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Blockchain-Enabled Information Sharing Within a Supply Chain: A Systematic Literature Review

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ABSTRACT A supply chain consists of many stakeholders such as suppliers, carriers and customers. It is often complex due to the rapid development of economic globalization and the intense competition pressure in the market which resulted in information sharing within a supply chain to be fragmented. Blockchain technology can solve this problem by having only a ''one trusted ledger'' that could reshape the element of data trust. The goal of this paper is to identify and understand the impact of blockchain technology for information sharing within a supply chain. The decentralized nature of blockchain technology offers a high level of transparency and has gained the attention from various sectors to deploy this technology. A systematic literature review in the academic literature was conducted using different databases. Blockchain-enabled information sharing can add value to enhance collaborative work in different types of supply chains such as health and medical, construction and smart city. From our findings, one potential impact of deploying blockchain-enabled information sharing within a supply chain is that it ensures all members in the chain can obtain verified information which enhances collaborative partnerships. Through this in-depth research, we highlighted potential barriers that could impede the development of blockchain technology in supply chain such as the lack of understanding of blockchain technology in businesses and conflict of interests. Future work such as information hiding, in parallel with information sharing, could close the gap in deploying this technology within a supply chain. Understanding the nature of different supply chain is also important to better prepare the deployment of blockchain. We acknowledge that our approach in selecting literatures in our systematic review may exclude certain literatures. Nonetheless, we tried to include as many relevant literatures as possible, to develop a roadmap on the current situation of blockchain-enabled information sharing within a supply chain.

INDEX TERMS Blockchain, smart contract, supply chain management, information sharing.

I. INTRODUCTION

A supply chain comprises many stakeholders such as suppliers, manufacturers, retailers, carriers and customers [1]. With the rapid development of economic globalization and the intense competition pressure in the market, supply chains have become highly complicated and dynamic [2]–[4]. This is mainly due to the fact that customers are now more demanding, expecting better customized products and better customer service that comes with an acceptable speed and cost. In order to adapt efficiently to the changes in the market and remain competitive, companies are now focusing on their core function, and are moving towards a collective and collaborative effort [4] such as outsourcing, development of advanced value chains, and open innovation [5]. Consequently, the numbers of members within a supply chain have increased rapidly. These members are often scattered globally, which result in information to be highly fragmented. Thus, to better manage and facilitate information sharing among the members within a complex supply chain, a higher co-ordination cost is needed in the form of e.g. quality systems, production standards, etc. However, information asymmetry still exists in the current supply chain.

Information asymmetry is often connected to opportunism in transaction cost economics [6], where information is not fully shared among collaborative partners, and creates room for dishonesty between partners. This interpretation is not what this paper deals with. Our understanding of information asymmetry is defined as hidden information [7], [8], which could be either intentional or unintentional. This happens

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when not all members within a supply chain obtain product information equally and indiscriminately [3]. Typically, product manufacturers have advantages in controlling and hiding the volume, accuracy and types of information to share with other members, and even to consumers [3], [9]. Conflict of interest is one of the main reasons for hiding information from other members [10]. This low transparency and highly controlled information flow reduce data trust among members and the efficiency of a supply chain. Data trust in this context refers to the reliability of information and data provided by trade partners within a supply chain or central authority [11]. Accurate data trust in information sharing can act as a catalyst to improve the efficiency in a supply chain.

To decrease the transaction cost, information sharing is identified as an important strategy. Information sharing is where members within a supply chain share information such as product specification, the state of product, ownership, location of data, and even the environmental impact [11]. Information sharing is important for firms which go beyond decision making processes such as increasing profit margin and logistics planning. It is also a key element to enhance collaborative work among members. However, information is constantly transforming from the beginning to the end of the supply chain [10] and the volume of information increases exponentially. With the large volume of information distributed, this could confuse firms and buyers on which data to trust [3], because there is no verification of the truthfulness of the information provided. Thus, there is a need for a better information sharing tool to combat fraud, pilferage, and enhance poorly performing supply chains [12].

Blockchain technology can solve this problem by having only a "one trusted ledger" that could reshape the element of trust. It is a type distributed ledger technology that can be a solution to a trustable information sharing, by providing a permanent digital footprint to all members in the network. This means every approved transaction occurred throughout the supply chain is recorded in a tamper-evidence environment. Any malicious attempt to alter the information will be obvious and evidential. Blockchain technology can also couple with the Internet of things (IoT) and smart devices to digitize and automate processes to collect and share information in real-time with other members, which improves the transparency and increases the efficiency of a supply chain. These potential impacts on supply chain has caught the attention of many researchers. However, the holistic contribution and barriers of blockchain-enabled information sharing within a supply chain remain unclear. Therefore, in this paper, we will investigate and understand how blockchain technology can change current information sharing within a supply chain.

