Challenges and opportunities for Blockchain Technology adoption: A systematic review

Full Paper

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Abstract

Blockchain technology promises to significantly impact current business processes in industries from various sectors and reduce transactional cost. Firms, suppliers, government, financial institutions etc. are anticipating a business model transformation through blockchain by accomplishing a decentralized architecture of interorganizational dealings without intermediaries. In spite of its immense potential, however, there are key challenges of blockchain implementation which need to be studied for identifying the opportunities arising and for its successful implementations in future. In this paper, we aim to identify these challenges for blockchain adoption and classify them for clearer understanding. To pursue this effectively, this paper follows a hybrid model of systematic literature review. This paper also explicitly enumerates future research opportunities to lead industry and researchers in correct directions.

Keywords: Blockchain, Adoption, Challenges, Opportunities

1   INTRODUCTION

Blockchain, the underlying technology for bitcoins, is considered as a solution to many business problems. Initiated as a peer to peer network (Nakamoto 2008), it was originally launched with the idea of performing financial transactions without the need of intermediaries (Al-Saqaf and Seidler 2017). The strong point of blockchain is data integrity and this is why it can be seen as a strong candidate for other services and applications such as supply chain, decentralized trading etc. (Yli-Huumo et al. 2016). As per the Gartner's Hype cycle 2016, it was seen reaching the peak of inflated expectations. According to recent cycle, it is placed in the top 5 technology trends (Morkunas et al. 2019).

One of the reading by a Gartner researcher said that "the original concept by Satoshi Nakamoto in 2008 only discusses Block of records and chain them, it did not describe the noun termed "Blockchain", and it was just peer to peer version of electronic cash" (Gartner 2018). Though many popular organisations are trying to tie either their roots or leaves with the name blockchain, as it can reduce the cost of transactions and, if adopted widely, reshape the economy (Iansiti and Lakhani 2017), as a human, there are still doubting questions that arise when it comes to this disruptive technology. The image of the blockchain we are dealing with, is losing its' trust or it is unable to gain the value as a result of the lack of security that bitcoin encountered (Iansiti and Lakhani 2017). Anonymity, data integrity and security set a lot of challenges and questions need to be solved and assessed with high quality research (Yli-Huumo et al. 2016). There are still many open issues that need to be further researched and analysed to create more workable and effective industrial applications that can fully benefit the use of blockchain and achieve the intended goals (Al-Jaroodi and Mohamed 2019). Major blockchain projects are a result of failed innovation and not using blockchain at appropriate places which leads to false sense of blockchain based business model (Gartner 2018). A research mentioned that if the problem is organizational rather than interorganizational then blockchain would not be the right solution to implement (Wang et al. 2019). Applying blockchain technology without appropriately guaranteeing its operation or applying it to scenarios where cost does not compensate, is an important risk one can fall under easily (Reyna et al. 2018).

There are several studies to show the challenges associated with blockchain in various terms. Regardless of the numerous applications of blockchain there are challenges and risks that need to be considered and addressed to yield a positive outcome impact on the society (Al-Saqaf and Seidler 2017). Albeit the key idea behind blockchain seems simple but the implementation holds a great number of challenges (Reyna et al. 2018). This paper aims to identify these challenges in relation to adoption of blockchain by organisations. Also to review the emerging trend of blockchain issues and identify the recent research opportunities in the area. And this in turn will enable the decision-makers to prioritize the challenges to be addressed at first.

The rest of the paper is organised as follows. The second section provides the background about blockchain and its' applications followed by third section that discusses the systematic review method. Fourth section gives the contribution of the paper by identifying the challenges as per the literature and summarising them in a domain. The last section brings out the future research opportunities and conclusion.

2   BLOCKCHAIN BACKGROUND

There are numerous definitions of blockchain but it is commonly referred as shared and distributed database of transactions (Carson et al. 2018; Casino et al. 2018). Blockchain is a distributed ledger or an accounting book (Al-Saqaf and Seidler 2017). For this study we use to define blockchain as "a technology that enables immutability and integrity of data in which a record of transaction made in a system is maintained across several distributed nodes that are linked in a peer to peer network" (Viriyasitavat and Hoonsopon 2019).

