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Blockchain for Businesses: A Scoping Review of Suitability Evaluations Frameworks

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ABSTRACT Blockchain is an emerging technology that is increasingly being applied in both industrial and academic contexts. Cryptocurrency is a major application of blockchain in the financial sector, but the technology is expected to disrupt other industries. In fact, it has influenced many businesses and reshaped private and public sector activities. Therefore, there is growing interest in blockchain-based solutions, and applications have evolved in finance, insurance, logistics, government, education, and healthcare. Applications built on blockchains benefit from fair access, transparency, and immutability; these properties have attracted business owners and practitioners to explore blockchain opportunities beyond cryptocurrency, motivating them to investigate how they can benefit from the technology and also to evaluate its compatibility with their strategic orientation. Suitability evaluation (or applicability evaluation) has always been a crucial step for the successful adaptation of any innovative technology, including blockchain. Hence, this paper investigates how the current literature has addressed blockchain suitability evaluation for business cases beyond cryptocurrency. A scoping review is presented that examines the evaluation models and frameworks that have been developed to assist decision-makers regarding blockchain adoption. The results indicate that blockchain evaluation methodologies have utilized varied approaches and serve diverse objectives, which are applicable for different technology adoption stages. Through this scoping review, blockchain evaluation initiatives are classified into five categories, and a critical analysis is offered of the evaluation models under each category. As such, this scoping review overviews existing methodologies for blockchain evaluation approaches with a focus on context, identified assessments factors, assessment process, and evaluation dimensions.

INDEX TERMS Blockchain, distributed ledger, suitability evaluation, applicability evaluation, decision models, multi criteria decision making (MCDM), scoping review.

I. INTRODUCTION

Blockchain technology is based on the use of distributed ledger technology (DLT). It enables transactional data sharing across multiple untrusted participants with decentralized management, where agreement on a transaction is reached without relying on a central trusted third party (TTP) [1]. Blockchain has created new forms of distributed system architectures that are empowered by smart contracts and a consensus mechanism [2]. This means that blockchains are robust against faults and attacks through the use of redundant checking of multiple nodes [3]. It is widely recognized that blockchains have unique differences compared to previous technologies [4]. As noted by IBM's CEO, Ginni Rometty, 'What the Internet did for communications, blockchain will do for trusted transactions' [5].

The features of blockchain allow for the development of applications with capabilities such as asset tokenization, immutable transactions, smart contracts, and digital signatures. These applications mean that blockchain is a promising and indispensable technology for improving everyday operations [6]. For example, many studies have documented the significant potential of blockchains in a corporate context, principally because they can increase competitiveness by enabling the traceability and verifiability of transactions, as well by establishing trust without the need for costly third parties [7], [8]. According to the survey conducted in 2019 by Deloitte's Global Blockchain [9],

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the perception of the blockchain is presently reaching the point of no return, with the corporate focus shifting from exploring the technology's potential to creating productive business applications [10]. Indeed, 50% of business leaders in Europe expect that blockchains will be incorporated into their operating models, while 33% report that blockchains will entirely replace their existing operating models [11].

Although many organizations have exhibited an interest in implementing blockchain technology within their industries, the fact that blockchain is an emerging technology, paired with some of the distinctive, intrinsic properties that make it different compared to other elements of the current technology infrastructure, mean that it may not be suitable or beneficial in all business cases. Usually, the introduction of disruptive technologies to any sector brings with it multiple challenges and complexities across technical, business, regulatory, social, and usability-related areas [12]. In addition, many heterogeneous factors have been identified and reported as criteria for blockchain applicability assessments or to be used in the development of suitability evaluation frameworks [13]. However, a key question relates to the matter of how to determine whether a blockchain solution is suitable for a given business; if so, which configuration of a blockchain system should be used? Moreover, what other considerations could affect a successful blockchain implementation? Answering these questions presents major challenges for business owners and decision-makers because each blockchain project requires a carefully considered analysis that is based on the specificities of the individual application.

With the above considerations in mind, the main research question that this paper seeks to address is the following:

RQ1: How has previous literature addressed the evaluation of blockchain's suitability for businesses?

To guide the investigation, the following sub-questions were established:

- RQ1.1: What methodologies are used to help decision-makers evaluate the suitability and applicability of blockchain for businesses?
- RQ1.2: What assessment factors have been identified in the previous literature?

To answer each of these questions, this paper surveys the extant literature that has dealt with evaluation frameworks or decision models that assist decision-makers when adopting blockchain solutions. A scoping review was chosen because it is a useful framework for synthesizing literature in disciplines where evidence is continually emerging [14]. Furthermore, the existing body of literature that discusses blockchain suitability evaluations for business has not yet been comprehensively reviewed, and it still exhibits a large, complex, and heterogeneous nature, thereby making a more precise systematic review challenging and impractical to undertake [15].

The scoping review presented in this paper resulted in the identification of more than 50 research articles that have addressed aspects of blockchain evaluation. We categorized the results under five main evaluation approaches that address different evaluation aspects. To the best of our knowledge, no prior study has addressed the blockchain evaluation problem comprehensively or differentiated between business and technical evaluations. Therefore, the results presented here are expected to offer academic researchers clear insights into the current methodologies and factors that have been used to evaluate blockchain suitability for different purposes; in addition, the results will assist practitioners across diverse business sectors by outlining the decision-making paths that should be considered, as well as indicating how to assess the feasibility of a potential blockchain solution. More broadly, the results of this scoping review will benefit organizational decision-makers in terms of understanding the business implications of blockchain adoption.

The first part of this paper presents a brief background relating to blockchain technology and notable business cases. In turn, a review of studies that have addressed evaluation issues for blockchains in business is presented. Following this, a description is given of the utilized scoping review methodology, and notable findings are highlighted. In the rest of the paper, an analysis is offered of the scoping review results under five main categories of evaluation types, and under each one, a summary is provided of studies that have tackled specific blockchain evaluation issues. We focus on grouping comparable research articles in terms of the evaluation methodology adopted and the industry in which blockchain was applied. Additionally, a comprehensive comparison of the identified factors used for evaluating each category is given.

II. BACKGROUND

The concept of blockchain first appeared in 2008, as proposed by an unknown person (or group) using the pseudonym "Satoshi Nakamoto." Nakamoto's research proposed a methodology for a new digital currency application that combined cryptology in an open distributed ledger [1]. Thus, blockchain technology was built based on distributed ledger technology (DLT), which securely records information across a peer-to-peer (P2P) network [16]. To offer a technical definition of a blockchain, as found in [17], it is "a distributed database, decentrally stored across a peer-to-peer network, that maintains a continuously-growing list of data records (transactions) secured from tampering and revision. It consists of blocks, holding batches of individual transactions. Each block contains a timestamp and a link to a previous block."

When a transaction is created by a network participant (i.e., a node), a new block with new transactions must attain consensus, after which it receives permission to link together with the existing chain. The cornerstone of blockchain is the consensus mechanism [18], which operates as a validity agent to ensure that the information entered in the blocks is correct and consistent with network rules. There are many ways to reach consensus, but the most widely-used approaches are proof of work (PoW) and proof of stake (PoS) [19].

For further information on consensus protocols, the authors in [20] provided a taxonomy and comparison of the different consensus protocols used in blockchain.

According to the consensus mechanism, blockchain governance can be classified based on the following dimensions: public/private and permissioned/permission-less [21]. An overview of these forms of governance is given as follows:

- *Public/permission-less blockchain:* In this form of blockchain governance, the network is fully decentralized, meaning that everyone can read, write, and validate information. It requires the PoW or PoS consensus mechanisms to achieve agreement on system updates. For example, in cryptocurrencies such as Bitcoin and Ethereum, it is not necessary for participants to trust each other; instead, trust only needs to be placed in the logic of gaining money on the platform.
- *Public permissioned blockchain* (i.e., hybrid): This is a centralized blockchain where only authorized and predefined participants can read and write transactions. Under this form of blockchain governance, participants determine the consensus mechanisms. An example is enterprises consortia (e.g., Ripple), where predefined nodes in the network are trustful nodes, and deal directly with each other to support a P2P transaction exchange.
- *Private permissioned blockchain:* This is a fully centralized blockchain where access authorization is usually given only to a small number of nodes. The nodes that have been authorized to read data also need to be authorized to broadcast transactions. Typically, business organizations use private permissioned blockchains for their implementations (e.g., Hyperledger).

