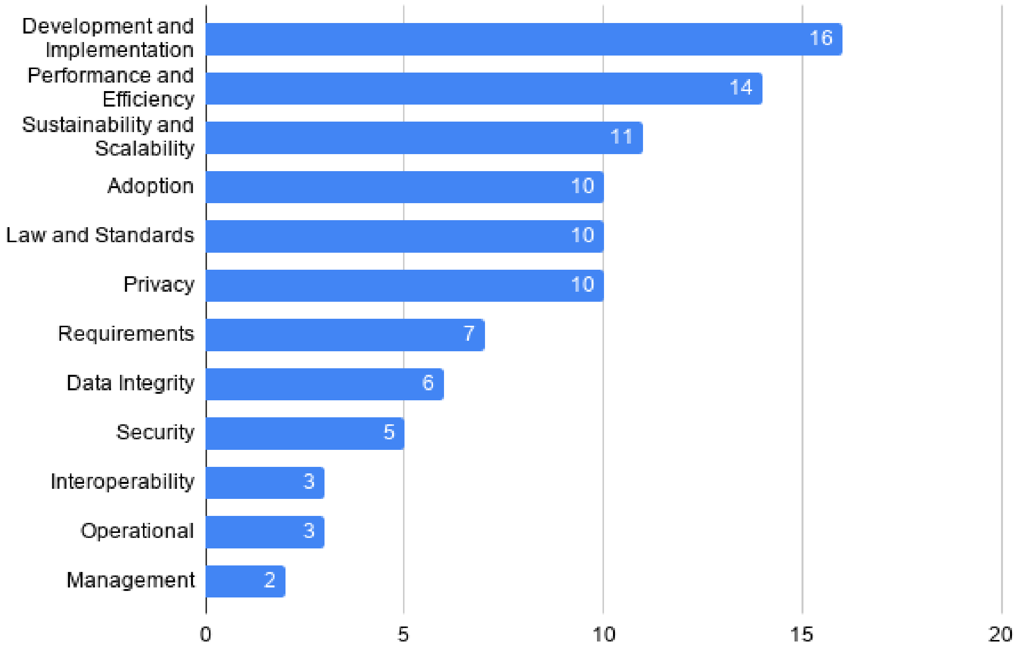

Figure 5. Count of Paper Describing Each Challenge Category

built might be hard, but they have to be decided early. Sometimes organizations even need to develop their own. There are many problems to be solved concerning validation method, such as performance, scalability, security, and privacy (Lu, 2019).

Blockchain as an append-only database keeps on growing and will be very huge. Therefore, blockchain should only keep data needed by customers (those who use the data) and only the needed parts (Edwards & Chan, 2019). Determining which data to store and share might be quite difficult.. Deciding how the data should be structured and validated is also a challenge. The original blockchain was meant for cryptocurrencies so checking account balances works and is enough, but for other uses, it might be more complex and there might not be enough examples available (Misic et al., 2019).

Every design decisions such as permissioning, ownership, privacy, and consensus protocols should be decided early. Bad design will make it perform worse than conventional centralized systems. Latency, availability, and flexibility should also be addressed. Some informations might also be difficult to include in the blockchain thus should also be addressed. Some information might also be considered confidential so its access should be limited. (Kamilaris et al., 2019)

Blockchain is a new technology, so there is lack of experts and knowledge (Kumar & Mallick, 2018; Saberi et al., 2019; Yadlapalli et al., 2019). Both its developer support (tools) and end-user support (understanding) are also lacking (Mendling et al., 2018). There is also no standard method to blockchain system development (Edwards & Chan, 2019; Yadlapalli et al., 2019). Most literatures are either conceptual, framework proposals, or case studies (Edwards & Chan, 2019), while most blockchain implementation has very complex structure so it is hard to take as an example (Yadlapalli et al., 2019). Most of the proposed frameworks weren't evaluated to design real systems either (Tribis et al., 2018).