To get a deep insight into a blockchain world, it is better to start with the brief structure. In plain terms, blockchain can be seen as a basic data structure like linked list. This list is linked as a network of nodes. Nodes can also be referred to as an entity that connects to blockchain (Casino et al. 2018). These nodes are the decision makers in blockchain for a transaction validation (Koteska et al. 2017). The core process of any business is to keep a track record of every transaction (Iansiti and Lakhani 2017). When a transaction enters into blockchain, it is verified and validated through stages of confirmation by the nodes (Koteska et al. 2017). Once a transaction is broadcasted it cannot be hampered. Nodes group the transactions into blocks and the nodes that verify the blockchain rules for transactions are known as full nodes (Casino et al. 2018).

Blockchain can empower trade, expression, democratic participation, social interaction and financial freedom (Al-Saqaf and Seidler 2017). Most of the developers and researchers are well aware of the potentials of blockchain and are on the way of exploring various blockchain applications across sectors (Christidis and Devetsikiotis 2016). Blockchain has the immense potential to disrupt the energy related products and commodities, and as they become digital assets they can be traded interoperably (Andoni et al. 2019). Blockchain enables promising applications in financial, healthcare, logistics, manufacturing, agriculture and food, robotics, entertainment and construction domains (Al-Jaroodi and Mohamed 2019). The unique requirement of healthcare like authentication, interoperability, data sharing , the transfer of medical records and considerations for mobile health can be fulfilled by a blockchain solution (McGhin et al. 2019). Blockchain allows individuals and organisations in a supply chain to make and verify transactions without a central controlling authority (Wang et al. 2019). There are many literatures that say that blockchain is a transformative foundational technology (Iansiti and Lakhani 2017). Some of them have even compared it with the development of other foundational technologies like TCP/IP or Internet (Iansiti and Lakhani 2017; Tapscott and Tapscott 2016).

A report by Deloitte (Deloitte 2018) suggested that in their survey, 74% of the respondents see a fruitful business case with blockchain technology. As per an IBM report, (IBM 2017) almost 33% of C-class executives declare considering blockchain or have already started engaging into it. Another survey from a German energy agency (Burger et al. 2016), suggested that almost 20% of the decision makers in energy industry believe that blockchain technology is a game changer for energy suppliers. Several researches prove that blockchain reduces the cost of transactions (Iansiti and Lakhani 2017; Morkunas et al. 2019). Companies have started investing in blockchain, because along with minimising the transaction cost, they see the potential of decentralized architectures (Casino et al. 2018).

Even with the growing implementation of blockchain in various projects, most of the IT specialists are unable to comprehend the fundamental reason of using a blockchain especially from data management view (Casino et al. 2018). Companies face a problem in deciding which blockchain opportunities to start with (Carson et al. 2018). Before implementing blockchain based application the decision makers should realise the suitability of blockchain against the requirements (Lo et al. 2017). Companies on the way of blockchain adoption must address the key issues like smart contract design, data management, channel configuration, endorsement policies etc. (Kumar et al. 2019). A research indicated that blockchain applications need to be ameliorated in several terms like latency, scalability, throughput, cost-effectiveness etc. (Koteska et al. 2017). Unstructured experimentation of blockchain is another challenge that will lead to failure of implementation and many companies will not see their return on investment (Carson et al. 2018). These challenges are the bottleneck on the way of blockchain adoption. Companies can avoid the lure of developing a solution by addressing the critical challenges (Carson et al. 2018).

Business executive must be convinced that they understand and have the idea of the impact and risk on business model before making any transformation (Iansiti and Lakhani 2017). Therefore there is a need to systematically review the challenges associated with blockchain.

