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To join or not to join?–A framework for the evaluation of enterprise blockchain consortia

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Within the past years, enterprise blockchain solutions were frequently developed within different industry consortia. In most cases, this resulted in isolated solutions competing against each other due to similar approaches and goals. Today, decision makers do not necessarily need to establish entirely new blockchain consortia, as established ones already exist, and participation is a considerable way to avoid unreasonable efforts. In this paper, we apply an iterative literature review to identify different factors relevant for practitioners, who face the challenge of joining an existing enterprise blockchain consortium. In a second step, we discuss these factors utilizing supply chain management as a role model. As a main finding, we propose an evaluation framework for the purpose of enterprise blockchain consortium analysis. Additionally, we provide several questions relevant for practitioners during their evaluation stages. With our evaluation framework we contribute to blockchain research, where - despite its high relevance - the topic of consortium evaluation has so far been neglected. We also contribute to research in the field of technology evaluation by proposing and merging five different evaluation dimensions.

KEYWORDS

distributed ledger technology, blockchain, enterprise consortia, supply chain management, technology evaluation model

1 Introduction

By their (technical) nature, enterprise blockchain applications are mostly implemented in decentralized interorganizational settings. Respective collaboration models vary from partnerships to consortia or joint ventures (Rauchs et al., 2019). These models are used to enable the initiation of enterprise blockchain consortia and interorganizational cooperation, not unusually on a coopetition basis (Henke, 2003). Accordingly, academic literature provides practitioners with recommendations by means of decision and evaluation frameworks for assessing the usability of blockchain technology (Lo et al., 2017). But it might not always be necessary to build up a new enterprise blockchain consortium, as this is not only accompanied by enormous complexity due to multiple involved parties: in addition, it can be quite difficult to scale and achieve a corresponding market penetration, particularly for small and medium enterprises (SMEs) (Ilbiz and Durst, 2019). A possible alternative to establishing a new consrotium could be to participate in an already existing one. This might be promising

due to the desired outcome being achieved in a faster and more efficient way. Likewise, and from the perspective of an existing enterprise blockchain consortium, new members joining would also help to scale faster. Considering such a participatory approach, decision makers face new challenges, as potential benefits of existing enterprise blockchain consortia in terms of strategic, technical, but also organizational and social impacts need to be evaluated (Henke et al., 2020). Additionally, legal and other jurisdictional questions need to be considered. Whether it is about an existing blockchain consortium, which can be used for different use cases[1] or whether it is about a tailor made solution designed for a specific enterprise purpose[2]: An evaluation model considering diverse blockchain specific criteria is required to support decision makers. Within this paper we provide insights from different industries, academic literature and prior research related to supply chain management and discuss the question:

"Which dimensions and respective factors have to be considered for the evaluation of enterprise blockchain consortia?"

The reminder of this paper is structured as follows: section 2 provides detailed information about our unit of analysis. Additionally, existing approaches for technology evaluation will be discussed with regard to their suitability for answering the indicated research question. Based on a gap identified with regard to existing evaluation approaches, section 3 describes the applied methods to answer the research question. Section 4 provides an overview on the identified relevant dimensions and factors for enterprise blockchain consortium evaluation. Section 5 summarizes the findings and highlights managerial and theoretical contributions made.

2 Background

2.1 Unit of analysis | Blockchain in supply chain management as example

Blockchain consortia are a type of strategic alliance among enterprises that exchange resources, or collaborate in the development of products, services or technologies (Gulati, 1998; Yuthas et al., 2021). They are not restricted to a particular blockchain type and may be grounded in different technical frameworks (Shrestha et al., 2020; Vadgama and Tasca, 2021). Hence, our unit of analysis focuses on enterprise blockchain consortia in general, including different technical blockchain types with the following common ground: the development of inter-organizational blockchain solutions with multiple involved parties (physical layer) that perform a blockchain-based information exchange (information layer) and share a common ledger on transactions, risks, rewards or else (logic layer) (Smits and Hulstijn, 2020). Enterprise blockchain consortia account for multiple factors to be considered before participation can be approved. The identification of these factors and respective assessment criteria will be focused in our research. Examples from supply chain management will serve as an illustration throughout the paper, as respective blockchain use cases in supply chain consortia consist of multiple interconnected participants (Gürpinar et al., 2022b).

As an enterprise function, supply chain management (SCM) involves the planning and charge of material flow, information flow and capital flow from suppliers to manufacturers, distributors or customers, as well as the necessary information to support smooth operations of processes. Its essence is the integration of various resources and processes among different types of business partners in the supply chain. SCM emphasizes the importance of information sharing, cooperation, and organizational coordination among supply chain partners. It also helps diverse stakeholders monitor the supply chain to promote its responsiveness and resilience (Yoo and Won, 2018). Thereby, several challenges are encountered in SCM. Firstly, during information construction, hardware and especially software costs are increasing due to more functionalities and a bigger scope. Secondly, the multiple partners of a supply chain may not provide transparent information but experience poor trust relationships and coordination, as well as a lack of accountability. These challenges become a bottleneck restricting the development of enterprise collaboration (Saberi et al., 2019; Große et al., 2021).

Blockchain technology addresses trust-, transparency- and traceability challenges in the supply chain by using tamper-proof records and a distributed storage for transactions. With blockchain technology being the most prominent distributed ledger technology (DLT), we use the term interchangeably throughout the rest of the paper and imply that also other DLT's could be put in place. Supply chain participants benefit from these systems when integrated with IoT devices in the following way: First of all, they can supervise information of the material- and the respective information flow, helping to predict emergency events and manage the supply chain. In addition, real-time accessibility of information facilitates supply chain risk management and process automation (Saberi et al., 2019). Blockchain technologies are piloted in a wide variety of industries (such as agriculture, pharma and automotive) and in a lot of different use cases (such as tracking and tracing of products, information sharing and automatized payments) (Shrestha et al., 2020; Gürpinar et al., 2021). As technical frameworks, current projects most often utilize private and consortium

1 see for instance: evan.network (https://evan.network/)

2 see for instance: Tradelens (https://www.tradelens.com/)

blockchain solutions (such as Hyperledger Fabric), in some cases hybrid solutions are put in place (Cui et al., 2020).

As mentioned in the previous paragraphs, we focus on a certain evaluation perspective, i.e., firms considering to participate in an enterprise blockchain consortium. As indicated by the title ("To join or not to join?") this evaluation can lead to two different results. Either a firm decides to participate in an enterprise blockchain consortium or it does not. Both decisions implicate different consequences. The former requires corresponding involvement in the consortium. The degree of involvement may vary, e.g., depending on the possibilities to participate or the role and responsibilities the firm takes or is able to perform. For instance, node operation and voting participation on certain governance topics might require certain technical, financial and/or human resources. For the latter, the following options remain:

- Search for another enterprise blockchain consortium
- Propose amendments regarding critical points for participation
- Establish a new enterprise blockchain consortium
- Go for a centralized solution, either offered by the firm itself or by trusted intermediaries

All four options come along with certain advantages/disadvantages, which will be briefly described. The first option offers the possibility to participate in another already existing consortium, which meets the desired consortium design. Arguments against this option might be that it is not always possible to find a respective consortium, especially in case the consortium depends on certain (affiliated) partners to implement a certain use case. Additionally, this option requires a new evaluation, which might also lead to a negative result, i.e. no participation. Therefore, a second option would be to propose amendments regarding critical points, which led to rejection in the first evaluation round. This option requires the consortium to accept the desired changes. The more extensive the amendments, the less likely their acceptance might be. Apart from the extent of the proposed changes, there are other factors of success, such as meaningfulness, significance or importance of the requesting party to the consortium. The third option offers the possibility to design a completely new consortium according to own needs and wishes. On the other hand, it requires certain technical, organizational and legal efforts, as well as persuasion and integration of new consortium members. Last but not least, it might also be an option to generally change the approach and go for a rather centralized solution, either offered by the firm itself or by trusted intermediaries. This option may facilitate certain things, such as decision-making or coordination and voting, but it would question the legitimacy of an already existing consortium built on a decentralized basis in general. That is, the last option can only be considered valid in case there is a realistic chance for a single trusted party to offer a respective solution (either the company itself or a vendor).