A systematic review will provide a clearer picture on current exploration and research work on information sharing within a supply chain [13], [14]. This can give a deeper knowledge by identifying the potential benefits which are unclear, challenges that hinder the growth of blockchain technology, and knowledge gap in this domain. Our systematic literature review aims to answer the following research question (RQ):

- RQ1: How blockchain technology has an impact on information sharing in the supply chain

To answer our main research question, we have defined 3 research tasks (RT):

- RT1: To identify industries where blockchain technology can have a significant impact on information sharing within a supply chain
- RT2: To investigate the current potential challenges or barriers in the deployment of blockchain within a supply chain
- RT3: To identify future development of information sharing using blockchain technology within a supply chain

This paper begins with a summary of the various methods in managing information sharing among members within a supply chain in section II, and is followed by the introduction of blockchain technology and smart contract in section III. Section IV explains the research methodology in conducting the systematic literature review and material collection. Section V discusses the current state-of-the-art and the findings from our defined research questions. We conclude the paper in section VI.

II. VARIOUS METHODS IN FACILITATING AND MANAGING INFORMATION SHARING

Currently, there are many methods to facilitate information sharing (e.g. Quality assurance with third party intermediaries, direct integration, hub-and-spoke architecture and verbal communication). These methods exhibit many challenges that inhibit the efficiency of a supply chain. We understand that there are other means of managing information but in this paper, we focus methods such as third-party intermediaries, institutional trust and communication as summarized in Table 1.

These methods are still commonly used for information sharing. However, the level of trust-worthiness of the documented data and distributed information is of poor quality and often fragmented [15]. The lack of data trust is a huge barrier for the integration of business process across organizations [15], [16]. Thus, new technology such as blockchain technology could solve these challenges by enabling a new form of digital data trust.

III. WHAT IS BLOCKCHAIN TECHNOLOGY AND SMART CONTRACT

Blockchain technology offers a decentralized environment that is built on data trust using a digital approach [22]. Weber *et al.* [16] insisted that blockchain could be an emerging technology for decentralized and transactional data sharing across a network of untrusted participants. It distributes validated, immutable transactions that are consistent to a large number of members in a network [22], [23]. In this decentralized environment, there is no member in the network that can control, tamper with or falsify important information, because

TABLE 1. Summary of current methods in facilitating and managing information sharing.

Methods	Purpose	Challenges	Authors
Third party intermediaries (Centralized database System)	To store and manage information and data in a centralized database system **Example: Medical and health sector:** To store and secure various forms of sensitive medical records. **Manufacturing sector:** To store and share information such as quality, certifications, site documentation.	1. Vulnerable to abuse 2. Incur high cost 3. Strict legal regulation for sharing 4. Fragmented and scattered information 5. Paper-based documentation 6. Difficult to justify the accuracy of information 7. Vulnerable to hacking	[15] [17] [18] [15] [12]
Institutional trust (Textual contract and agreement)	To regulate and control behaviour of members in the network based on legal framework and agreement	1. Textual agreement is subjective and inherent with ambiguity 2. Legal action are lengthy and bureaucratic	[4, 19] [20]
Communication (phone, face-to-face, field visit)	To understanding the production process flow, existing quality certifications and to share common values	1. Time consuming 2. Incur high cost 3. Difficult to manage communication efficiently with all suppliers	[21] [3]

it is no longer a single-point storage within a centralized system.

Every single transaction is verified through consensus within the decentralized system and stored in a block format. Reaching a consensus agreement by all participants in the network, before recording it permanently, is the key feature of blockchain technology [24], [25]. The participants of the network then proceed to validate the information and create a block. Each block is linked with another block forming a chain [26], [27]. This provides traceable and transparent information to all members. Smart contract is one of the most salient features [22], and can be embedded in blockchain.

Smart contract removes the requirement for a centralized third-party to manage, verify and store information in real-time [24]. It enables a whole new type of regulation by transposing legal rules and contract agreements into technical and software rules [20], [28]. It relies on formal algorithms and mathematical code to execute transactions autonomously when all the requirements are fulfilled, as defined in the smart contract [29]. This resulted in lesser human interaction being needed, which saves cost of negotiation and time needed to communicate with members that are scattered globally [22]. Although blockchain technology is still at its early stage when it comes to application in businesses apart from cryptocurrencies like bitcoin, there is a growing interest in transforming and building a more robust data trust in various industries.

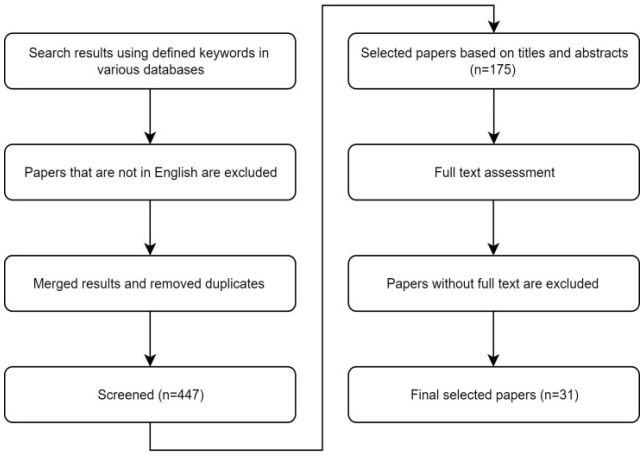

FIGURE 1. Systematic literature review process.

