

Mahyuni, Luh Putu et al.

## Article

# Mapping the potentials of blockchain in improving supply chain performance

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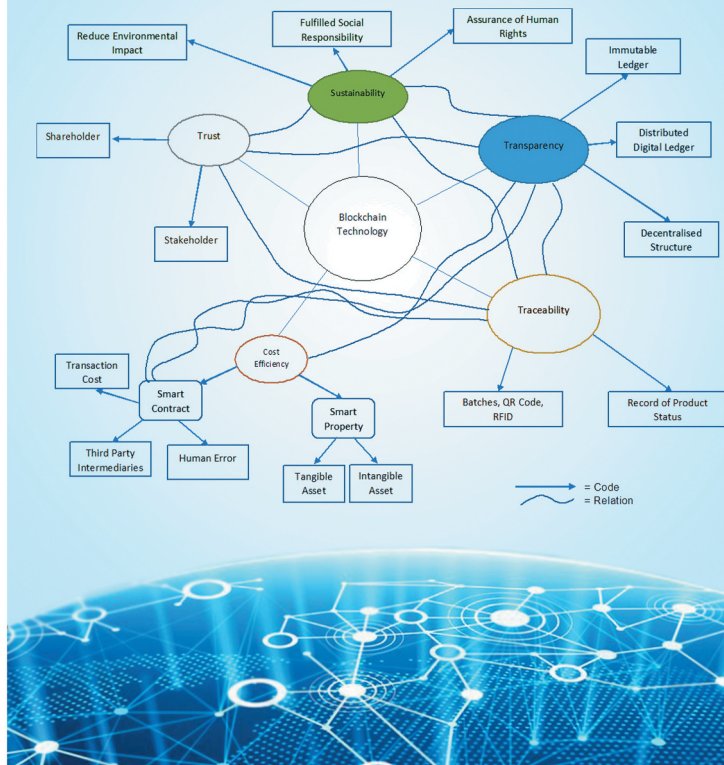
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## MANAGEMENT | REVIEW ARTICLE

# Mapping the potentials of blockchain in improving supply chain performance

Luh Putu Mahyuni<sup>1\*</sup>, Richard Adrian<sup>1</sup>, Gede Sri Darma<sup>2</sup>, Ngakan Nyoman Kutha Krisnawijaya<sup>3</sup>, I Gusti Ayu Agung Pradnya Dewi<sup>1</sup> and Gusi Putu Lestara Permana<sup>1</sup>

**Abstract:** This paper aims at reviewing and systematically mapping research on blockchain potentials in improving supply chain performance. Articles were retrieved from several prominent databases, selected, reviewed, grouped into several themes and synthesized. This paper suggests that applying blockchain in the supply chain could improve its performance in terms of transparency, traceability, sustainability, trust, and cost-efficiency. As a cutting-edge technology, blockchain has not been widely implemented in supply chain industries. Research on blockchain application in the supply chain is also relatively limited. This paper contributes to the literature by offering a comprehensive map of research on blockchain potentials in improving supply chain performance. The findings of this study will also be beneficial for managers who seek for a comprehensive understanding of how blockchain technology affects their companies particularly in supply chain management.

**Subjects:** Management of IT; Business, Management and Accounting; Supply Chain Management

**Keywords:** blockchain potentials; supply chain performance; transparency; traceability; sustainability; trust; cost-efficiency



Luh Putu Mahyuni

### ABOUT THE AUTHOR

All authors are the members of a research group of Universitas Pendidikan Nasional (Undiknas University) that focuses on the application of information technology to improve business performance. Furthermore, this research group is concerned with how technology innovation can vastly improve a company's overall efficiency and performance. There are several research projects that have been done by this research group such as the impacts of information technology investment on organizations; the application of e-commerce to improve the competitive advantages, and the evaluation of the information technology by the users based on technology acceptance model. Systematic literature review reported in this paper relates to in-progress research investigating the impacts of supply chain performance on business performance.

### PUBLIC INTEREST STATEMENT

Blockchain has gained its prominence in several years since it would disrupt any field of business sectors including supply chain. It can be applied in goods tracking and payment. The purpose of this paper is to systematically map and review the potential of blockchain for improving supply chain performance. This study used the data that were taken from several credible databases. The results revealed that blockchain implementation could enhance the performance of supply chain in terms of transparency, traceability, sustainability, trust, and cost-efficiency. The findings of this study will be beneficial for practitioners who seek for a comprehensive understanding of how blockchain technology affects their companies particularly in supply chain management.

## 1. Introduction

Nowadays there are many products being manufactured and distributed every day through supply chains that extend around the world. Goods in supply chain industries travel through a vast network of manufacturers, distributors, and retailers, yet in many cases, complete information related to the product that flows along the supply chain is not available (Galvez et al., 2018; Xia & Yongjun, 2017).

Supply chain visibility is still an important business challenge, with most companies having little or no information on their own second and third tier suppliers (Chen, 2016). Supply chain transparency can assist model the flow of products, from raw materials to processing and finishing products, that enable a new kind of analysis in the supply chain (Agrawal et al., 2018).

Besides transparency, traceability is also important to improve supply chain performance. Currently, traceability is becoming an urgent requirement and an important feature to differentiate many supply chain industries including food sector, pharmaceutical and medical products, and high-value goods (Galvez et al., 2018).

Blockchain technology application is believed to have great potentials to improving supply chain performance (Pearson et al., 2019). Blockchain can be applied for creating contracts, tracking goods and payment. Blockchain records every transaction on a block across multiple copies of the ledger that are shared with every party, and the record is transparent. Anyone can add data to the block by doing transaction in the network, see these data, but no one can hack or modify them. As a result, blockchain is immutable data of network activities, which are shared among all parties in the shared network.

