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Author(s)	:	Josephine Permata Sari and Joniarto Parung
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SMART CONTRACT IN THE SUPPLY CHAIN

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Smart Contract in the Supply Chain

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Abstract

Over the past 10 years, blockchain technology has been increasingly applied in various industrial and scientific fields, including in the supply chain. Blockchain applications in the supply chain field that are starting to develop are decentralized applications without involving third parties, known as smart contracts. Smart contract applications are computer protocols designed to facilitate, verify, and automatically enforce negotiations and agreements between multiple parties who may not yet know each other. However, how the form of smart contract applications and how successful this application is has not been widely discussed. This paper will review 11 literatures selected based on the criteria of publisher, year of publication, and number of citations. This literature review resulted in the grouping of smart contract applications in various sectors in the supply chain, the methodology used, and the outputs of previous research. In addition, an analysis of keywords and future research on those articles was carried out.

Keywords: *Smart contract, supply chain, blockchain*

1. INTRODUCTION

The supply chain involves many processes from raw material procurement, production, delivery of finished products, to post-sales support (Koirala, Dahal, and Matalonga 2019). This process, of course involves a large number of entities and a very complicated traceability process (Wang et al. 2019). This makes it difficult to trace information that occurs in the supply chain. For this reason, blockchain technology is an option that makes it possible to track and follow every product from raw materials to its entire life cycle (Koirala, Dahal, and Matalonga 2019). This blockchain traceability can also provide transparency in several processes such as during manufacturing, delivery, or payment (Swan 2015).

Blockchain is a decentralized database that exists as a copy on a computer network (Michael Crosby, Nachiappan, Pradan Pattanayak, Sanjeev Verma 2016). The characteristics of blockchain are traceability, data storage, privacy, and automation in supply chain processes (Shuchih Ernest Chang, Chen, and Lu 2019). Blockchain cannot be manipulated so that all parties involved in the supply chain can gain high visibility through security in data sharing mechanisms (Dolgui et al. 2020).

Blockchain can execute smart contracts as transactions (Dolgui et al. 2020). Smart contracts can be said to be the most promising technology for better traceability while maintaining transparency and privacy (Koirala, Dahal, and Matalonga 2019). Smart contracts offer autonomous delivery scenarios by improving supply chain performance (Younus and Younus 2021). Not limited to tracing functions, smart contracts can also automate bidding procedures so that they are more transparent and reliable and automatically trigger payments after the contract agreement has been fulfilled (Koirala, Dahal, and Matalonga 2019). Smart contracts are able to perform tasks in real time at low costs with a higher level of security (Kumar Mohanta and Jena 2018). The use of smart contracts on blockchain in the supply chain can improve accuracy, speed, security, and trust building with resulting transparency, traceability and efficiency (Dolgui et al. 2020).

2 RESEARCH METHODOLOGY

Article selection is done through several criteria fulfillment. The selection of whether the article can meet the criteria is done with the Harzing Publish or Perish application which was accessed in April 2022 and was carried out from Scopus and the Web of Science. There are three defining criteria. The criteria are publisher, year of publication, and number of citations. Articles that are selected was articles that published by IEEE Access and Elsevier. Then, the next criteria are articles that published within the last 5 years or between 2018 and 2022. In addition, there is also a criteria for the number of citations where the selected articles have been citation more than or equal to 15 times in April 2022.

The search was carried out on articles with two main keywords, namely smart contracts and supply chain. The selected articles must have a relationship or application between the supply chain and blockchain, especially smart contracts. Based on the criteria mentioned above, 38 eligible papers were obtained. However, due to limitations, this research will focus on 11 articles.

3 SMART CONTRACTS

3.1 An Introduction to Smart Contracts

The concept of a smart contract was first introduced by Nick Szabo in 1994. A smart contract is defined as a computer-based transaction protocol that carries out the terms of the contract (Kumar Mohanta and Jena 2018). A smart contract is a set of programs that can verify and execute themselves through the use of distributed database technologies such as blockchain thereby helping to minimize the need for third parties (Kumar Mohanta and Jena 2018; Younus and Younus 2021). In its operation and development, legal protection is needed like a legal agreement in general. Legal protection for technology protection measures and rights management information on smart contracts is collectively referred to as Digital Rights Management (DRM) (Younus and Younus 2021).

Smart contract consist of values, functions, addresses, and states (Bahga and Madisetti 2016). Generally, smart contract will store 5 data, namely timestamp, amount of currency sent, sender information, recipient information, and other required data (Qu, Haddad, and Shahriar 2019). This technology runs an "if-then" condition in such a way that the user will pay a predetermined amount if the prerequisites in the contract have been met (Younus and Younus 2021). Smart contract also allow parties to impose a requirement that if one transaction occurs then another transaction will also occur (Norta 2017).