In short, blockchain technology can enable a new form of data trust to mitigate those challenges as shown in Table 1. It has also been speculated to have a strong impact on supply chains on how information is shared among members in a secure manner, with no centralized third party to govern data and information. It also redefines the rules and regulation of information sharing using smart contract. Today, attention from the academic sphere on this emerging technology within a supply chain is increasing.

IV. RESEARCH METHODOLOGY

A. CONDUCTING SEARCH

This paper will perform a systematic literature review to investigate the topic of blockchain-enabled information sharing within a supply chain. This methodology provides a transparent and reproducible process of selection, analysis and reporting of previously conducted research of selection on a specific topic [30], [31]. The main purpose is to explore the current existing state-of-the-art of academic research on information sharing and blockchain. In order to have a widest coverage of all published literature, we carefully planned our systematic literature review process and is summarized as shown in the Fig 1 as shown below.

The review of material starts as early as in 2008, since the term blockchain was firstly introduced, until December 2019 prior to the submission of this paper. Material collection was carried out through various databases (Scopus, Web of Science, Emerald Insight, IEEE Xplorer digital library and Business Complete) to gather widest possible samples.

In order to capture blockchain technology across different industries, and to be as comprehensive as possible, generic keyword strings such as ''blockchain technology'', ''information flow'', ''information sharing'', ''information asymmetry'' and ''supply chain'' were employed as research

FIGURE 2. The number of literatures collected in each year.

criteria to collect literatures. And the keyword strings were structured and combined as shown below:

- "blockchain technology" AND "information flow", AND "supply chain"
- "blockchain technology" AND "information sharing" AND "supply chain"
- "blockchain technology" AND "information asymmetry" AND "supply chain"
- "blockchain technology" AND "supply chain"
- "information sharing" AND "supply chain"
- "information asymmetry" AND "supply chain"
- "information flow", AND "supply chain

B. MATERIAL COLLECTION

After a thorough screening according to our systematic literature review flow, we selected a total of 31 literatures. All these literatures which met the requirements are exported to EndNote and Microsoft Excel to generate tables and figures for analysis.

In addition to that, some literatures that did not meet all the requirements but consists of relevant information are also exported to Excel sheet under different tab. This is important for us to gain a more comprehensive knowledge in different types of supply chains.

C. MATERIAL ANALYSIS

From Fig 2, the earliest selected literature is published in the year 2017 (n =3) and with a visible growth in 2018 (n= 12). 16 literatures were collected in 2019. This increasing trend highlights the growing interest of researchers in the field of deploying blockchain-based solutions for information sharing within a supply chain. This is due the potential of blockchain in enhancing the traceability and transparency within a complex supply chain.

From Fig 3, in Asia, highlighted in green, has the highest total number of literatures of (n=21) from different countries such as Singapore (n=1) and Japan (n=2). In this region, China (n=16) has published the highest number of literatures within this field. In Europe, bars in orange, United Kingdom and the Netherlands (n=2) have the most literatures published compared to the rest of the European nations. USA has published 2 literatures in North America.

Among the collected literatures, the majority of the research work is within the health and medical sector domain (8/31 literatures) and general supply chain (15/31 literatures) as shown in the Fig 4. below.

In our analysis, we categorized the selected literatures into information sharing and information asymmetry. As shown

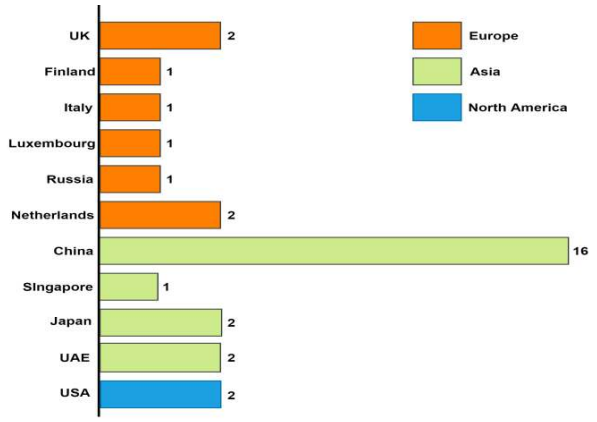

FIGURE 3. The number of literatures published based on countries.

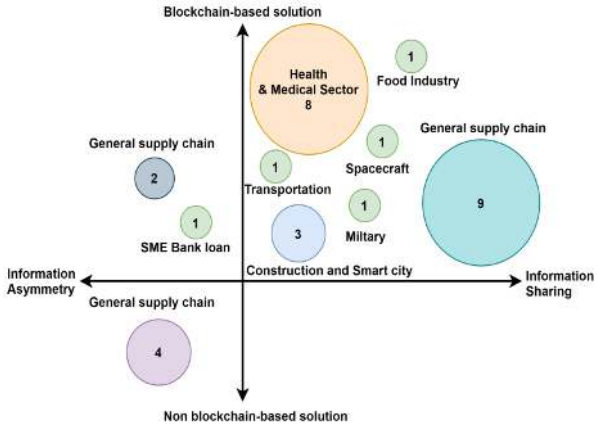

FIGURE 4. The number of literatures sorted based on the types of supply chain, information and solution.

in Fig 4, 24/31 (77%) literatures focused on information sharing. Different types of supply chains such as health and medical, transportation and even military focused on how blockchain-enabled information sharing with high data trust can increase the efficiency in their respective supply chain. While the remaining literatures focused on information asymmetry within a supply chain.