This is why blockchain technology innovation is regarded as a game changer on global scale by all actors. Several potential benefits of blockchain technology application are identified from the literature (Ko et al., 2018), such as reduction of transaction costs, exclusion of intermediaries which diminishes the risk of human error, and generation of a highly secured platform for communication and trade globally.

Previous researches exploring the potentials of blockchain application in the supply chain have shed some light into the relation between blockchain and traceability systems of supply chain (Petersen & Jansson, 2017), traceability and transparency (Jeppsson & Olsson, 2017), and trust and transparency (Chiou et al., 2005). However, to obtain a comprehensive understanding of the potentials of blockchain technology application in improving supply chain performance, a systematic literature review is needed. This paper aims at offering a comprehensive map of how blockchain technology application could improve supply chain performance. The rest of the paper is structured as follows. The next section provides an overview of technical terms regarding blockchain, how blockchain works, peer-to-peer distribution system, and supply chain. Then, research methodology is explained, followed by literature review, findings, and discussion. The study concludes with conclusions and practical implications.

## 2. Overview of technical terms

### 2.1. Blockchain

Blockchain is a novel technology rooted in cryptography which was first applied to develop a cryptocurrency (bitcoin) (Nakamoto, 2008). Blockchain is a transaction database or data management technology which contains information about all the transactions ever executed in the past and works on Bitcoin protocol (Singh & Singh, 2016; Yli-Huumo et al., 2016).

Blockchain is a decentralised digital ledger with many functions that can be applied for making contracts, tracking goods, and making payment (Westerkamp et al., 2018). Blockchain records every transaction on a block across multiple copies of the ledger that are shared with many parties, and the record is transparent.

Blockchain has a highly secured system because every block is linked together (Wood et al., 2015). Essentially, blockchain is a public ledger that contains information on every transaction made within a peer to peer system.

Blockchain is defined as a giant global google spreadsheet document representing the accounting of transactions and registry of both asset types, tangible and intangible, such as currency, physical property, or documents. In addition, blockchain has a function for tracking and monitoring assets, sharing of information, and executing long-term and conditioned contracts (Hua & Notland, 2016; Tian, 2016).

## **2.2. How blockchain works**

Awaysheh and Klassen (2010) explain how blockchain works. It starts with an identity, known as participant A, informing the network of his arrangement with participant B (another identity). Then, B announces its acceptance, by using his public-key, to the network and simultaneously informs the nodes within the network to determine the authenticity of the transaction.

The verification is conducted with the use of miners. Miners extract the information from the block, in which it has been stored after B's acceptance, and turn it into a hash by applying a mathematical formula to it. The validity of the hash is then processed within a proof-of-work system to guard the transaction from double-spending. When the validity is confirmed, a timestamp is added and the hash is placed in chronological order on a platform creating a blockchain. Hashes are built-off of each other, which grant legitimacy to every block that is created later on along the chain. In effect, tampering with one block would alert the whole network because alterations would contradict the proof-of-work applied in the previous blocks.

The only mode of procedure that could overturn a blockchain is if the culprit controls 51% of the network processing power. In short, the transactions that have been proven valid will be recorded in the public ledger. This makes them unalterable due to the networks' awareness to action. When a block is admitted to a chain, the transaction is considered completed (Biggs et al., 2017; Biswas et al., 2017; Figorilli et al., 2018; Lin, 2018).

## **2.3. Peer-to-peer distribution system**

Peer-to-peer (P2P) system offers a significant improvement to digital distribution of services such as information and resource sharing (Swan & Reilly, 2015). In a simple centralized model, resources are stored by the server and only shared with the client upon request. It functions in a kind of one-to-many distribution model, where the client is dependent on the centralized entity for information.

P2P computing consists of an interconnected network where peers (computers) share resources and information without the use of central server. In short, peers are identical and all hold the attributes of both the client and server. Therefore, requests placed on the network can be reciprocated by any peer that holds the desired information. The system has the equivalents of a many-to-many distribution model, where all participants have the same authority to respond to an enquiry in a decentralized manner excluding a centralized entity. Direct access to multiple servers for information sources instead of a single one creates a faster execution and higher efficiency. Utilization of this system provides communication and information to all peers regarding task distribution.

## **2.4. Supply chain**

Supply chain is defined as lines of various points involved in manufacturing and delivering goods, from the procurement stage to the final consumer. Supply chain consists of various stages and locations. This causes tracking of an event to be difficult along the supply chain. Due to lack of transparency, buyers and consumers cannot ensure the true value of the goods or service offered (Dickson, 2017).

In the supply chain network, it is hard to investigate who is responsible for illegal events that occur. This could be the reason why the world is still facing problems of counterfeiting, forced



labor, and bad conditions in factories. With regard to this issue, blockchain technology offers a solution to fix supply chain problems. Even basic implementation of blockchain technology can bring huge benefits to the supply chain. Dickson (2017) highlights the main function of the blockchain that is considered very useful in the supply chain:

- (1) The availability of information to the public. They can access and provide an opportunity to track goods from their origin to the final consumer.
- (2) A decentralized-based structure allows participation of each party in the network.
- (3) Basic cryptographic and basic structures that cannot be changed provide security and trust.