3.2 Smart Contracts in Supply Chain Research

A smart contract is a set of digital agreements represented in code and executed by a computer after a certain event (Dolgui et al. 2020). This makes it possible to initiate transactions between supply chain units that can coordinate and optimize the entire supply chain with the aim of minimizing transaction costs and resulting in transactions that are irreversible and resistant to disruption (Younus and Younus 2021). Companies such as Maersk, Walmart, and Everledger have also explored the use of smart contracts for tracking at various scales of shipments of goods such as meat, containers, and even diamonds (Koirala, Dahal, and Matalonga 2019).

Based on research conducted by Feiyang Qu, Hisham Haddad, and Hossain Shahriar in 2019 regarding the manufacture of smart contracts in a business-to-consumer security-based supply chain system, a conclusion was found that compared to traditional systems in retail, smart contracts have advantages in data traceability, auditing data, identity management, and uniformity of data verification.

3.2.1 Sector, Methodology, and Output Analysis

In this sub-chapter, an analysis is carried out regarding the sectors discussed, the methodology used, and the outputs generated from the 11 selected articles. The existing supply chain sectors are divided into 6 sectors, namely agricultural, agri-food (agricultural and food), medical, grain, humanitarian, and general supply chain. Meanwhile, the methodology is divided into 3 methods, namely analysis, design and implementation, and systematic literature review. Sector determination and methodological grouping looks like table 3.1.

(Authors, Year)	**Title**	**Sectors**	**Methodology**		
			Analysis	**Design model and implementation**	**Systematic literature review**
(Lin et al. 2020)	Blockchain Technology in Current Agricultural Systems:	Agricultural supply chain	✓		

	From Techniques to Applications				
(Shahid et al. 2020)	Blockchain-Based Agri-Food Supply Chain: A Complete Solution	Agri-Food supply chain		✓	
(Ahmad et al. 2021)	Blockchain-Based Forward Supply Chain and Waste Management for COVID-19 Medical Equipment and Supplies	Medical supply chain		✓	
(Zhang et al. 2020)	Blockchain-based safety management system for the grain supply chain	Grain supply chain		✓	
(Salah et al. 2019)	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	Soybean (Agricultural and food) supply chain		✓	
(Wan, Huang, and Holtskog 2020)	Blockchain-Enabled Information Sharing within a Supply Chain: A Systematic Literature Review	General supply chain			✓
(Debe and Omar 2020)	Enhancing vendor managed inventory supply chain operations using blockchain smart contracts	General supply chain		✓	
(Baharmand and Comes 2019)	Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-based Smart Contracts	Humanitarian supply chain	✓		
(Wang et al. 2019)	Smart contract-based product traceability system in the supply chain scenario	General supply chain		✓	
(Prause 2019)	Smart Contracts for Smart Supply Chains	General supply chain	✓		
(Shuchih E. Chang and Chen 2020)	When blockchain meets supply chain: A systematic literature review on current development and potential applications	General supply chain			✓

Table 3.1 Sector determination and methodological grouping

Based on selected articles related to smart contracts in the supply chain, there are different output results. Each of these outputs is shown in table 3.2.

(Authors, Year)	**Title**	**Sectors**
(Lin et al. 2020)	Blockchain Technology in Current Agricultural Systems: From Techniques to Applications	Techniques and applications of blockchain technology used in the agricultural sector
(Shahid et al. 2020)	Blockchain-Based Agri-Food Supply Chain: A Complete Solution	A complete solution for blockchai-based Agriculture and Food (Agri-Food) supply chain
(Ahmad et al. 2021)	Blockchain-Based Forward Supply Chain and Waste Management for COVID-19 Medical Equipment and Supplies	A decentralized bloackchain-based solution to automate forward supply chain processes for the COVID-19 medical equipment and