The public image of blockchain has slowly disassociated away from cryptocurrencies, especially given the once-dominant association between blockchain and Bitcoin. This has partly been driven by the strong desire to discover new application areas and use cases for blockchain technology, especially those that might be as disruptive to another industry as cryptocurrency was for the financial sector. In recent years, blockchain evolution has moved from digital currencies to financial applications and, in turn, to many service applications. Based on blockchain applications, blockchain is often classified as having four generations, as discussed below [2], [13], [22].

- *Blockchain 1.0:* This generation is concerned with the use of digital currency in the form of cryptocurrency. The most popular Blockchain 1.0 application is Bitcoin.
- *Blockchain 2.0:* This new wave of blockchain was incorporated with the use of smart contracts and a set of applications that extended beyond cryptocurrency transactions to the decentralized market, including decentralized applications (Dapps) and decentralized autonomous organizations (DAOs). Blockchain 2.0 enabled a wide range of applications such as smart property, securities trading, supply chain finance, anti-fraud systems, banking instruments, establishing credit systems, and mutual insurance.
- *Blockchain 3.0:* This generation extended blockchain technology into more aspects of social life [13], including government, health, science, the Internet of things (IoT), and the arts. Blockchain 3.0 was characterized by its attempt to resolve issues relevant to industrial applications, including scalability, integrity, and sustainability.
- *Blockchain 4.0:* This ongoing generation of blockchain technology is marked by its attempt to uncover the potential of artificial intelligence (AI) 23], as well as the introduction of the concepts of blockchain-as-a-service (BaaS) by the market leaders for business blockchain solutions [24]. Examples include IBM (on Hyperledger) and Microsoft (on Ethereum).

III. RELATED WORK

There is limited research dedicated to conducting critical literature reviews of blockchain evaluation methodologies. However, a comparative analysis of 30 existing blockchain decision schemes was undertaken in [25]. The focus of the comparison was to describe whether the decisions were reached by answering questions or following a decision tree, and to categorize each scheme based on types and number of solutions that can be recommended. In addition, the authors classified the questions involved in the reported decision schemes into a number of classes. Methodological limitations were apparent in the research, where most of the sources included in the review were online articles published in magazines or technical blogs; as such, the proposed evaluation schemes were not scientifically validated or approved. However, the authors in [26] critically analyzed 14 blockchain applicability evaluation models, where the focus was to compare each model across attributes, domains, and the sources of model inputs.

A systematic literature review of blockchain evaluation initiatives was conducted by Smetanin *et al.* [10] to investigate the state of the art of blockchain evaluation approaches, emphasizing the measurement of performance and the identification of corresponding metrics. The authors used their results to assess publicly accessible blockchain tools to report on their performance and recommend improvements. Another work that is related to the present paper's scoping review is Colomo-Palacios *et al.*'s [13] critical review of blockchain assessment initiatives, which focused on the technology evolution perspective. These authors analyzed 9 evaluation frameworks in terms of research approach, assessment processes, factors, and the blockchain generations that the proposed initiatives belonged to (e.g., Blockchain 1.0, 2.0, and so on). Lastly, blockchain and technology adoption theories were the main focus of the systematic literature review presented in [27]. In particular, the authors reviewed articles that utilized technology usability and adoption to examine the implications and challenges of blockchain.

Significantly, the scoping review presented in this paper – to the best of our knowledge – is the first to offer a comprehensive treatment of the topic of blockchain evaluations. It covers a wide range of aspects associated with evaluation and assessment to enrich the literature with a credible source regarding the existing models and frameworks that have been proposed to evaluate key dimensions of this innovative and emerging technology.

IV. METHODOLOGY

To identify the key publications addressing the suitability evaluation approaches for business blockchains, a literature search was undertaken using scientific databases following the Preferred Reporting Items for Systematic Reviews and Meta Analyses Extension for Scoping Reviews (PRISMA-ScR) [14]. A scoping review was chosen due to the novelty of blockchain technology and the multidisciplinary nature of the research problem. Scoping reviews are particularly useful for synthesizing literature in disciplines with emerging evidence [14]. Moreover, a body of literature addressing blockchain suitability for business has not yet been comprehensively reviewed, and it still exhibits a large, complex, and heterogeneous nature, thereby making it challenging and impractical to conduct a systematic review [15].

To identify relevant research articles, we searched six bibliographic databases. This ensured that the differing perspectives that the topic has been raised in were considered. For example, we included Science Direct, Web of Science, and Springer Link for the general science and economics perspectives, while IEEE Xplore and ACM Digital Library were included to ensure coverage of publications related to computer science. Additionally, we included the AIS Electronic Library (AISeL) from an information systems perspective. To retrieve relevant articles and papers, we applied the following search string: (Blockchain OR "Distributed Ledger") AND (Evaluation OR Decisions OR Suitability OR Applicability). Also, given that this research focused on blockchain applications for business beyond cryptocurrencies, the search was restricted to papers published between January 2016 to May 2021. The rationale for this decision was because blockchain was disseminated between business consortiums between 2016 and 2017 [1]. We considered limiting the results to journal articles, but given the novelty of the technology and the topic, we disregarded this condition and included both conference and journals publications. Both grey literature and pre-print publications were excluded.

In total, we retrieved 1,464 relevant publications, and after removing duplicates, there were 871 unique resources. In turn, screening was applied for the titles, keywords, and abstracts of the retrieved publications, thereby identifying papers and articles that satisfied the inclusion criteria. Regarding the inclusion criteria, the papers included in this review were required to meet the following: first, a focus on the business applications of blockchain; second, a description or development of at least one evaluation method to assess the suitability or applicability of blockchain to a business application beyond cryptocurrencies; and third, the existence of any means for validation or verification of validity.

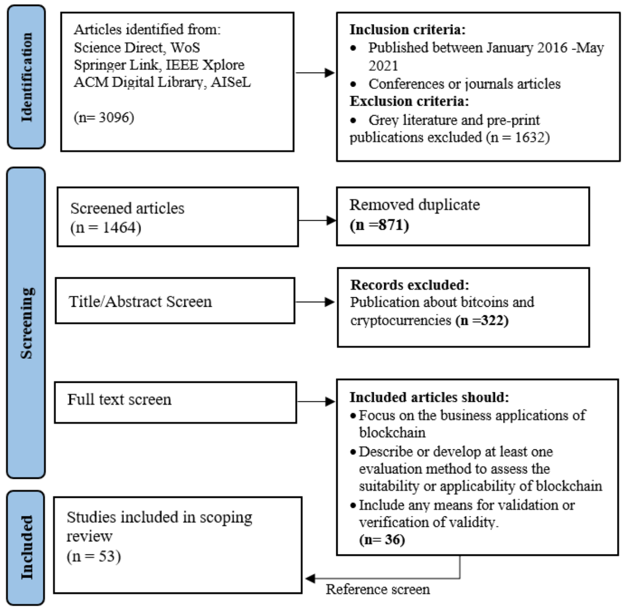

FIGURE 1. Search strategy flow diagram.

After screening the 871 research articles, a total of 36 publications were identified that were are eligible for inclusion. To further extend our literature sample, we conducted backward and forward reference list checking (snowball effect) on the included studies, thereby leading to the identification of additional articles relevant to the research. This process resulted in a total of 53 publications. Figure 1 provides an overview of the search strategy applied in this scoping review. Once the literature selection process was completed, the selected articles were read to identify the suitability evaluation method in terms of the aim of the study, the context, the modeling approach, factors, and criteria identified as decision constructs. We also checked the existence of any means of validation methods. In turn, we classified the extracted literature into five main categories, a description of which is presented in the next section.

V. FINDINGS AND DISCUSSION

In this section, general remarks about the scoping review findings are highlighted in a descriptive manner, after which our classification of important themes in the included studies is presented. Under each theme, we performed a critical analysis of the research to identify significant studies and important factors. Therefore, we drew attention to the research gaps that still require scholarly contributions.

