Review Article

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

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Smart contracts have been well-received by researchers and practitioners for the unique features of automatic execution, transparency, and nontampering in a blockchain environment. However, little is known about the current development status of knowledge and practice regarding the application of smart contracts in various industries, especially from the procurement perspective. Thus, this paper aims to address the gap with a mixed method of bibliometric analysis and systematic literature review. Based on the evaluation of 174 filtered publications, the review has analyzed the current development status of this research area with its distributions in years and journals, cooperation networks between authors, institutions, and countries, keywords cooccurrence network, and classifications of the application of smart contracts. The results show the application of smart contracts has attracted global attention since 2016 with the Ethereum and Hyperledger fabric as the main platforms in various industries, especially in information communication technology (ICT), public management, supply chain, energy, finance, and healthcare. Various functions and benefits of smart contracts, as well as their potential advantages, have been identified and articulated from the procurement perspective. A research framework has also been developed to highlight future procurement needs in business operations across the industries via an integrated procurement approach of smart contracts.

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 procurement perspective?

RQ3. What are the potential advantages of smart contracts in the procurement process?

The mixed-method approach of bibliometric analysis and systematic review was adopted to analyze the research works on smart contracts' applications. Subsequently, a research framework of smart contracts was developed for future procurement needs from both theoretical and practical perspectives. The remainder of this paper is organized as follows. Section 2 provides a brief background overview of blockchain, smart contract, and procurement; Section 3 describes the research methodology; Sections 4 and 5 present the results; Section 6 presents the discussion and future procurement requirements0020framework; Section 7 summarizes the research conclusions and research limitations.

2. Background

2.1. Blockchain. 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 management and service costs, and improving business process efficiency as they are typically deployed on and protected by blockchain [5]. In this connection, smart contracts are expected to provide a better solution to the current transaction mode in various industries.

2.3. Procurement. Procurement is the act of acquiring goods or services from an external source [19]. Ordinary purchases are simple acts in procurement, while a complex procurement includes more complicated processes such as requirement determination, source selection, quotation request, vendors selection, etc. In general, the traditional procurement system requires employees to coordinate vast amounts of paperwork [20]. Apart from that, there are many intermediaries, long processing times, potential collusions, information delay, and trust issues in the traditional procurement system, which hinder the efficiency of the overall procurement performance [21]. Nowadays, based on the digital technology, procurement has begun to change from traditional procurement system to an electronic procurement approach, which can be described as a comprehensive ICT process to establish agreements for the acquisition of products or services (contracting) or purchase products or services in exchange for payment (purchasing). This electronic procurement approach will alter the way businesses or individuals purchase. It could overcome certain shortcomings of the traditional procurement system, such as low transaction security, lack of trust, repetitive verification, and payment delays.

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 non-repudiation, 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 initially in January 2020, and it was updated and supplemented with more papers for the final analysis in June 2020. The generic term "smart contract" was used for the retrieval to cover as many publications as possible for this review. The formulated search string was as follows: (TITLE ("smart contract") OR ABS ("smart contract") OR KEY ("smart contract")).

3.2. Publication Selection and Evaluation. The subsequent screening procedure was carried out to filter the relevant publications based on the following three steps. First, articles were screened through the topic refinement within the databases to eliminate any duplicate articles. Second, the filtered papers were further analyzed for their titles and abstracts from the procurement perspective. Finally, the related publications were downloaded in full and reviewed systematically after checking against inclusion and exclusion criteria, as shown in Table 1. Considering that the topic is still relatively new, the literature search was conducted without any time restrictions until June 2020. We focused only on the literature in academic journals and conference papers to ensure the quality and coverage of the scientific knowledge of smart contracts in various industries. Meanwhile, we excluded articles focused on the technical aspects or algorithms' developments in blockchain and smart contracts. The whole screening process was completed by three members, two of whom were screened in a back-to-back manner. Then, the results were compared, and three members 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.

Based on the above, we also synthesized the data by looking at the year of publication, type of publication, blockchain platform, and application domain. Apart from these, the application level of smart contract was classified according to Udokwu et al. [194] and Batubara et al. [195]. The results were presented in appendix A. The level of application was segmented as theoretical description, proposed framework/method, system architecture, prototype, and implementation. Besides, a preliminary descriptive statistical analysis was further conducted to understand the selected publications better. We used VOS viewer software to analyze the keyword cooccurrence network, cooperation networks between authors, institutions, countries, and author cocitation network. In this way, more intuitive answers could be uncovered for the research questions.

4. Results of the Bibliometric Analysis

In this section, we attempt to find an answer to RQ1. What is the current development status of smart contract applications?

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.

Table 1: Inclusion and exclusion criteria.

Selection criteria	Scientific database
Inclusion	Without time-frame restrictions Article or conference paper Related to the application, use, and adoption of smart contracts
Exclusion	Non-English articles, articles with missing abstract, full text not available A generic literature review Technical aspects of smart contracts, e.g., algorithms' developments, contract testing, code analysis, etc. Only relevant to the law Blockchain's technical development

Table 2: Research papers included in the systematic review and their characteristics.