### 3. Methodology

To address the objective of this research, a systematic literature review was applied. This study followed Kitchenham's (2004) procedures for performing systematic reviews. Firstly, relevant articles were collected from Google Scholar and ScienceDirect Database. The keywords typed to search for the articles were: "blockchain in supply chain", "P2P network", "blockchain impact on supply chain transparency", "blockchain impact on supply chain traceability", "blockchain impact on supply chain sustainability", "blockchain impact on supply chain trust", and "blockchain impact on supply chain cost-efficiency"

Secondly, precise identification of research studies for possible inclusion was conducted.

This step involved developing a means for determining the similarities of studies by comparing stated research purposes, research questions asked, data collection techniques, data analyses, and kinds of findings reported.

Thirdly, the research findings of the articles were analyzed and synthesized. The related studies were identified by analyzing key concepts or themes from the research findings in the selected studies. Finally, the synthesis of findings across studies was presented.

### 4. Literature review

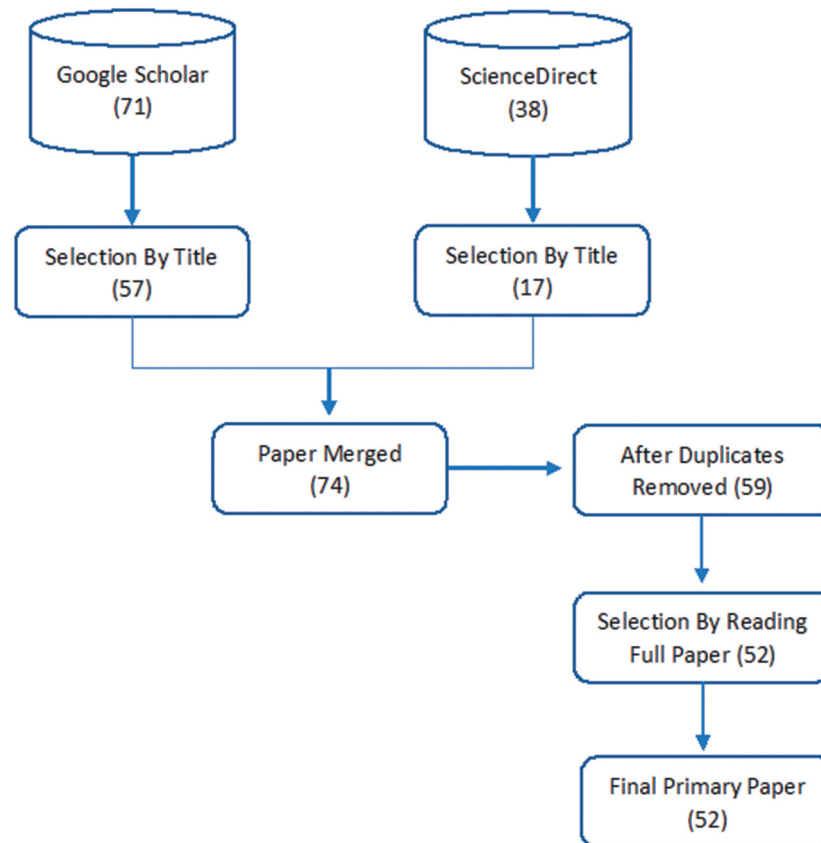
In this section, the results of systematic literature review are presented. With our search protocol, we were able to retrieve 109 papers from Google Scholar and ScienceDirect Database. After the first screening, which was based on the titles of the papers, 35 papers were excluded, leaving 74 papers for further screening. The removed papers were not related to supply chain performance.

Out of 74 papers, 15 were found to be duplicates, leaving only 59 papers for further analysis. All 59 papers were then read thoroughly to precisely identify the similarities of the studies. In this step, we found seven more papers need to be excluded for not intensively discussing supply chain performance. These papers mentioned supply chain performance in one subsection only, as a potential area of application of blockchain. At the end of the screening process, there were 52 papers selected for inclusion in the study. Figure 1 depicts the selection process of relevant papers, and the full list of the selected papers is presented in Table 1.

Even though there was no year limit in searching for the papers, all selected papers were published from 2015 to 2019. Figure 2 shows the publication years of the papers, with the majority were published in 2018 (31 papers). The number of studies in the area of blockchain application in supply chain performance was growing rapidly from 1 paper in 2015 to 5 and 11 papers in 2016 and 2017 consecutively. Up to the mid of 2019, we found only 4 papers that suited the purpose of this study.

After reading all selected papers thoroughly, we identified five major themes discussed as key factors of how blockchain technology application could improve supply chain performance, namely: traceability, transparency, sustainability, trust, and cost-efficiency. Possible relations between themes were also suggested. Figure 3 completely depicts the themes and the relations between them.

**Figure 1. Selection process of relevant articles.**



The themes that were identified are represented by the various size of ovals. The size of the ovals signifies the number of papers that discuss certain themes. Thus, traceability is the most discussed theme, followed by transparency, sustainability, trust, and cost-efficiency.

Besides identifying five major themes, we also classified several codes as part of certain themes. The codes were drawn as rectangular. Table 2 shows the themes and codes identified as the results of thoughtful reading and analyses of the selected papers.

#### 4.1. Findings and discussion

Blockchain is essentially a decentralized digital ledger that has many applications and can be used for making any contracts, tracking goods, and payment. Blockchain records every transaction on a block and across multiple copies of the ledger that are shared with many parties, and the record is transparent. Blockchain is also highly secured because every block links to the block before it and after it. A decentralized system of blockchain makes it extremely efficient and scalable. And ultimately, blockchain can improve the efficiency and performance of supply chains. It improves processing, delivering, and payment.