3   SYSTEMATIC REVIEW METHOD

The systematic literature review is defined as a technique used for hypothesis testing, assessing the consistency among previous studies and for summarising the results of existing studies (Higgins and Green 2011). By reviewing the previous work, systematic literature review is a time framed, process oriented and effective approach to uncover the yet covered issues in the literature enabling to provide new research directions. It also promises that all the relevant literature for a domain is well considered. Thus having a systematic literature review is a suitable approach in understanding the challenges associated with blockchain adoption.

 To pursue this we mixed two approaches. The overall framework adopted to conduct the review is a methodological framework in a step by step format that not only produces "systematic" results but also "scientific" outcomes which is designed to generate reproducible outcomes (Okoli and Schabram 2010). The suggested approach included eight steps- purpose of review, protocol and training, search of the literature, practical screening, quality appraisal, data extraction, synthesis of studies, and writing the review. For this study, we modified the framework for search and practical screening of literature and adopted the inner circle of search and acquisition of literature from hermeneutic framework for literature review (Boell and Cecez-Kecmanovic 2014). The iterative nature of circle of search resulted in better understanding and extension of preunderstandings and ideas in the literature.

The first step is to define the purpose of review that clearly identifies the purpose and intended goals of the review (Okoli and Schabram 2010). At this step, we discovered the purpose of this study, which is to

identify the emerging challenges with blockchain, and by identifying the theme in the literature provide a framework for classification of those challenges and analyse the future research opportunities out of the work reviewed. This step is generally addressed in the introduction section as to why there is a need of this literature review (Okoli and Schabram 2010). The second step is also associated with the planning phase for research- protocol and training. A protocol is a "plan that describes the conduct of a literature review" (Keele 2007). At this step the research questions are formulated, research protocol is created and the reviewers are trained (Okoli and Schabram 2010). For this study, we identified the following research questions:

1. What are the blockchain adoption challenges mentioned in the literature?

2. What blockchain research opportunities are highlighted by the literature?

To answer these questions we followed a plan to review the major databases – Scopus, ScienceDirect, Elsevier, Springer etc. Then came up with the road map to be followed for the review. In the third and fourth step the actual framework concludes the selection of literature by searching the literature and practical screening (Okoli and Schabram 2010). For this study we studied various frameworks of conducting a systematic literature review and identified hermeneutic framework, which is based on hermeneutic philosophy, enabling rich theoretical base for understanding and describing the review process (Boell and Cecez-Kecmanovic 2014). Although the hermeneutic framework consist of two circles- inner circle for search and acquisition and a wider circle for analysis and interpretation. For this study, we adopted a part of this framework, the search and acquisition circle as it provides a rigorous process of identifying relevant literature.

The more literature we gather and acquire the more imperative it becomes to interpret, clarify and understand the diversity of ideas and findings in the literature (Boell and Cecez-Kecmanovic 2014). Searching the major databases mentioned, we sorted the citations from the year 2016 to 2019, to gather the recent trend of literature. Selecting the relevant literature by using keywords "Blockchain", "Adoption", "Challenges" and "Opportunities", we acquired 139 papers on Scopus and 70 from other databases. Limiting the language to English and with only full paper availability, the study started with full paper reading of 58 papers. By reading individual papers, new literature sources of potential interest are identified which refines the search strategy and the hermeneutic circle continues (Boell and Cecez-Kecmanovic 2014). However, due to novelty of technology, scarcity of literature on the specific key terms, lack of availability of papers on databases and rigorous refinement of quality work in literature, the study was left with 35 papers. Most of the methods do not differentiate between the quality standards for qualitative and quantitative studies (Okoli and Schabram 2010), but following this approach provided us a good understanding to focus on quality of literature selected for the study.