Blockchain is complex and hard to implement, so there might be poorly developed or maintained code which will become vulnerabilities for hackers. Vulnerability in smart contract might be fatal since it will execute code on every nodes. The DAO "hack" is a common example for the possible damage caused by that. The logical error in the smart contract caused $50m of virtual currency to be stolen. Human intervention was required to solve the issue, leading to questions on whether self-executing smart contract is a good idea. (Behnke & Janssen, 2019)

Blockchain is complex and hard to set up (Kamilaris et al., 2019; Mahmood et al., 2019), and for supply chains, it usually integrates many components such as IoT, RFID, sensors, and even robots. In fact, to be functional, blockchains must rely on external entities to obtain information. They might be hardware (e.g. sensors), software (e.g. other system), or human (manual input). There are various platforms that blockchain can use and finding the optimal combination isn't easy. (Kamilaris et al., 2019; Min, 2019)

3.2. Performance and Efficiency

Blockchain requires huge computing power and high bandwidth which is neither easy nor cheap. This forces the blockchain to use cheaper validation method which might end in centralization thus losing some of its main benefits and original purpose (Ahlstrand, 2018; Min, 2019). However, some centralization might not be much a problem in supply chains. Meanwhile, modern supply chains often use IoT which has low computation resource and storage. (Meng & Qian, 2018)

Despite requiring high resource, blockchain has low throughput (transaction rate) and it can't compare to centralized systems (Costa, 2018). In Bitcoin, a transaction can only be 1MB at maximum. Bitcoin and Ethereum can only process three to thirty transactions per second, while Visa can process 50,000-60,000 transactions per second at average (Aliyu et al., 2018; Kleinman, 2019; Mendling et al., 2018). There are alternative designs that can increase throughput. Using permissioned system with optimized consensus model will improve the rate significantly in exchange for some degree of open-ness and security (Behnke & Janssen, 2019). Red Belly blockchain has achieved more than 400,000 tps in lab test, but it's still experimental (Mendling et al., 2018). However, even though the information flow of one company might be slower, the flow between companies, specially new blockchain members, might be much faster. The decrease in speed is not all negative; it is traded with more functionality.(Costa, 2018)

Due to the chain-broadcast structure of the network, every transaction takes quite some time, specially for public blockchains and smart contracts (Mendling et al., 2018; Tribis et al., 2018). This also give birth to the fork problem which may lead to double spending and be abused (Aliyu et al., 2018; Tribis et al., 2018). It takes 10 minutes to create a block and an hour for a transaction to be considered as commited in Bitcoin, Ethereum transaction takes 3 to 10 minutes, while VISA transactions take just a moment (Aliyu et al., 2018; Mendling et al., 2018; Mohsin et al., 2019; Wang et al., 2017). The validation method used and number of participants play big roles here (Guo & Liang, 2016).Techniques have been developed to solve this, but it's still unlikely to achieve latencies as low as centralized systems. Among blockchain types, consortium blockchains performs better than private and public blockchains for healthcare systems (Kombe et al., 2018). However, such efficiency won't meet requirements of supply chains with high transaction rate. (JieYu, 2019).

3.3. Sustainability and Scalability

Blockchain transactions are immutable, so the blockchain is append-only and it will keep growing and become too large and not be sustainable because every node has to keep a copy of it (Behnke & Janssen, 2019; Costa, 2018; Kumar & Mallick, 2018; Meng & Qian, 2018; Mohsin et al., 2019; Saberi et al., 2019; A. Zhang et al., 2020). In 16 December 2016, Bitcoin took 100GB of disk space. The increase in size also impacts performance negatively (Mohsin et al., 2019). However, the size and the problem it causes depends on the data stored, transaction frequency, and number of participants (Behnke & Janssen, 2019; Costa, 2018). Although using lightweight nodes can solve this to some extent, better solutions still need to be researched (Lu, 2019). Bitcoin-NG tries to solve this by decoupling the ledger into two parts: microblock to store transaction and key block for leader election (Meng & Qian, 2018).

Changes in blockchain may make the previous version invalid (hard fork) (Mendling et al., 2018). Most participants have to agree and implement the changes in order for it to work. Although controversial for public chains, hard fork isn't really an issue for private and consortium blockchains. Organizations should also embed sustainability at all organizational levels if they wish for sustainabilit (Saberi et al., 2019).