We then further categorized the literatures in the blockchain based and other solutions. From Fig 4, 27/31 literatures (87%) used blockchain-based solutions to reduce information asymmetry or to facilitate information sharing. There are 4 literatures which use other solutions in making decisions under information asymmetry. These 4 literatures are selected is because it highlights the knowledge gap where blockchain can be deployed not only for information sharing but information hiding as well. The total list of 31 selected literatures are summarized in Table 2.

V. FINDINGS AND DISCUSSIONS

A. CURRENT PERSPECTIVE ON INFORMATION SHARING USING BLOCKCHAIN TECHNOLOGY WITHIN A SUPPLY CHAIN

The number of academic publications in this topic is increasing, starting from 2017, which shows that researchers have started to recognize the potential impact of blockchain

TABLE 2. Summary of selected literatures.

Authors	Methodology	Key findings(s)
Information Sharing – Blockchain-based solution		
General supply chain (9 literatures)		
Al Barghuthi, et al. [32]	Case study	A blockchain-enabled technology in facilitating the exchange and sharing of information without the involvement of intermediaries acting as arbitrators. This removes the risks of centralization and enhance trade procedures in handling and processing of data throughout the trade supply chain
Teslya and Ryabchikov [33]	Architecture	An integration of IoT and a blockchain-based technology in solving issues such as durability and unchangeability of information. Smart contract can also be used to execute under certain condition.
Cui and Idota [3]	Case study and platform	Inconsistency of information will lead to decision-making mistakes or delay decision. A blockchain-based platform to transform the current information sharing and interaction in supply chain. Transactions are verified and confirmed without third-party intermediary.
Nakasumi [10]	Proposed solution	Supply Chain Management systems provide information sharing and analysis to companies and support their planning activities but are often asymmetric which lead to disturbance of the planning algorithm. A blockchain-based solution to solve the problem of asymmetric information between companies.
Wen, et al. [1]	System model	Information sharing among entities such as suppliers, manufacturer, carriers, retailers and customers has always been one of the major challenges in the field of supply chain management. The Industrial Internet of Things (IIoT) can help entities to get real-time data in the supply chain to share key information and reduce costs. However, it is still at the risk of a single point of failure and privacy issue. A blockchain-based solution by combining IIoT devices to blockchain to monitor, record and store real-time data in the network by smart contract.
Du, et al. [34].	Research	Using blockchain technology to achieve the goal to increase efficiency for information sharing and data fusion between different business information systems. The processes of data transmission and conversion can also be simplified.
Engelenburg, et al. [35]	Software Architecture	Businesses are obliged to share certain information. However, due to the highly competitive business environment, they are reluctant to share more information. A blockchain-based architecture is designed to store events and rules for information sharing that are controlled by businesses. This could solve the fear of sharing sensitive information.
Nizamuddin, et al. [36]	Framework	Blockchain-based solution and framework for document sharing and version control to facilitate multi-user collaboration and track changes. The solution could also be extended to shared digital assets and content which may include video, audio and photos.
Huang, et al. [37]	System models	Group data sharing enables information sharing among multiple parties for co-operative purposes but not all parties in the same organization want to share data. A blockchain-based data sharing scheme can achieve information sharing for multiple groups with anonymity and traceability.
Health and Medical Sector (8 literatures)		
Xiao, et al. [18]	Framework	EMRshare is a blockchain-based framework for medical record sharing with the goal to resolve trust issues, which is resulted from existing centralized database system, among different participants such as patients, clinicians, researchers and other relevant parties.
Shen, et al. [38]	Framework	A blockchain-based solution called MedChain which integrates blockchain technology to replace questionable third party. This could be a new service for healthcare information sharing and to achieve a higher efficiency in data sharing.
Chen, et al. [39]	Platform	Medical information is private and valuable for medical research. However, data might be manipulated improperly and privacy issue making information sharing challenging. Blockchain technology can solve this issue by recording and sharing verified information among parties without an intermediary.
Jiang, et al. [40]	Architecture	A blockchain-based model in solving how information sharing among members of different role (e.g. patients are mainly to authorized information sharing and doctors mainly are to submit requests). This model can also improve communication among medical institutions and effectiveness of medical resources.
Fan, et al. [17]	Framework	Current electronic medical records (EMRs) lack a standard data management and sharing policy. MedBlock, a blockchain-based framework, handles patients' information by allowing an efficient access to and retrieval sensitive medical information from EMRs. Patients can have an ownership of their personal data.
Alam Bhuiyan, et al. [41]	Framework	A blockchain-based solution that can eliminate healthcare breaches and better facilitate healthcare coordination through information sharing. Smart contract can be a solution where access to medical record is automated and regulated entirely.
Liang, et al. [42]	Application	A blockchain-based technology mobile healthcare system for personal health data collection, sharing and collaboration among individuals, healthcare providers, insurance companies and research purposes. Tree-based data processing and batching method to handle large sets of data collected.