Continuing with the eight step approach, we reached the next stage of quality appraisal and decided not to include poor quality "grey literature" for the review, however we included some good quality business reviews and press releases like one from Australian Computer Society, Deloitte etc. With limiting the quality of reviewed work to peer reviewed journals, good quality conference papers, expert business reviews and reports- the study finalised to conduct a review of 32 papers. At the next step, the data was extracted qualitatively that enabled us to identify various challenges on blockchain and potential research opportunities. At the next step, for this study we analysed the data, identified the thematic nature arousing from the literature and provided a framework for classification of blockchain adoption challenges, which are discussed in the next section of the paper. This modified framework adopted from (Boell and Cecez-Kecmanovic 2014; Okoli and Schabram 2010) helped to assure a rigorous review and provided an effective reproducibility of results.

4   BLOCKCHAIN CHALLENGES

The review of literature reveals a theme of technical and non-technical challenges for blockchain. When further investigated the technical issues more precisely, relate to the computational parts of blockchain. Although there are other interoperability and security issues that seem to be technical but literature has considered them as a separate domain. Other challenges like standardization and the lack of legacy systems for blockchain emerge as more of societal and concerns the government and legal authorities of a geographical area. The lack of skills, resources and the platform capabilities required for blockchain implementation has more to do with the business capabilities who is trying to implement blockchain. Thus, this study identifies the theme of the challenges and issues discussed and classifies the challenges as- organisational, governmental, technical and security and privacy issues and propose a framework illustrated in Figure 1. This classification will help identify the decision makers to address the organisational issues prior to actual start of the blockchain project. They could take specific solutions to

integrate the blockchain with the current system effectively by identifying and addressing the integration loop holes in their project.

The following table (Table 1) presents the summarisation of challenges from the literature review:

Challenges	Sub Categories	Reference from the literature
Organisational challenges	▪ Lack of blockchain professionals ▪ Cultural resistance ▪ Lack of infrastructure for blockchain computation	(Kumar et al. 2019), (Al-Jaroodi and Mohamed 2019), (Andoni et al. 2019), (Fraga-Lamas and Fernandez-Carames 2019), (Lu et al. 2019), (Moin et al. 2019), (Reyna et al. 2018), (Viriyasitavat et al. 2019), (Wang et al. 2019), (Dai and Vasarhelyi 2017), (George et al. 2019), (Mendling et al. 2018), (Wang et al. 2016), (Tönnissen and Teuteberg 2018), (Koteska et al. 2017), (Siyal et al. 2019), (ACS 2019), (Yli-Huumo et al. 2016)
Governmental challenges	▪ No legal laws for disputes ▪ No government support ▪ Lack of standardization	(Varghese et al. 2018), (Kumar et al. 2019), (Al-Jaroodi and Mohamed 2019), (Andoni et al. 2019), (Fraga-Lamas and Fernandez-Carames 2019), (Lu et al. 2019), (Moin et al. 2019), (Reyna et al. 2018), (Unal et al. 2019), (Vitaliy Vladimirovich and Kalyuzhnova 2018), (George et al. 2019), (Lin and Liao 2017), (Siyal et al. 2019), (ACS 2019), (Yli-Huumo et al. 2016)
Technical challenges	▪ Increasing size ▪ Performance issues ▪ High computational power ▪ Latency issues ▪ Blockchain integration	(Varghese et al. 2018), (Kumar et al. 2019), (Al-Jaroodi and Mohamed 2019), (Andoni et al. 2019), (Fraga-Lamas and Fernandez-Carames 2019), (Lu et al. 2019), (Moin et al. 2019), (Mott 2018), (Reyna et al. 2018), (Viriyasitavat et al. 2019), (Vitaliy Vladimirovich and Kalyuzhnova 2018), (Wang et al. 2019), (Dai and Vasarhelyi 2017), (George et al. 2019), (Mendling et al. 2018), (Wang et al. 2016), (Lin and Liao 2017), (Tönnissen and Teuteberg 2018), (Koteska et al. 2017), (Siyal et al. 2019), (ACS 2019), (Yli-Huumo et al. 2016)
Security and privacy challenges	▪ Possible security threats ▪ The majority attack ▪ Data confidentiality	(Varghese et al. 2018), (Kumar et al. 2019), (Al-Jaroodi and Mohamed 2019), (Andoni et al. 2019), (Fraga-Lamas and Fernandez-Carames 2019), (Moin et al. 2019), (Mott 2018), (Reyna et al. 2018), (Unal et al. 2019), (Viriyasitavat et al. 2019), (Vitaliy Vladimirovich and Kalyuzhnova 2018), (Wang et al. 2019), (George et al. 2019), (Mendling et al. 2018), (Wang et al. 2016), (Lin and Liao 2017), (Koteska et al. 2017), (Siyal et al. 2019), (Yli-Huumo et al. 2016)