No.	Author (year)	Source type	Application domains	Blockchain platform	Level of application
1	Bogner et al. (2016) [27]	Conference	Sharing economy	Ethereum	System architecture
2	Christidis and Devetsikiotis. (2016) [28]	Journal	IoT	N/A	Theoretical description
3	Nugent et al. (2016) [29]	Journal	Healthcare	Ethereum	Prototype
4	Yasin and Liu (2016) [30]	Conference	Online identity	N/A	System architecture
5	McCorry et al. (2017) [31]	Conference	Voting	Ethereum	Implementation
6	Thomas et al. (2017) [32]	Conference	Energy	Ethereum	Prototype
7	Hans et al. (2017) [33]	Conference	Finance	Ethereum	Theoretical description
8	Kounelis et al. (2017) [34]	Conference	Energy	Ethereum	Prototype
9	Gazali et al. (2017) [35]	Conference	Education	Ethereum	Prototype
10	Hahn et al. (2017) [36]	Conference	Energy	Ethereum	Prototype
11	Álvarez-Díaz et al. (2017) [37]	Conference	Logistics management	Ethereum	Proposed method
12	Saravanan et al. (2017) [38]	Conference	ICT	Ethereum	Proposed method
13	Sreehari et al. (2017) [39]	Conference	Public management	Ethereum	Proposed method
14	Shermin (2017) [40]	Journal	Governance	Bitcoin, Ethereum	Theoretical description
15	Mason (2017) [41]	Journal	Construction	N/A	Theoretical description
16	Kirkman (2018) [42]	Conference	Cloud	Ethereum	Proposed framework
17	Wang et al. (2018) [43]	Conference	Prediction market	Ethereum	Implementation
18	Hou et al. (2017) [44]	Conference	Electric vehicles	NA	Proposed method
19	Yeh et al. (2018) [45]	Journal	Mobile payment	Ethereum	Proposed method
20	Desai et al. (2018) [46]	Conference	Data sharing	Ethereum	Proposed framework
21	Mahmoud et al. (2018) [47]	Conference	Finance	Ethereum	Prototype
22	Rozario and Vasarhelyi. (2018) [48]	Journal	Finance	NA	Theoretical description
23	Chen et al. (2018) [49]	Conference	E-commerce	Ethereum	System architecture
24	Zhao and O'Mahony (2018) [50]	Conference	Entertainment	Ethereum	Prototype
25	Zhong et al. (2018) [51]	Conference	Electric vehicle	Ethereum	Proposed method
26	Gupta and Bedi (2018) [52]	Conference	Public management	Ethereum	Prototype
27	Griggs et al. (2018) [53]	Journal	Healthcare	Ethereum	Prototype
28	Zhou et al. (2018) [54]	Conference	IoT	Ethereum	System architecture
29	Arumugam et al. (2018) [55]	Conference	Supply chain	Ethereum	Prototype
30	Stefanović et al. (2018) [56]	Conference	Public management	Ethereum, Hyperledger	Proposed method
31	Islam and Kundu (2018) [57]	Conference	E-commerce	N/A	Proposed method
32	Hasan and Salah (2018) [58]	Journal	ICT	Ethereum	Prototype
33	Cruz et al. (2018) [59]	Journal	ICT	Ethereum	Prototype
34	Niya et al. (2018) [60]	Conference	E-commerce	Ethereum	System architecture
35	Fedosov et al. (2018) [61]	Conference	E-commerce	Ethereum	System architecture
36	Pãnescu and Manta (2018) [62]	Journal	Research data rights management	Ethereum	Prototype
37	Fotiou and Polyzos (2018) [63]	Conference	IoT	N/A	Proposed method
38	de Souza et al. (2018) [64]	Conference	Public management	N/A	Theoretical description
39	Norta et al. (2018) [65]	Conference	Commercial property	Ethereum, Hyperledger, Qtum	System architecture
40	Gu et al. (2018) [66]	Conference	Business	Ethereum	Proposed framework

TABLE 2: Continued.

No.	Author (year)	Source type	Application domains	Blockchain platform	Level of application
41	Xu et al. (2018) [67]	Journal	IoT	Ethereum	Prototype
42	Cheng et al. (2018) [68]	Conference	Education	Ethereum	System architecture
43	Gatteschi et al. (2018) [69]	Journal	Insurance	Bitcoin	Theoretical description
44	Król et al. (2018) [70]	Conference	ICT	Ethereum	System architecture
45	Kim et al. (2018) [71]	Conference	ICT	Ethereum	Proposed framework
46	Bedi et al. (2020) [72]	Conference	Education	Ethereum	Implementation
47	Lamberti et al. (2018) [73]	Journal	Insurance	Ethereum	Prototype
48	Omar and Basir (2018) [74]	Conference	IoT	Ethereum	Implementation
49	Nayak et al. (2018) [75]	Conference	Cloud	Ethereum	System architecture
50	Novikov et al. (2018) [76]	Conference	Healthcare	Ethereum	Theoretical description
51	Uriarte et al. (2018) [77]	Conference	Cloud	Ethereum	Prototype
52	Zhou et al. (2018) [78]	Conference	Cloud	Ethereum	Prototype
53	Yu et al. (2018) [79]	Conference	Energy	Ethereum	Proposed framework
54	Papadodimas et al. (2018) [80]	Conference	IoT	Ethereum	Implementation
55	Jangir et al. (2019) [24]	Conference	Supply chain	Ethereum	Proposed framework
56	Lyu et al. (2019) [81]	Conference	Voting	Ethereum	System architecture
57	Pham et al. (2018) [82]	Conference	Healthcare	Ethereum	Prototype
58	Augusto et al. (2019) [83]	Conference	Supply chain	Ethereum	Prototype
59	Aleksieva et al. (2019) [84]	Conference	Finance	Ethereum	Prototype
60	Le et al. (2019) [85]	Journal	E-commerce	Ethereum	Proposed framework
61	Li et al. (2019) [86]	Conference	Public management	Ethereum	Proposed method
62	Pittl et al. (2019) [87]	Conference	Business	Ethereum	Implementation
63	Philipp et al. (2019) [88]	Journal	Supply chain	NA	Theoretical description
64	Palma et al. (2019) [89]	Journal	Education	Ethereum	Prototype
65	Kiran et al. (2019) [90]	Conference	ICT	Ethereum	Prototype
66	Manimaran and Dhanalakshmi (2019) [91]	Conference	E-commerce	Ethereum	System architecture
67	Pee et al. (2019) [92]	Conference	Energy	Ethereum	Prototype
68	Wang et al. (2019) [93]	Journal	E-commerce	N/A	Proposed framework
69	Luo et al. (2019) [94]	Conference	Construction	Hyperledger	Proposed framework
70	Wu et al. (2019) [95]	Journal	E-commerce	Ethereum	Implementation
71	Singla et al. (2019) [96]	Conference	Education	Ethereum	System architecture
72	Nguyen et al. (2019) [97]	Conference	Public management	Ethereum	System architecture
73	Liu et al. (2019) [98]	Journal	Electric vehicle	Ethereum	Proposed method
74	Liu et al. (2019) [99]	Conference	Public management	Ethereum	System architecture
75	Asfia et al. (2019) [100]	Conference	Electric vehicle	Ethereum	Proposed framework
76	Pham et al. (2019) [101]	Conference	IoT	Ethereum	Prototype
77	Neiheiser et al. (2019) [102]	Conference	Public management	Ethereum	Prototype
78	dos Santos et al. (2019) [103]	Journal	Food manufacturing	Ethereum	Prototype
79	Malan and Steyn (2019) [104]	Journal	Finance	N/A	Theoretical description
80	Baharmand and Comes (2019) [105]	Journal	Supply chain	N/A	Theoretical description
81	Wang et al. (2019) [7]	Journal	Finance	Hyperledger fabric	System architecture
82	Nguyen et al. (2019) [106]	Conference	Finance	NEO	Proposed framework
83	Yang et al. (2019) [107]	Conference	Finance	Ethereum	System architecture
84	Duan et al. (2019) [108]	Journal	Electric vehicles	N/A	Proposed method
85	Giordanengo (2019) [109]	Journal	Healthcare	N/A	Theoretical description
86	Zaghloul et al. (2019) [110]	Conference	Healthcare	Ethereum	Proposed method
87	Voutos et al. (2019) [111]	Conference	Agriculture	Ethereum	Theoretical description
88	Zhang et al. (2019) [112]	Journal	Ride-hailing service	Ethereum	Prototype
89	Hasan et al. (2019) [6]	Journal	Supply chain	Ethereum	Prototype
90	Bader et al. (2018) [113]	Conference	Finance	Ethereum	Prototype
91	Qu et al. (2019) [114]	Conference	Supply chain	Ethereum	Prototype
92	Hanada et al. (2018) [115]	Conference	IoT	Ethereum	Prototype