It is also hard to extend the platform to third parties such as logistics providers. Implementing smart contracts and splitting the blockchain into one that stores data and one that executes contracts may be a solution. (Fosso Wamba et al., 2018)

Blockchain is still immature, specially for supply chains. Most proposed blockchain frameworks were only tested on limited scale. Most blockchain implementation in the real world are also practically small. New challenges may arise when the system is scaled highly in the real world. (Tribis et al., 2018)

3.4. Adoption

It's difficult to have participants collaborate to invest time and effort to deploy blockchain systems. Although it might provide great future competitiveness and opportunities, the cost is high and it is risky (Kesharwani, 2019). Most blockchain technology is untested and experimental (Rabah, 2017). Adopting blockchain would require new IT tools. This might be a challenge for some supply chain members (Saberi et al., 2019). Aside from that, blockchain as a potentially disruptive technology may require legacy system changes or even replacement (Saberi et al., 2019).

Even just convincing parties to share data using blockchain can be hard (Fosso Wamba et al., 2018; Wang et al., 2017). Supply chain actors don't really understand blockchain's benefits, how it works, and its ease of use, but they have to, specially the top management and stakeholders (Edwards & Chan, 2019; Tribis et al., 2018; Yadlapalli et al., 2019). This understanding will affect their decision on whether to adopt blockchain or not. It is also believed that blockchain is costly and requires expensive hardware to be successful (Yadlapalli et al., 2019). Blockchain is also slower than centralized system, so parties have to understand the benefit gained from trading the speed. (Ahlstrand, 2018)

Blockchain is a disruptive technology which might make and require transformation in organizations. Organizations may find it hard to manage those changes. Their existing systems was already costly and took time to build. Developing blockchain system is expensive so the cost of change will be really big. Many supply chain still use traditional methods for many things so the change might be hard to manage. (Kleinman, 2019; Wang et al., 2017)

3.5. Law and Standards

Blockchain as a distributed ledger with high privacy can bypass government's interference, so the government might press blockchain users through various regulations and legal restrictions and they might reduce its usefulness. For example, the Korean government was reported to be trying to cooperate with China and japan to regulate or ban cryptocurrencies powered by blockchain. However, the high privacy and lack of regulation isn't a good thing either. It makes blockchains vulnerable to potential scammers and little can be done about it. (Guo & Liang, 2016; Min, 2019)

Currently, there is little to no regulation regarding blockchain (Kumar & Mallick, 2018). Regulation and policies related to blockchain are important barriers for its wider adoption. Without them, the technology can't be considered trustful to be used in supply chains.(Kamilaris et al., 2019). Lack of regulation is a challenge also because it is unclear on how the system should be built and new regulation might appear anytime and the already-built system might need to be adjusted.(Saberi et al., 2019). The lack of regulation also means lack of standard, making blockchain implementations so diverse with low interoperability. (Kesharwani, 2019; Tribis et al., 2018)

There might not be many specific regulations concerning blockchain, but there are many concerning accountability, data ownership, and privacy (Kleinman, 2019). Some legal issues had arisen; they're about accountability for the documents, implications of compromised data integrity, security, and accuracy, and privacy and jurisdiction (Lu, 2019; Mohsin et al., 2019).

3.6. Privacy

In the original blockchain, the data is transparent. Everyone can access the data and it was designed to be like that. However, some data might be confidential for supply chains, so access has to be controlled. Blockchain doesn't support this by default and it is not easy to implement. Some blockchain have recognized this and enable access control, such as Hyperledger. (Behnke & Janssen, 2019; Rabah, 2017)

Anonymity still doesn't mean privacy even when the information stored isn't sensitive. People might still be able to infer information with the anonymous data, which might be unwanted. Those information are transparent in public blockchains. Aside from that, if someone gets to know someone else's public key, then he can know all of his transactions. (Du et al., 2019; JieYu, 2019; Meng & Qian, 2018; Mohsin et al., 2019)

Aside from confidentiality, there are also issues with privacy and data ownership; healthcare systems can be taken as an example for this. In healthcare, the health records are considered as the patients' property and it is protected by law. The records should be available for the patients at any time with some legal exceptions. Access to the records should be limited with the patients' authorization. The access can also be limited to just some information, such as diagnoses only or prescriptions only. The patients should also be able to revoke access to their data, but it's hard to do with blockchain. The system can't force someone to "forget" the key used to access the data and the data can't be erased or edited. (Misic et al., 2019)