Blockchain is a cutting-edge technology. The sector that first implemented the blockchain was the financial sector (Fernandez-vazquez et al., 2019). In its development, blockchain technology was also used by other sectors. Sony global education in collaboration with IBM publishes articles and diplomas on the blockchain network so that they cannot be falsified, damaged, or lost. Another example is Alibaba in collaboration with Pricewaterhouse Coopers to help resolve China's food security (Webb, 2017).



**Table 1. List of selected papers and papers' category**

| No. | Authors                      | Year | Publication type | Category   |
|-----|------------------------------|------|------------------|--|
| 1   | Benedict Lutzenburg          | 2017 | Thesis           | Supply Chain Transparency                          |
| 2   | Kristoffer Francisco. et al. | 2018 | Journal          | Supply Chain Transparency                          |
| 3   | Jiri Chod. et al.            | 2019 | Journal          | Supply Chain Transparency                          |
| 4   | Fabian Sander. et al.        | 2018 | Journal          | Supply Chain Transparency and Traceability         |
| 5   | Enbo Chen                    | 2017 | Thesis           | Supply Chain Transparency and Traceability         |
| 6   | Sudhir Pai. et al.           | 2018 | Journal          | Supply Chain Transparency and Trust                |
| 7   | Anders V. Hua. et al.        | 2016 | Thesis           | Supply Chain Transparency and Trust                |
| 8   | Jonathan Biggs. et al.       | 2017 | Thesis           | Supply Chain Transparency and Trust                |
| 9   | Frank Yiannas                | 2018 | Journal          | Supply Chain Transparency                          |
| 10  | Amina Badzar                 | 2016 | Thesis           | Supply Chain Transparency                          |
| 11  | Gavin Wood. et al.           | 2015 | Journal          | Supply Chain Transparency                          |
| 12  | Rajarshi Mitra               | 2018 | Journal          | Supply Chain Transparency                          |
| 13  | John Liu. et al.             | 2018 | Journal          | Supply Chain Transparency                          |
| 14  | Abeyratne, S. A. et al.      | 2016 | Journal          | Supply Chain Transparency and Traceability         |
| 15  | Mohamed Awwad. et al.        | 2018 | Journal          | Supply Chain Transparency and Traceability         |
| 16  | Andre Jeppsson. et al.       | 2017 | Thesis           | Supply Chain Transparency and Traceability         |
| 17  | Taehyun Ko. et al.           | 2018 | Journal          | Supply Chain Transparency and Cost-efficiency      |
| 18  | Debabrata Ghosh. et al.      | 2018 | Journal          | Supply Chain Transparency, Trust, and Traceability |
| 19  | Xia Jiang. et al.            | 2017 | Journal          | Supply Chain Trust                                 |
| 20  | Haan Johng. et al.           | 2018 | Journal          | Supply Chain Trust                                 |
| 21  | Kamanashis Biswas. et al.    | 2017 | Journal          | Supply Chain Traceability                          |
| 22  | Martin Westerkamp. et al.    | 2018 | Journal          | Supply Chain Traceability                          |
| 23  | Reshma Kamath                | 2018 | Journal          | Supply Chain Traceability                          |

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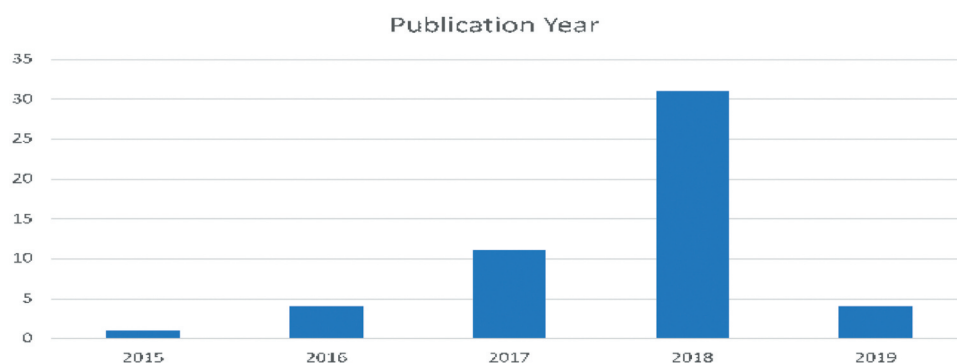
**Table 1. (Continued)**