2.2 Existing approaches for technology evaluation

For many years enterprises have faced challenges in evaluating technologies in order to make valid investment (make or buy) decisions (Uebel and Helmke 2013). In the information systems domain, Delone and McLean (1992) developed a framework on the success of information systems and found that besides technical aspects and system quality, influences on the organization itself need to be considered. Ballantine et al. (1996) found that within the evaluation domains, multiple factors need to be considered and for each factor partners within the organization would be needed to assess them. They further found that in organizations both the evaluation factors as well as appropriate evaluation partners are only known to a very limited extent. Kesten et al. (2013) agree that in most cases the identification of evaluation factors is key and propose an impact chain analysis to identify and present dependencies between evaluation factors. Similar to that, in the field of innovation management, Prasad et al. (2018) propose the application of the total interpretive structural modeling to elaborate critical success factors for evaluation. The approaches have in common that they focus on factors relevant for the profitability of the respective systems, but neglect the consideration of further evaluation domains.

With regard to blockchain solutions, technology evaluation can be even more challenging due to several different stakeholders and domains being affected. Furthermore, the evaluation process gets more complex, as it might require engaging with existing enterprise blockchain consortia (Düdder et al., 2021). Literature on blockchain and distributed ledger technologies propose guidelines helping to determine the usefulness and appropriateness of blockchain technology. These guidelines were successively refined and supplemented by recommendations on which blockchain type to choose or what challenges to consider for integration processes. In recent years, these guidelines were also complemented with other aspects such as sustainability (Lo et al., 2017), or transformed into comprehensive models to take into account regulatory aspects (Pai et al., 2018; Lyons et al., 2019). Recently, further dimensions were brought up by blockchain scholars that are deemed necessary to consider when evaluating enterprise blockchain consortia. Most prominently, opportunities and risks that are associated with system security (Iqbal and Matulevičius, 2019), as well as rights and obligations that are incorporated in the blockchain governance (Beck et al., 2018).

Summarizing, the preceding explanations show that some approaches for technology evaluation already exist. Nonetheless, these approaches show several shortcomings: Firstly, most of

them are not intended to be used in the blockchain context and fall short when considering blockchain specifics such as node operations, forks, consensus mechanisms, etc. (Seebacher and Schüritz, 2019). Secondly, and only in case of approaches specifically developed for blockchain evaluation, the focus is rather on the provision of a rationale for the usage of the technology, e.g., decision paths guiding practitioners with regard to the overall plausibility of using blockchain technology (Önder and Treiblmaier, 2018). Thirdly, most of the existing approaches follow a certain perspective, i.e., they deal with profitability only, or focus on a specific organization and use case. Hence, none of the existing approaches provides sufficient evaluation domains and assistance for the evaluation of enterprise blockchain consortia.

3 Methodology

As shown in the previous section, we already identified several blockchain evaluation perspectives that are still scattered in literature (profitability, governance, regulation and compliance, technology and security engineering, as well as sustainability). In order to elaborate concrete evaluation criteria associated with these perspectives, we chose to apply an iterative literature review process. On the one hand, a literature review offers the possibility to collect views on relevant factors based on different research fields related to blockchain technology. On the other hand, a literature review seems appropriate as a starting point for subsequent empirical research activities. Literature reviews in academic studies can either follow a systematic or traditional process (Jesson et al., 2011). The traditional literature review utilizes a summarization of knowledge without a prescribed methodology, while systematic approaches establish more transparency and discussion regarding the selection process (Easterby-Smith and Lyles, 2011). We followed the traditional approach using the data sources JSTOR, IEEE Xplore, Wiley, Science Direct, Springer Link, Wiley, and Scopus. Concerning the coverage, the search aimed at collecting as many relevant publications as possible, while focusing on qualitative papers with a representative character. A keyword search was used as an initial technique to cover the various perspectives of our paper. The search was conducted based on the occurrences of the search terms in the title, abstract, and keywords of the papers. Proceeding from the iterative research idea, the search terms were adapted in the course of the literature analysis. After applying the exclusion criteria (languages other than English or German; older than 2015, grey literature), 95 sources were identified in total. The review was not restricted with regard to publications by certain authors, geographic location, particular research designs or sources of financial support. By screening the abstracts that appeared to be relevant for answering the research question, 38 papers remained and were supplemented by another 9 papers through backward and forward screening.

Based on this approach, the analysis focused on statements within the retrieved papers representing one or more of the five different dimensions. We searched for detailed information about respective factors relevant for each dimension. The citations in section 4 illustrate the distribution of the retrieved papers: 8 papers were assigned to the profitability dimension, 10 papers were assigned to the governance dimension, 3 papers were assigned to the regulation and compliance dimension, 5 papers were assigned to the technology dimension and 15 papers were assigned to the sustainability dimension. As an assignment of papers was possible to each of the previously identified dimensions, no further ones were added afterwards. The next section will now describe the five different dimensions, the linkage to enterprise blockchain consortia and key factors for each of them.

4 Blockchain evaluation perspectives

In this chapter we want to introduce the identified perspectives for the evaluation of enterprise blockchain consortia in supply chain management. To this end, we follow a certain structure for each of the perspectives: firstly, we provide a short motivation for the inclusion of each perspective. Secondly, we link each perspective to the topic of interest (enterprise blockchain consortia). Thirdly, we list concrete factors that need to be considered before joining an enterprise blockchain consortium. Finally, the dimensions and key questions representing the main factors are integrated in a consolidating framework and a structured table at the end of the paper.

4.1 Profitability

Motivation

One important factor to be considered when planning blockchain projects is their profitability and generated business value. However, the challenge of making technology generated profits measurable has been intensifying for years (Önder and Treiblmaier, 2018). In the course of digitalization, technologies offer more and more functionalities and expand their strategic scope within a single and across multiple companies (Uebel and Helmke, 2013). In particular blockchain solutions have numerous points of contact within companies, as they involve IT, procurement, sales, supply chain management and further functions (Düdder et al., 2021). Moreover, several external stakeholders can be connected to an enterprise blockchain consortium, which leads to an even higher number of distributed costs and benefits. All these

factors can potentially have an influence on profitability to a varying degree, and become harder to collect and quantify the more interdependencies exist among them. This in turn, might complicate investment decisions.

Profitability and enterprise blockchain consortia

As of now, for the consideration of profitability and business value for enterprise blockchain consortia, the following approaches exist:

- Guidelines: Recently, especially guidelines and decision trees are used to assess whether a blockchain project is meaningful for a specific use case or application area. The statement for meaningfulness is then used as a first step towards profitability. Nevertheless, these guidelines do not yet deliver information on concrete costs or benefits (Li et al., 2019; Pedersen et al., 2019).
- Process models: In some cases, the prior given guidelines were transformed into more comprehensive process models that take into account indicators such as opportunities and risks, or, as in the case of Fill and Meier (2020), who suggest an evaluation scheme to compare use cases. Monetary aspects are not considered in these models (Pai et al., 2018).
- Evaluation models and taxonomies: Gürpinar et al. (2020) propose an integration model with several evaluation steps included and extend it with multiple methods to assess blockchain-based costs and benefits, while Weking et al. (2020) propose a business model taxonomy to support enterprises with relevant dimensions and characteristics to move towards profitability analysis.