Table 2: Continued.

No.	Author (year)	Source type	Application domains	Blockchain platform	Level of application
93	Prause and Boevsky (2019) [116]	Journal	Supply chain	N/A	Theoretical description
94	Prause (2019) [117]	Journal	Supply chain	N/A	Theoretical description
95	Asgaonkar and Krishnamachari. (2019) [118]	Conference	E-commerce	N/A	Theoretical description
96	Chang et al. (2019) [119]	Journal	Supply chain	N/A	Proposed framework
97	Koirala et al. (2019) [120]	Conference	Supply chain	Ethereum	Prototype
98	Terzi et al. (2019) [121]	Conference	Supply chain	N/A	Implementation
99	Mohanta et al. (2019) [122]	Journal	IoT	Ethereum	Proposed framework
100	Zhao et al. (2019) [123]	Journal	Entertainment	N/A	System architecture
101	Lin et al. (2019) [124]	Conference	Public management	Ethereum	Implementation
102	Gong et al. (2019) [125]	Conference	Healthcare	Ethereum	Prototype
103	Vidhyalakshmi et al. (2019) [126]	Journal	Real estate	Ethereum	Prototype
104	Hasan and Salah (2019) [127]	Journal	ICT	Ethereum	Prototype
105	Wang et al. (2019) [128]	Journal	Supply chain	Ethereum	Implementation
106	Chang et al. (2019) [21]	Journal	International trade	Ethereum	Implementation
107	Jaiswal et al. (2019) [129]	Conference	Agriculture	Ethereum	Proposed framework
108	You et al. (2019) [130]	Conference	Energy	Ethereum	Proposed framework
109	Yang et al. (2019) [131]	Conference	Healthcare	Ethereum	System architecture
110	Batista and Weingaertner (2019) [132]	Conference	ICT	N/A	Proposed method
110	Sheth and Subramanian (2019) [133]	Journal	Insurance	Ethereum	Theoretical description
112	Putra et al. (2019) [134]	Conference	IoT	Ethereum	Implementation
113	Kumar and Raja Kumar (2019) [135]	Journal	E-auction	Ethereum	Prototype
114	Zhao and Wu (2019) [136]	Conference	Electric vehicles	N/A	System architecture
115	Jintapitak et al. (2019) [137]	Conference	Insect industry	N/A	Proposed framework
116	Wang et al. (2019) [138]	Journal	Energy	Ethereum	Implementation
117	Poptawski and Szczypiorski (2019) [139]	Conference	Energy	N/A	Proposed method
118	Bracciali et al. (2019) [140]	Conference	Public management	Ethereum	Prototype
119	Mihelj et al. (2019) [141]	Journal	Public management	Ethereum	Prototype
120	Ekici et al. (2019) [142]	Conference	ICT	Hyperledger fabric	Implementation
121	Vinayak et al. (2019) [143]	Conference	Financial	Hyperledger fabric	Implementation
122	Li and Liu (2019) [144]	Conference	Business	Ethereum	System architecture
123	Li et al. (2019) [145]	Journal	Energy	Ethereum	Implementation
124	Poorni et al. (2019) [146]	Conference	Education	Ethereum, Hyperledger fabric	System architecture
125	Qian et al. (2019) [147]	Conference	Digital resource copyrights	Hyperledger fabric	System architecture
126	De Giovanni (2019) [148]	Journal	Supply chain	N/A	Proposed method
127	Chen et al. (2019) [149]	Journal	Public management	N/A	System architecture
128	Bagozi et al. (2019) [150]	Conference	ICT	Ethereum, Hyperledger fabric	Proposed method
129	Moudoud et al. (2019) [151]	Conference	IoT	Ethereum	System architecture
130	Kovalenko et al. (2019) [152]	Conference	Financial	Ethereum	System architecture
131	Dai et al. (2019) [153]	Journal	Public management	Ethereum	Proposed framework
132	Lin et al. (2019) [154]	Conference	Business	EOSIO	System architecture
133	Nugraha et al. (2019) [155]	Conference	Public management	Hyperledger fabric	System architecture
134	Montes et al. (2019) [156]	Conference	Supply chain	Hyperledger fabric	Proposed framework
135	Omar et al. (2019) [157]	Conference	Healthcare	Ethereum	Proposed method
136	Avizheh et al. (2019) [158]	Conference	ICT	Ethereum	Implementation
137	Le and Mutka (2019) [159]	Conference	IoT	Ethereum	Prototype
138	Khatoon (2020) [8]	Journal	Healthcare	Ethereum	Implementation
139	Kumar et al. (2020) [160]	Conference	Land transaction	Ethereum	System architecture
140	Wang et al. (2020) [161]	Journal	ICT	N/A	System architecture
141	Dorsala et al. (2020) [162]	Journal	ICT	Ethereum	Implementation
142	Yu et al. (2020) [163]	Journal	Food manufacturing	Ethereum	Prototype
143	Neiheiser et al. (2020) [164]	Journal	Public management	Ethereum	Prototype