TABLE 2. *(Continued.)* **Summary of selected literatures.**

Zhang, et al. [43]	Architecture	A blockchain-based architecture called FHIRchain can solve siloed clinical data which creates barriers to efficient information exchange and impedes effective treatment decision made for patient. This architecture fulfils the requirements and standard for shared clinical data.
Smart Construction and Smart City (3 literatures)		
Qian, et al. [44].	Framework	Platforms for information sharing for construction of smart cities is progressing but only between governmental agency and department. A blockchain-based approach enables an effective information sharing with non-trusted organizations and public during construction while preventing any illegal access and tampering of data.
Zheng, et al. [45]	Architecture	Smart construction relies on BIM for manipulating information flow, data flow, and management flow but little efforts focusing on information security. A blockchain-based architecture called "BcBIM" can guarantee the data integrity and provenance. BcBIM can keep track of the last record modification without tampering.
Li, et al. [46]	Review	Blockchain technology can address trust issues and information sharing in construction industry. One of the methods is by integrating blockchain technology with building Information modelling (BIM).
Food Industry (1 literature)		
Wu, et al. [47]	Framework and case study.	Supply chain management suffers from issues such as lack of information sharing, long delays for data retrieval, and unreliability in product tracing. A case study about the food supply chain with the development of a blockchain-based food tracing system is designed to tackle food safety issue.
Logistics and Transportation (1 literature)		
Imeri, et al. [48]	Conceptual solution	An efficient information sharing is crucial for a sustainable process of transportation. A blockchain-based model can be a solution for the current operations which have several drawbacks in terms of data security and trust among stakeholders.
Spacecraft (1 literature)		
Zheng, et al. [49].	System model	The spacecraft supply chain is full of high risks characterized by intensive knowledge and technology. In order to minimize enterprise risks and improve its overall profit, a blockchain-based solution is applied to decision-making problems in a spacecraft supply chain. The use of blockchain technology can reduce transaction costs among spacecraft supply chain stakeholders and fulfil information sharing, thus improving the overall profit.
Military sector (1 literature)		
Zaerens [50].	Framework	Open information sharing within military alliance (circle of trust) such as NATO gets complicated. Open information sharing might increase the risk of revealing too much information. A blockchain-based solution can enhance information sharing, trust and openness without compromising security issue.
Information Asymmetry – Blockchain-based solution		
Bank credits and finance (1 literature)		
Wang, et al. [51]	Theoretical model	A blockchain-based theoretical model that allows low-risk and high quality small and medium-sized enterprises (SMEs) to display their credibility and risks through information distribution.
General supply chain (2 literatures)		
Longo, et al. [52]	Model simulation	Conventional ICT has reduced information asymmetry and increased the degree of interorganizational collaboration, but trust issues still exist. A blockchain-based model can solve trust issue by establishing a single, immutable record that can be viewed by anyone with rights
van Engelenburg, et al. [53]	Architecture	Information is not shared could due to members in supply chain do not have direct contact and/or do not want to share competitive and sensitive information. Such information asymmetry contributes bullwhip effect. The feasibility of blockchain-based architecture for reducing information asymmetry and bullwhip effect is explored. Requirement such as only provide access to data to the appropriate parties is very crucial in supply chain management.
Information Asymmetry – Non blockchain-based solution		
General supply chain (4 literatures)		
Jinfa, et al. [54]	Case study	Information held by members of the supply chain often is asymmetric and many retailers prefer pursuing risk.
Lai, et al. [55]	Case study	Information asymmetry is beneficial to the reseller, but is inefficient to the manufacturer and the whole supply chain.
Wang, et al. [56]	Proposed solution	Information asymmetry does not always lead to inefficiency of the supply chain.
Yang, et al. [57]	Model	Information asymmetry affects the decisions of the involved partners' and reduces performance of a traditional retail supply chain. A model for dual-channel supply chain under asymmetry of revenue between manufacturer and retailers.

on information sharing within a supply chain. The growth is owing to the decentralized nature of blockchain, which eliminates the dependence on unreliable centralized third parties to govern sensitive information and decrease the transaction cost. With blockchain technology, every information is recorded permanently and distributed to every member in the network, which improves transparency and traceability in supply chain. This capability drives the momentum of deploying blockchain.

Blockchain-based solution improves traceability of the information of a product [58]. This solution can be adopted

into various complicated supply chain to enable the fight against food fraud, counterfeit medicine and luxury jewellery like blood diamonds. Improving the information traceability throughout the entire collaborative processes within a supply chain can increase the level of data trust since each information flow is recorded permanently. In Perboli *et al.* [58] study, they suggested that information such as certification and authentication of its product units from all producers along the chain must register a batch ID and store it in blockchain. This can result in a higher visibility of all the processes which can guarantee the provenance of the product. This decentralized structure in blockchain improves transparency of information.