Considerable factors

In order to evaluate the profitability and business value of blockchain projects, the below mentioned factors can be analyzed (Gürpinar et al., 2020; Weking et al., 2020). It is important to note that the impacting factors interact with each other and can occur throughout the entire value chain. For that reason, it is not trivial to gather all relevant factors and measure them as multiple uncertainties have to be considered (Hirnle and Hess, 2004).

- Potentials and challenges: With the help of a SWOT analysis or other tools from strategic management, a broad consideration can be applied to balance potentials and challenges of a certain blockchain use case. The potentials and challenges can then be collected and used as a basis to derive more concrete revenue streams.
- Revenues: After the preliminary evaluation of meaningfulness, and with the help of an impact chain analysis, indirect benefits (like trust and transparency) can be associated with concrete revenue streams, e.g. savings in working time, or resources. With regard to resources, profitability considerations can also be connected to the sustainability dimension, as e.g. paperless trade influences both cost savings and emissions (Wunderlich and Saive, 2020). In this step, business processes of the use case should have already been analyzed and used as a basis.
- Costs: Finally, on the basis of the identified challenges and the technical framework, as well as the utilized governance concept, costs can be derived along all project phases - from initiation until integration and system maintenance. The costs can then be balanced with the priorly derived revenues to obtain a profitability statement.

Apart from obvious costs, such as node operations, other factors may also constitute a matter of expense. For instance, governance costs, which can result from obligations such as employees taking part in votings, discussions or meetings within an enterprise blockchain consortium. Governance efforts should not be underestimated, especially in cross-company collaboration approaches and are subject of discussion in the next section.

4.2 Governance

Motivation

IT governance can be defined as "the framework for decision rights and accountabilities to encourage desirable behavior in the use of IT (...). IT governance is not about what specific decisions are made. That is management. Rather, governance is about systematically determining who makes each type of decision (a decision right), who has input to a decision (an input right), and how these people (or groups) are held accountable for their role" (Weill, 2004, p.3). For blockchain-based enterprise consortia, it is particularly important to note that blockchain technologies come along with several special features compared to other IT systems. On the one hand, there are various new roles that can be responsible for executing a decision (validators, miners, etc.). On the other hand, blockchain technologies may include forks, tokens (for incentivization), oracles, but also new ways of implementing governance. Often a distinction is made between on-chain and off-chain governance (Honkanen et al., 2019). On-chain governance describes the implementation and the execution of governance via software code on the blockchain architecture itself (De Filippi and McMullen, 2018). This offers potential for process automation, but it can pose risks to processes in the event of technical errors or in case reverse changes are necessary. Off-chain governance describes governance mechanisms not implemented on the blockchain protocol and related to the operations of the system itself (De Filippi and McMullen, 2018). In other words, blockchain technology is not only a technology to be governed (off-chain governance), but offers possibilities to execute certain governance mechanisms by directly inscribing them on the protocol (on-chain). This in turn led to different research approaches on the topic of governance (Schwarzer, 2021). In

case of an enterprise blockchain consortium, off-chain governance can be operationalized and applied through personal meetings, for instance. It is important to note that on-chain and off-chain governance are not necessarily mutually exclusive, but can be used in a complementary manner to cope with the drawbacks each approach might come along with (De Filippi and McMullen, 2018).

Governance for enterprise blockchain consortia

The fact that governance is a key requirement for long-term success of enterprise blockchain collaborations is confirmed by various studies (BCG, 2019; Deloitte, 2020). Referring to examples from the field of supply chain management, even the German Federal Ministry for Economic Affairs and Energy highlights the necessity for effective governance models in the logistics sector within their blockchain strategy paper. Use cases mentioned in the course of this section by the ministry vary from temperature monitoring to digitization of paper based logistics processes (German Federal Ministry for Economic Affairs and Energy, 2019).

A review of the underlying governance model of an enterprise blockchain consortium reflects a check from a strategic and organizational, but also from a legal perspective. The corresponding governance model may already include technical components and may also be implemented on the blockchain infrastructure itself, as mentioned before. Despite its importance for (long-term) project success, design recommendations for governance models of enterprise blockchain applications are still very rare in academic literature (Lacity, 2018; Ziolkowski et al., 2019). Beck et al. (2018) address this problem and propose a research agenda on blockchain governance.

Considerable factors

Within a cross-company collaboration approach, the definition of decision rights and paths is usually associated with an increased complexity, simply due to a higher number of companies involved. For supply chain consortia, several different types of members are possible depending on the use case. For reasons of hedging, but also for reasons of efficiency, an independent legal entity could be a possible way to address governance issues (Zavolokina et al., 2020). If that applies to an enterprise blockchain consortium, the legal entity must be evaluated accordingly. If this is not the case, the company considering joining such an initiative has to examine how efficient cooperation is ensured. It must be clarified how the parties involved relate to each other and how IP rights, responsibilities, tasks and decision-making paths are controlled and distributed. This also includes the distribution of financial and development efforts, conflict resolution and how contractual relationships with new members or third parties can be concluded (if necessary) (Zavolokina et al., 2020). This legal review can therefore reveal corresponding possibilities to exert influence on decisions, rights of intervention, escalation processes in case of disputes, and also respective sanction mechanisms for different types of misbehavior. Additionally, a governance model could also include technical aspects. This could possibly include decision rights about the technical design and handling of forks and oracles. And it may also include corresponding (technical) roles such as validators, endorsers or orderers, who (depending on the framework and consensus mechanism) are responsible for the validation and finality of transactions. In case blockchain tokens are used, e.g., as mechanism for incentivization, for on-chain voting or other reasons, corresponding issuer risks or liability issues should be clarified depending on the type of tokens issued (e.g. payment tokens, security tokens, utility tokens) (Sunyaev et al., 2021).

Furthermore, governance should also outline how to proceed in the event of new or leaving members and define appropriate on-boarding and off-boarding strategies for such business consortia (Sunyaev et al., 2021). As mentioned previously, it is conceivable that parts of the governance are mapped directly to the underlying blockchain protocol (on-chain governance). This could include governance compliance monitoring of the participating parties, which can be verified and enforced through the use of smart contracts. Due to the large number of potential topics to be covered by a governance model, a governance model itself can face the tension between supporting quick and effective results versus slowing down processes because of over-regulation (Zavolokina et al., 2020). Therefore, it is indispensable to check whether a governance model follows principles of transparency, openness and inclusiveness, but also simplicity to enable efficient work and to ensure that the consortium is always capable of acting (Zavolokina et al., 2020). Obviously, use case, governance and regulatory aspects are important and interdependent factors for an enterprise blockchain consortium. Apart from regulatory and legal factors relevant for an consortium itself, external factors such as antitrust-, competition-, tax-law and others (possibly also of different jurisdictions) have to be considered for a compliance check as well. These regulation and compliance matters will be discussed in the next section.

4.3 Regulation and compliance

Motivation

Regulation and compliance are closely intertwined fields. “The importance of compliance has dramatically increased over the last few years for businesses in several industry sectors. Essentially, compliance is ensuring that business processes, operations and practice are in accordance with a prescribed and/or agreed set of norms. Compliance requirements may stem from legislature and regulatory bodies (...), standards and codes of practice (...) and also business partner contracts” (Sadiq et al., 2007, p.149). Hence, compliance means

not only being compliant with legal and regulatory requirements, but also meeting own company standards and those of the participating business partners.