Companies also value their privacy and security of their information, so they might not want to share too much information (Costa, 2018). Moreover, organizations and even countries may have different privacy policies related to information. Supply chain systems should address this early, specially blockchain which adaptability is low. Lack of solid rules will affect collaboration negatively. Lack of collaboration will disturb sustainability. (Saberi et al., 2019)

3.7. Requirements

Systems are diverse, but they all have to be powerful enough to run the heavy computation of blockchain (Kumar & Mallick, 2018). This is also the case with storage, because every node stores a copy of the blockchain. Since the data needed to be stored is big, it's also bandwidth demanding. (Mendling et al., 2018). Supply chains might span accross countries and the technology gap between countries, specially developed and developing ones, might be a challenge. For example, in food supply chain, the farmers might not have the technology required or they do but it's just not feasible with their current technology (Kamilaris et al., 2019; Tribis et al., 2018).

Blockchain is costly, so only big corporations might be able to afford it, and even when they do, it may still be hard to decide on whether to adopt it or not (Kleinman, 2019). The cost to integrate all the parties which might already have their own systems is likely high too. The cost of the system might even be higher than the product. For example, the cost for food traceability is higher than the value of the food itself. (*Chen_et_al_Poster*, n.d.)

3.8. Data Integrity

Data integrity is blockchain's strong point, but it doesn't cover errors before it gets into blockchain, specially if the data is inputted by human. The data might have also been tampered with. The problem here is the immutability of blockchain transactions. This results in immutable bad data. Due to the immutability, errors might be irreversible, and even if it can be fixed, the old, garbage data will still be there and waste storage. The data quality in supply chains is generally poor, but sensors and IoT can help. Verification of transactions in cryptocurrency is supported fully, but it is hard to fully support verification of complex data from supply chain. (Blossey et al., 2019; *Chen_et_al_Poster*, n.d.; Du et al., 2019; Guo & Liang, 2016; A. Zhang et al., 2020)

The data in the blockchain might be digital representation of a physical thing. This means that it has to be consistent with reality. Errors and unforeseen changes happen in the real world, but the blockchain is append-only. The blockchain has to support this issue, but that might mean wasting its immutability and storage space. (Kleinman, 2019)

3.9. Security

Although considered as highly secure technology, blockchain does have some vulnerabilities. The 51% attack, although may not be feasible in most cases, can control the whole blockchain. It is when a party acquires 51% of power in the pool and use it to control the blockchain. The kind of power may differ depending on the validation method. For proof-of-work, it would be 51% computing power. (Aliyu et al., 2018; Mohsin et al., 2019)

There are also some design flaws in blockchain. Private key is too important yet light so that when you "lose" it, there's no "getting it back". Double spending is also a problem due to how blockchain nodes communicate, leading to users waiting for some period of time before being sure that transaction is actually commited. (JieYu, 2019; Mohsin et al., 2019)

Lastly, there are risk that the cryptography functions used at the moment might be broken in some years. In centralized functions, they can just roll an update. However, this kind of change is hard to do in blockchain and would require hard fork. It's not even certain that the replacement will be available on time. (Costa, 2018; JieYu, 2019)

3.10. Interoperability

Interoperability can be explained as the ability to convert Bitcoin into Ethereum without need for intermediary. In supply chain, a supplier might not only be connected to one supply chain. Those supply chains might also have their own systems. The supplier likely wouldn't want to be challenged with different blockchain architectures from different supply chains. This would lead to fragmentation and higher complexity because the blockchain systems would need to interface with each other. Standardization might be required, but interoperability standards in both SCM and blockchain is lacking. (Behnke & Janssen, 2019; Costa, 2018)

Interoperability is harder for blockchain because of the "fork" problem. When sharing information, that information is orphaned from the chain and might lose validity while it is being used by the other system. The resulting behaviour will not be valid anymore if the base information isn't valid anymore. To actually solve this, standardization is a must. (Kleinman, 2019)

3.11. Operational

In conventional SCM, every member has to participate, or it won't be as effective as hoped, because there will be missing data (*Chen_et_al_Poster*, n.d.; Kleinman, 2019). However, organizations may see information as competitive advantage which makes them less willing to share them (Saberi et al., 2019). This is also the case with blockchain systems for SCM.