| No. | Authors                       | Year | Publication type | Category                    |
|-----|-------------------------------|------|------------------|-----------------------------|
| 24  | Brian Abelseth                | 2018 | Journal          | Supply Chain Traceability   |
| 25  | Toufic Hirbli                 | 2017 | Thesis           | Supply Chain Traceability   |
| 26  | Tarun Kumar Agrawal. et al.   | 2018 | Journal          | Supply Chain Traceability   |
| 27  | Fredrik Jansson. et al.       | 2017 | Thesis           | Supply Chain Traceability   |
| 28  | Miguel Pincheira Caro. et al. | 2018 | Journal          | Supply Chain Traceability   |
| 29  | Feng Tian                     | 2018 | Thesis           | Supply Chain Traceability   |
| 30  | Feng Tian                     | 2016 | Journal          | Supply Chain Traceability   |
| 31  | Feng Tian                     | 2017 | Journal          | Supply Chain Traceability   |
| 32  | Simone Figorilli. et al.      | 2018 | Journal          | Supply Chain Traceability   |
| 33  | Juan F. Galvez. et al.        | 2018 | Manuscript       | Supply Chain Traceability   |
| 34  | Provenance, Ltd               | 2016 | Article          | Supply Chain Traceability   |
| 35  | RCS Global                    | 2017 | Article          | Supply Chain Traceability   |
| 36  | Jun Lin. et al.               | 2018 | Journal          | Supply Chain Traceability   |
| 37  | Minjae Yoo. et al.            | 2018 | Journal          | Supply Chain Traceability   |
| 38  | Melissa J. Rusinek. et al.    | 2018 | Journal          | Supply Chain Traceability   |
| 39  | Kay Behnke. et al.            | 2018 | Journal          | Supply Chain Traceability   |
| 40  | Rita Azzi. et al.             | 2019 | Journal          | Supply Chain Traceability   |
| 41  | Martin Westerkamp. et al.     | 2019 | Journal          | Supply Chain Traceability   |
| 42  | Simon Pearson. et al.         | 2018 | Journal          | Supply Chain Traceability   |
| 43  | M. Creydt. et al.             | 2019 | Journal          | Supply Chain Traceability   |
| 44  | Anna Ahlstrand                | 2018 | Thesis           | Supply Chain Sustainability |
| 45  | Sara Saberi. et al.           | 2018 | Journal          | Supply Chain Sustainability |
| 46  | Mahtab Kouhizadeh. et al.     | 2018 | Journal          | Supply Chain Sustainability |
| 47  | Nir Kshetri                   | 2018 | Journal          | Supply Chain Sustainability |
| 48  | Dianhui Mao. et al.           | 2018 | Journal          | Supply Chain Sustainability |
| 49  | Miriam Denis Le Seve. et al.  | 2018 | Journal          | Supply Chain Sustainability |

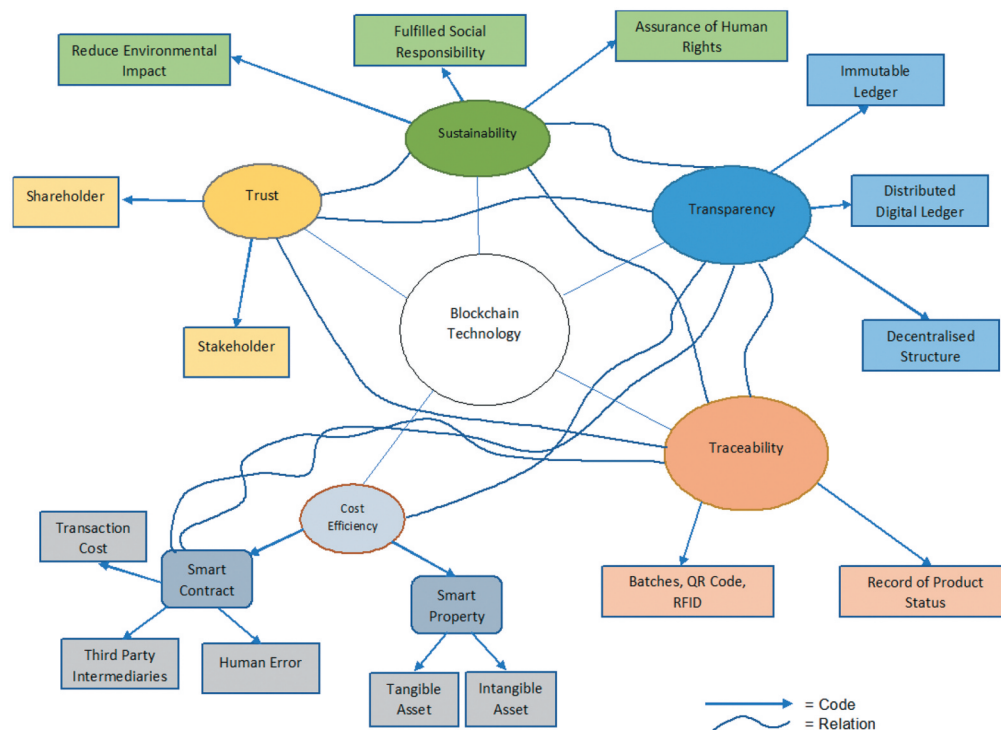
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| No. | Authors                     | Year | Publication type | Category                    |
|-----|-----------------------------|------|------------------|-----------------------------|
| 50  | Marina Niforos.<br>et al.   | 2017 | Journal          | Supply Chain Sustainability |
| 51  | Sachin S. Kamble.<br>et al. | 2018 | Journal          | Supply Chain Sustainability |
| 52  | Bailu Fu. et al.            | 2018 | Journal          | Supply Chain Sustainability |

**Figure 2. Selected papers grouped by year of publication.**



**Figure 3. Map of studies on the topic of blockchain technology in supply chain.**



**Table 2. List of themes and codes identified from 52 selected papers on the topic of blockchain technology in supply chain**

| No | Theme           | Code   |
|----|-----------------|--|
| 1  | Transparency    | (1) Distributed Ledger<br>(2) Immutable Data<br>(3) Decentralised Structure                              |
| 2  | Traceability    | (1) Record of Status Product<br>(2) Batches, QR Code, and RFID   |
| 3  | Sustainability  | (1) Reduced Environmental Impact<br>(2) Fulfilled Social Responsibility<br>(3) Assurance of Human Rights |
| 4  | Trust           | (1) Shareholder<br>(2) Stakeholder   |
| 5  | Cost-efficiency | (1) Smart Contract<br>(2) Smart Property   |

Thus, blockchain technology is basically a “digital transcript” created to avoid fraud and improve efficiency and performance but simultaneously allows access for third parties as needed. In addition, blockchain technology is also experiencing developments in usage in various sectors. Blockchain technology is inevitably becoming an important technology in almost every sector. Table 3 lists blockchain usage in various global sectors.