Regulation and compliance for enterprise blockchain consortia

With regard to the question of whether to join an existing enterprise blockchain consortium, it is important to consider that most blockchain applications have an inter-organizational setting by their nature. Different legal jurisdictions of participating parties may put even more complexity on regulatory and compliance checks. Additionally, several use cases exist within supply chain management, which are subject to special legal requirements as well. An example from supply chain management would be the transnational transport of dangerous goods with several parties involved (Consignor, forwarder, carrier, consignee, etc.) (Perez and Korth, 2020). Dangerous goods transportation is a process with several legal guidelines to be met due to reasons of safety. Blockchain technology itself can take two different roles here. On the one hand, it is of course an object of assessment, as regulatory requirements may apply to the underlying use case (e.g. dangerous goods transportation). However, on the other hand, the technology may also serve as a tool for implementation, ensuring compliance (Mylrea and Gourisetti, 2018).

Considerable factors

Blockchain as a tool for implementation. If blockchain is used to make processes compliant, it is of course important to check whether the underlying jurisdiction recognizes a blockchain-based (digital) procedure. An example from supply chain management would be the digitization of freight documents, such as the DLT based bill of lading[3]. Here, it is important to know whether this procedure is legally accepted in the respective countries and whether relevant participants (governmental/regulatory bodies, customs, banks etc.) are part of the solution designed (Jugović et al., 2019). If the respective solution is not recognized by official authorities yet, it is necessary to check until when regulatory changes can be expected and whether these changes match with a companies' expectations.

Blockchain as an object of assessment. In addition to the possibility of using blockchain technology as a tool for realizing compliant processes (compliant with different legal and regulatory requirements), the technology itself and the way of its implementation should also be assessed. Depending on the use case there may be standards (technical, procedural, etc.) that must be met. For both cases it is necessary to check whether the compliance rules followed by an enterprise blockchain consortium are in accordance with the compliance rules of the company interested to join. With regard to the technology, special checks may be necessary. In case of the usage of a public permissionless blockchain, for instance: A compliance check could consider the question which mining companies are remunerated for operating the public permissionless system used. Theoretically, mining companies could be supported, which use respective rewards from their mining activity for criminal activities (Whyte, 2019). Summarizing, two different perspectives can be considered with regard to regulation and compliance: On the one hand, blockchain can be used as a tool for the implementation of compliant processes; on the other hand, the technology itself is also an object to be evaluated in terms of compliance. Following up, the next section deals with technology and security engineering.

4.4 Technology and security engineering

Motivation

Possible technical designs of blockchain technologies have already been mentioned in chapter two. However, it should be noted that the technologies are rarely used in their pure form for enterprise applications, as information from external systems are often required for the realization of different use cases. Bridging concepts, such as blockchain oracles, can serve as data providing mechanisms between external systems and blockchains (Mammadzada et al., 2020). Examples from supply chain management would be any master data from customers, partners, etc. or relevant data from existing transport/warehouse management systems (TMS/WMS). Furthermore, IoT devices in combination with a light-node architecture are frequently used as means of data provision (Reilly et al., 2019). Therefore, the following remarks should not only be considered with regard to blockchain technology itself, but rather be thought of as a set of factors to be considered for the evaluation of enterprise blockchain applications.

Technology and security engineering for enterprise blockchain consortia

The topic technology and security engineering is also closely related to the topics of profitability, governance and compliance. This is because tasks, duties (minimum) requirements, costs and risks must also be examined and assessed for technical factors. Additionally, it is also necessary to consider external standards and requirements for specific use cases. As mentioned within the previous paragraph, blockchains might be combined with IoT devices, oracles and other data providing sources leading to data breaches (Gürpinar et al., 2022a). For that reason security engineering is of increased importance not only for the blockchain technology used, but for all included technological factors. This also includes privacy preserving mechanisms,

3 see for instance: CargoX (https://cargox.io/)

applied privacy-by-design concepts and the overall integrity of the different technology stacks (Düdder et al., 2021).

Considerable factors

Relevant factors to be examined before joining an enterprise blockchain consortium can be of different nature: Minimum requirements for node operation, handling of forks and oracles, as well as tasks and duties (which may also be conducted by a third-party provider). In addition, there may be requirements for different data storage approaches (cloud vs. on-premise) (Paik et al., 2019). Special for blockchain use cases is the topic of interoperability. Either interoperability with other blockchains, interoperability of different applications on one blockchain or between a blockchain network and other systems (e.g. TMS/WMS) (Besançon et al., 2019). Certainly, and especially for enterprises, it is of interest how identities are managed within an enterprise blockchain consortium. This can not only be thought of as identities for employees, but also identities for vehicles, sensors or (digital) assets in general connected with IoT devices, for instance. It should be checked how the identity management is set up, managed and, with regard to new concepts such as self-sovereign-identity, who is in charge of the underlying blockchain infrastructure (Kulabukhova et al., 2019). Basically, all of these topics should not only be reviewed, but also checked for technical conclusiveness and usefulness. After all, it is not always the case that a business problem has to be solved by using blockchain technology. Additionally, it might also be necessary to evaluate the technological framework (and its consensus mechanism) used within a blockchain consortium from a sustainability perspective.

4.5 Sustainability and corporate social responsibility

Motivation

One important factor to be considered when deciding for a blockchain project is the impact on sustainability. Sustainability is at the center of many strategic decisions of enterprises and often aligned to a corporate social responsibility (CSR) concept. Sustainability in a supply chain context is defined as "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains" (Carter and Rogers, 2008, p. 368). With their definition, Carter and Rogers (2008) build upon the Triple Bottom Line (TBL) concept that was developed by Elkington (1997). It entails the three dimensions of society, environment, and economy that should be used to assess, measure, report and promote the sustainability of organizations. The emergence of CSR concepts originated in the first half of the 20th century through debates on responsibility towards stakeholders. The topic of CSR is diverse and therefore overlaps with other concepts like business ethics, corporate social responsiveness, or social performance (Nikolaou et al., 2018). According to Martínez-Ríos et al. (2020), CSR is a management concept that takes into account particular social and environmental concerns in corporate businesses. Through CSR commitment, enterprises can attract interested parties, for example buyers or employees, which are more conscious in terms of sustainability. In most cases, the main corporate goals in applying both concepts lie in complying with regulatory restrictions, generating savings and driving long term growth. Additionally, it is about reducing risks by transforming the value chain from the supply of materials to product design, operations, sales and marketing, as well as end-of-life management (Nauclér, 2021).

Sustainability and enterprise blockchain consortia

Blockchain projects address and support these goals by enabling or optimizing sustainability concepts and approaches, based on the blockchain functionalities described in chapter 2.1. For decision makers considering to join an enterprise blockchain consortium, at least the following three concepts are relevant to understand the impact of a blockchain solution:

- Improving Circular Economy (CE) concepts: First, several blockchain projects focus on the improvement of CE concepts that aim at a redesign of value chains and try to build long-term resilience. The redesign in those concepts focuses on different concepts such as recycling, remanufacturing, refurbishment, reuse and reclamation (Kouhizadeh et al., 2019). Information systems supported by blockchain technology can improve CE performance at multiple levels: Its usage is proposed for waste management and reduction (Vogel et al., 2019); energy saving management as well as protection of the consortium and its biodiversity (Zhang et al., 2020); recycling and reuse management (Zhang et al., 2020); improving production and resource efficiency (Kouhizadeh et al., 2019; Große et al., 2020); and product life cycle management (Leng et al., 2020).
- Enhancing collaboration and information sharing: Second, and due to its distributed and secure characteristics, blockchain technology enhances the involvement of suppliers and other external stakeholders in order to achieve transparent processes and smoother coordination. In particular, blockchain based information sharing mechanisms can be used for decentralized emission trading (Saberi et al., 2019) and the compliance reporting of ethical business practices, for instance (Tiscini et al., 2020).
- Traceability of products and information: Third, the traceability of products and information is focused in several blockchain projects with regard to a stronger involvement of customers and end-consumers. Especially