Given the multidisciplinary of the topic, the included studies used diverse terms to describe their intended objective of developing evaluation methods, which affected the initial search. For example, studies in this scoping review contained a set of different expressions, including "Decision Models," "Evaluation Frameworks," "Implementation Decisions," or

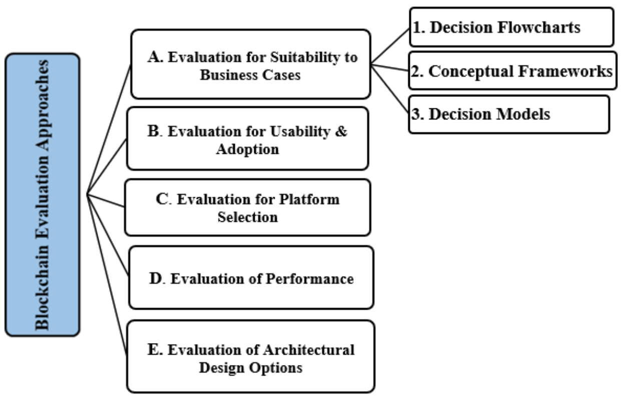

FIGURE 2. The classification of blockchain evaluation approaches.

"Adoption," which were primarily used to assess "Suitability," "Applicability," or "Feasibility." Diversity in language could affect the purpose of the research and, as a consequence, the approach used to address the problem. Among this variety of interest in business blockchain evaluations, our work focused on reporting the applied methodologies, identified factors, and criteria to facilitate the assessment process and the existing validation processes, as well as how they validated the proposed methodologies. In addition, from a scientometric perspective, we noticed an increase in the number of publications covering suitability evaluation methods in the 2018-2019 period compared to 2016-2017. Furthermore, while we observed a kind of generalization in the earlier blockchain suitability evaluation initiatives, such initiatives were more specialized to the business context in later research conducted in the 2020-2021 period. Moreover, earlier approaches tended to focus on proposing evaluation factors and modeling them as decision trees or flowcharts, whereas the most recent approaches were more sophisticated and, as such, typically deployed decision models that were built based on justified decision matrices. However, research works collected for the purpose of this scoping review were classified under five general evaluation approaches as demonstrated in Figure 2. The classification was based on the primary objectives of the paper and the aim of the developed solution.

The main approaches for blockchain evaluation initiatives were the following:

1. Evaluation of blockchain technology and its suitability to business cases, where scholars examined blockchain capabilities and features and mapped these to business needs.
2. Evaluation and decisions for blockchain adoption or readiness in specific contexts, in which scholars applied existing theories of technology adoption and acceptance. These consequently touched on organizational, economic, and other ecosystem-related factors.
3. Evaluation for platform selection, where this approach considered the technical details of each blockchain option under study and matched these to the functional and non-functional requirements of the assessed system.
4. Evaluation of performance, which focused on performance evaluation parameters and metrics for different blockchain frameworks.
5. Evaluation of architectural design options, where this approach addressed evaluating design options that are suitable for a given business use case, including governance models (consensus protocol), authority management (access controls), data storage and distribution (blocks and node production), and cross-industry interoperability (transaction processing).

The following section provides details about each approach, followed by a comparison and specification of each type of blockchain evaluation methodology.

VI. BLOCKCHAIN EVALUATION APPROACHES

A. EVALUATION OF BLOCKCHAIN SUITABILITY TO BUSINESS CASE

This approach was usually combined with in-depth analysis that captures a holistic view of the business case, which influences the whole ecosystem. In this evaluation approach, researchers aimed to provide practitioners with methods or tools to help assess the appropriateness of a blockchain to their business cases. In total, the proposed evaluation initiatives under this category were 33 studies, accounting for 62% of the studies included in the scoping review. The evaluation process was addressed using different methodologies and solution approaches. A considerable number of publications presented an analytical discussion that was based on the authors' knowledge and experience [1], [28]–[30], whereas some studies took this a step further and offered structured conceptual frameworks. In addition, most of the studies were devoted to proposing evaluation factors and modeling these in the form of decision trees or flowcharts, whereas other studies deployed decision models that were established based on justified decision matrices. In the following subsections, a summary is given of the important findings of these evaluation initiatives under three areas: decision flowcharts, conceptual frameworks, and decision models.

1) DECISION FLOWCHARTS

Decision flowcharts (or decision trees) were identified as the basic methodology that most of the included studies used to assist decision-makers in their attempts to adopt blockchains in a business context. In this category, users can arrive at a recommended decision by answering several questions or creating a flow series of nodes in a decision tree or flowchart. Based on the scoping review results, this methodology came to represent the fundamentals of blockchain technology in the form of questions such as the existence of multiple users who lack a means of trusting each other or checking if it is necessary to involve trusted third parties (TTPs). In addition, there are considerations relating to issues such as data and access control mechanisms. We briefly provide an overview of the twelve flowcharts identified in our scoping review, after which the identified decision constructs are mapped to each flowchart.

One of the earliest articles included in this scoping review that proposed a decision flowchart was undertaken by peck [31] and published in IEEE Spectrum in October 2017. The decision flowchart was intended to be used as a tool to guide business decision-makers. Although the flowchart was not established based on scientific research, it is considered an important reference for researchers because it represents the industry experience of an innovative technology. The flowchart contained seven questions to help decision-makers arrive at one of three possibilities: first, not use blockchain; second, to use a permissioned blockchain; or third, to use a public blockchain. The questions were the following: (1) Do traditional databases meet the needs of the business? (2) Does more than one participant need to update the data? (3) Do the participants need to trust each other? (4) Are redundant copies in distributed computers required? (5) Is data privacy required? (6) Is update control required? (7) Is there a need for a TTP?

Wust and Gervais [32] critically analyzed the question of whether blockchain is the most suitable technical solution for different application scenarios. They developed a decision tree that helped to differentiate between three decision options: permission-less blockchains, permissioned blockchains, and a centrally managed database. According to the researchers, using a blockchain is only a viable option when there is a requirement to store transactions between multiple entities who mutually collaborate in the system, and who are not willing to agree on an online TTP. Those factors were viewed as fundamental in determining whether to use blockchain or not.

However, other studies, including [33], argued that there is no existence of an always-online TTP in the real world. These researchers also undertook an important modification to handle the risk that can occur when a single writer tampers with critical data. In contrast, the research undertaken by [34] extended the decision framework of Wust and Gervais [32] by including a question relating to the possibility of decentralizing the TTP, providing a private permissionless decision option, and adding an additional stage to assess several of the constraints proposed by the authors. Similarly, the blockchain suitability evaluation framework proposed in [35] differentiated between private, public, and consortium blockchains by including different decision paths based on access authority and data security.

In addition, the investigation of non-functional requirements was the driver behind the decision flowcharts proposed in the studies undertaken by [36] and [37]. The authors sought to investigate the design requirements of potential use cases in order to translate these into decision determinants of the proposed flowcharts. Issues such as transparency, immutability, and scalability were used to reach a recommended decision regarding blockchain suitability. Moreover, the authors in [38] and [39] established their proposed decision flowcharts based on a comparative analysis of blockchain and classical database technologies, the aim being to highlight the intrinsic properties of blockchains that make them a more suitable option for certain business cases compared to traditional solutions.

Koens and Poll [25] conducted a comprehensive analysis of 30 existing decision schemes developed to determine when a blockchain is needed. They argued that previous decision-aid diagrams were incomplete for two major reasons: first, they neglect to consider blockchain's limitations; and secondly, they typically ignore other suitable alternatives. However, the authors synthesized the principal questions used to guide decisions in previous decision-aid diagrams, subsequently classifying them into four classes: database questions, system design questions, process questions, and questions concerning the limitations of blockchains. In turn, they proposed their own decision flowchart in which they attempted to account for the shortcomings of the reviewed decision schemes. It is worth mentioning that most of the references used in the review were online articles published in technical blogs, magazines, or the social media accounts of expert practitioners. Therefore, Koens and Poll's [25] references were excluded from our scoping review because they failed to meet the predetermined inclusion criteria.

The work undertaken by Betzwieser *et al.* [40], entitled "A Decision Model for the Implementation of Blockchain Solutions," proposed yet another decision model for blockchain implementation. The authors used a literature review with qualitative research methods (specifically, interviews) to conceptualize the model. Their sequential decision model included three steps: preconditions, business and technical considerations, and design decisions. The manner in which the researchers categorized the factors makes this particular article distinct compared to the others that used decision flow diagrams, especially given that business considerations and design options were rarely covered by other articles in the same publication period.

