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A Review of Smart Contracts Applications in Various Industries: A Procurement Perspective

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1. Introduction

With the advent of blockchain technology, smart contracts have become one of the most sought-after technologies [1]. Smart contract is a new technology that can automatically negotiate, fulfil, and enforce the terms of an agreement in a blockchain environment [2]. Compared with traditional contracts, smart contracts have the advantages of diminishing risk, cutting down administration and service costs, and improving the efficiency of business processes [3]. More importantly, smart contracts have the capacity to create trust between parties in what we term no-trust contracting environments [4]. In this regard, it will reshape business processes and even transform conventional practices [5].

Due to these benefits, smart contracts have recently fueled extensive research interests [2]. Smart contracts have the potential to be used in various industries. For example, Hasan et al. [6] proposed a method based on smart contracts for effective shipment management. Wang et al. [7] pointed out that smart contracts can be applied to the financial loan management system. Khatoon [8] revealed the practical benefits of smart contracts in healthcare management. Moreover, researchers also attempted to evaluate the application of the smart contract. For example, Macrinici et al. [1] identified 16 smart contract problems and offered corresponding solutions through a literature review. Wang et al. [9] presented several typical application scenarios of the smart contract and discussed the future development trends. Rouhani and Deters [2] reviewed the security, performance, and application of smart contracts. Zheng et al. [5] compared several major smart contract platforms and categorized smart contract applications.

The current procurement system faces greater challenges in transaction security, information exchange, business process, payment delay, and traceability [10]. Smart contracts have the characteristics to solve these issues digitally. The potential of smart contracts is of significance to the improvement and transformation of the traditional procurement pattern [11, 12]. While prior studies have shed some lights on the application of smart contracts, there is still a lack of holistic understanding across industries, especially from the procurement perspective. To address this gap, the purpose of this study is to systematically review the application of smart contracts in various industries, which is mainly to answer the following questions:

RQ1. What is the current development status of smart contract applications?

RQ2. What are the benefits of smart contracts applications in various industries from the

Blockchain technology originated from the foundational paper “Bitcoin: A peer-to-peer electronic cash system” published by Satoshi Nakamoto in 2008 [13]. This technology is essentially a decentralized database as per its underlying bitcoin technology, which provides new technical solutions without relying on a third party to carry out the storage, verification, transmission, and communication of network data through its own distributed nodes. It is also considered the most disruptive technology innovation after the invention of the Internet [14]. The reason is that, based on its clever mathematical cryptography and distributed algorithm, participants can reach consensus and transmit trust and value reliably at a meagre cost without the third-party intermediate [4].

The development of blockchain technology can be generally categorized into three stages, that is, the application of digital currency in the initial 1.0 stage, the application of smart contract in the 2.0 stage, and the programmable blockchain 3.0 stage [15, 16]. It is currently in the second stage of development, where blockchain is still mainly used in small-scale local applications, with few real industry-level or eco-level applications. Even so, the unique features of blockchain technology have started spreading over many industries [17].

2.2. Smart Contract

The concept of smart contracts was first proposed in the 1990s by Nick [18]. However, smart contracts were buried and failed to attract the attention of the industry and academia for quite some time as there was no platform to execute smart contracts before the emergence of blockchain technology in 2009 [3]. By contrast, the heyday of smart contracts has already begun. Especially since the establishment of Ethereum based on blockchain technology, the development of smart contracts has become popular. Up to date, except Ethereum, there are numerous alternative blockchain-based platforms for executing smart contracts including Hyperledger fabric, Corda, Stellar, Rootstock, EOS, etc. [5]. In this way, the blockchain and smart contracts have been growing and functioning mutually.