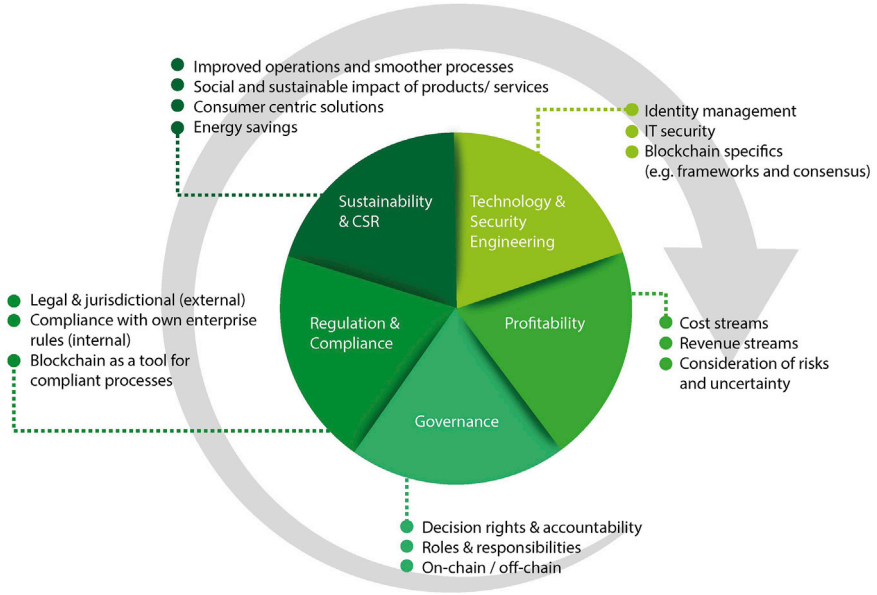

FIGURE 1
Framework for enterprise blockchain consortium evaluation.

by increasing the reliability, consistency and availability of data on provenance and current location, blockchain projects can have a high impact for society. Respective projects use blockchain technology for tracking and recording of product ingredients and working conditions throughout the value chain (Saberi et al., 2019; Tiscini et al., 2020; Park and Li, 2021). With regard to CSR, blockchain technology also allows for optimizing traceability of emission levels and operational costs (Manupati et al., 2020).

Considerable factors

In order to evaluate the impact on sustainability that a blockchain project has or will have in the future, the following factors can be analyzed:

- Operations: The enterprise operations should be characterized by digitized (therefore less paper work) (Martínez-Ríos, 2020) and smoother (less disruptions and recalls) processes (Kshetri, 2021). Also, the amount of waste should decrease through improved CE concepts. As a result industry consortia should demonstrate less bureaucracy and more compliance to regulations (Martínez Ríos, 2020).
- Product: The product or service of the enterprises should demonstrate a higher perceived value for society during its entire life cycle (Vogel et al., 2019). Therefore, highly innovative management decisions should come together with the involvement of selected investors and sponsors that pursue sustainable goals (Benzidia et al., 2021).
- Customer: Finally, the customer satisfaction should be higher, resulting in more trust and loyalty (Rane et al., 2020), as well as the willingness to pay a higher price for the sustainable products or services (Esmaeilian et al., 2020).
- Technology: In case the blockchain solution utilizes a public or hybrid framework, where proof-of-work consensus is involved, the electricity usage has to be considered. Apart from that it is of general interest to consider electricity and resource usage resulting from redundant data storage and other processes related to blockchain operations (Sedlmeir et al., 2020).

As a summary of our research we provide a framework for the evaluation of enterprise blockchain consortia (see Figure 1) and a summary of possible relevant questions for decision makers (see Table 1). Limitations, recommendations and other findings will be discussed in the last section.

5 Findings and conclusion

Referring to Figure 1 and Table 1, we highlight the fact that an evaluation of enterprise blockchain consortia is not a one-time task, as such initiatives can be subject to changes over time. May it be due to (new) members joining or leaving, due

TABLE 1 Possible relevant questions for enterprise blockchain consortium evaluation.

Building blocks	Selection of possible relevant questions
Profitability	- Does your blockchain use case solve real problems and do the potentials outweigh respective challenges?
	- On the basis of concrete business processes: Are relevant cost savings and revenue streams generated?
	- Costs: Do the long-term benefits exceed respective costs over all stages of the blockchain project?
	- Are particular types of costs considered (development, consulting, training and operational costs)?
Governance	- Which other companies are involved in the project and are decision rights and accountability allocated in a satisfying manner?
	- How is governance implemented, executed and controlled (on-chain/off-chain governance)?
	- What is the legal foundation of the governance model and are potential risks and points of conflicts (e.g. IP rights) addressed?
	- How does the organizational structure look like, and which responsibilities or tasks does the structure imply?
	- Which mechanisms for incentivization exist (e.g. tokens)? Are these mechanisms considered adequately for the purpose of the network and compliant with regulation?
	- How are conflicts resolved and are escalation mechanisms defined?
	- Which procedures are defined for on- and off-boarding of (new) members?
	- Is the governance model considered flexible in terms of balancing tensions between overregulation and ensuring the collaboration's capability to act and make decisions?
Technology & Security Engineering	- What type of blockchain is used (private permissioned, public permissionless, hybrid)?
	- Which external systems and devices are connected to the blockchain and how is interoperability addressed?
	- Are there any (minimum-) requirements for participation (data storage approach, IT-security, etc.)?
	- Which tasks, roles and duties are required (node operation, maintenance, etc.)?
	- How are forks and oracles handled?
Regulation & Compliance	- Do relevant jurisdictions accept blockchain-based implementations?
	- To what extent do relevant authorities acknowledge blockchain-based implementations?
	- Are relevant processes compliant with regulation and external standards?
	- Does the overall approach adhere to a company's own compliance rules?
Sustainability & CSR	- Is the planned blockchain project outcome in line with corporate sustainability goals?
	- Does the project have a long-term positive impact on business processes, the product or service and does it deliver a value for society and environment likewise?
	- Does the customer appreciate the added value of sustainable products and services and is he willing to pay a corresponding price?

to legal or regulatory changes or due to technical developments. Furthermore, the framework presented above (see Figure 1) does not imply a certain sequence of tasks and checks, as we think all tasks are closely related and may be conducted in different orders depending on the use case or project stage. An iterative process is necessary to cope with potential changes during different possible project stages, e.g. decision, implementation and live stage. As has been shown, the realization of blockchain use cases is highly interdisciplinary (Düdder et al., 2021). Hence, we recommend a team consisting of different experts in respective fields for the process of evaluation. We certainly know that substantial further research is necessary to shed light on all different dimensions and factors and we do not claim completeness of the framework. As mentioned in the introduction, the decision to join an existing blockchain network may not only be of interest for large enterprises, but particularly for SMEs due to possible lower initial efforts, network effects and reasons of market penetration. We encourage other researchers to conduct further research either on single dimensions/factors of the evaluation framework or on enterprise blockchain consortia in general. For particular dimensions it is of interest how to evaluate them with regard to maturity or readiness levels. Today, different tools exist, e.g. TRL (Rodriguez et al., 2019; Holm and Goduscheit, 2020) for the technology dimension or the COBIT (De Haes et al., 2020) maturity model for the governance dimension. Subsequent research could focus on the question how these measurement tools can be applied to the identified dimensions. With regard to enterprise blockchain consortia, it is of interest to identify other potential factors driving their success, for instance, socio-technical factors, which might have an impact on the performance of blockchain-based inter-organizational approaches (Paliwal et al., 2020).