Table 1: Blockchain Challenges summary

4.1   Organisational Challenges

There are several organisational factors that challenge the mainframe adoption of blockchain like lack of awareness, organisational culture, implementation cost etc. With the continuous shortage of skilled technical workforce, it is a challenge to find and train the required professionals for blockchain projects (Al-Jaroodi and Mohamed 2019). Moreover, intermediaries may become reluctant of blockchain adoption as they may have the fear of being removed (Wang et al. 2019). For example, banks may resist to coordinate business transactions enabled by blockchain. Result of this cultural resistance and the traditional business processes are a major challenge in blockchain adoption. The cost of implementing a blockchain application can also be an issue as it require technical and specialised expertise for its participation (Wang et al. 2019). The mainstream adoption of blockchain technology in large corporate systems completely depends on the project development of large storage systems, wider bandwidth for data transmission and increase in the computational power (Dai and Vasarhelyi 2017). For an example the data synchronization capability of the system may be lower than the number of transactions required to be stored over blockchain (Al-Jaroodi and Mohamed 2019).

4.2   Governmental Challenges

Many countries are thinking to adopt blockchain applications in government setting (Ølnes et al. 2017). Although blockchain based smart contracts can provide proof of technical authorship, the legal system still lacks the laws for technical disputes in blockchain application. For an example the smart contract technically binds the parties together without them knowing each other directly, which would lead them to disputes and the problem of legal issues may arise (Al-Jaroodi and Mohamed 2019). With the increasing number of blockchain adoption there will be an increasing need to address the issue of standardization (Ølnes et al. 2017). Blockchain based industrial applications require additional level of

government support in various ways and capacities (Al-Jaroodi and Mohamed 2019). It is important that all the blockchain solution are studied from the perspectives of law and order and solutions are deployed with supported regulations (Al-Jaroodi and Mohamed 2019).

4.3   Technical Challenges

To start with the technical complexities with blockchain technology makes it difficult to understand for the user (Wang et al. 2019). The continuous increasing size of blockchain is another issue. Current applications of blockchain require huge amount of transactions to be processes and linked which degrades the performance (Al-Jaroodi and Mohamed 2019). Unfortunately, to process this huge amount of corporate data blockchain demands substantial storage and computational resources (Dai and Vasarhelyi 2017), which is other big challenge with blockchain. This also results in environmental concerns in terms of energy consumption (Wang et al. 2019). Latency is another barrier in which a verified block is added to the ledger every time (Wang et al. 2016). Blockchain applications do not work in isolation and are generally integrated with other distributed applications in an organisation and beyond organisational boundaries. The different challenges need to be addressed to provide solutions that make blockchain more attractive and easier to incorporate in industrial applications (Al-Jaroodi and Mohamed 2019). Effective integration of blockchain applications with current legacy systems in organisations require careful analysis and effective approaches that will facilitate the integration while preserving the original operational standards of the legacy system (Al-Jaroodi and Mohamed 2019). Also the integration of two blockchain or the interoperability of blockchain is an unaddressed issue that falls under this classification. This challenge creates hindrances in the effective communication of data (Boulos et al. 2018).