Unlike contracts in the real world, smart contracts are entirely digital and essentially containers of code that encode [1]. Smart contracts refer to a computer protocol, which can be self-executed and self-verified once developed and deployed without any human interventions [14]. Smart contracts can create trust among parties in a no-trust contracting environment [4]. The terms and conditions embedded in smart contracts will be enforced automatically when certain criteria have been satisfied. Compared with traditional contracts, smart contracts have the advantages of decreasing transaction risk, diminishing

The development of blockchain and smart contracts provides new possibilities for procurement. Blockchain, especially smart contracts, is subverting the traditional procurement model. Kamali [22] pointed out that the application of blockchain and smart contracts can prevent corruption and fraud in the procurement process. Chong and Diamantopoulos [23] indicated that smart contracts effectively address the security of payment problems in the construction industry. Hasan et al. [6] demonstrated that smart contracts could be used to manage shipment conditions, automate payments, legitimize receiver, and issue a refund in case of violating the predefined terms. Jangir et al. [24] revealed that smart contracts could help achieve user privacy protection, data transparency, immutability nonrepudiation, real-time tracking of commodities, and demand-supply management. Elghaish et al. [11] underlined the possible future extension for smart contracts, which would be revolutionizing the structure of traditional procurement systems, such as the design-build (DB) method. From the procurement perspective, smart contracts constitute business logic that is related to purchasing transactions [10]. In summary, smart contracts have a great potential to extend existing procurement tools or practices by automatizing their transactional processes.

3. Methodology

A combination of bibliometric analysis and systematic review was adopted to locate and analyze existing research related to the application of smart contracts in various industries. The systematic review is defined as a literature review method that identifies, evaluates, and analyzes published primary studies to answer specific research questions [25]. It mainly relies on personal and intentional selected materials deemed important, enabling researchers to go beyond their own experience and conduct a comprehensive search of all existing publications of interest. More importantly, the systematic evaluation reduces the bias of researchers because it uses a predefined sequential search strategy, thereby increasing the transparency of the method and thus allowing future replication [26]. The specific review process and strategy are as follows.

3.1. Information Sources and Search Strategy

Scopus and Web of Science were selected as the main sources of retrieval due to their more comprehensive coverage of scientific publications and quicker indexing processes. That would help in increasing the possibility of retrieving more relevant publications. The data collection was conducted

discussed the results with differences until a consensus was reached. Finally, 174 publications were selected for this review paper, as shown in Table 2. Figure 1 illustrates the overall flow of the review process and strategy.

Table 1

Inclusion and exclusion criteria.

Table 2

Research papers included in the systematic review and their characteristics.

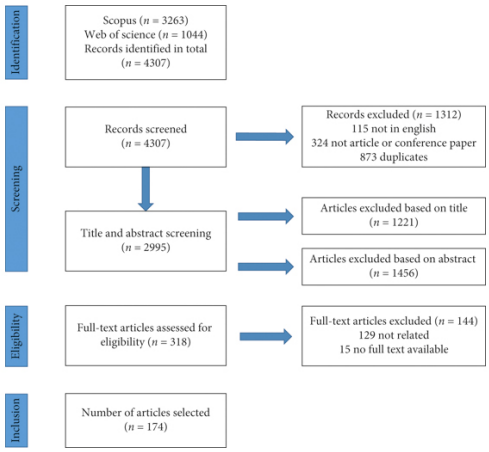

Figure 1

4.1. Chronological Publication Trend

Figure 2 shows the publication trend of related research on smart contract applications. Although we did not set a time limit, the first related paper emerged in 2016. That indeed indicates that the research of smart contracts is relatively new. Apart from that, it can be found from the trend line that both journal papers and conference papers have been developing rapidly in recent three years. Among them, 83 publications were published in 2019, and 38 publications were published in the first half of 2020. It is worth noting that the number of conference papers had increased faster than journal papers in the initial stage. That was mainly due to the reporting of the preliminary research outcomes or proof-of-concept studies at the early stage of research development. Still, the number of journal papers had grown significantly faster since 2019, indicating that the research has become more established and popular in academia.