Transparency is compromised, due to many discrete activities that are not visible and difficult to track in a globalized and complicated supply chain. ElMessiry and ElMessiry [59] studied within the supply chain of textile industry, and they pointed that many discrete activities of the production are outsourced, where it contributes the most value to the product. Often these discrete outsourcing activities occurred in developing nations, where manufacturing rules and regulation on quality standards are less enforced. This could result in producing lower quality products. ElMessiry and ElMessiry [59] also proposed a blockchain-based framework solution that all transactions involved in the supply are recorded in blockchain to increase transparency. Smart devices with sensors can be integrated with blockchain to send real-time information.

Blockchain-enabled real-time information tracking has a huge potential in changing the way information is shared and distributed among multiple partners. For example, using of IoT sensors to send information regarding the storage and traffic condition of the road in real-time. The information is then recorded permanently in blockchain, and distributed to members such as logistics and transportation firms [3]. This allows firms to take appropriate emergency actions when unplanned activities occurred. The integration of smart contract embedded in blockchain can also be explored where tasks can be executed autonomously, and send notification to logistics firm in real-time information using IoT enabled sensors and devices [60]. This can increase real-time decision-making process of members in the chain and efficiencies.

Within a supply chain, document sharing and version control can benefit from blockchain technology [36]. Version control of documents, regardless of whether they are in paper or digital formats, has become one of the most important aspects when collaboration between different parties increases, primarily for sharing information. However, information asymmetry is one of the challenges in using digital information, and 83% of productivity is consumed by version management issues [61]. Existing documents version control systems are mostly centralized, where changes and updates to any documents without the knowledge of users is possible [36]. Nizamuddin *et al.* [36] proposed a blockchain-based solution for version control for digital documents embedded with smart contract, to facilitate multi-user collaboration. Any changes must be validated and tracked without a centralized third party. Blockchain technology ensures a secured and high level of trust of information sharing among different parties in a supply chain. Application of blockchain is still at a very early stage and thus, it is important to understand the significant impact of using this technology for information sharing in different industries within a supply chain.

B. RT1: TO IDENTIFY INDUSTRIES WHERE BLOCKCHAIN TECHNOLOGY CAN HAVE A SIGNIFICANT IMPACT ON THE INFORMATION SHARING WITHIN A SUPPLY CHAIN

1) MEDICAL AND HEALTH INDUSTRY

Blockchain technology can provide an effective collaborative treatment and care decision which brings advancement in medical and healthcare domain [43]. This technology can remove information silos which are impeding information sharing among patients and medical professionals. Medical data and information are continuously generated every time when someone visits a clinic or hospital [41]. And to this day, traditional paper-based are still utilized to record medical information. To better manage the high volume of information, it is common for hospital to engage a centralized databased system, with such electronic medical records (EMR) to store and manage highly sensitive data. This method, however, is vulnerable to leakage and alteration without leaving any traces.

Getting access to correct and verified information of the patients during emergency situation is a matter of life and death [41]. Medchain [38], EMRshare [18], MedBlock [17] and FHIRchain [43] are some blockchain-based solutions and frameworks to distribute trusted information in medical and health sector. Among those solutions, Medchain is a blockchain-based solution that facilitates information sharing among multiples roles like patient, requesters and healthcare providers which achieve higher efficiency and satisfy security requirements in information sharing [38].

Currently, data protection is not up to par, and is vulnerable to data breaching where the patient's information is stolen or lost [41], [62]–[64]. This results in a series of complicated procedures which is bounded by strict legal regulations, when it comes to medical data sharing outside an organization [18]. This bureaucratic procedures in obtaining information impedes medical professionals in performing a better treatment and diagnosis, when someone goes to a hospital that is not where he/ she is from. Blockchain can shift the ownership from a centralized third party to patients themselves.

Blockchain-based technology enables patients to have the ownership over their own medical record data and information. Smart contract enables patients to grant authorization and access his/her accurate medical records since medical information belongs to the patient. Academic researchers have come up with different blockchain-based solutions that enable sharing of information without compromising privacy, security and ethics [18]. Thus, improvement such as diagnostic accuracy, gathering information and confirmation,

preventing inadequacies and errors in treatment plan and medication is expected with use of blockchain technology in this sector. [43], [65]–[68]

2) SMART CONSTRUCTION AND SMART CITY

The construction sector is perceived as one of the slow industries in the adoption of digital technology [69], [70]. For example, there is some evidence that building information modelling (BIM) is gradually being utilized in architecture, engineering and construction (AEC) industries. It uses construction information from various databases to manage the essential building design throughout its life cycle [45], [71]. However, the adoption of BIM in construction has been slow, mainly due to the fact that the updated information in BIM cannot be tracked, and often revision history is not retained. Even if revision histories are stored and available, the integrity of the historical data is not validated and thus making it very hard for users to fully trust it. Information sharing using blockchain-based solution can increase data trust.

Zheng *et al.* [45] suggested a blockchain-based framework called bcBIM that can solve integrity of the information shared and recorded in BIM. For example, information is stored chronologically and is falsification free guaranteed [45], [72]. When someone adds to and updates the BIM model, information will be stored in blockchain, and distributed to all participants that are working on the same model [46]. In addition to that, recorded information in BIM with blockchain-based solution is validated and verified. Users can now work on the BIM model, and be able to know who is responsible for those changes. This adds a new layer of trust to the information, by providing the ownership of the changes transparently. This can lead to a higher degree of collaboration work.

