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Blockchain for requirements traceability: A qualitative approach

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Abstract

Blockchain technology has emerged as a "disruptive innovation" that has received significant attention in academic and organizational settings. However, most of the existing research is focused on technical issues of blockchain systems, overlooking the organizational perspective. This study adopted a grounded theory to unveil the blockchain implementation process in organizations from the lens of blockchain experts. The results revealed three main categories: key activities, success factors, and challenges related to blockchain implementation in organizations, the latter being identified as the core category, along with 17 other concepts. Findings suggested that the majority of blockchain projects stop at the pilot stage and outlined organizational resistance to change as the core challenge. According to the experts, the following factors contribute to the organizational resistance to change: innovation–production gap, conservative management, and centralized mentality. The study aims to contribute to the existing blockchain literature by providing a holistic and domain-agnostic view of the blockchain implementation process in organizational settings. This can potentially encourage the development and implementation of blockchain solutions and guide practitioners who are interested in leveraging the inherent benefits of this technology. In addition, the results are used to improve a blockchain-enabled requirements traceability framework proposed in our previous paper.

KEYWORDS
blockchain technology, grounded theory, interorganizational software projects, requirements traceability

1 | INTRODUCTION

Blockchain (BC) has been considered a cutting-edge technology with the potential to disrupt conventional domains and business models,[1] as pervasively as the Internet had done.[2] The Internet changed humans' understanding of time and space by intensifying social relations, creating a global ecosystem.[3] Within this global ecosystem, BC is transforming the nature of human relations and organizations by enabling smart contracts (SC) that ensure trust among individuals and organizations.[3] From an architectural perspective, BC is a distributed ledger technology that stores all committed transactions in an ever-growing chain of blocks.[4] The fundamental feature of BC is peer-to-peer data sharing and storage, removing the need to entrust central authorities for the maintenance of the ledger.[5] Although BC research is on the rise,[6] most of this research is focused on a technical perspective and takes a simplistic view on organizational issues.[7] Our preliminary research suggested little empirical evidence on how BC is implemented in organizational settings. Beck and Müller-Bloch[8] concluded that BC is a radical innovation, and as such, organizations engage with this technology by means of three main processes: discovery, incubation, and acceleration. Similarly, Dozier and Montgomery[9] used a grounded theory (GT) approach to unveil the BC evaluation process. To explain the evaluation process, the authors presented the proof-of-value model that is composed of three main activities: understand, organize, and test. Despite these valuable efforts, further empirical evidence is needed to enhance the understanding of the implementation process of BC in organizations.

Inherent benefits of BC, such as disintermediation, automation, trust, cost reduction, and non-repudiation have generated growing interest[10] across a variety of industry sectors ranging from financial services to manufacturing and public services.[7] Recently, an increasing number of BC applications has been noticed in the software engineering (SE) landscape.[11] BC has also been proposed to keep track of artifacts and trace links created by distributed stakeholders in interorganizational software projects.[12] This study is an extension of our previous study presented in EuroSPI conference.[12] The authors aim to improve the proposed BC-enabled requirements traceability (RT) framework by using categories and concepts grounded in data. GT was identified as the most suitable approach to unveil these categories and concepts, given the novel and multi-faced nature of BC. Data were collected through semi-structured and in-depth interviews with BC experts and analyzed by means of GT coding techniques. The results revealed the core category, *blockchain implementation in organizations*; three related categories, *key activities*, *success factors* and *challenges*; and 17 concepts to further expound on the categories.

The contributions of this study lie in two main dimensions: (i) providing evidence on the implementation process of BC in organizational settings from the lens of BC experts. This evidence may serve as a guide for researchers and practitioners who are interested in this technology, enhance the comprehension of this technology, and consequently encourage the development and implementation of BC solutions. Another is (ii) improving our previous BC-enabled RT framework[12] by supporting it with categories that are grounded in empirical data.

The sections of this study are as follows: Section 2 presents the extant literature in the fields of BC-enabled SE, and RT. Section 3 describes the research approach followed in this study, the experts' selection process, data collection, and analysis. Section 4 provides a thorough description and explanation of the key results of the study. Section 5 discusses the validity of the results and limitations of the study. In addition, this section puts the results in the context of a specific use case on the application of BC for RT in interorganizational software projects. Finally, Section 6 concludes the study and presents a set of potential future research directions.