In the recent publication of [41], a decision flowchart was used to identify suitable business activities concerning blockchain implementation in an electricity company. The authors suggested first identifying the business area to focus on, then specifying the business process, and then following the sequence of the flowchart, which assessed the business process from two perspectives: first, the transactions or data transferred; and second, the actors involved. However, the study indicates how blockchain suitability evaluation can become remarkably narrow in terms of examining a specific business process within a specific business area within a specific context. Nevertheless, the approach adopted in [41] appears to have significant practical value for practitioners because it critically analyzes the applicability of blockchains in a well-defined business domain, helping to facilitate decision-making by considering the flow of the business process in the whole system.

Lastly, Table 1 offers a summary of the important decision constructs that frequently appeared in the above-mentioned decision flowcharts.

TABLE 1. Appearance of frequent decision constructs in the reviewed flowcharts.

Decision Constructs	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]	[39]	[25]	[40]	[41]
Data Store		✓		✓		✓	✓			✓		
Multiple Participants	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Participant Trust	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
Data Privacy	✓		✓	✓	✓	✓			✓			
Trusted Third Parties	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓
Public Verifiability		✓		✓			✓	✓	✓			
Access Control	✓		✓	✓		✓	✓		✓	✓	✓	
Transaction History		✓	✓		✓		✓			✓		✓
Immutability					✓	✓	✓	✓	✓		✓	✓
High Performance				✓	✓				✓	✓		
Scalability			✓	✓				✓	✓	✓	✓	
Data Durability	✓				✓		✓	✓				✓
Data Replication		✓							✓		✓	

2) CONCEPTUAL FRAMEWORKS

In this category, we grouped the research articles that sought to address blockchain suitability evaluations comprehensively, specifically by proposing frameworks reflecting the researchers' reasoning concerning the factors influencing the successful adoption of blockchain technology (whether with regard to or regardless of the context). The frameworks under this category were developed based on the capabilities and features of blockchain technology rather than being derived from the existing theories and conceptual frameworks that are usually used to evaluate innovative technology adoption, readiness, or maturity. We identified six conceptual frameworks in this category based on the scoping review results. Our review emphasizes how the scholars developed their frameworks, what concepts were identified, and how the validation was performed to verify the effectiveness and applicability of the frameworks.

Scriber [42], based on the author's experience in the practical implementation of blockchain projects, proposed a conceptual framework to assess blockchain suitability for a given use case. The author drew attention to 10 blockchain characteristics or architectural features, after which an arrangement of these factors was proposed, which was weighted through an evaluation matrix to determine blockchain's level of fit. The factors include immutability, transparency, trust, identity, distribution, workflow, transactions, historical record, ecosystem, and inefficiency. For validation purposes, the author used the proposed framework to evaluate 23 projects in the proof of concept stage. The assessment resulted in the discovery of problems and use cases that were ill-suited for blockchains, where only four projects reached the testing stage. This is an important indication that in order to avoid expensive failures, suitability assessment is a crucial step for any blockchain project.

Moving to a more structured framework, the study of [43] first performed a use case identification step, the purpose being to assist practitioners in analyzing the use case from three important perspectives: intermediary, data, and process. The second stage in this conceptual framework was to complete the "use case canvas," which helps to understand exactly how the blockchain would impact the use case. The "canvas" includes five elements that need to be specified: added value, data and process integrity, decentralized network, values and rights, and automation. The user lists the relevant aspects of the concern under each element, and after that, each aspect is rated in the rating column as high, medium, or low (depending on its business importance). This approach offers the user a space in which to think critically about the use case and to rate its value to the business. This framework was validated by testing it on four different applications, where the outcome was the successful recommendation of three of them as suitable cases for blockchain adoption. For effective use of this framework, the evaluator suggested having prior knowledge of blockchain technology.

Another important finding from the scoping review was that multi-layered frameworks have been proposed in the literature, specifically in [16] and [44], to address technical and managerial issues. The framework proposed in [16] highlighted several factors that are essential to have in place before the commencement of blockchain projects. These factors were classified into four categories: first, blockchain innovation, where non-functional requirements are identified; followed by blockchain platform design, inter-organizational integration, and implementation ecosystem. In addition, the

TABLE 2. Components of conceptual frameworks.

Concepts of Frameworks	[42]	[43]	[16]	[44]	[45]	[46]
Data and Storage	-Immutability -Historical records	- Integrity	- Integrity - Availability -Confidentiality -Interoperability	- Integrity - Data retention -Interoperability - Accessibility	- Immutability - Auditability -Interoperability	- DB suffices - Historical assets -Redundant dataset
Process and Transactions	-Workflow - Transactions	-Automation		-Functional operation	- Identity verification and authentication	
Participants and Stakeholders	-Distribution - Trust - Identity	-Decentralized network -Intermediary check	- Trust - Permissions - Modularity	-Participant control - Identity	-Multiple writers - Participant & intermediary trust - Ownership of data	-Multi-stakeholders -Access authority
Design Issues	-Inefficiency -Transparency	-Automation	- Scalability -Consensus mechanism - Anonymity -Transparency - Governance	-Transparency - Scalability - Flexibility - Efficiency	-Transparency - Security	- Data protection requirements
Regulation Issues		-Values and rights	-Ecosystem requirements - Regulations	-Legal foundation - Data privacy	-Governance rules	-Regulation readiness
Business Issues		- Added value	- Cost - User adoption	- Maintenance & operational costs	-Financial considerations	-Risk identification -Business process identification -Resource planning
Validation	Applied to test 23 projects in proof-of-concept stage	Applied to four applications	Expert interviews	Semi-structured interviews	Interviews	Applied to assess suitability of a power utility network project

framework proposed in [44] suggested a suitability evaluation framework for public sector organizations. The researchers proposed a set of criteria to assess the advantages of different blockchain solutions for the asylum process. These criteria need to reflect technical aspects and functional requirements, and they must consider legal boundaries and statutes. Both frameworks were validated based on expert opinions obtained through questionnaires or interviews.

It is notable that the identification of the impact of blockchain on an ecosystem points the way toward a new direction in terms of blockchain suitability evaluation. For example, the ethical design framework proposed in [45] incorporated a decision point to determine blockchain suitability by answering 10 multiple choice questions categorized under the topics of participants, rules, and data. In turn, the framework iteratively moves through a detailed analysis of six root issues for ethical consideration: governance, identity, verification and authentication, access, data ownership, and security. The framework was validated through a series of interviews.

Additionally, the Blockchain Implementation Assessment Framework (BIAF) developed by [46] serves as a tool for considering the ecosystem when evaluating blockchain as a solution. The BIAF consists of two levels of assessment: first, checkpoint questions, which ensure that the case is a suitable one for blockchain adoption; and second, a triangle assessment of Process-People-Technology, where each side of the triangle is associated with a number of considerations to guarantee that the readiness of the ecosystem prior to blockchain implementation. This framework was validated by adopting it for a power utility network project, which indicated to the project stakeholders that blockchain was a suitable solution based on the given situation. Noteworthily, the framework developed in [41] used the BIAF to identify suitable business activities for blockchain implementation in an electric utility company. In particular, the BIAF was used to identify the business areas that blockchain technology can be used to enhance. In Table 2, a comprehensive summary of the six conceptual frameworks discussed above is presented, alongside an attempt to aggregate the dimensions of the different frameworks into more generalized concepts.

3) DECISION MODELS

Since suitability evaluation is a complex and multi-dimensional problem, which includes both qualitative and quantitative factors, several researchers have treated the decision about whether to adopt blockchain technology as a multi-dimensional problem. As such, they have proposed decision models that combine multiple factors and analyze their interrelationships. This scoping review resulted in the identification of 11 decision model proposals, seven of which aimed to evaluate the suitability of blockchains for supply chain applications, with the others proposing general evaluation models for the evaluation of blockchains for different application areas. These attempts included the adoption of mathematical models such as multiple criteria decision-making (MCDM) or rank-weight methods. In this section, a summary is given of the included studies that proposed such decision models within the blockchain domain. A description is also given of the decision process and assessment method for each defined model, and important suitability evaluation factors are highlighted.