In terms of managerial implications

- It was shown that participation in an existing enterprise blockchain consortium can be a viable way to simplify blockchain usage and adoption for different use cases.

The proposed framework can be used as a guiding evaluation tool for decision makers and is generalizable for different industries.

- Different dimensions and criteria to be necessarily considered for the evaluation of enterprise blockchain consortia were discussed.
- The proposed framework can be used in case the intention is to build a new enterprise blockchain consortium, as it provides foundational building blocks relevant to convince possible new members and partners. For that case, the evaluation dimensions should certainly be thought of as dimensions, which have to follow certain design principles to incentivize consortium participation, e.g. (1) inclusiveness and stakeholder orientation for the governance dimension or (2) consensus protocol selection for the profitability dimension. Future research could therefore also shed light on design principles for successful blockchain enterprise consortia development by taking the different dimensions as a starting point. It should be considered that the importance of the evaluation dimensions could depend on different aspects, for instance:
  - The use case: If the underlying use case is of utmost importance for parties considering to join a consortium, certain criteria might experience less importance, e.g. co-determination rights in a respective governance model.
  - The consortium: Apart from the problem solved, it can be of interest for the party considering to join a consortium, which other parties are part of the consortium and how it relates to them (competitor, possible customers, etc.). Hence, and as mentioned above, possible network effects may play a substantial role in the decision making process.
  - The joining party: SMEs, for instance, might have different incentives, but also possibilities to actively participate in a consortium, whereas large enterprises have respective resources to do so.

In terms of theoretical implications

- The paper contributes a gap, not only in literature of information systems, as so far none of the existing evaluation frameworks or guidelines provided a solution for the evaluation of enterprise blockchain consortia.
- The paper provides a starting point for further research on theories of new institutional economics. Mentioning blockchain as a tool for the implementation of regulatory compliant processes (see section 4.3) could suggest the usage of smart contracts for the automation of procedural checks, for instance. Same applies to the topic of governance, where smart contracts could be responsible for supervising the adherence of members to previously defined governance rules. These examples indicate lower ex post transaction costs through the usage of blockchain technology relevant from a transaction cost theory perspective (Coase, 1937).

Additionally, sustainability and social implications were discussed with regard to the usage of blockchain technology.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors contributed to the article and approved the submitted version. MS: focused on the research and discussion of governance, regulation and compliance topics, as well as technology and security engineering. TG: focused on the research and discussion of profitability, sustainability, as well as corporate social responsibility. MH: focused on the overall structure and scientific approach.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Ballantine, J. A., Galliers, R. D., and Stray, S. J. (1996). Information systems/technology evaluation practices: Evidence from UK organizations. *J. Inf. Technol.* 11 (2), 129–141. doi:10.1177/026839629601100204

BCG (2019). Resolving the blockchain paradox in transportation and logistics. Boston Consulting Group. Available at: http://www.bcg.com/publications/2019/resolving-blockchain-paradox-transportation-logistics (Accessed 04 09, 2022).

Beck, R., Müller-Bloch, C., and King, J. L. (2018). Governance in the blockchain economy: A framework and research agenda. *J. Assoc. Inf. Syst.* 19 (10), 1020–1034. doi:10.17705/1jais.00518

Benzidia, S., Makaoui, N., and Subramanian, N. (2021). Impact of ambidexterity of blockchain technology and social factors on new product development: A supply chain and industry 4.0 perspective. *Technol. Forecast. Soc. Change* 169, 120819. doi:10.1016/j.techfore.2021.120819

Besançon, L., Da Silva, C. F., and Ghodous, P. (2019). "Towards blockchain interoperability: Improving video games data exchange," in *2019 IEEE international conference on blockchain and cryptocurrency (ICBC)* (Seoul, South Korea: IEEE), 81–85.

Carter, C. R., and Rogers, D. S. (2008). A framework of sustainable supply chain management: Moving toward new theory. *Int. Jnl. Phys. Dist. Log. Manage.* 38 (5), 360–387. doi:10.1108/09600030810882816

Coase, R. H. (1937). The nature of the firm. *economica* 4 (16), 386–405. doi:10.1111/j.1468-0335.1937.tb00002.x

Cui, Z., Xue, F., Zhang, S., Cai, X., Cao, Y., Zhang, W., et al. (2020). A hybrid blockchain-based identity authentication scheme for multi-WSN. *IEEE Trans. Serv. Comput.* 13 (2), 241–251. doi:10.1109/TSC.2020.2964537

De Filippi, P., and McMullen, G. (2018). *Governance of blockchain systems: Governance of and by distributed infrastructure*. Toronto, ON: Blockchain Research Institute and COALA. Research reporthal02046787.

De Haes, S., Grembergen, W., Joshi, A., and Huygh, T. (2020). "COBIT as a Framework for Enterprise Governance of IT," in *Enterprise Governance of Information Technology* (Springer, Cham: Management for Professionals). doi:10.1007/978-3-030-25918-1_5

Deloitte (2020). Deloitte's 2020 global blockchain survey - from promise to reality. Available at: https://www2.deloitte.com/content/dam/insights/articles/US144337_Blockchain-survey/DI_Blockchain-survey.pdf (Accessed 04 09, 2022).

Delone, W. H., and McLean, E. R. (1992). Information systems success: The quest for the DependentVariable. *Inf. Syst. Res.* 3 (1), 60–95. doi:10.1287/isre.3.1.60

Düdder, B., Fomin, V., Gürpinar, T., Henke, M., Iqbal, M., Janavičienė, V., et al. (2021). Interdisciplinary blockchain education: Utilizing blockchain technology from various perspectives. *Front. Blockchain* 3, 578022. doi:10.3389/fbloc.2020.578022

Easterby-Smith, M., and Lyles, M. A. (2011). In praise of organizational forgetting. *J. Manag. Inq.* 20 (3), 311–316. doi:10.1177/1056492611408508

Elkington, J. (1997). *Cannibals with forks: The Triple Bottom line of 21st century business*. Oxford: Capstone.

Esmaeilian, B., Sarkis, J., Lewis, K., and Behdad, S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0. *Resour. Conserv. Recycl.* 163, 105064. doi:10.1016/j.resconrec.2020.105064

Fill, H. G., and Meier, A. (2020). *Blockchain - grundlagen, Anwendungsszenarien und Nutzungspotenziale*. Wiesbaden: Springer.

German Federal Ministry for Economic Affairs and Energy (2019). Blockchain strategy of the federal government. Available at: https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/blockchain-strategy.pdf?__blob=publicationFile&v=3 (Accessed 04 09, 2022).

Große, N., Gürpinar, T., and Henke, M. (2021). "Blockchain-enabled trust in intercompany networks applying the agency theory," in Blockchain and Internet of Things Conference, Ho Chi Minh City, Vietnam.

Große, N., Leisen, D., Gürpinar, T., Schulze Forsthövel, R., Henke, M., and ten Hompel, M. (2020). "Evaluation of (De-)Centralized IT technologies in the fields of cyber-physical production systems," in Proceedings of the Conference on Production Systems and Logistics : CPSL 2020, Hannover, 377–387.