TABLE 2: Continued.

No.	Author (year)	Source type	Application domains	Blockchain platform	Level of application
144	Chong and Diamantopoulos (2020) [23]	Journal	Construction	Hyperledger	System architecture
145	Chen et al. (2020) [165]	Journal	ICT	N/A	Proposed method
146	Wang et al. (2020) [166]	Journal	Electric vehicles	Multiple platforms	Implementation
147	Patel and Das (2020) [167]	Conference	Education	Hyperledger	Prototype
148	Nakamura et al. (2020) [168]	Journal	IoT	Ethereum	Prototype
149	Shahab and Allam (2019) [169]	Journal	Public management	N/A	Theoretical description
150	Sultana et al. (2020) [170]	Journal	IoT	Ethereum, Spyder	Prototype
151	Debe et al. (2020) [171]	Journal	ICT	Ethereum	Implementation
152	Elghaish et al. (2020) [11]	Journal	Construction	Hyperledger	Implementation
153	Han et al. (2020) [172]	Journal	Energy	Ethereum	System architecture
154	Xuan et al. (2020) [173]	Journal	Data sharing	N/A	Proposed method
155	Fu et al. (2020) [174]	Journal	Electric vehicle	Ethereum	Implementation
156	Matai et al. (2020) [175]	Journal	Real estate	Ethereum	Prototype
157	Vyas et al. (2020) [176]	Conference	Healthcare	Ethereum	Implementation
158	Jamil et al. (2020) [177]	Journal	Healthcare	Hyperledger fabric	Implementation
159	Prashar et al. (2020) [178]	Journal	Supply chain	Ethereum	Prototype
160	Reniers et al. (2020) [179]	Conference	Data sharing	Ethereum	Implementation
161	Kurnia et al. (2020) [180]	Conference	Supply chain	N/A	System architecture
162	Habib et al. (2020) [181]	Conference	Supply chain	N/A	Proposed framework
163	Neysen (2020) [182]	Journal	Recording industry	N/A	Theoretical description
164	Zghaibeh et al. (2020) [183]	Journal	Healthcare	Hyperledger fabric	System architecture
165	Luchoomun et al. (2020) [184]	Journal	Automotive industry	Hyperledger fabric	Implementation
166	Chiacchio et al. (2020) [185]	Journal	Pharma industry	Ethereum	Prototype
167	Makmur et al. (2020) [186]	Journal	Energy	Ethereum, bitcoin	System architecture
168	Gong et al. (2020) [187]	Conference	IoT	Ethereum	Implementation
169	Pertiwi et al. (2020) [188]	Journal	Entertainment	Ethereum	Theoretical description
170	Adrian et al. (2020) [189]	Journal	E-logistics	N/A	Proposed framework
171	Gürsoy et al. (2020) [190]	Journal	Healthcare	Ethereum	Prototype
172	Shurman et al. (2020) [191]	Conference	IoT	Ethereum	Proposed framework
173	Gupta et al. (2020) [192]	Conference	Financial	N/A	Theoretical description
174	Panja et al. (2020) [193]	Journal	E-voting	Ethereum	Implementation

4.2. Journals. Among the 174 selected publications, 102 were from conferences, and 72 were from journals. As shown in Figure 3, the 72 journal papers come from 53 journals, reflecting a wide variety of multidisciplinary sources. Of these, eight journals had published at least two articles, such as automation in construction, sensors, IEEE Access, etc. The rest published one per journal.

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.

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
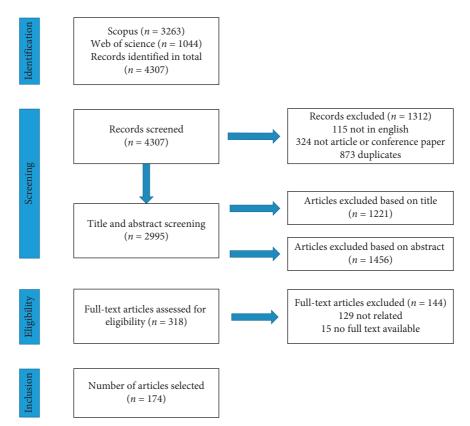
FIGURE 1: Overall flow of the review process and strategy.

FIGURE 2: Paper distribution by year of publication.