#### 4.1.1. Blockchain technology application for improving supply chain transparency

Blockchain could counteract information asymmetries in the supply chains. The reasoning for this is based on the open access to the ledger and the usage of tagging and registering the handling of items along the supply chain (Badzar, 2016). Blockchain can greatly improve the transparency issues within supply chain industries through the use of immutable record of data, distributed storage, and controlled user accesses (Abeyratne & Monfared, 2016). A decentralized distributed system that blockchain technology uses will collect, store, and manage key product information of each individual product throughout its life (Abeyratne & Monfared, 2016).

Such distributed information will potentially create a secure, shared record of transaction for each individual product along with specific product information. It is made possible by its decentralized ledger that can assist in tracking and recording the movement of products through supply chains from the origin to the consumer. Tracking products by using blockchain provides the ability to directly validate an item’s provenance and authenticity, allowing the customers to obtain the relevant information needed to make the choices to buy the product or not (Lützenburg, 2017).

Blockchain technology transparency offers the ability to record and tract the product journey from their origin until the point they get delivered to the customer. Thus, the information is visible for everyone involved in the supply chain. Transparency of information then could improve trust among various parties in the supply chain network (Awwad et al., 2018; Wood et al., 2015).

Blockchain immutability provides assurance to all parties that all activities recorded in the network are free from the hands of malicious actors (Liu et al., 2018; Mao et al., 2018). Such strong security is achieved by applying cryptography algorithm. Supply chain transparency could also be a way to eliminate potential scandals such as the discovery of dangerous chemicals in toy products (Badzar, 2016). It is made possible by the recording and auditing functions of blockchain technology and the

**Table 3. Blockchain usage in various global sectors**

| No | Sector               | Blockchain usage   |
|----|----------------------|--|
| 1  | Health sector        | Patient's record or medical record. For example, a medical record of one patient in a hospital can be accessed by hospital B when the patient is admitted to hospital B in a short time, because it has been recorded on the blockchain network.   |
| 2  | Food industry sector | Manufacturing processes & Internet of Things (IoT) device management. For example, IBM collaborated with food producers and distributors to decrease contamination in the global supply chain, so that if there was a case of food contamination, it would be very easy for the involved authorities to track the source of the contamination and conduct quick isolation. |
| 3  | Government sector    | Voting, tax, and tender process.   |
| 4  | Finance sector       | Foreign exchange, remittance, and trading platforms.   |
| 5  | Insurance sector     | Ensure ownership, sales and underwriting, information authorization, and P2P insurance.  |
| 6  | Retail sector        | Capital asset management, identifying management, loyalty points, and letter of credit.  |
| 7  | Supply chain sector  | Improving transparency, preventing counterfeit products, inventory and pilferage tracking, reduced cost, etc.  |

near-real-time tracking of the transaction. As a result, the need for external auditors can be minimized, hence could reduce audit cost (Awwad et al., 2018).

The use of smart contracts over blockchain in supply chain can reduce additional cost and delay, which in turn will create a more efficient supply chain. The smart contracts are the contracts written in the digital form on top of blockchain technology (Francisco & Swanson, 2018; Sander et al., 2018; Yiannas, 2016). Dynamic demand chain produced by the smart contract is more efficient than the existing rigid supply chain in maintaining the online transactions on track (Badzar, 2016; Hua & Notland, 2016; Jeppsson & Olsson, 2017). The history of the products from the manufacturer, along with transaction data could be documented as the products pass from one node to another node in supply chain network. This makes the supply chain process more efficient and trustworthy by reducing time delays, added costs, and human error (Awwad et al., 2018).

The success of the system depends on the coordination between parties in the supply chain network. The manufacturer firstly embeds the product with a code, which would be hashed and placed on the blockchain to ensure its existence and originality. The product movement through the supply chain would be recorded on the ledger by scanning or registering the code (Badzar, 2016).

Supply chain transparency will certainly improve supply chain performance. The retailers are being able to share information and prove to consumers that their products originate from safe and sustainable producers. This, in turn, could increase customer loyalty and trust.

#### 4.1.2. Blockchain technology application for improving supply chain traceability

The application of blockchain technology can greatly improve supply chain industries particularly in traceability department. By implementing blockchain technology, every actor can remotely trace all information along the supply chain, such as raw material quality, the timestamps of material journey through the supply chain, various actors involved in manufacturing and distribution (Agrawal et al., 2018).

Traceability can improve product safety and public confidence. Should any defect product reach a consumer, the system can pinpoint which product should be discarded without jeopardizing an entire product line. This holistic traceability model has the capability to cut costs of product recalls, reduce process inefficiencies, and enable retailers to track individual products in seconds (Kamath, 2018).

Blockchain technology is appropriate for establishing a higher traceability level to end user by printing the relevant data directly on the packaging (Creydt & Fischer, 2019). One or two-dimensional Quick Response (QR) codes or Radio Frequency Identification (RFID) tags are usually used because the codes and tags are compact and cheap, especially RFID which is re-usable. These codes can be read out by the consumers using their own smartphones.

Each transaction in the blockchain is recorded in the form of hash code showing which parties were involved, transaction detail and timestamp with a digital signature of authentic party or vendor. In the supply chain, each product or good is represented in the form of unique serial number, barcode or tag represented in physical form (Visser & Hanich, 2018). Then, blockchain encrypts data and delivers them to all peers for verification. Once the other peers “accept” the changes, the transaction block is added to the digital ledger. This consensus serves as an audit trail for each transaction in the network so that if there is any unauthorized change in any block, other peers will either validate the change as “valid” or “reject” the change based upon written smart contracts.