Gulati, R. (1998). Alliances and networks. *Strateg. Manag. J.* 19 (4), 293–317. doi:10.1002/(sici)1097-0266(199804)19:4<293::aid-smj982>3.0.co;2-m

Gürpinar, T., Austerjost, M., Kamphues, J., Maaßen, J., Yildirim, F., and Henke, M. (2022a). "Blockchain technology as the backbone of the internet of things - a taxonomy of blockchain devices," in Proceedings of the Conference on Production Systems and Logistics: CPSL 2022, Hannover. Editors D. Herberger and M. Hübner, 733–743. doi:10.15488/12170

Gürpinar, T., Große, N., Schwarzer, M., Burov, E., Stammes, R., Ioannidis, P., et al. (2022b). "Blockchain technology in supply chain management - A discussion of current and future research topics," in *Science and Technologies for Smart Cities*. SmartCity 360 2021. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. Vol. 442. Springer, Cham. doi:10.1007/978-3-031-06371-8_32

Gürpinar, T., Guadiana, G., Ioannidis, P., Straub, N., and Henke, M. (2021). *The current state of blockchain applications in supply chain management*. Shanghai: International Conference on Blockchain Technology. doi:10.1145/3460537.3460568

Gürpinar, T., Harre, S., Henke, M., and Saleh, F. (2020). *Blockchain technology – integration in supply chain processes*, 29. Hamburg, Germany: Hamburg International Conference of Logistics.

Henke, M., Besenfelder, C., Kaczmarek, S., and Fiolka, M. (2020). "A vision of digitalization in supply chain management and logistics," in Proceedings of the Conference on Production Systems and Logistics : CPSL, Hannover. Editors P. Nyhuis, D. Herberger, and D. Hübner. doi:10.15488/9669

Henke, M. (2003). *Strategische Kooperationen im Mittelstand: Potentiale des Coopetition Konzeptes für kleine und mittlere Unternehmen (KMU)*. Dissertation. Verlag Wiss. und Praxis.

Hirnle, C., and Hess, T. (2004). Rationale IT-Investitionsentscheidungen: Hürden und Hilfsmittel. *Z. Control. Manag.* 48, 86–95. doi:10.1007/bf03255759

Holm, K., and Goduscheit, R. C. (2020). "Assessing the technology readiness level of current blockchain use cases," in IEEE Technology & Engineering Management Conference (TEMSCON), 1–6. doi:10.1109/TEMSCON47658.2020.9140147

Honkanen, P., Westerlund, M., and Nylund, M. (2019). "Governance in decentralized ecosystems," in *Cloud computing* (Venice: The Tenth International Conference on Cloud Computing, GRIDs, and Virtualization), 49–54.

Ilbiz, E., and Durst, S. (2019). The appropriation of blockchain for small and medium-sized enterprises. *J. Innovation Manag.* 7, 26–45. doi:10.24840/2183-0606_007.001_0004

Iqbal, M., and Matulevičius, R. (2019). "Blockchain-based application security risks: A systematic literature review," in *Advanced information systems engineering workshops*. Editors H. Proper and J. Stirna (Cham: Springer), 349. CAiSE 2019. Lecture Notes in Business Information Processing. doi:10.1007/978-3-030-20948-3_16

Jesson, J., Matheson, L., and Lacey, F. (2011). *Doing your literature review: Traditional and systematic techniques*. London: Sage.

Jugović, A., Bukša, J., Dragoslavić, A., and Sopta, D. (2019). The possibilities of applying blockchain technology in shipping. *Pomorstvo* 33 (2), 274–279. doi:10.31217/p.33.2.19

Kesten, R., Müller, A., and Schröder, H. (2013). *IT-Controlling: IT-Strategie, Multiprojekt- management, Projektcontrolling und Performancekontrolle*. 2nd Ed. Vahlen.

Kouhizadeh, M., Sarkis, J., and Zhu, Q. (2019). At the nexus of blockchain technology, the circular economy, and product deletion. *Appl. Sci.* 9, 1712. doi:10.3390/app9081712

Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. *Int. J. Inf. Manag.* 60, 102376. doi:10.1016/j.ijinfomgt.2021.102376

Kulabukhova, N., Ivashchenko, A., Tipikin, I., and Minin, I. (2019). "Self-sovereign identity for IoT devices," in *International conference on computational science and its applications* (Cham: Springer), 472–484.

Lacity, M. C. (2018). Addressing key challenges to making enterprise blockchain applications a reality. *MIS Q. Exec.* 17 (3), 201–222.

Leng, J., Guolei, R., Jiang, P., Xu, K., Liu, Q., Zhou, X., et al. (2020). Blockchain-empowered sustainable manufacturing and product lifecycle management in industry 4.0: A survey. *Renew. Sustain. Energy Rev.* 132, 110112. doi:10.1016/j.rser.2020.110112

Li, J., Greenwood, D., and Kassem, M. (2019). Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. *Automation Constr.* 102, 288–307. doi:10.1016/j.autcon.2019.02.005

Lo, S. K., Xu, X., Chiam, Y. K., and Lu, Q. (2017). "Evaluating suitability of applying blockchain," in 2017 22nd international conference on engineering of complex computer systems (ICECCS), Fukuoka, Japan (IEEE), 158–161.

Lyons, T., Courcelas, L., and Timsit, K. (2019). Legal and regulatory framework of blockchains and smart contracts. Available at: https://www.eublockchainforum.eu/sites/default/files/reports/report_legal_v1.0.pdf (Accessed 04 10, 2022).

Mammadzada, K., Iqbal, M., Milani, F., García-Bañuelos, L., and Matulevičius, R. (2020). "Blockchain oracles: A framework for blockchain-based applications," in *International conference on business process management* (Cham: Springer), 19–34.

Manupati, V. K., Schoenherr, T., Ramkumar, M., Wagner, S. M., Krishna, S., and Singh, I. R. (2020). A blockchain-based approach for a multi-echelon sustainable supply chain. *Int. J. Prod. Res.* 58 (7), 2222–2241. doi:10.1080/00207543.2019.1683248

Martínez-Ríos, F. O., Marmolejo-Saucedo, J. A., and Abascal-Olascoaga, G. (2020). "A new protocol based on blockchain technology for transparent operation of corporate social responsibility," in *Strategy, power and CSR: Practices and challenges in organizational management*. Editors S. García-Álvarez and C. Atristain-Suárez (Bingley: Emerald Publishing Limited), 205–233. doi:10.1108/978-1-83867-973-620201012

Mylrea, M., and Gourisetti, S. N. G. (2018). "Blockchain for supply chain cybersecurity, optimization and compliance," in *2018 resilience week (RWS)* (Denver, CO: IEEE), 70–76.

Nauclér, T. (2021). Sustainable enterprise, McKinsey sustainability. Available at: https://www.mckinsey.com/business-functions/sustainability/how-we-help-clients/sustainable-enterprise (Accessed 08 25, 2021).

Nikolaou, I., Tsalis, T., and Evangelinos, K. (2018). A framework to measure corporate sustainability performance: A strong sustainability-based view of firm. *Sustain. Prod. Consum.* 18, 1. doi:10.1016/j.spc.2018.10.004

Önder, I., and Treiblmaier, H. (2018). Blockchain and tourism: Three research propositions. *Ann. Tour. Res.* 72 (C), 180–182. doi:10.1016/j.annals.2018.03.005

Pai, S., Buvat, J., Lise, O., Karanam, T., Sevilla, M., Schneider-Maul, R., et al. (2018). Does blockchain hold the key to a new age in supply chain transparency and trust? Available at: https://www.capgemini.com/de-de/wp-content/uploads/sites/5/2018/10/Digital-Blockchain-in-Supply-Chain-Report-3.pdf (Accessed 04 10, 2022).