One example of this approach is the Blockchain Applicability Framework (BAF) [26]. This framework is built on the relative-weight approach, where the state of the selected factor is associated with relative weight values. The framework seeks to determine three factors: first, blockchain's suitability for an application; second, the need for a public or private blockchain; and third, the most suitable consensus mechanism for the application. The indicators in the BAF are divided into the following domains: data and participation, technical attributes, security, trust parameters, and performance and efficiency. In turn, these domains are divided into 18 subdomains, and the creators of the BAF constructed 100 questions as assessment controls for the subdomains. The study identified a wide range of factors that should be incorporated into any future research concerning blockchain applicability evaluation. Subsequently, the BAF was used in [47] to assess the level of blockchain applicability for the integrity of data shared in smart buildings, and it was also used in [48] to evaluate the feasibility of building a blockchain solution for medication anti-counterfeiting and traceability.

This scoping review revealed that MCDM techniques have been extensively adopted by researchers for blockchain suitability evaluation. For example, in [49], multiple measurements were identified as determinants of successful blockchain adoption by organizations and modeled as decision problems using the analytical hierarchy process (AHP). The study identified several factors and classified them as either motivating or impeding factors, after which the AHP was used to prioritize them, thereby identifying the most influential factors. In addition, AHP, fuzzy AHP (FAHP), and the fuzzy technique for order preference by similarity to ideal solution (FTOPSIS) were used in the literature to propose a decision model for the best fitting blockchain platform for a knowledge-based conversation system (KBCS) [50]. Although it appears to be a platform selection problem, the researchers undertook requirements analysis for the given case study (i.e., the KBCS) and, based on this, identified four groups of important decision determinants, including items related to decentralized architecture, storage and sharing, computing performance, and scalability. These were selected to match the design requirements. In turn, for each group of decision items, corresponding blockchain configurations were chosen as evaluation criteria to select the most suitable blockchain platform.

In more recent studies, blockchain suitability evaluations have adopted a deeper approach in terms of becoming more sector-oriented. Hence, researchers have attempted to investigate the specific requirements of different sectors and, in turn, to align these with the capabilities of blockchains that may enhance or improve the current situation. For example, a comprehensive list of feasibility indicators was identified in [51] to assess quantitively the feasibility of blockchain for various industries (e.g., logistics, supply chains, healthcare, finance, energy, pharmaceuticals, and agriculture). Following this, FAHP and FTOPSIS were used to assess the feasibility in a comparative way by using data gathered from a group of experts. Feasibility indicators were identified to assess the potential of blockchain to enhance business activities, financial performance, and other technical issues. It is noteworthy blockchain suitability evaluations for supply chain and logistics operations have received the most attention from scholars. In the rest of this section, we briefly summarize the included studies that adopted MCDM techniques as a decision aid for evaluating the applicability of blockchain technology for the logistics industry.

First, a decision framework was proposed in [52] to investigate the feasibility of blockchain application in the logistics industry by using MCDM, which incorporated ahp into VIKOR (i.e., a serbian term for ''multi-criteria optimization and compromise solution'') [53]. This integration offers different solutions and rankings based on different decision-making strategies, and it also captures uncertainty in the evaluation process. The authors used FAHP to calculate the importance weights of their proposed decision criteria, which were indicated as scalability, privacy, interoperability, audit, latency, visibility, trust, and security. By contrast, fuzzy VIKOR was used to rank the appropriateness of blockchains for specific logistics operations (e.g., materials handling, order processing, warehousing, packaging, and vehicle routing). The proposed decision framework was applied in a large-scale logistics company located in Turkey. The results demonstrated that the most important criteria were security, visibility, and audit, whereas the most feasible logistics operations for implementation with blockchain technology were transportation, materials handling, warehousing, order processing, and fleet management. Noteworthily, this study incorporated AHP into VIKOR, which represents an original contribution in the blockchain context.

Second, the fuzzy decision-making trial and evaluation laboratory (DEMATEL) was used in [54] to assess critical factors for successful blockchain technology implementation in logistics companies. The authors initially inspected the characteristics of blockchains in detail, after which they identified the situations in which blockchain offers an advantage over traditional databases. In turn, experts were asked to report on the key factors and benefits that drive any business case toward blockchain adoption. Finally, fuzzy DEMATEL was used to clarify the complexity in the relationships of factors, where they prioritized the factors and classified them into cause and effect factors. It is worth mentioning that the same author, in [55], contributed to the process of blockchain suitability evaluation for a logistics company by applying the fuzzy analytical network process (ANP). This was used to determine and evaluate the interrelationships between the suitability attributes identified

TABLE 3. Decision models for blockchain suitability evaluation.

Reference	Context	Decision Model	Decision Model Specifications
[26] [47]	General	Relative-weight approach	BAF has 100 controls under 5 main domains and 18 subdomains: **Data and participation:** attributes, authority, reader, and writer **Technical attributes:** codebase and network, smart contracts, transaction constraints, process, miner, and consensus **Security:** governance, security attributes, and access control **Trust parameters:** visibility, integrity, and validation **Performance and efficiency:** system performance, expandability, and market design
[49]	General	AHP	**Motivating factors:** reliability, automation of transactions, decentralization, transparency, and immutability **Impeding factors:** scalability, interoperability, cost, technical maturity, and knowledge
[50]	Knowledge-based conversation system (KBCS)	AHP, FAHP, FTOPSIS	Proposing a decision model for the best fitting blockchain platform for KBCS: **Decentralized architecture, storage and sharing, computing performance, and scalability**, along with network performance, attack resistance, fault tolerance, deployment cost, reliability, availability of service, flexibility and opening, processing speed, concurrent capacity, and space recovery
[51]	General	AHP, TOPSIS	Assessing the feasibility of blockchain technology in different industries and identifying 15 factors: 1- Existence of regulations 2- Level of technology maturity 3- Proportion of digitized assets 4- Richness of ecosystem 5- Potential to increase revenue 6- Potential to reduce cost 7- Enhanced security and data integrity 8- Building trust 9- Potential to increase transaction speed 10- The need for improved visibility 11- Enhanced audibility 12- Potential to improve efficiency 13- Potential to yield high return on investment 14- The need for reduced fraud 15- The need for improved traceability
[52]	Logistics	AHP, VIKOR	Evaluating the feasibility of blockchain technology in logistics operations by identifying: **Criteria**: scalability (C1), privacy (C2), interoperability (C3), audit (C4), latency (C5), visibility (C6), trust (C7), and security (C8) **Alternatives:** identifies 9 distinct operations, including materials handling, warehousing, order processing, transportation, packaging, fleet management, labeling, vehicle routing, and product returns management
[54]	Supply chains	Fuzzy DEMATEL	Evaluating the factors affecting decisions to adopt blockchain technology in a logistics company: **Cause:** peer-to-peer networks, instant money transfer, distributed ledger, smart contracts, immutability, authentication, and security **Effects:** cryptocurrency creation, transparency, privacy, traceability, real-time processing, and reduced transaction delays.
[55]	Logistics	Fuzzy ANP	Suitability evaluation of blockchain-based systems using fuzzy ANP using the case study of a logistics company **Trust:** lack of trusted third parties, accountability, immutability, multiple non-trusting writers, and peer-to-peer transactions **Context:** traceability of transactions, verifiability of transactions, data transaction notarization, data transparency, security, and privacy **Performance:** latency and transaction speed, maintenance costs, redundancy, and scalability **Consensus:** rules of engagement, need for verifiers, and autonomous/dynamic transactions between transactions of different writers
[56]	Shipping companies	BOCR, Fuzzy FAHP	Analysis of key factors influencing integration of blockchain into shipping companies in Taiwan by identifying: **Benefits:** reducing intermediary costs, reducing information delays, reducing bribery and fraud, and reducing transaction costs **Opportunities:** maintaining transaction security, Reducing trust risks, increasing network effects, and improving transaction efficiency **Costs:** platform construction costs, system management costs, manpower training costs, and system conversion costs **Risks:** information research and development speed, data security and privacy, incomplete regulatory systems, and incomplete response mechanisms
[57]	Supply chains	MCDM, GRA	Adoption of blockchain in supply chains based on an analysis of the following influencing factors: **Organizational factors:** inter-organizational trust and relational governance **Technological factors:** data transparency and data immutability **Social:** social influence and behavioral intention **Operational:** interoperability and product type
[58]	Supply chain management	HF-AHP HF-FTOPSIS	A multi-criteria evaluation model based on hesitant fuzzy sets for blockchain technology in supply chain management classifying factors under 5 main criteria and 17 sub-criteria, as follows: **Customer:** satisfaction, traceability, reliability, and transparency **Product:** quality, safety, value, sustainability, and flexibility **Implementation**: suitability, market needs, and technology **Logistics:** speed and inventory management **Cost:** implementation, maintenance, and consumption **Five different sectors** (i.e., food, medicine, energy, jewelry, and textiles) were determined using the Delphi approach and comprehensive literature analysis

by [1]. In turn, the ANP was applied to prioritize blockchain attributes and, therefore, to decide on the most suitable alternative.