4.4   Security and Privacy Challenges

Although blockchain promises to have an extremely secure data structure, hacking and other cyberattacks are still possible. As blockchain applications are available all over internet they are vulnerable to various cyber-attacks such as stealing, spy attempts and Denial of service (Al-Jaroodi and Mohamed 2019). For example, the data malleability attack can intercept, modify and rebroadcast a transaction causing the transaction issuer to believe that the original transaction was not confirmed (Yli-Huumo et al. 2016). The most famous of all is the 51 % attack or commonly known as the majority attack where a group miner has power over more than 50 % of the participating nodes in the blockchain (Wang et al. 2019). However, this type of attacks have been seen where the blockchain implementation was in a small community and the number of miners were less (Al-Jaroodi and Mohamed 2019). But the possibility still exists. While hacking in permissionless blockchain requires significantly high computational and monetary powers, but in case of permissioned blockchain where the community of participant is small, may be more prone to these type of cyber-attacks (Patel et al. 2017).
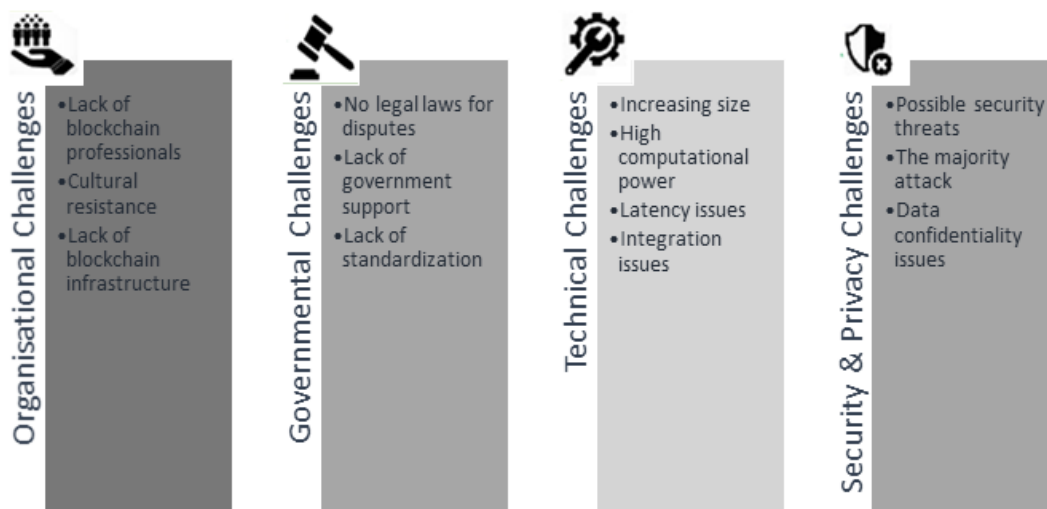

Figure 1: Proposed framework for Blockchain challenges in literature

5   FUTURE RESEARCH OPPORTUNITIES

Many blockchain project have already started getting implemented in various industries. However, the classification of challenges in this study identified critical research gaps and suggest the following 7 key future research opportunities:

- Effective integration of blockchain with the traditional legacy systems and current business processes is much required in the literature. This would help in an effective and smooth implementation process of any blockchain project. Any integration model should assure the correctness and reliability of the existing system and consistency of business data. Vigilant analysis and constructive approaches are needed to facilitate the integration of blockchain by preserving the operational standards of the current legacy system (Al-Jaroodi and Mohamed 2019).

- An empirical study examining the real time business problems that could be addressed through blockchain. There is need of framework that identifies the suitability of a business case for blockchain or vice versa. Methods that foster decentralized approaches in traditional business processes are much needed (Fraga-Lamas and Fernandez-Carames 2019). Research and reviews are suggested to realize full potential of blockchain for industrial applications (Andoni et al. 2019; Kumar et al. 2019). Cultural barrier in blockchain adoption and misinformation about it is another area that needs deliberation (Fraga-Lamas and Fernandez-Carames 2019). Blockchain applications will transform the business models. Therefore, blockchain based business models should be carefully analysed in various aspects like management control, quality and measurement etc. (Al-Jaroodi and Mohamed 2019).