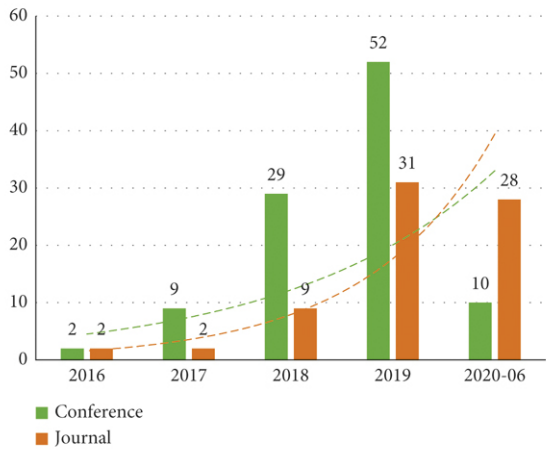

Figure 2

Paper distribution by year of publication.

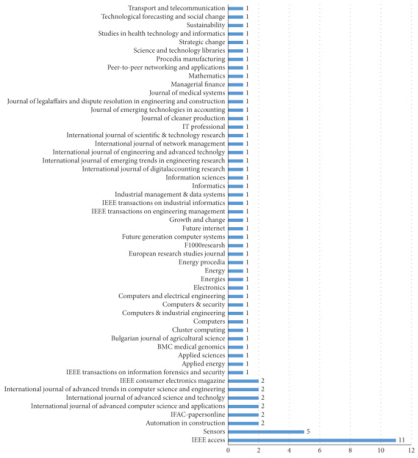

Figure 3

Journal/conference publications and number of papers published.

4.3. Analysis of Collaborative Networks of Authors, Institutions, and Countries

The visualized collaboration network can reflect, to a certain extent, the closeness of research collaboration among authors, institutions, and countries. It also allows us to track some of the major research institutions and authors quickly. The authors' collaboration network is shown in Figure 4. 606 authors have researched on this topic. However, only two authors have published more than three papers, Salah K. (5 papers) and Prause G. (3 papers). The percentage of authors who published only one paper was 93.7%. That indicates that the current research on the application of smart contracts in various industries is still in the primary stage. Few scholars have published many publications, and cooperation between authors is lacking. For example, the scholar with the most collaborative connections, Salah K., had a total link strength of only twelve.

The collaboration network among institutions is shown in Figure 5. A total of 238 institutions have researched this topic, most of which have published only one paper. Only nine institutions have published more than three papers, among which Tsinghua University and Khalifa University have published the most, each with four papers. As can be seen from the figure, there are few links and cooperation between institutions. Among them, National University of Singapore, Tsinghua University, and University of Aizu have many links with other institutions, but the number of links of each is only five.

Figure 5

A network of cooperation between institutions.

Meanwhile, this argument is also supported by the network of cooperation between countries. In Figure 6, each node represents a country, and its size reflects the number of papers contributed by authors from that country. China is the country with the largest number of published papers (47 papers), followed by India (24 papers). The United States, United Kingdom, and Italy have published a few articles as well. It is noteworthy that the United States, while not the most publishing country, is the most cited, with 1,329 citations. The links in Figure 6 denote the collaboration between countries, and their thickness explains

Figure 6

A network of cooperation between countries.

4.4. Cooccurrence Analysis of Keywords

To construct the knowledge domains of smart contracts applications in various industries, a keyword cooccurrence analysis was performed on the selected publications using VOS viewer. Choose network visualization to present the results of bibliometric analysis on smart contracts applications literature. The output of the VOS viewer is a distance-based map, where the distance between two keywords reflects the strength of the relationship between the keywords. A smaller distance usually indicates a stronger relationship. The size of the keyword label reflects the number of publications where the keyword was found. The larger the size of the keyword label, the more publications are containing the keyword. Different colors represent different keywords' groups that clustered by the clustering technology of VOS viewer. The information of 174 publications obtained from Scopus and Web of Science databases was input into the VOS viewer. Set the threshold of keyword occurrences to four to improve the representativeness and comprehensiveness of the clustering results. As a result, 54 of the 1336 keywords