In addition, the study of [56] explored shipping companies in taiwan and sought to identify the main influencing factors affecting the application of blockchain. The authors first reviewed the relevant literature and, in turn, divided the factors according to the BOCR (Benefits, Opportunities, Costs, and Risks) framework. Following this, they adopted the FAHP to rank the importance of key factors influencing shipping companies considering blockchain implementations. Similarly, [57] identified and prioritized the influencing factors affecting blockchain's adoptability in a supply chain context. After identifying the factors, they were classified under four main categories: organizational, technological, social, and operational challenges. They adopted an MCDM approach, specifically the grey relational analysis (GRA) methodology, with the results ranking factors such as inter-organizational trust, interoperability, and relational governance as the top three influencing factors potentially affecting blockchain adoption within the worldwide shipping industry.

In the research of [58], different domains within the supply chain management (SCM) industry were investigated regarding blockchain suitability. The authors applied hybrid MCDM methodologies consisting of multiple phases. The first phase was to determine important criteria for suitability decisions by means of the delphi method and comprehensive literature analysis. This resulted in the identification of 17 suitability criteria under the following domains: product, customer, implementation, logistics, and cost. In addition, other sectors with the potential to benefit from blockchain were identified in this phase, including food, medicine, energy, jewelry, and textiles. In the second phase, the weights of the main criteria and sub-criteria were obtained and assessed using hesitant FAHP (H-FAHP). According to the results, medicine SCM was nominated as the most suitable alternative sector for blockchain implementation, whereas the jewelry sector was ranked as the least suitable candidate for the implementation of blockchain solutions. Table 3 provides a holistic summary of the defined decision models.

It is important to recognize that the given decision models identified under this evaluation approach tended to assess blockchain suitability by considering its feasibility with respect to business functions and priorities. Therefore, the specifications and specialties of each domain were analyzed and subsequently critiqued regarding blockchain's capabilities. Practically speaking, it is clear that this evaluation approach must be conducted with the support of domain experts and blockchain technology consultants, who play an essential role in identifying areas for improvement and recognizing feasible solutions that blockchain can confer to the business. On the other hand, the MCDM technique was adopted as the main tool to translate the identified factors of blockchain suitability into measurable components for easier decision-making.

B. EVALUATION OF BLOCKCHAIN ADOPTION, MATURITY, AND READINESS

The second theme observed in this scoping review's analysis of blockchain evaluation initiatives identified those evaluation approaches that facilitated the evaluation by drawing on existing theories and frameworks concerning technology adoption, maturity, or readiness within an organizational context. Although evaluation constructs of this kind were initially proposed in a theoretical setting, scholars have adapted these concepts to blockchain technology and investigated the critical factors affecting organizations when blockchain decisions must be made. Therefore, articles under this theme focus on the use of individual adoption, acceptance models, and articles that consider social-technical factors when proposing blockchain evaluation frameworks. The scoping review results demonstrate that in recent years, there has been a significant increase in blockchain adoption research, which reflects blockchain's extensive diffusion in society and the growing attention dedicated to blockchain and its applications by industry practitioners. This section summarizes the included studies that considered blockchain evaluations for the above-mentioned objectives and highlights the grounded theories or frameworks.

A review of blockchain adoption was undertaken in [27] with a focus on individual adoption theories, industry, country, and other important factors. The results showed that the field of supply chains received the most attention in the studies, whereas there are still limitations in adoption studies in other fields such as health and education. Among seven technological adoption models, the review paper demonstrated that the studies commonly relied on the technology acceptance model (TAM) model along with the unified theory of acceptance and use of technology (UTAUT). Significantly, perceived ease of use and perceived usefulness were considered the most important factors. These findings were consistent with [59], in which a combination of TAM and technology-organization-environment (TOE) framework was used to build a predictive decision support system to forecast the probability of blockchain adoption within an organization. The latter authors drew attention to the substantial influence of technical know-how and competitive pressures on blockchain adoption decisions.

In addition, the research of [60] investigated the energy sector regarding the factors influencing blockchain implementation. They utilized the diffusion of innovations (DI) theory, institutional economics, and the TOE framework to establish the evaluation factors. This work classified potential use cases in the energy sector and mapped them onto the critical factors that could influence blockchain decisions. Their approach is useful to mitigate the complexity of blockchain and the highly dynamic and regulated nature of the energy sector. Therefore, they considered competitive pressures (market power) and regulatory environment in the evaluation framework. Additionally, the study of [61] investigated the features of blockchain and their impact on supply chain management practices, as well as the operational performance of these practices. The study validated the proposed framework by applying it to a case study from the oil industry, which was chosen due to its special importance in the world economy, politics, and geopolitics.

On the other hand, managerial and organizational factors affecting blockchain adoption have also been addressed and evaluated in the literature [12], [62]–[64]. For example, in [12], which focused on inter-organizational relationships and information technology capabilities as drivers of competitive advantages, the authors examined how companies could secure competitive advantages from blockchain in an inter-organizational context. The study identified immutability and traceability as the most influential factors with respect to a company's competitive performance. Additionally, in the study of [62], institutional, market, and technical factors were combined in a conceptual framework, with the authors arguing that blockchain adoption is a strategic decision that must involve a holistic view of an organization. In [63], technical, social, and political implications of blockchain adoption were investigated, and several challenges and risks that should be accounted for when evaluating blockchain suitability were highlighted. Also, in the research of [64], economic, social, personal, and technical factors were aggregated to form an evaluation framework that was examined in two contexts: namely, the healthcare and financial sectors.

Blockchain adoption challenges and incentives were identified in [65], where acceptance of business partners and trust were identified as the critical challenges. In contrast, cost reduction and transparency were identified as the greatest incentives for blockchain adoption within supply chain firms. In conclusion, this evaluation approach is equally as important compared to the other suitability evaluation approaches described in previous sections. This is because an evaluation with regards to usability and adoption has considerable complexity. This type of adoption decision necessitates the transformation of different aspects of an organization, and changes must be handled from multiple dimensions, including individuals, transactions, business processes, and the overall ecosystem and organizational culture. Therefore, both technical and organizational factors are essential to consider when developing a blockchain evaluation framework or model that is effective in assessing the potential impacts of blockchain adoption on specific business cases.

C. EVALUATION FOR PLATFORM SELECTION

Moving to the third category of blockchain evaluation initiatives, where the functional suitability of blockchain is already checked, the decision now is principally informed by the question of selecting the best-suited blockchain platform from the available software products. In this scoping review, we identified a set of research articles that proposed evaluation methods by identifying sets of criteria and metrics to help in selecting a suitable blockchain platform. Research in this category engages deeply with the functional features of each platform, often proposing different methodologies based on the functional requirements of a specific system. This scoping review retrieved 8 relevant research articles following this approach, and in the remainder of this section, a description of these works and a brief overview of their methodologies are given.

A framework for evaluating blockchain platforms was proposed in [66], which involves extracting blockchain platform evaluation criteria with regard to architectural components and qualitative features. The identified criteria cover a wide range of important assessments such as security, privacy, data storage, system interactions, and support communities. These criteria were categorized into three main groups: governance type, architecture, and support facilities for specific platforms. The authors analyzed 10 blockchain platforms and ranked each of them based on their proposed set of criteria. In the context of supply chain networks, another evaluation framework proposed in [67] drew attention to 45 criteria under 10 dimensions as important requirements that should be considered when choosing a blockchain platform. Although their work was developed for a specific domain, the collected requirements presented by the authors offer useful guidance for the development of blockchain-based platforms within other organizational systems.