- Assessing the security and privacy concerns associated with blockchain and to have tried and tested solutions. Research to focus on blockchain specific issues and attacks should be carried out (McGhin et al. 2019). There is a demanding need of blockchain specific security model to enable unbreakable confidentiality bond for industrial applications (Al-Jaroodi and Mohamed 2019). Framework that provides a comprehensive trust based model fulfilling the use of blockchain should be created (Fraga-Lamas and Fernandez-Carames 2019).

- Blockchain laws and regulation to understand the implementation of smart contracts and various disputable parts in blockchain setup are an area of concern. This would enable the government agencies to bring blockchain related regulation in practice for people. Appropriate methods are required to evaluate the endorsement policies (Kumar et al. 2019).

- There is a need to explore as to how the power consumption of blockchain can be reduced to the levels acceptable at environmental concerns. There is need to create a lightweight blockchain model that will consume less amount of resources for consensus mechanism and transaction processing (Aggarwal et al. 2019). Frameworks should be developed to provide better performance optimization of blockchain network. Research efforts should be carried out to avoid the excessive underlying complexity in blockchain implementation (Fraga-Lamas and Fernandez-Carames 2019).

- Blockchain scalability is a major area of concern for researchers and industrialists. Several researchers have suggested to address the scalability of blockchain (Al-Jaroodi and Mohamed 2019; Andoni et al. 2019). Therefore, this issue is required to be adequately addressed and tested.

- Interoperability of blockchain is an important issue with blockchain implementation. Different partners in a supply chain may join two or more different Blockchains platforms (Kumar et al. 2019). An integration model is required to consider the interoperability of blockchain while maintaining the security of all the applications involved (Al-Jaroodi and Mohamed 2019).

If we map these research opportunities with the proposed framework in Figure 1. We can clearly see that most of the suggested future research directions would address the industry specific issues, which would supporting the decision-makers for better blockchain implementation. It can be mapped as shown in Table 2.

Research Opportunities	Organisational Challenges	Governmental Challenges	Technical Challenges	Security & Privacy Challenges
Integration model	✓		✓	
Suitability framework	✓			
Security solutions	✓			✓
Blockchain laws	✓	✓		
Blockchain optimization framework	✓	✓	✓	
Blockchain scalability	✓		✓	
Interoperability of Blockchain	✓		✓	✓

Table 2: Mapping of future research opportunities that would address the challenges identified in the proposed framework

6 CONCLUSION

The study investigated the current state of challenges on the way of blockchain adoption. This has been achieved through a systematic literature review on blockchain challenges and opportunities. The findings revealed that although blockchain is seen as a promising candidate for applications in almost every industry and most of CIOs consider undertaking a blockchain project, there are still many unaddressed challenges that are being overlooked. There is a notable gap of a process to have a successful implementation of blockchain. Moreover, the lack of skilled professionals makes the task difficult to have a mainstream adoption of blockchain in major organisations. There is a need for institutions and courses dedicated for blockchain learning and implementation. This study identified all the major challenges and developed a framework that classifies all the challenges into 4 main categories- organisational, governmental, technical and privacy and security challenges. This work will help the industry managers to identify their business level issues, and as to what legal laws they need from the government, effective integration of blockchain with other blockchain and traditional system, the technical risks with blockchain and the potential security threats to the confidentiality. This will certainly help them to answer the infrastructure needed, resources and legal terms required, the data to be kept off-chain and on-chain assuring the privacy and security and the integration level issues prior bringing blockchain in the actual run. The study had some constraints mainly due to the scarcity of peer reviewed journal papers on blockchain challenges. Although this study used a broad range of keywords for search databases. The limit on the length of paper and lack of availability of literature in research journals and databases was another constraint encountered in the study. The highlighted future research opportunities will help overcome most of the literature gaps encountered and would direct IS researchers for future research in blockchain technology.

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