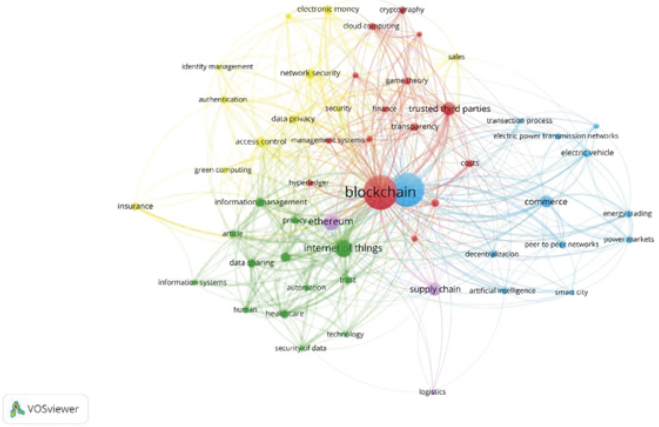

Figure 7

Keywords cooccurrence network.

Table 3 lists the detailed quantity information of the popular keywords in Figure 7 (all greater than nine). The occurrences show the number of occurrences of each keyword from the keywords retrieved from the selected publication. For instance, except for the keyword blockchain and smart contract, the Internet of Things, Ethereum, trusted third parties, and supply chain are the most frequently occurring keywords, which shows that they have been extensively studied in existing research. The average year published shows the average time period in which a given keyword has been investigated by researches. For example, keywords Internet of Things, Ethereum, and commerce received more attention around 2018, while research on supply chain, data storage, access control, and healthcare had the greatest publication frequency in 2019. That indicates that the latter represents an emerging topic in the research of smart contracts applications in various industries. Links are the number of links between a given keyword and others, while the total link strength reflects the total strength linked with a specific keyword. For example, the total link strength of supply chain is 74, which is at the high level of all the keywords and shows the strong interrelatedness between supply chain and smart contract.

and management of medical sensors. Apart from that, we also analyze cocited authors in selected publications, as this helps researchers quickly locate key scholars and articles in the area. Figure 8 reports the visualization of cocited authors, where the minimum number of citations for an author is set to 10, and the total link strength is set to 100. Node size is proportional to the number of citations, and different colors represent different clusters. Satoshi Nakamoto is one of the pioneers in smart contract research. Unsurprisingly, he is the most cocited scholar.

Table 4

The top 10 cited articles.

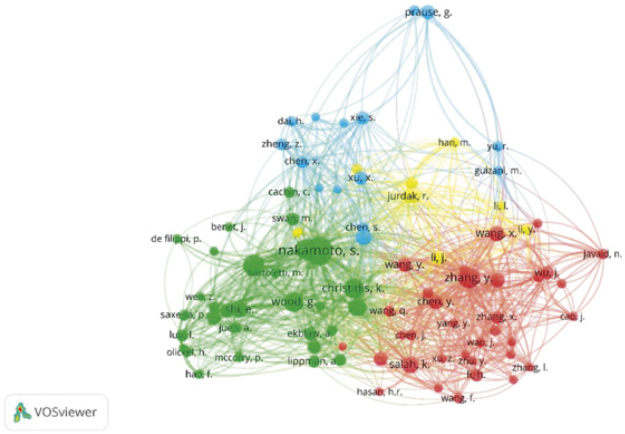

Figure 8

Cocitation authors analysis.

Figure 9

Classification of the application of smart contracts in various industries.

In the selected publications, 62 publications (35.63%) focused on theoretical descriptions or proposed frameworks/methods and 76 publications (43.68%) were related to abstract prototyping or implementation of smart contracts. Although the papers from the abstract prototyping or implementation made up a larger proportion, there were not many practical applications or cases yet, indicating that the development of smart contracts is still in the preliminary stage of exploration. Besides, Ethereum and Hyperledger fabric were the leading technology for smart contract applications in various industries, as most of the smart contracts were hosted on these platforms.

5. Results of the Systematic Review

In this section, we attempt to answer RQ2 and RQ3.