One of the many companies that has implemented blockchain technology to improve its supply chain traceability is Provenance. Provenance has demonstrated how mobile technology, such as blockchain and smart tagging, can trace tuna caught by fishermen with a verifiable social sustainability claim.

Provenance demonstrates the capabilities of a blockchain-based system in tracking yellowfin and skipjack tuna fish from catching to consumer. Provenance implements blockchain-based system in three phases (Baker & Steiner, 2015):

Phase 1, The “First Mile”:

- (1) The first mile includes setting up local fishermen with the blockchain system and implementing the framework that connects fishermen to suppliers.
- (2) Local NGO verifies social and environmental conditions of the fishermen and the fish at the location.
- (3) Fishermen send messages to register their catch. Each message issues an asset into the blockchain system.
- (4) The asset is transferred from the fishermen to the supplier in the form of physical and digital on the blockchain. The asset that has been transferred has a permanent ID that is immutable.

Phase 2, Integration with existing systems:

- (1) The blockchain traceability system is further integrated downstream with the processing firms and other organizations.
- (2) Records of the catch are recorded on the blockchain, which is identified by a unique identifier that is attached to items, such as RFID tag or QR code.
- (3) Standards by GSI are enforced and allow separate and independent systems to communicate using the same structures and identifiers.



Phase 3, End consumer experiences:

- (1) Creates the end consumer experience and integrates the Provenance system into physical retail outlets.
- (2) Consumers can use their smartphones to track any provenance's item.

#### 4.1.3. Blockchain technology application for improving supply chain sustainability

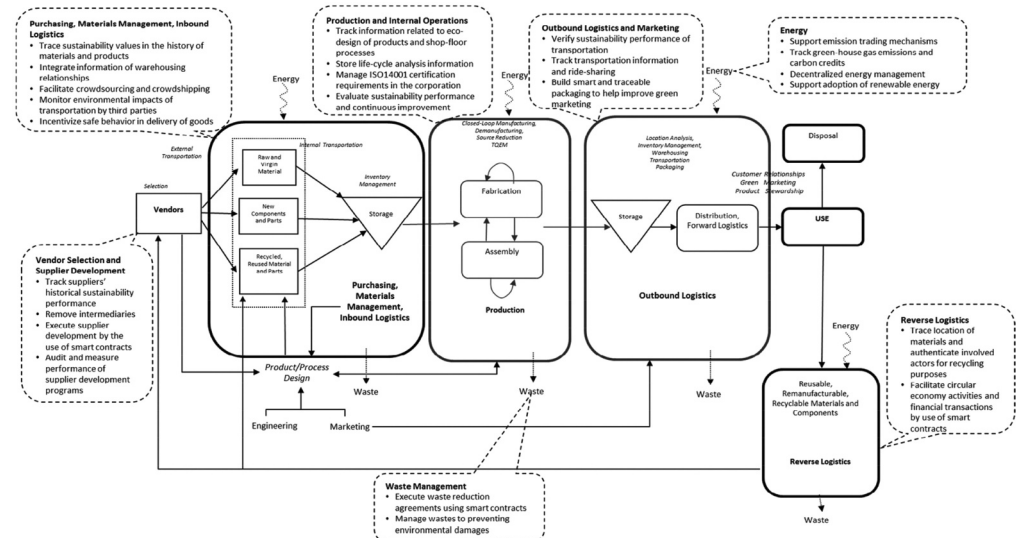
Like other industries, supply chain industry also experiences higher pressure from the society to implement sustainable business practices (Ahlstrand, 2018). Supply chain industry is accused of being contributive to global warming by producing extensive amount of carbon emissions along the process of product distribution from the manufacturer to the consumer (Sabeti et al., 2019). Therefore, there is an increasing need to “green” the supply chain.

Blockchain technology offers great potentials to improving supply chain sustainability. Blockchain technology application allows dangerous products and materials to be traced effectively, environmental compliance along the supply chain can also be well monitored (Sabeti et al., 2019). Other benefits of blockchain technology application to greening supply chain are: First, blockchain technology application is able to trace defected goods precisely, so that it could decrease the need of products rework and recall, which in turn will decrease resource consumption and waste; Second, blockchain technology application can decrease the need to transmit electricity over long distances and subsequently save a big portion of energy wasted over long-distance transmission. It would also remove the necessity for energy storage which saves its resources (Sabeti et al., 2019).

Given that information in blockchain cannot be altered without the permission of concerned actors, blockchain can help prevent corrupt individuals, governments, or organizations from seizing the assets of people unjustly, thus improving social justice. A blockchain-based supply chain can provide better assurance of human rights and fair work practices. For example, a transparent record of product information assures buyers that the product being purchased is supplied and manufactured from a verified ethical source. Kouhizadeh and Sarkis (2018) offer an illustration of how blockchain could improve supply chain sustainability as depicted in Figure 4.

**Figure 4. Blockchain application in improving supply chain sustainability.**

(Kouhizadeh & Sarkis, 2018)



#### 4.1.4. *Blockchain technology application in improving supply chain trust*

Expansion of size and complexity of supply chains has led to trust concerns among various partners in supply chains. The level of trust and willingness to share information rarely exists in large and multi-tiered supply chains (Creydt & Fischer, 2019). As supply chains are getting more global right now, trust is considered an integral asset to develop long-term partnerships (Badzar, 2016). A trust-based supply chain partnership could result in reduced uncertainty and information asymmetry (Mao et al., 2018). This makes credible information sharing become critical for supply chain industries (Wu et al., 2017).