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 the collaboration strength between the two countries. For example, China researchers had established a network of collaboration with twelve countries across the world, followed by the United Kingdom with seven countries. Although some links have been established at the national level, there is still room for improvement.

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 reached the threshold. In Figure 7, the cooccurrence keywords are grouped into five clusters with various colors. Cluster 1 (red) refers to the blockchain, with primary keywords including trusted third parties, transparency, cost, finance, game theory, and contracts; cluster 2 (green) refers to the Internet of Things, with primary keywords including digital storage, privacy, data sharing, information management, trust, privacy, automation, and healthcare; cluster 3 (blue) refers to smart contract and commerce, with primary keywords
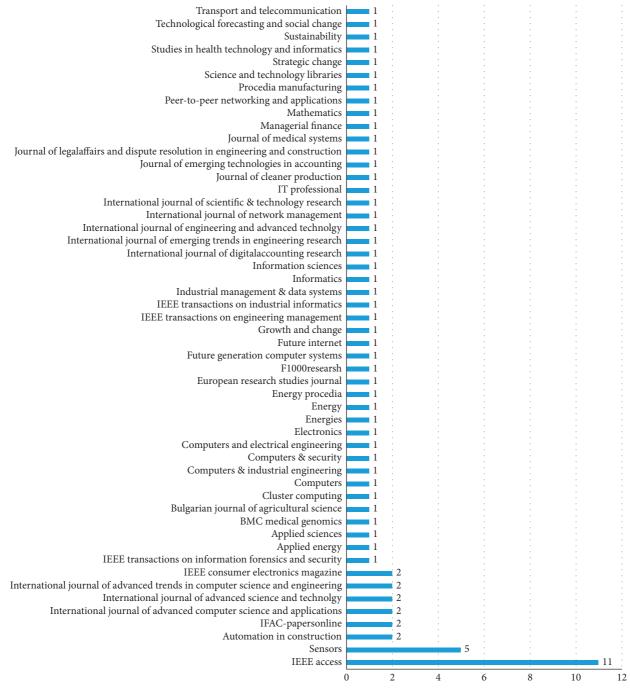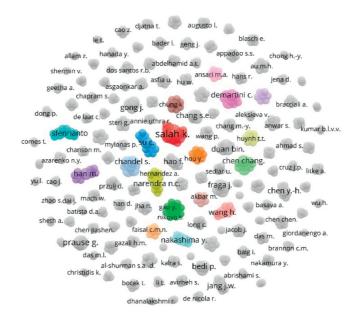
FIGURE 3: Journal/conference publications and number of papers published.

including electric vehicle, transaction process, decentralization, energy trading, artificial intelligence, and peer-to-peer networks; cluster 4 (yellow) refers to security, with primary keywords including data privacy, identity management, green computing, access control, and insurance; cluster 5 (purple) refers to supply chain, with primary keywords including Ethereum and logistics.

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.
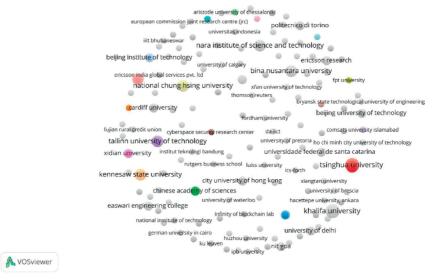
Figure 4: A collaborative network of authors.

Figure 5: A network of cooperation between institutions.

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.

4.5. Citation Analysis. Since citations are considered a vital indicator of the paper's impact, a citation analysis was conducted to determine the degree of acceptability for this field research. Table 4 shows the 10 most frequently cited publications. The most cited publication is [28], with 2,545 citations. It focuses on integrating blockchain and IoT and points out that the combination of blockchain and the Internet of Things can bring significant changes to many industries. That also demonstrates that the combination of blockchain and smart contracts with IoT has received extensive attention from scholars. The second most cited publication is [31], with 291 citations. It introduces a decentralized and self-tallying Internet voting protocol with maximum voter privacy using blockchain and smart contract. The third most cited publication is [53], with 241 citations. It proposes utilizing blockchain-based smart contracts to facilitate the security analysis and management of medical sensors. Apart from that, we also analyze cocited
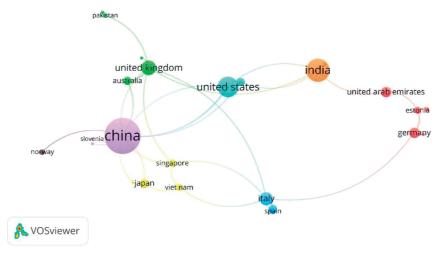
Figure 6: A network of cooperation between countries.
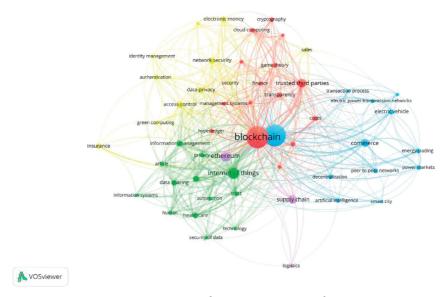
Figure 7: Keywords cooccurrence network.

Table 3: Top keywords in smart contracts applications literature.

Keywords	Occurrences	Average year published	Links	Total link strength
Blockchain	155	2018.83	53	548
Smart contract	148	2018.84	53	516
Internet of Things	38	2018.61	42	171
Ethereum	36	2018.61	36	153
Trusted third parties	23	2018.96	36	111
Supply chain	23	2019.13	22	74
Commerce	18	2018.50	27	77
Digital storage	12	2019.00	20	50
Network security	11	2018.73	26	58
Access control	11	2019.09	25	56
Data privacy	10	2018.80	25	57
Information management	10	2018.80	21	46
Healthcare	9	2019.22	22	46
Electronic money	9	2018.67	17	42
Data sharing	9	2019.22	19	41
Transparency	9	2019.11	18	37

TABLE 4: The top 10 cited articles.