Smart contracts have many advantages for a wide range of potential applications that could benefit business transactions and management across industries. In principle, smart contracts do not rely on any human interventions, and their implementations are guided and overseen by other nodes in the blockchain network. Once the contract is triggered, the scripted contract will self-execute and proceed to the next transaction. In this way, smart contracts can increase the speed of a wide variety of business processes and greatly reduce turnaround time. For example, Chong and Diamantopoulos [23] demonstrated that smart contracts' automatic execution function solves the delayed payment in the construction industry. Nugraha et al. [155] highlighted that smart contracts address high cycle time and low activity time efficiency in official documents business process. Aleksieva et al. [84] articulated that smart contracts can reduce operational costs and time to process claims for losses in the insurance industry.

Automated transactions are not only faster but also less error prone. The automation exhibit in smart contracts avoids most of the wastes and issues found in traditional contracts. Stefanović et al. [56] mentioned that smart contracts could improve the transaction registration process and eliminate the possibility of "double spending" in land administration systems. Hasan et al. [6] underlined that smart contracts could be used to manage shipment conditions, automate payments, legitimize receiver, and issue a refund if violating the predefined conditions. Shahab and Allam [169] indicated that using smart contracts can lower the transaction costs of tradable permission programs. Khatoon [8] mentioned that smart contracts could simplify the transaction process in the healthcare industry and thus reduce the management burden and cut down transaction costs.

Since the terms and conditions of the contract become explicitly visible to participants involved in the specific blockchain, transparency and trust are facilitated, and fraud issues are eliminated. Wang et al. [93] stated that smart contracts could enhance transaction transparency in the consumer electronics industry and reduce fraud. Neiheiser et al. [164] revealed that smart contracts could improve the transparency and reliability of the recruitment process, further increasing the likelihood of a fair selection process. Zhao and O'Mahony [50] stated that, with smart contracts, music rights holders could automatically receive royalty payments from the music industry rather than relying on intermediaries. Gu et al. [66] considered that smart contracts could guarantee information and privacy security in the crowdsourcing process at a lower cost without the participation of trusted third-party institutions. Jaiswal et al. [129] indicated that smart contracts could better return to farmers by reducing the overall cost at the end-user side through removing intermediaries.

Smart contracts have privacy protection and tamper-proof functions. Contracts implemented in an

data sharing in the Internet of Things. The healthcare industry has always been faced with the issue of data sharing. By setting access rights through smart contracts, users can achieve efficient and safe peer-to-peer data sharing without worrying about data leakage and tampering, and data reliability is fully guaranteed.

5.2. RQ3. What Are the Potential Advantages of Smart Contracts in the Procurement Process?

There are many intermediaries in traditional procurement processes that hinder the overall procurement performance's efficiency [21]. Smart contracts then have opened a new procurement method that enhances trust and transparency between transaction parties while reducing or eliminating intermediaries. That will increase operational efficiency through a more efficient way of contracting in the procurement process. From the procurement process perspective, three main impact areas have been identified from the current development and application of smart contracts, such as supplier management, contract management, and logistics management, as shown in Table 7.

Table 7

Potential advantages of smart contracts in the procurement process.

First, from the supplier management aspect, evaluation indicators/requirements of suppliers could be written into smart contracts. For example, the credit rating could be carried out to help select the appropriate supplier. Smart contracts could handle all bidding transactions without a third party [91], and this tamper-proof function helps ensuring transparency and fairness as well as preventing bidder collusion and corruption in the bidding process [79, 95]. Moreover, the trust and transparency provided by smart contracts could further improve the relationship between suppliers and promote collaboration and mutual benefit between suppliers.

Second, regarding the contract management aspect, smart contracts could be a platform to ensure integrity and transparency during multiround bilateral negotiations, where buyers and suppliers could exchange their offers in an effective and trustworthy manner [87]. More importantly, smart contracts could reduce the effort spent on manual operation and confirmation, which greatly reduce workloads and

have extended the original functions of smart contracts and made them more comprehensive and efficient to their project needs, such as cross-organizational collaboration and optimization of business processes.