Collaboration within a partnership can increase in this industry when information is more transparent and shared more freely [46]. For example, the construction sector can trust information obtained from the logistics partner, to ensure materials are arriving as expected to reduce potential delay. This decentralized platform can also track and trace the provenance of the material purchased for construction. This can simplify the procurement activities, because the construction company does not need to incur additional cost to audit the materials and practices in a supply chain.

The development of smart city has progressed steadily mostly due to the increase of the availability of digitized information and data [44]. Government agencies are also actively encouraging business enterprises and research institutions to use government data to make innovative applications to move towards smart city [44]. However, the current information sharing only flows among governmental department or registered/trusted social agencies, while non-trusted institution such as private or SMEs are not granted access. This is due to various forms of potentially national security risks. The use of blockchain-based platforms increases information sharing among non-trusted institutions, which breaks the wall between trusted and non-trusted parties with smart contract embedded in the platform. For example, an organization would send a request to obtain certain piece of information, and a smart contract would only execute information sharing when the other party agreed and digitally signed. This can facilitate and secure information flow without putting the institution at risks.

3) OTHER INDUSTRY

a: BANK LOAN FOR SMES

Blockchain-based technology increases opportunities for low-risks and high potential small and medium-sized enterprises (SMEs) to obtain bank loans and other forms of financial aid. However, many of them are not able to display their credit quality effectively to obtain monetary help [73]. Information asymmetry between banks and SMEs, along with insufficient collateral are making it harder for them to obtain bank loans [51]. Wang *et al.* [51] proposed a blockchain-based solution to mitigate information asymmetry, by storing verified information such as financial statement and assets of SMEs. The process of verifying financial document enables low-risks and high-quality SMEs with non-tampered financial statement to be visible to banks which could potentially increase their opportunities of getting a loan. The use of blockchain technology can filter out high risk SMEs where they could not produce credible financial statements to banks. In the long run, this can also slowly eliminate the requirement of having enough collateral from SMEs as part of the assessment to get bank loans approved.

b: TEXTILE SUPPLY CHAIN

Information sharing has a significant positive effect in collaborative work in a complex global supply chain such as the textile industry [74]. However, information sharing among members throughout the chain on quality related issues is close to non-existent [59]. This is due to many discrete activities which are not visible and difficult to track, starting from raw material to final product, making necessary investigation of the root cause challenging. ElMessiry and ElMessiry [59] studied within the supply chain of textile industry, and pointed out that losses by discarding the final finished textile due to quality issues can reach up to 40%. To solve this issue, they [59] proposed a blockchain-based framework so that all information and transactions involved within the supply chain are recorded in blockchain to increase transparency of the provenance of the product. This may prevent unethical acts like child labour from entering the chain because every piece of information about the textile is recorded and validated. It is important to identify the potential barriers that impede the advancement of blockchain technology in the supply chain.

C. RT2: TO INVESTIGATE THE CURRENT POTENTIAL CHALLENGES OR BARRIER IN THE DEPLOYMENT OF BLOCKCHAIN WITHIN SUPPLY CHAIN

Unwillingness to share information among members within a supply chain due to conflict of interest is a challenge that slows down the momentum of deploying blockchain [52]. Blockchain-enabled solution which offers

a high transparency, on the contrary, may not contribute to, but could further increase, the unwillingness of organization to use this solution to store and share information. This is due to having a high visibility of information and transaction to inappropriate members is not ideal for any company because of the highly competitive nature of supply chains. Such conflict of interest makes companies less inclined to deploy or even reject blockchain as a solution, despite the extent of the literature emphasizing the benefits of information sharing using blockchain [75], particularly in the context of a global supply chain operation where members are scattered globally or do not trust each other [76]. The lack of understanding of blockchain further retards the adaptation.

Normally, the main challenge of digital transformation is the lack of understanding of digitization in the industry. For example, there is a limitation in knowledge and understanding of BIM in the construction sector [77], resulting in organizations' misconception of what this digital technology can achieve [46]. This often ended up with abandonment and the inability to embrace the technology in this sector [78], [79]. Similarly, blockchain technology may face the similar challenge, despite having the capabilities to offer various benefits such as facilitating immutable information sharing among partners, increase transparency and traceability of a product.

The hype of blockchain being disruptive has gained interest beyond financial industries, but many business leaders remain unsure what that means for their companies, and what blockchain is. In a survey of 308 senior executives at large companies in the United States, 39% of the respondents had little or no knowledge about blockchain technology [80]. Till today, many SMEs claimed that they have little knowledge about blockchain [52], [81]. Investment of both time and money are needed to overcome the barrier of deployment of blockchain are inevitable at this infancy stage. More efforts in closing these knowledge gaps are needed to understand the potential of this technology in supply chain.