No.	Author and year	Title	Total citations
1	Christidis and Devetsikiotis (2016) [28]	Blockchains and smart contracts for the Internet of Things	2545
2	McCorry et al. (2017) [31]	A smart contract for boardroom voting with maximum voter privacy	291
3	Griggs et al. (2018) [53]	Healthcare blockchain system using smart contracts for secure automated remote patient monitoring	241
4	Gatteschi et al. (2018) [69]	Blockchain and smart contracts for insurance: Is the technology mature enough?	224
5	Shermin (2017) [40]	Disrupting governance with blockchains and smart contracts	152
6	Nugent et al. (2016) [29]	Improving data transparency in clinical trials using blockchain smart contracts	142
7	Bogner et al. (2016) [27]	A decentralized sharing app running a smart contract on the Ethereum blockchain	137
8	Cruz et al. (2018) [59]	RBAC-SC: Role-based access control using smart contract	119
9	Hahn et al. (2017) [36]	Smart contract-based campus demonstration of decentralized transactive energy auctions	97
10	Hasan and Salah (2019) [127]	Combating deepfake videos using blockchain and smart contracts	92

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.

4.6. Application Industry, Level of Application, and Platform. Figure 9 shows the classification of application of smart contracts in various industries. It can be categorized into 12 industries. The industries from information communication technology (ICT), public governance, supply chain, energy, business, finance, and healthcare accounted for 85.63%. In other words, they are the major industries smart contract applied in.

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.

5.1. RQ2. What Are the Benefits of Smart Contracts Applications in Various Industries from the Procurement Perspective? By comparing and analyzing selected publications, we summarized the main benefits of smart contracts in various industries (see Table 5). Besides, we also compared the benefits of smart contracts in different industries, as shown in Table 6.

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
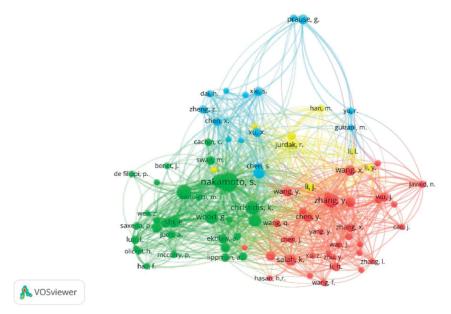
FIGURE 8: Cocitation authors analysis.
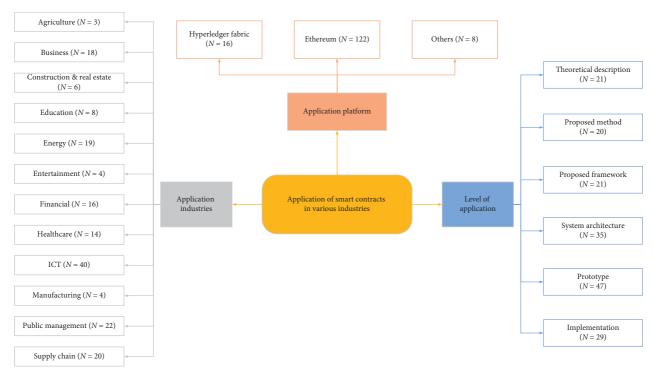
FIGURE 9: Classification of the application of smart contracts in various industries.

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 encrypted manner could enhance the security of the transaction and thwart any malicious activity that may alter the execution

TABLE 5: Benefits of utilizing smart contracts in various industries.

Industry domain	Benefits
Agriculture [111, 129, 137]	Improve product quality and the associated supply chain and agricultural logistics [111]
	Reduce costs, eliminate intermediaries, increase transparency and safety [129]
	Automatic execution agreement, safe and real-time transactions, product traceability [137]
Business [21, 27, 49, 57, 60, 61, 65, 66, 85, 87, 91, 93, 95, 112, 118, 135, 144, 154]	Eliminate the need for a trusted third party [27, 49, 61, 65, 66, 91, 95, 112, 118, 135, 144]
	Avoid the bid price leaked by the lead bidder [49]
	Preserve privacy [27, 57, 60, 66, 76]
	Ensure time-efficient and secure transactions [60, 112]
	Provide cost reductions, faster transaction times, greater transparency, and reduced regulatory burdens [65]
	Prevent fraud [85, 118]
	Improve the efficacy of transactions and prevent counterfeiting electronics trading [93]
	Ensure the integrity and transparency and tamper-safe negotiation process [87]
	Prevent bidder collusion [95]
	Mitigate endeavors spent on manual manipulation and confirmation [21, 144]
	Ensure the agreements will not be breached [154]
Construction & real estate [11, 23, 41, 94, 126, 175]	Automate construction payments [41, 94]
	Provide more secured and transparent transactions [23, 175]
	Record and monitor transactions without the need for of a trusted third party [126]
	Execute all financial transactions automatically [11]
Education [35, 62, 68, 72, 89, 96, 146, 167]	Solve the issue of default payments of study loans [35]
	Promote research data rights management [62]
	Provide accurate and reliable information on digital certificates [68, 72]
	Decrease bureaucracy in terms of document validation, saving in storage and labor [72, 89]
	Manage leave applications and prevent corruption [96]
	Prevent forgery of certificates [146]
	Improve transcript management [167]
Energy [32, 34, 36, 44, 51, 79, 92, 98, 100, 108, 130, 136, 138, 139, 145, 166, 172, 174, 186]	Automated negotiation, settlement, and payment [32, 136]
	Eliminate the need for a trusted entity oversight [34, 36, 44, 79]
	Protect the data privacy of transactions [44, 100]
	Improve the security and completeness of the transaction [51, 108, 172]
	Ensure the fairness, transparency, and immutability of the transaction [79, 92, 98, 139, 145, 166, 172, 174, 186]
	Automate execution without third-party intervention [92, 98, 130, 139, 145, 166, 172]
	Energy demand management [138]
	Substitute for written contracts and save file storage space [186]
Entertainment [50, 123, 182, 188]	Improve music copyright protection [50]
	Provide digital rights management [123, 182]
	Provide instant payment, eliminate some intermediaries [182, 188]
Financial [7, 33, 43, 47, 48, 69, 73, 84, 104, 106, 107, 113, 133, 143, 152, 192]	Lower execution risk, reduce the number of insurance intermediaries [33]
	Predict for market conditions [43]
	Automate insurance payment, privacy protection [47]
	Improve audit quality [48]
	Speed up insurance claims processing and reduce operating costs [69, 84, 106, 113, 133]
	Lower policy modification costs and limit insurance fraud [73]
	Reduce manual labor and back-office workloads as well as the removal of reconciliation and corporate actions [104]
	Improve the transparency, security, and traceability for the loan business [7]
	Improve the problems of insufficient supervision ability and low loan efficiency in the transaction process [107]
	Decrease information asymmetry [133]
	Automate transaction execution without intermediary [143, 152]
	Reduce the possibility of corruption and embezzlement [152]
	Reduce corporate frauds [192]