This scoping review revealed that decision models for the blockchain platform selection problem have also been proposed as an MCDM problem. For example, the decision model in [68] contained the following sources for a decision meta-model: first, decision criteria, including software quality attributes (e.g., interoperability, maturity, and performance of blockchain platforms) and blockchain domain features (e.g., smart-contracts and on-chain transactions); and second, platform alternatives matched with identified qualities and features. Furthermore, an automated decision-making framework was proposed in [69] to determine the most applicable alternative platforms based on the provided requirements and preferences. Those two examples match the needed requirements with quality features (i.e., ISO 25010), after which different platforms are benchmarked against selected features.

Moreover, a comprehensive framework of blockchain software selection was proposed in [70] by adopting FAHP to present a hierarchy of selected criteria and to specify related attributes. In turn, weighting criteria were used to provide detailed instructions concerning the evaluation of a potential blockchain platform. The main identified criteria were cost, speed, privacy, functionality, and developer availability. Likewise, the simple multi-attribute rating technique (SMART) was used in [71] to propose a selection methodology for a suitable blockchain platform for an enterprise system (ERP). The significant contribution of this work was the differentiation between technology-based selection methodologies and a domain-specific selection process. The authors argued that traditional software selection methodologies are not suited to blockchain platform selection given that the latter has a broader perspective. A decision methodology for suitable blockchain platforms for an enterprise system was also proposed by [53]. This study used the VIKOR method to select the most suitable business blockchain platform.

Lastly, blockchain solutions were critically examined in [72] to assess their capacity to address the needs of IoT applications. To achieve this, the paper focused on

TABLE 4. Blockchain platform selection criteria.

Reference		[66]	[67]	[68]	[69]	[70]	[71]	[53]	[72]
Context		General	Supply Chains	General	Supply Chains	Logistics	ERP	ERP	IoT
Categories of criteria	Usability		✓	✓	✓		✓	✓	
	Functionality	✓	✓	✓	✓	✓	✓	✓	✓
	Performance	✓	✓	✓	✓	✓	✓	✓	✓
	Platform Support	✓	✓	✓		✓	✓	✓	
	Security			✓	✓		✓		✓
	Privacy		✓			✓	✓		✓
	Network Topology	✓	✓	✓	✓		✓		
	Modularity	✓					✓	✓	
	Interoperability	✓	✓		✓	✓	✓	✓	✓
	Cost					✓	✓	✓	

the three important issues facing IoT project development: namely, security, privacy, and performance. The authors also emphasized the need to check the availability of some functional capabilities such as network setup, consensus protocols, and smart contracts.

Based on the above-mentioned scoping review results, Table 4 offers an overview of the main categories of the criteria that identified from prior studies concerning the selection of a suitable blockchain platform in a business context. According to the surveyed papers, we notice that the suggested methods of platform selection highly rely on the functional features and performance properties of the platform. On the other hand, the criteria about platform modularity and cost were not underlined as critical factors when selecting a blockchain platform for a business.

D. EVALUATION OF PERFORMANCE

The fourth approach to blockchain suitability evaluation that this scoping review identified is that of performance evaluation. At the outset, it is worth noting that the scalability issues of blockchain constitute the main driver of research contributions that have addressed the performance evaluation problem. According to this scoping review's results, two research works were identified that approached blockchain suitability evaluation from the performance perspective. The reason for including these studies in this scoping review's results is to enable a holistic approach to address performance evaluation issues; in particular, each study provided a systematic review of the available initiatives, tools, and solutions, which enriched our scoping review with important directions for measuring blockchain performance. In this section, therefore, a summary is given of the main contributions of each research article.

The first research article is the recent critical review undertaken by [10], which analyzed state-of-the-art blockchain performance evaluation approaches and identified current challenges and prospects in blockchain simulation and modeling. The most valuable input to the field made by the research article is its presentation of the main perspectives and metrics that can be used to measure private and public blockchain performance. In addition, the authors proposed a classification for blockchain modeling approaches and then analyzed existing projects in industry that have developed performance testing tools. Although the authors highlighted major challenges associated with blockchain performance evaluation, they noted that blockchains are still far away from replacing traditional database systems in terms of data processing and workloads.

This is an indication of the need to conduct further research and experiments to enhance blockchain performance and increase the attractiveness of blockchains for business adoption.

The second research article, undertaken by [73], provided a systematic survey of blockchain performance evaluation tools and categorized them into two general categories: first, empirical analysis, which comparatively reviews the current empirical blockchain evaluation methodologies, including benchmarking, monitoring, experimental analysis, and simulation; and second, solutions that address performance through analytical modeling. The authors also investigated the stochastic models applied to the performance evaluation of mainstream blockchain consensus algorithms. Through their work, the authors extracted important criteria that can be used to select the most suitable evaluation technique for optimizing the performance of blockchain systems based on their identified cases.

In addition, many other contributions are available, including [74] and [75], that have focused on specific platforms. These research articles investigated the throughput and latency characteristics of selected platforms with different workloads and consensus algorithms that they support. Through the use of a suite of micro-benchmarks, they explored how certain transaction and smart contract parameters can affect transaction latencies. However, performances evaluation is an essential factor to boost blockchain adoption decisions for every business application. Therefore, it is regarded as an open research direction that still has substantial potential for further innovation and development, particularly in terms of performance enhancement and performance monitoring.

E. EVALUATION FOR ARCHITECTURAL DESIGN OPTIONS

The last approach to blockchain suitability evaluation identified by this scoping review relates to the critical analysis of a potential blockchain business case in order to evaluate it from a system architectural perspective. Blockchain has introduced a new approach to software engineering in which software is built based on decentralized, distributed systems characterized by heterogeneity and integrity among the participants who join the same blockchain business environment. System engineers and researchers contribute to the development of architectural design patterns to guide blockchain project managers and developers to achieve a better understanding of blockchain applications. For example, the researcher in [76] demonstrates how the use of the Architecture Trade-off Analysis Method (ATAM) can enable decision-makers in government elections to understand the risks, prospects, and challenges that could be associated with a blockchain e-voting system for national elections.

An ongoing research avenue demonstrated in [77] focused on the architectural design for blockchain-oriented applications and proposed an approach that helped to identify the elements of an application architecture that had the potential to benefit from the use of blockchain technology. The proposed methodology suggests that to derive an architectural draft, the system architect must investigate the details of the business case and identify the following three important elements: participants, trust relations between participants, and interactions between participants. Each element will shape the design options.

In [78], the researchers proposed a decision model for selecting patterns in blockchain-based applications based on the characteristics of the business case and trade-offs implicit in the identified blockchain patterns. The research built on prior studies that proposed multiple blockchain design patterns where they developed and aggregated these patterns in a sequence decision model. The identified patterns include data management, data access, authentication, authorization, and patterns for interaction with the external world.

Other work [79] proposed a taxonomy that captures major architectural characteristics of blockchains and the impact of their principal design decisions. This taxonomy classifies blockchains and blockchain-based systems based on some considerations such as the performance and quality attributes to assist with the design and assessment of software architectures. Additionally, a conceptual architecture of DLT developed in [80] that is a taxonomy designed and provide a rigorous classification of DLT systems is made using real-world data. Noteworthily, attention to the blockchain architectural design has recently increased [2], [18], particularly given the popularity of blockchain in business and the high level of investment from companies to adopt competitive blockchain projects.

VII. DISCUSSION

This scoping review clearly indicates the growing interest associated with utilizing blockchain technology outside the scope of Bitcoin and other cryptocurrency applications, particularly since 2017. As these results indicate, there has been a substantial increase in the number of blockchain-based applications explored and deployed across a variety of business domains, which has taken place in parallel with growth in investments in research for investigating blockchain technology's impact on business models and operating systems.

According to a 2019 Accenture report [81], organizations are aggressively investing to understand the potential role of emerging technologies such as artificial intelligence and blockchain in their business. Business organizations have realized that the ''Fourth Industrial Revolution'' has arrived, and they understand the need for innovation in their developed solutions to prevent them from disruption. Therefore, many leading firms have already invested in exploratory research to investigate blockchain-related opportunities for business development. These investigations typically move along the blockchain adoption path [81], which comes to a halt at some point between the proof-of-concept stage and production (see Figure 3).