		enable information exchane among all the stakeholders
(Zhang et al. 2020)	Blockchain-based safety management system for the grain supply chain	A new system architecture for guaranteeing food quality and safety process traceability
(Salah et al. 2019)	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	An approach for soybean tracking and traceability across the agricultural supply chain
(Wan, Huang, and Holtskog 2020)	Blockchain-Enabled Information Sharing within a Supply Chain: A Systematic Literature Review	An identification and understanding to the impact of blockchain technology offers a high level of transparancy and has gained the attention from various sectors to deploy this technology
(Debe and Omar 2020)	Enhancing vendor managed inventory supply chain operations using blockchain smart contracts	A blockchain-based approach using smart contracts to transform VMI supply chain operations
(Baharmand and Comes 2019)	Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-based Smart Contracts	The application of blockchain-based smart contracts to humanitarian supply chains (HSCs)
(Wang et al. 2019)	Smart contract-based product traceability system in the supply chain scenario	A product traceability system based on blockchain technology
(Prause 2019)	Smart Contracts for Smart Supply Chains	By considering the case of autonomous delivery robots, the concepts of Industry 4.0, blockchains and smart contracts fit structurally well together and complement each other by adding self-enforcing to the already well-known Industry 4.0 features of self-organising and self-optimising
(Shuchih E. Chang and Chen 2020)	When blockchain meets supply chain: A systematic literature review on current development and potential applications	Exploration of the current status, potential applications, and future direction of blockchain technology in supply chain management

Table 3.2 Output

3.2.2 Keyword Analysis

Of the 11 selected articles, there are 38 different keywords. The keyword that appears most often is blockchain as much as 14%. Then in the next sequence, smart contract, smart contracts and traceability each have a percentage of 6%. Followed by Ethereum and supply chain management at 5% each. The rest there are 32 keywords that occupy as much as 3% and 2% as shown in Table 3.3. There are 3 articles that do not have smart contract or smart contracts keywords in the keywords section. But it clearly includes smart contract or smart contracts in the abstract section and discusses smart contracts in the entire article so that the three articles still meet the researchers' criteria.

Keywords	**Amount**	**Percentage (n=63)**
Blockchain	9	14%
Smart Contract	4	6%
Smart Contracts	4	6%
Traceability	4	6%
Ethereum	3	5%
Supply Chain Management	3	5%
Accountability	2	3%
Data Integrity	2	3%

Food Safety	2	3%
Supply Chain	2	3%
Agricultural Applications	1	2%
Agricultural Supply Chain	1	2%
Blockchain Applications	1	2%
Blockchain Technology	1	2%
COVID-19	1	2%
Credibility	1	2%
Digital Ledger	1	2%
Distributed Ledger Technology	1	2%
Food Supply Chains Management	1	2%
Forward Supply Chain	1	2%
Grain Supply Chain	1	2%
Hyperledger	1	2%
Humanitarian Supply Chain	1	2%
Industry 4.0	1	2%
Information Sharing	1	2%
Logistics	1	2%
Logistics Service Providers	1	2%
Medical Waste Management	1	2%
Partnerships	1	2%
Reputation	1	2%
Security	1	2%
Security Analysis	1	2%
Shared Ledger	1	2%
Smart Supply Chains	1	2%
Soybean	1	2%
Systematic Literature Review	1	2%
Trust	1	2%
Value Chain	1	2%

Table 3.3. Distribution of 38 keywords in the 11 selected journals

The existing keywords are then divided into three major categories. The first is infrastructure and technology which includes blockchain and smart contracts. Furthermore, there are categories of characteristics of smart contracts in the supply chain such as traceability and accountability. The third category is the sector or implementation of smart contracts in the supply chain sector, such as in the agricultural supply chain and humanitarian supply chain.

In the infrastructure and technology category, blockchain ranks first at 14%. Followed by smart contract and smart contracts with a percentage of 6% each and closed with Ethereum as much as 5%. Furthermore, for the characteristic category of smart contract in the supply chain, the characteristic of smart contract in the supply chain that most often appears is traceability as much as 6%. Followed by several other characteristics, namely accountability and data integrity as much as 3%. In addition, there are several other characteristics such as credibility, digital ledger, distributed ledger technology, Hyperledger, security, shared ledger, and trust. Smart contract, in this case in the supply chain, are implemented in various sectors such as agricultural supply chains, food supply chains, grain supply chains, humanitarian supply chains, logistics, and smart supply chains.

Keywords are then clustered based on co-occurrence through the VOS Viewer application. Of the 38 existing keywords, 6 of them have a relationship as shown in Figure 3.1. The distance between keywords indicates the relationship between keywords while the same color indicates that the keywords are often used together.