TABLE 5: Continued.

Industry domain	Benefits
Healthcare [8, 29, 53, 76, 82, 109, 110, 125, 131, 157, 176, 177, 183, 190]	Improve data transparency in clinical trials [29, 157] Secure automated remote patient monitoring [53, 82, 177] Improve the security and privacy of electronic medical records [76, 110, 131] Protect patient privacy [82, 125, 176, 183] Improve data sharing [109, 176, 183] Simplify procedures, reduce transaction costs, reduce administrative burdens, and remove intermediaries [8] Reduce query pharmacogenomics data time [190]
ICT [28, 30, 38, 42, 45, 46, 54, 58, 59, 63, 67, 70, 71, 74, 75, 77, 78, 80, 90, 101, 115, 122, 127, 132, 134, 142, 150, 151, 158, 159, 161, 162, 165, 168, 170, 171, 173, 179, 187, 191]	Automate complex multistep processes [28, 46, 58, 70, 75, 132, 142, 171, 187, 191] Improve IoT services [54, 71, 80, 115, 191] Improve information and security management [63] Access control [59, 67, 90, 134, 168, 170] Improve identity management [30, 74, 165, 179] Enhance the security of IoT data sharing management [71, 101, 151, 170] Increase the security and privacy [122, 159] Reduce the turnaround time of transactions without third party [38, 173] Improve trust in the cloud [42, 75, 77, 78, 150] Safer mobile payment [45] Combat deepfake videos [127] Promote a verifiable computation [158, 162] Provide public cloud storage auditing [161] Improve data sharing [173, 179]
Manufacturing [103, 163, 184, 185]	Utilize the autoexecution to achieve reliable and efficient quality monitoring [163] Implement a consumer trustworthy ingredient certification scheme [103] Enhance trust and traceability, prevent tampering with vehicle information and mileage [184] Improve and strengthen the traceability process [185]
Public management [31, 39, 40, 52, 56, 64, 81, 86, 97, 99, 102, 124, 140, 141, 147, 149, 153, 155, 160, 164, 169, 193]	Protect the voter's privacy [31, 81] Make testament tamper-proof, secure, transparent [39] Reduce transaction cost and bureaucracy [40, 169] E-waste management [52] Improve the process of registering transactions in the land administration system [56, 160] Reduce corruption [64, 149] Eliminate a trusted third party [81, 97, 140, 169, 193] Manage value-added tax payment [97] Enable secure and privacy-preserving identity management [99] Reduce the required workforce needed for the recruitment selection process and add more transparency and trust [102, 164] Ensure the unique data source of government data resources [124] Provide traffic event detection and source reputation assessment [141] Realize digital resource copyrights transactions and protection [147] Avoid malicious and false payment [149] Automate routine audit processes [153] Improve official document management [155]
Supply chain [6, 24, 37, 55, 83, 88, 105, 114, 116, 117, 119–121, 128, 148, 156, 178, 180, 181]	Increase transparency and trust [24, 37, 55, 83, 105, 119, 156, 180] Monitor products and automate the tracking and clearance processes [6, 24, 55, 83, 114, 121, 128, 178] Improve quality management and demand-supply management [24] Reduce intermediaries, transaction costs, and time [6, 88, 114, 116, 117, 156, 178] Manage shipment conditions, automate payments [6, 116] Improve business process reengineering across enterprise borders [116, 117, 119] Streamline the administrative processes and automatize the transactions [120, 148, 181]

sequence or execute invalid transactions. Niya et al. [60] pointed out that the application of smart contracts can secure users' privacy and transactions. Giordanengo [109] pointed out that smart contracts may be an effective way to solve the security and privacy challenges in the healthcare industry. Han et al. [172] underlined that as smart contracts strictly execute the trading and payment rules without

artificial intervention, the security and fairness of energy trading are significantly enhanced.

Based on the above analysis and Table 6, some smart contracts' benefits are universal in different industries, such as trust, transparency, traceability, elimination or reduction of intermediaries, secure transactions, privacy protection, simplification of transaction processes, reduction of human

Table 6: Comparison of smart contract benefits in different industries.