The blockchain adoption path usually begins at the proof-of-concept stage, which ensures the applicability of the technology and its compatibility with the strategic orientation of the business. This often necessitates suitability evaluation, the purpose of which is to match blockchain's capabilities to the requirements of the business case. The blockchain adoption path then moves to the value proposition stage, which is concerned with analyzing the impact of integrating blockchain with the whole business ecosystem and attempting to create innovative business values. The blockchain adoption path reaches the production stage when all previous assessments and investigations pass the suitability evaluation and gain the approval of top management for investment.

Significantly, the findings of this scoping review indicate that the decision process for blockchain adoption and other evaluation activities can be aligned with the blockchain adoption path. Given that this scoping review sought to explore what suitability evaluations are needed to recommend blockchain for a certain business case, retrieved over 50 research articles that have made contributions to solve the blockchain suitability evaluation problem. We classified the results under five main categories of evaluations, as illustrated earlier in this paper. Meanwhile, we mapped the identified evaluation approaches to one or more stages of the adoption path shown in Figure 2. In the rest of this section, we demonstrate this relationship between the adoption path and the identified blockchain evaluation approaches, thus providing an adequate answer to the main research question:

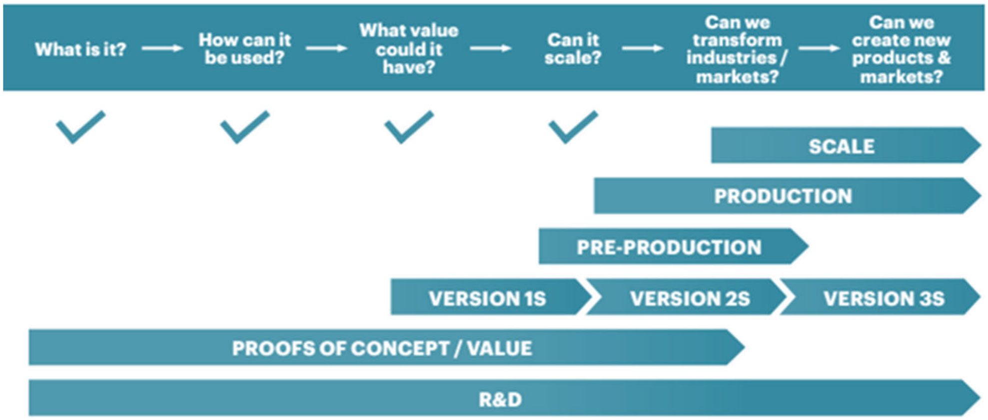

FIGURE 3. Blockchain adoption path [81].

'How has previous literature addressed the evaluation of blockchain's suitability for businesses?'

As shown in Figure 2, organizations move through this adoption path when an innovative technology (e.g., blockchain) is under consideration for implementation. Overall, this path has three main stages: the proof-of-concept stage, the multi-leveled value identification stage, and the pre-production and production stages. All of these adoption stages have different aspects to evaluate and dimensions to assess in order to reach the final decision (i.e., either implementing a blockchain solution or finding another suitable technology).

An important contribution of this scoping review is that it has succeeded in identifying the different approaches for blockchain suitability evaluation that are applicable for use during each stage of the blockchain adoption path. First, when a blockchain is proposed as a solution for a business case, the organization initializes a proof-of-concept stage, during which relevant personnel checks the suitability of blockchain to the business case by examining technical capabilities and features, thus mapping it to the identified business case requirements. In this regard, this review identified 28 research articles that have proposed methodologies to assist organizations in determining the level of blockchain suitability. These methodologies were categorized into three groups: decision flow charts, conceptual frameworks, and mathematical decision models. It is worth noting that the categorization scheme was based on the decision-making procedure employed in each of the 28 research articles.

The second stage, after evaluating the level of suitability, is to analyze the implications of blockchain adoption for the whole business ecosystem, including people, systems, and organizations. For this purpose, this scoping review's results show that there are multiple research works and initiatives that can be leveraged to identify the factors for successful blockchain adoption, along with methodologies to assess the organization's readiness to implement blockchain solutions. Articles under this approach focus on adopting theories of individual adoption, technology acceptance models, and readiness frameworks, which significantly raise the importance of considering socio-technical factors when proposing a blockchain evaluation framework. Noteworthily, the scoping review's results indicate that there has been a significant increase in blockchain adoption research since 2017, which reflects the broad diffusion of this technology due to the growing attention allocated to it by businesses, especially those involved in supply chains and logistics.

Moving to the next stage of adoption, this scoping review identified three additional evaluation approaches that are applicable when the organization reaches the pre-production and production stage. At this stage, the focus is on how to choose a suitable blockchain platform, as well as the question of what architectural design will capture the needs of the business and help to gain the best business and process optimization. In addition, the organization will start to consider the performance parameters and metrics that are important to them. We provide a review for the above evaluation purposes, and we classify the articles based on the objective of evaluation: either for platform selection, performance, or architectural design options.

Although this scoping review retrieved a large collection of research articles addressing blockchain suitability evaluation issues in the business context, it is important to emphasize that further research is needed to address this problem. This is especially the case given the growing number of real-world blockchain projects and the rapid evolution of this technology. At the same time, and even more importantly, we have clearly noticed a shift in adoption among businesses, which has been supported by government strategies and regulatory policies announcing blockchain project frameworks and roadmaps, including the Australian National Roadmap [82], Blockchain in California [83], and the Indian National Strategy for Blockchain [84].

This review provides an answer to the main research questions by presenting an overview of the state of the art in solving the blockchain suitability evaluation problem for business blockchains. In addition, we have analyzed a wide range of methodologies and frameworks that were developed to help decision-makers with blockchain adoption decisions. We also attempted to identify the assessment factors that have been used for the different evaluation processes, a synthesis and categorization of which is presented in Tables 1-4. Our classifications and representations of the factors are expected to prove useful as reference materials for scholars who are interested in blockchain evaluation for either technical or business-oriented initiatives.

VIII. CONCLUSION

This scoping review was conducted to provide an overview of state-of-the-art evaluation approaches and initiatives that have been proposed to offer concrete insights into the suitability of blockchain adoption in a business context. It has focused primarily on the methodologies used during the evaluation process and the adoption decisions made when a business case is assessed in terms of the applicability of blockchain adoption. Notably, this scoping review has centered on the business applications of blockchain technology beyond the well-known use of blockchains for money transfers and cryptocurrencies. The literature search was undertaken following the guidelines of the PRISMA-ScR technique, which was chosen due to its effectiveness in synthesizing information relating to emerging topics such as blockchain. The results clearly reflect the rapid increase in blockchain adoption in different business domains, which accordingly implies an increase in the number of research articles that have proposed methodologies and frameworks to help business managers and decision-makers assess the suitability of blockchain for their operations.

Reaping the full potential of any innovative technology, such as blockchain, necessitates a thorough evaluation that considers various perspectives. Therefore, our scoping review identified 53 relevant articles that have addressed this problem and classified them under five main evaluation approaches, each of which can be leveraged to assess different evaluation purposes. In turn, we provided an analysis of the reviewed methodologies with an emphasis on the proposed evaluation procedures and the identified assessment factors and criteria. To the best of our knowledge, this review is the most comprehensive to be published to date. However, it suffers from the lack of unified evaluation concepts and the heterogeneities in application domains and, therefore, assessment factors; this represents a limitation with regard to the completion of a systematic review.

This review paper is intended to serve as a reference for scholars interested in developing blockchain evaluation techniques, as well as decision-makers seeking to understand what is involved in blockchain adoption decisions, and who may be searching for decision aid methodologies. Nevertheless, blockchain technology has enormous potential to transform the business landscape, and there is still scope for future technical developments and the introduction of more capabilities; this may further augment the business value derived from blockchain adoption. Consequently, evaluation approaches and methodologies must continue to develop, thereby maintaining pace with the rapid evolution of blockchain.

To this end, we encourage further research contributions that address business concerns in the evaluation process, with a special emphasis on elaborating the evaluation by matching blockchain capabilities and the potential to add value to the whole business (e.g., in terms of cost reduction, improving business processes and productivity, and promoting transparency, auditability, fairness, and other issues that businesses usually experience). In addition, researchers should understand that blockchains have been diffused with relative issues such as low scalability, security, and privacy, as well as high cost and high computational power usage. Therefore, it is necessary to raise awareness of these issues when providing blockchain evaluation consultations or proposing specific assessment approaches.

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