Many companies are not willing to risk making large investments in blockchain that may not create large value to their organization [82] is also one of the barriers. Information and data are constantly generated and flowing among different partners across the supply chain. A blockchain solution is ideal when crucial pieces of information are recorded and stored in blockchain after verification. However, this technology comes at a cost. Companies may not be willing to spend time and money to develop an architecture framework that integrates blockchain technology that supports and fits into their overall business strategy [82] due to fear of low returns. If a company plans to adopt blockchain in their organization, time and effort are required in sorting and identifying the suitable type of blockchain (permissioned or permissionless) to be employed, who has rights and who are restricted [83]. Without this step, a company may end up spending a large amount of money, with low value added to their firm. In addition, many companies feel that their current information sharing system are functioning fine. To deal with such challenges, a new business model for blockchain service with less cost and less risk should be developed.

D. RT3: TO IDENTIFY FUTURE DEVELOPMENT OF INFORMATION SHARING USING BLOCKCHAIN TECHNOLOGY WITHIN A SUPPLY CHAIN

Information hiding using smart contract embedded in blockchain should be focused in parallel with information sharing within a supply chain. Information sharing can provide operation benefits [52], but the feasibility, in reality, for any firms in global supply chains agreeing to this may be very low. For example, high level of information sharing in medical service such as medical diagnosis and prescriptions from medical professional like doctors may result in resistance towards the implementation of blockchain-based technology. This is because some doctors would perceive this as a threat to their autonomy or even as a form management control tool [84], [85]. With the use of smart contract, part of the information, such as the name of the doctors and hospitals, would be hidden, without compromising the integrity of the information, if a patient would like to obtain second opinions from other hospitals. Therefore, effort focusing on information hiding using smart contract to hide certain of information and granting access upon request should also be a part of the solution framework design.

Reported work lacks the sharing of performance evaluation of using blockchain technology [18]. Many researchers have attempted to address this issue by designing blockchain-based architecture and visual framework solutions. From the Table 2, 8/31 in the medical sector designed different blockchain-based solutions but only 3 published literatures provided performance evaluation analysis. Sharing of such evaluation and analysis on the performance remains very limited. ElMessiry and ElMessiry [59] is another example in the textile industry, where they attempted to use computer simulation on their framework, but they pointed out that the use of blockchain is very new, and is difficult to demonstrate the improvement on transparency. Without the documented performance in real industry, it is difficult to persuade enterprise and gain support from the top management [12] to deploy this new digital tool for information sharing. In short, effort in measuring and comparing the effective of using blockchain on information sharing can be the next step of the development of deploying blockchain in a supply chain.

Despite many literatures expect blockchain to achieve various strategic supply chain objectives, for example reducing cost through the elimination regulatory compliance cost and increasing the speed through digitization [86], it is not a one-size-fit-all technology. It is crucial to place a strong focus in understanding the nature of the supply chain as a part of future development of blockchain. For example, identifying the boundary conditions [87], and addressing the key requirements [53] in developing an architecture for information sharing which fits the nature of supply chain that supports information sharing. This is to better prepare the adoption of blockchain technology in a real-world scenario.

VI. CONCLUSION

The high volume of information generated from members in a supply chain makes information sharing complicated and highly fragmented. To better facilitate information sharing, different methods, such as engaging a centralized third party, is still commonly used to facilitate information sharing among multiples parties within a supply chain. In addition to that, a legal contract is signed between two institutions or more to enhance collaboration work. However, malicious acts such as alteration to information in centralized database system, without leaving any traces, compromise data integrity and the level of transparency and traceability. Emerging technology such as blockchain technology may transform the current methods of storing information in a decentralization network where no single authority controls over information without compromising data integrity. This paper explored how blockchain-enabled information sharing can rebuild and fortify the element of information and data trust among members within a supply chain.

Blockchain technology has gained great interest within the supply chain due to the decentralized structured with high transparency and traceability. However, research focusing primarily on blockchain-enabled information sharing within a supply chain remains limited. In this systematic literature review, we contributed by identifying what are the significant impacts with the deployment of blockchain-enabled information sharing within a supply chain. The main finding is that this technology ensures members in the chain can obtain verified information which enhances collaborative partnerships. The use of blockchain-based platforms with embedded smart contracts can increase information sharing between trusted and non-trusted institutions with lower security risk. This can benefit any types of supply chain by removing information silos which often happen in reality.

Through this in-depth research, we also contributed by highlighting barriers in the development of blockchain technology in supply chains. One of the potential challenges is the unwillingness of firms to share information to other members, due to conflict of interests. The lack of understanding of this technology also impedes the deployment within a supply chain. Till today, many business leaders remain unsure what blockchain is, and how can it contribute to their businesses, while many SMEs claimed they have little knowledge on this. Hopefully these findings can draw a more comprehensive overview to researchers in developing relevant steps to overcome highlighted challenges.

In this paper, we also provided some potential future work for blockchain-enabled information sharing that is worth investigating by researchers, that could bring a positive impact on the expansion of this new technology. More effort in information hiding, in parallel with information sharing, could potentially close the gap in deploying this technology within a supply chain. Future work in understanding the nature of a supply chain is also important to better prepare the deployment of blockchain. Lastly, we acknowledge that our approach in selecting literatures in our systematic review may exclude certain literatures. Nonetheless, we tried to include as many relevant academic papers as possible, to develop a roadmap on the current situation of blockchain-enabled information sharing in supply chain.

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