Usage of traditional tools and manual works are still too common in supply chains. Emails are written and sent manually; documents are printed and mailed. The human resources might not be ready to use this new technology. (Costa, 2018)

3.12. Management

Top management support is a key factor to success of supply chain practices. However managers may fail to have long term commitment to support adoption of new technology and stick to sustainability. Lack of awareness and commitment will challenge resource allocations and financial decisions, while blockchain is costly. Lack of the needed organizational policies would make blockchain adoption hard, since blockchain might transform organizational cultures. (Saberi et al., 2019)

Aside from that, blockchain might make changes to how the organizations work and collaborate (Edwards & Chan, 2019). Automation and elimination of intermediaries from blockchain will significantly reduce human intervention, consequently reducing jobs. However, adopting blockchain also means requiring new roles, responsibilities, and expertise. All of this will have to be managed. (Kamilaris et al., 2019; Saberi et al., 2019)

4. Conclusion

This paper presented a systematic literature review of open-access papers explaining blockchain challenges with focus on its usage in supply chains information systems. The papers were published in 2016 to November 2019 with addition of one scheduled to be printed in 2020 but was already available online by November 2019; most of the papers were published in 2018 or 2019. The papers consist of mostly journal articles, some proceedings, and few theses.

The challenges were classified into 12 categories: development and implementation, performance and efficiency, sustainability and scalability, adoption, law and standards, privacy, requirements, data integrity, security, interoperability, operational, and management. Among those, the top three most discussed categories were development and implementation, performance and efficiency, and sustainability and scalability.

In development and implementation, the most discussed challenge is how blockchain is immature so there aren't enough experts, knowledge, nor tools. How complex both blockchain and the supply chain are is also a big challenge, because everything has to be considered and determined early. In performance and efficiency, the main issue is how blockchain is very resource demanding yet have low performance that can't compare to centralized systems. This high resource demand is also the main source of issues in sustainability and scalability; it's unrealistic because supply chains might be very wide and diverse. Aside from that, the adaptability and extensibility of the blockchain are issues too. In adoption, top management and stakeholders might be too optimistic because of the hype or, the opposite, too pessimistic because of blockchain's inefficiency, transparency, or disruption. Either way, they need to have more understanding of blockchain if they are considering it. In law and standards, the main issue is that there is little to no regulation for blockchain, which is both good and bad. Despite having no specific regulation, legal issues still arise regarding the data in the blockchain, including privacy issues. Originally, data in blockchain were meant to be transparent and that was fine because they were just balances of anonym account, while in more complex implementations, sensitive or confidential data might need to be stored in the blockchain. Also, anonymity does not mean privacy. Next, the high requirements of blockchain is a challenge in itself and might demotivate and restrict the adoption of blockchain. Although data integrity is blockchain's strong point, the data might've been erroneous before it gets into the blockchain and currently there is little to be done for it except using automation to reduce human errors. Blockchain is also considered a highly secure system, but it also has vulnerability. Some attacks are possible and there are some design flaws like the fork issue. Quantum computing is also a risk to the cryptography that forms the base of blockchain. Interoperability is a challenge specially in supply chains where it is needed but supply chains are so diverse and there is lack of standards for blockchain and supply chain interoperability. There is also operational challenge where participants might not want to fully participate or they're unable to due to lack of skill. Lastly, management is a challenge because of the complexity and the changes that blockchain requires or makes and the top management has to keep their commitment or it will fail.

This research is primarily meant to be a warning for those who want to jump into the blockchain hype in SCM context, but it is also hoped to help this technology mature by making those challenges be known so, hopefully, researchers will try to solve them. Therefore, it is hoped that there will be future researches to solve those challenges. However, this research didn't determine the significance of the challenges. Some of them might be insignificant while researches should focus on significant challenges. Therefore, research can also be done to determine the significance of the challenges. Lastly, future researches can further strengthen this topic by doing similar research with more or better papers, such as ones from reputable international journals, because the papers used in this literature review were very limited. There may be many challenges not covered here or more details to add to the challenges already covered here.

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