Industry	Benefit											
	1	2	3	4	5	6	7	8	9	10	11	12
Agriculture	●	●	●	●	●				●	●		●
Business	●	●		●	●	●		●	●			●
Construction & real estate			●		●	●				●	●	
Education					●	●	●	●				●
Energy	●			●	●	●				●		●
Entertainment					●							●
Financial		●	●	●	●			●			●	
Healthcare			●				●	●	●		●	●
ICT		●		●	●	●		●			●	●
Manufacturing		●		●								
Public management	●	●		●	●	●	●	●		●	●	
Supply chain	●	●	●	●	●			●	●	●		●

Note: 1 = Trust, 2 = Transparency, 3 = Traceability, 4 = Eliminate or reduce intermediaries, 5 = Secure transaction, 6 = Privacy protection, 7 = Prevent corruption, 8 = Simplify the process, 9 = Reduce costs, 10 = Reduce human error, 11 = Data sharing, 12 = Time-efficient.

error, and time saving. However, some industries have specific advantages, such as education, finance, and public management, where smart contracts have the potential to reduce corruption. The emergence of smart contracts reduces the possibility of corruption and embezzlement in distributing and transferring funds of the main organization between its instances. The integration of blockchain and smart contracts can prove the identity of bidders and bidding entities, automate the bidding process, and provide audit and audit support. Smart contracts also provide a solution for electronic voting systems, ensuring the fairness of the voting and personnel recruitment process. They provide barriers to fraud and corruption in public procurement. In the healthcare and ICT industries, improving data sharing is its unique advantage. Data sharing is the key support for the scale application of the Internet of Things. Blockchain-based smart contracts can provide a decentralized, secure, efficient, low-cost, and extensible distributed framework for 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.

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 disputes occurring in paper contracts [106]. Furthermore, smart contracts could also fully automate contract management via enabling instantaneous transactions payment from buyers to suppliers [11, 181]. That not only shortens the cash payment cycle but also eliminates human errors, overpayments, and duplicate payments.

Regarding the logistics management aspect, smart contracts could track procurement workflows (notably decisions and documentation), strengthen trails immutability, and provide real-time traceability of irregularities [128]. For example, the combination of smart contracts and the Internet of Things could play a complimentary role for product monitoring, tracking, and clearing [55]. Moreover, all interactions, communications, and transactions in the supply chain network between all stakeholders could be monitored and managed [6, 178].

6. Discussion and Framework

The review has identified many applications of smart contracts via the detailed analysis of the related publications. However, despite a plethora of research, the application of smart contracts in various industries is different and secreted around to their operational requirements. The actual use of smart contracts is still very limited in practice, especially from the procurement perspective. Nevertheless, the review also found that the widespread research and development of smart contracts in various industries 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

TABLE 7: Potential advantages of smart contracts in the procurement process.

| Potential impact areas	Papers
Supplier management	
Supplier selection	
Bidding	[34, 36, 49, 79, 91, 95, 129, 135, 166, 184]
Relationship management	
Contract management	
Negotiation	[11, 21, 23, 32–34, 36, 40, 41, 44, 45, 47, 50–52, 56, 60, 61, 65, 70, 73, 75, 79, 84, 85, 87, 88, 92–94, 98,
Documentation sharing	100, 106, 108, 112, 113, 115, 118, 129, 136–138, 143, 145, 149, 154, 155, 160, 172, 174, 175, 181, 184,
Payment	186, 187]
Audit	
Logistics management	
Time and material conditions	
Monitoring	[6, 24, 33, 55, 88, 103, 105, 114, 116, 117, 119–121, 128, 129, 148, 151, 156, 163, 178, 180, 181, 185,
Logistics information	189]
Goods receipts and storage	
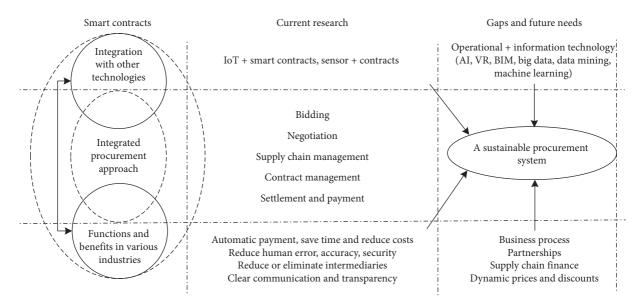
FIGURE 10: A research framework for smart contracts in future procurement.

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.

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 enhance the tracking and control of goods throughout the chain of custody in the entire supply chain [6]. Supply chain management in logistics is very suitable for integrating smart contracts and IoT [55, 83]. The integration will become a driving force to digitalize the procurement practices or functions in the project [10]. In addition, artificial intelligence, virtual reality, big data, machine learning, etc., will also provide new

opportunities for enhancing traditional procurement approaches' performance. For example, big data and data mining can help filter out better partners. Artificial intelligence can automatically trigger replenishment requests, and virtual reality can simplify supplier visits and on-site audits. All these processes can be registered and synchronized under the nodes of smart contracts in improving business operations. The integration of smart contracts with other emerging technologies is the future development trend and research focus, for example, in the construction procurement activities, the integration of smart contract and BIM, in logistics management, the integration of smart contracts with IoT and artificial intelligence, etc.

Future procurement systems will also need to achieve complete predictability of suppliers' information, prices, and costs. In bidding processes, smart contracts can automatically evaluate and recommend the best suppliers based on preset criteria and provide or optimize the best contract prices based on the number of goods and supplier discounts.

In this situation, the procurement process can fully achieve smart and efficient supplier selection and contract signing and subsequent execution via the self-service procurement operations within smart contracts. For example, the procurement operations will 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 environment. Secondly, the search queries

may not have been sufficiently comprehensive to capture all publications related to smart contracts application. Future Delphi studies can be conducted by analyzing the experts' knowledge in the field to avoid biases in the analysis of the selected works due to the interdisciplinarity of the research topics. Lastly, as the development of smart contracts is still in its infancy, this study only reviewed research articles. It did not perform a market review to identify the market trends of smart contracts currently used in different industries. In the future, with the increase of the breadth and depth of the application of smart contracts and the increase of practical use cases, we will conduct a more comprehensive study in combination with market development.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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