Apart from that, a research framework of smart contracts has been developed for future procurement needs based on this mixed-method review, as shown in Figure 10. On the one hand, most studies have found the benefits of smart contracts, but current research has not gone beyond conceptual proposals and recommendations and lacks in-depth research on smart contracts in terms of procurement. How will smart contracts change the current procurement workflow? How to build an automated financial system through smart contracts? How will smart contracts affect customer relationships? All of these will be significant breakthrough points to achieve sustainable procurement in the future.

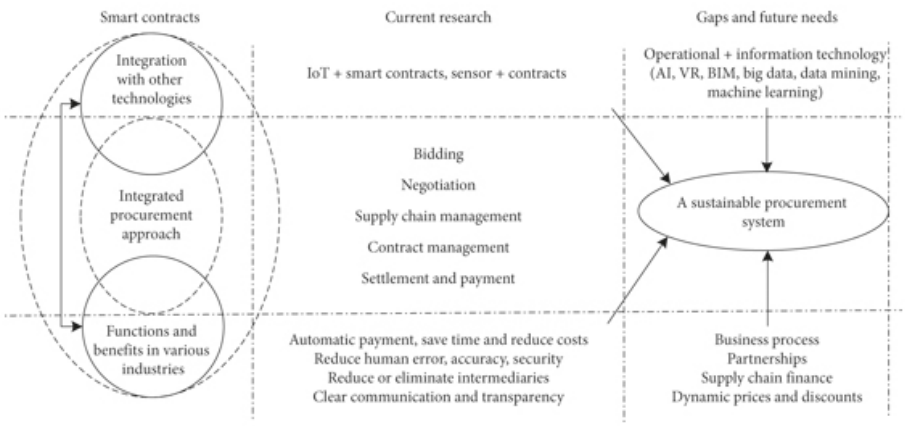

Figure 10

A research framework for smart contracts in future procurement.

On the other hand, the integration of smart contracts with other emerging technologies has received widespread attention from academia and industry by combining smart contracts with IoT devices that can

automatically sense material requirements and trigger replenishment requisitions and automatically execute contract terms based on rules and trigger payment. In this regard, it will shorten the approval cycle and eliminate manual errors, and subsequently, it will greatly improve the overall efficiency of business operations. The entire procurement life cycle can be digitalized and improved via smart contracts: the fairness of bidding, the speed of negotiation, the transparency of the supply chain, the convenience of contract management, and the automation of confirmation and payment. Moreover, purchasing based on smart contracts will transform from a purely cost-driven transaction to a value-oriented process among project stakeholders. In sum, this framework provides insightful theoretical ideas and practical references of integrated procurement approach based on smart contracts, which is a sustainable procurement system for future procurement needs in business operations across the industries.

7. Conclusion

This research has conducted a mixed-method review on the application of smart contracts in various industries to understand their current status, benefits, and potential advantages from the procurement perspective. The research results reveal that the current development of smart contracts is still in its infancy. However, smart contracts have the potential to be widely used across industries, especially in leveraging each industry's strengths or developments in addressing inefficient processes in the current conventional procurement systems. The paper has made contributions to the existing literature of smart contracts in three aspects. First, this article categorizes the application of smart contracts in various industries, summarizes the benefits and functions, and analyzes the current development status. That lays a beneficial foundation for future studies in this field. Secondly, this study uses a systematic and bibliometric review method. The combination of qualitative and quantitative methods provides better methodological reliability in reviewing and analyzing the application of smart contracts in various industries. Third, based on the analyzed data's inductive approach, we establish a research framework for future procurement needs. The proposed integrated approach of the sustainable procurement system provides new insights and opportunities for researchers and procurement practitioners to rethink and reexamine the current procurement system and process.

Nevertheless, certain limitations should be noted in this paper. Firstly, there are still many challenges and technical problems in certain applications of smart contracts, for example, legal uncertainty, technology maturity, and security concerns. Future studies should extend the review to discuss the detailed problems and challenges in applying smart contracts across the perspectives of organization, technology, and