The distributed nature and immutable data promised by blockchain make actors with established relationships of trust do a transaction with high confidence based on the information that is available from the blockchain (Abeyratne & Monfared, 2016). This transparency, which cannot be separated from all actors, becomes the evidence of truth because all activities are recorded and produce an audit trail that can settle disputes quickly (Pearson et al., 2019). Due to the transparency of information under the blockchain environment, the evaluation of trust between actors can be carried out based on the actual transaction information. Blockchain application allows all transactions to be saved in the same account and transparent to all participants in the supply chain network (Xia & Yongjun, 2017). Thus, it is possible to evaluate all parties' credibility within the blockchain environment.

Blockchain relies on cryptography-based, decentralized, and distributed ledgers to provide all participants with trust (Mao et al., 2018). The validated transactions that are shared to all participants create a decentralized ledger, every participant has the same version of ledger (Saber et al., 2019). There is no conflict regarding transactions because all participants have the same ledger, and therefore, an agreement is reached.

Blockchain's ability to track products can also improve trust between participants. For instance, if a customer receives a defected product, blockchain application could trace the history of the product from the retailer up to the manufacturer and even to the origins of its raw material and the material used which is probably causing defected product (Awwad et al., 2018).

#### 4.1.5. *Blockchain technology application for improving supply chain cost-efficiency*

Blockchain technology application could improve supply chain cost-efficiency in several ways, such as by decreasing the need for third-party intermediaries, lowering transaction cost, and minimising human error (Laaper et al., 2017). Blockchain application allows real-time transparency, thus removes the need for trusted intermediaries to mediate a transaction in supply chain. For instance: in a supply chain without blockchain, if A exports goods to B, an intermediary is needed to ensure that A holds sufficient goods or B has enough money. This practice occurs because these kinds of transactions generally take place sequentially; either A sends the goods prior to payments or B pays before the goods are sent. However, if B's financial affairs utilize blockchain technology, A can check B's account, allowing A to send the goods with confidence. Conversely, B can pay first with confidence if B is provided with the A's updated inventory information in the blockchain system. Therefore, blockchain application could minimize the need for intermediary. The elimination of this intermediary can reduce the risk of fraud and human error in supply chain and also reduce cost (Hua & Notland, 2016).

Real-time financial transparency in blockchain technology also allows supply chain industries to reduce verification and surveillance costs (Ko et al., 2018). Supply chain with blockchain technology can develop confident relationships among the parties involved, thereby eliminating the cost of trust and reducing verification costs (Francisco & Swanson, 2018). Verification costs are incurred due to lack of trust between parties. With blockchain, actors involved in the supply chain can provide their true financial status or real-time accounting to the other actors, causing rendering verification by an accounting firm to be unnecessary. Therefore, supply chain industries can save a significant amount of verification costs.

Blockchain technology can also reduce cost by implementing smart contract (Ko et al., 2018). Smart contract is defined by a code, and automatically enforced and executed when the term on the contract is fulfilled. A tamper-proof smart contract can be enacted when the exporter's goods successfully clear the requirement. Thus, as the exporter's goods clear the requirement in the smart contract, the exporter is automatically paid a certain amount from the counterparty's cryptocurrency account uploaded to the smart contract. Consequently, a trusted intermediary is less necessary, and intermediary costs fall.

## **5. Conclusions and practical implications**

### **5.1. Conclusions**

Blockchain technology application has significant potentials for improving supply chain performance, specifically in these five issues: transparency, traceability, trust, sustainability, and cost-efficiency. Blockchain can greatly improve the transparency and traceability issues within supply chain industries using immutable record of data, distributed storage, and controlled user accesses. Every actor can remotely trace all information along the supply chain because each transaction in the blockchain is recorded in the form of hash code showing which parties were involved, transaction detail, and the timestamp. This distributed nature makes blockchain become a trustable system which leads actors within the network can do the transaction with high confidence based on information available from the blockchain.

Additionally, blockchain technology can also promote green supply chain management to improve the sustainability by tracing products and materials effectively as well as monitoring environmental compliance along the supply chain. It can trace defected goods precisely, which will decrease resource consumption and waste as well as save a big portion of energy wasted over the long-distance transmission.

Finally, blockchain technology can reduce the transaction and enforcement costs in the supply chain by implementing smart contract to comply with self-enforcing contractual conditions without the need for an existing trusted third party. This contract possesses many advantages, such as transparency, accuracy, speed, security, efficiency, and trust.

### **5.2. Practical implications**

The results of this study will be useful for the managers who seek comprehensive understanding of how blockchain technology can further impact their own companies, particularly in supply chain management. The application of blockchain technology can minimise inter-organization dependencies by increasing information transparency and traceability. This can be a guidance for the managers to design supply chains that are more resilient by implementing an optimized level of decentralization.

Furthermore, managers will have a better understanding of how attributes of the blockchain can improve the cost-efficiency. Blockchain-based smart contract will greatly impact transaction costs because it is automatically executed by the network. Its transparent, autonomous, and secure nature can remove any possibility of manipulation, bias, or error. Therefore, it can also establish trusted systems among the parties involved. This might be a new option for the managers to execute an agreement among the actors in supply chain network.

On top of that, blockchain technology might improve supply chain sustainability by decreasing the need to transmit electricity over long distances and subsequently save a big portion of energy wasted over long-distance transmission. Managers can use this insight to design a more environmentally friendly supply chain management.

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