Paik, H.-Y., Xu, X., Bandara, H. D., Lee, S. U., and Lo, S. K. (2019). Analysis of data management in blockchain-based systems: From architecture to governance. *Ieee Access* 7, 186091–186107. doi:10.1109/access.2019.2961404

Paliwal, V., Chandra, S., and Sharma, S. (2020). Blockchain technology for sustainable supply chain management: A systematic literature review and a classification framework. *Sustainability* 12, 7638. doi:10.3390/su12187638

Park, A., and Li, H. (2021). The effect of blockchain technology on supply chain sustainability performances. *Sustainability* 13 (4), 1726. doi:10.3390/su13041726

Pedersen, A. B., Risius, M., and Beck, R.University of Queensland; IT University at Copenhagen (2019). A ten-step decision path to DetermineWhen to use blockchain technologies. *MIS Q. Exec.* 18, 115. doi:10.17705/2msqe.00010

Perez, G. C., and Korth, B. (2020). "Digital twin for legal requirements in production and logistics based on the example of the storage of hazardous substances," in *2020 IEEE international conference on industrial engineering and engineering management (IEEM)* (Singapore: IEEE), 1093–1097.

Prasad, S., Shankar, R., Gupta, R., and Roy, S. (2018). A TISM modeling of critical success factors of blockchain based cloud services. *J. Adv. Manag. Res.* 15 (4), 434–456. doi:10.1108/JAMR-03-2018-0027

Rane, S. B., Thakker, S. V., and Kant, R. (2020). Stakeholders' involvement in green supply chain: A perspective of blockchain IoT-integrated architecture. *Manag. Environ. Qual.* 32 (6), 1166–1191. doi:10.1108/MEQ-11-2019-0248

Rauchs, M., Blandin, A., Bear, K., and McKeon, S. B. (2022). Global enterprise blockchain benchmarking study. Available at: https://ssrn.com/abstract=3461765 (Accessed 04 09, 2022).

Reilly, E., Maloney, M., Siegel, M., and Falco, G. (2019). "A smart city iot integrity-first communication protocol via an ethereum blockchain light client," in *Proceedings of the international workshop on software engineering research and practices for the internet of things (SERP4IoT 2019)* (Marrakech, Morocco, 15–19. doi:10.1109/SERP4IoT47439.2019

Rodriguez, M., Nicolás, R., Rio-Belver, R., and Rodriguez-Andara, A. (2019). "Lessons learned in assessment of technology maturity," in Proceedings of the 11th International Conference on Industrial Engineering and Industrial Management. Editors A. Ortiz, C. Andrés Romano, R. Poler, and J. P. García-Sabater (Springer, Cham: Engineering Digital Transformation. Lecture Notes in Management and Industrial Engineering), 103–110. doi:10.1007/978-3-319-96005-0_14

Saberi, S., Kouhizadeh, M., Sarkis, J., and Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *Int. J. Prod. Res.* 57 (7), 2117–2135. doi:10.1080/00207543.2018.1533261

Sadiq, S., Governatori, G., and Namiri, K. (2007). "Modeling control objectives for business process compliance," in *) Business Process Management. BPM 2007. Lecture Notes in Computer Science*. Editors G. Alonso, P. Dadam, and M. Rosemann (Berlin, Heidelberg: Springer) Vol. 4714. doi:10.1007/978-3-540-75183-0_12

Schwarzer, M. E. (2021). "Governing blockchain networks," in *International purchasing and supply education and research association conference proceedings: 'Purchasing innovation and crisis management* (International Purchasing and Supplier Education and ResearchAssociation (IPSERA)). 30th Annual Meeting.

Sedlmeir, J., Buhl, H., Fridgen, G., and Keller, R. (2020). The energy consumption of blockchain technology: Beyond myth. *Bus. Inf. Syst. Eng.* 62, 599–608. doi:10.1007/s12599-020-00656-x

Seebacher, S., and Schüritz, R. (2019). "Blockchain - just another IT implementation? A comparison of blockchain and interorganizational information," in European Conference on Information Systems (ECIS 2019) (Stockholm, Sweden.

Shrestha, A. K., Vassileva, J., and Deters, R. (2020). A blockchain platform for user data sharing ensuring user control and incentives. *Front. Blockchain* 3, 497985. doi:10.3389/fbloc.2020.497985

Smits, M., and Hulstijn, J. (2020). Blockchain applications and institutional trust. *Front. Blockchain* 3, 5. doi:10.3389/fbloc.2020.00005

Sunyaev, A., Kannengießer, N., Beck, R., Treiblmaier, H., Lacity, M., Kranz, J., et al. (2021). Token economy. *Bus. Inf. Syst. Eng.* 63, 457–478. doi:10.1007/s12599-021-00684-1

Tiscini, R., Testarmata, S., Ciaburri, M., and Ferrari, E. (2020). The blockchain as a sustainable business model innovation. *Manag. Decis.* 58 (8), 1621–1642. doi:10.1108/md-09-2019-1281

Uebel, M., and Helmke, S. (2013). Analyse der Wirtschaftlichkeit von CRM-Lösungen. In: S. Helmke, M. Uebel, and W. Dangelmaier: *Effektives customer relationship management, 5*. Wiesbaden: Springer Fachmedien Wiesbaden, S. 311–324.

Vadgama, N., and Tasca, P. (2021). An analysis of blockchain adoption in supply chains between 2010 and 2020. *Front. Blockchain* 4, 610476. doi:10.3389/fbloc.2021.610476

Vogel, J., Hagen, S., and Thomas, O. (2019). "Discovering blockchain for sustainable product-service systems to enhance the circular economy," in International Conference on Wirtschaftsinformatik (WI 2019) (Siegen, Germany: Februar), 24–27.

Weill, P. (2004). Don't just lead, govern: How top-performing firms govern IT. *MIS Q. Exec.* 3 (1), 1–17.

Weking, J., Mandalenakis, M., Hein, A., Hermes, S., Böhm, M., and Krcmar, H. (2020). The impact of blockchain technology on business models – A taxonomy and archetypal patterns. *Electron. Mark.* 30 (2), 285–305. doi:10.1007/s12525-019-00386-3

Whyte, C. (2019). *Cryptoterrorism: Assessing the utility of blockchain technologies for terrorist enterprise*. Studies in Conflict & Terrorism, 1–24.

Wunderlich, S., and Saive, D. (2020). "The electronic bill of lading: Challenges of paperless trade," in *BLOCKCHAIN 2019* (Springer, Cham: Advances in Intelligent Systems and Computing), Vol. 1010. doi:10.1007/978-3-030-23813-1_12

Yoo, M., and Won, Y. (2018). A study on the transparent price tracing system in supply chain management based on blockchain. *Sustainability* 10 (11), 4037. doi:10.3390/su10114037

Yuthas, K., Yolanda, S., and Asad, A. (2021). Strategic value creation through enterprise blockchain. *JBBA.* 4, 1–10. doi:10.31585/jbba-4-1-(7)2021

Zavolokina, L., Ziolkowski, R., Bauer, I., and Schwabe, G. (2020). Management, governance and value creation in a blockchain consortium. *MIS Q. Exec.* 19 (1)–17. doi:10.17705/2msqe.00022

Zhang, A., Zhong, R. Y., Farooque, M., Kang, K., and Venkatesh, V. G. (2020). Blockchain-based life cycle assessment: An implementation framework and system architecture. *Resour. Conservation Recycl.* 152, 104512. doi:10.1016/j.resconrec.2019.104512

Ziolkowski, R., Parangi, G., Miscione, G., and Schwabe, G. (2019). "Examining gentle rivalry: Decision-making in blockchain systems," in 52nd Hawaii International Conference on SystemSciences (HICSS 2019) (Hawaii: Maui).