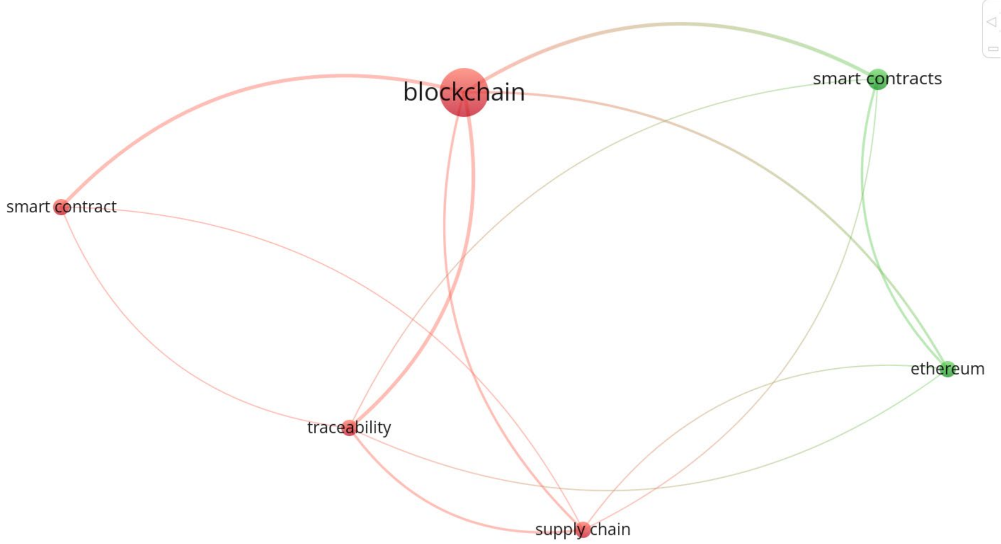

Figure 3.1. Keyword cluster

3.2.3 Future Avenues Analysis

In this sub-chapter an analysis of future research suggested by 10 of the 11 selected articles is carried out. The grouping is divided into three parts, namely sectors, future research topics, and methodologies. Suggested methods that can be used for further research are divided into 4 methods. These methods include analysis, case study, design and implementation, and systematic literature review. Analysis can be done on data, concepts, models, uses, or processes. Case study can mean qualitative research through empirical tests carried out directly on existing conditions. Design and implementation can be interpreted as observation or analysis of the model that will be created and programming the model into an application on the blockchain. Systematic literature review is research in the form of a review of existing articles.

In the sector, the research is divided into 6 sectors in the supply chain. In alphabetical order, the sectors are agricultural systems, agri-food (agricultural and food), general supply chain, humanitarian supply chains, IoT and blockchain, and medical supply chain. The grouping table equipped with future research topics looks like Table 3.4.

(Authors, Year)	Title	Sectors	Future Research Topic	Methodology / Approach
(Lin et al. 2020)	Blockchain Technology in Current Agricultural Systems: From Techniques to Applications	Agricultural systems	Empirical test of agricultural system case study	Case study
(Shahid et al. 2020)	Blockchain-Based Agri-Food Supply Chain: A Complete Solution	Agri-food	Refund and return mechanism in Agri-food products trading	Design and implementation
(Ahmad et al. 2021)	Blockchain-Based Forward Supply Chain and Waste Management for COVID-19 Medical Equipment and Supplies	Medical	Incentive system for the COVID-19 treatment hospitals to dispose of medical waste	Design and implementation
(Zhang et al. 2020)	Blockchain-based safety management system for the grain supply chain	IoT and blockchain	Ensure the credibility of information sources	Design and implementation
(Salah et al. 2019)	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	Soybean (Agricultural and food) supply chain	Integrate within the proposed solution automated payments and proof of delivery	Design and implementation
(Wan, Huang, and Holtskog 2020)	Blockchain-Enabled Information Sharing within a Supply Chain: A Systematic Literature Review	General supply chain	Information hiding in parallel with information sharing within supply chain	Design and implementation
(Debe and Omar 2020)	Enhancing vendor managed inventory supply chain operations using blockchain smart contracts	General supply chain	A decentralized applications to fully automate the VMI process for all stake holders	Design and implementation
(Baharmand and Comes 2019)	Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-based Smart Contracts	Humanitarian supply chains	Realizing shift in trust-based theories in HSCs	Analysis
(Wang et al. 2019)	Smart contract-based product traceability system in the supply chain scenario	General supply chain	Realize formatted upload of data by using IoT technology	Design and implementation
		General supply chain	Using QR code to promote process of product source querying, improve consumer consumption experience, and simplify the consumer operation process	Design and implementation
(Shuchih E. Chang and Chen 2020)	When blockchain meets supply chain: A systematic literature review on current	General supply chain	Blockchain technical issues as troughput, security, scalabiliity, and interoperability	Systematic literature review

	development and potential applications			

Table 3.4. Future research grouping

4 CONCLUSION

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