2 | BACKGROUND

2.1 | BC for SE

BC has made the concept of “shared registry” possible for a variety of application domains ranging from cryptocurrencies to potentially any system that requires decision-making to be decentralized, reliable, and automated in a multi-stakeholder environment.[5] Recently, BC has captured the attention of SE researchers who advocate for the cross-fertilization of SE with BC technologies.[13,14] Our recent systematic mapping study on this topic revealed an increasing trend of studies that have used BC in the SE landscape since 2018.[11] A set of these studies is presented as follows. Lenarduzzi et al.[15] proposed the automation of the acceptance phase and the payment to developers by means of SC. SC are created by the customer, and then the product owner registers the following artifacts: user stories, acceptance tests that are executed by developers, and the hash of expected output. The hash of the output is assessed against the hash of the expected output and once all the tests pass, Ethers are allocated to the address of the developer. According to the authors of this study, BC can potentially transform other phases of the software lifecycle that currently depend on human rationale.

Beller and Hejderup[16] introduced two BC-enabled models: (i) a decentralized continuous integration (CI) model that aims to replace the conventional Travis CI. In this model, developers enter builds and their respective rewards to the distributed network and interested entities perform the builds. Additionally, (ii) a user-run package management system as opposed to centralized package management systems allows entities to propose new packages and validate others' work.

Yilmaz et al.[17] focused on improving the integrity of large-scale agile software development. The authors proposed a BC model that considers developers who develop code as miners and testers as the validators of the work performed by developers.

Bose et al.[18] proposed Blinker, a BC-enabled framework for trusted software provenance. The framework monitors and captures provenance data that are generated from various tools used throughout the software lifecycle. The data are modeled according to standard provenance model specification. SC are also created to validate provenance data by voting mechanisms and for compliance checking.

Yau and Patel[19] used BC to ensure trusted coordination in complex and collaborative software development. In their proposal, software teams produce software specifications for different software lifecycle phases, such as requirements, implementation and testing in {key, value} format. These specifications are then evaluated against the output generated by the other teams.

Singi et al.[20] presented a token-based incentive framework that uses BC and SC to provide transparent and reliable incentives to those software engineers who contribute to any activities of the software lifecycle. The framework entails capturing incentive policies and their associated data, monitoring events, and recording events data on the distributed ledger. These data are then assessed against incentive policies and accordingly, incentives are distributed in the form of persistent wallet tokens in an automatic fashion by means of SC.

These studies focused on improving different aspects of the software lifecycle and contributed to software being built in a reliable, transparent, and auditable manner.[20] Despite these promising contributions, the BC-enabled SE field is still emerging and further research efforts are required.[11] In this study, the authors aim to contribute to this field by presenting a BC-enabled framework for RT in interorganizational software projects.

2.2 | Requirements traceability

As software-intensive systems are becoming increasingly important in industrial projects, and more innovative and high-quality systems are required to be brought to market in a quick fashion, there is a need for efficient requirements engineering.[21] Within the requirements engineering community, RT has gained importance, as a quality attribute for software for three decades now.[22,23] The foundational work in this field has been carried out by Gotel and Finkelstein[24] with their seminal study *An analysis of the requirements traceability problem*. The authors of this study defined RT as "the ability to describe and follow the life of a requirement, in both a forwards and backwards direction …." At a fundamental scope, traceability refers to the ability to relate artifacts' data and examine these relations.[25] These relations provide valuable information that contribute to a variety of software and systems engineering activities, such as software maintenance,[26] change and defect management,[27,28] and project management.[28] Ultimately, RT ensures visibility into required elements of the development process, which leads to a better understanding of the system under development.[25]

The theoretical importance of RT would suggest a widespread use of RT in practice. However, in practice, RT has been perceived as an optional task of low priority and performed by means of ad-hoc individual efforts.[24,29] Previous studies have proposed the inclusion of gamification elements[29] and voting features into traceability tools.[30] The former aims to enhance the motivation of developers to engage in traceability tasks, and the latter enables stakeholders to identify incorrect trace links or agree on related artifacts as a result of a joint effort.

The increased need for complex and large-scale software has paved the way for the distributed development paradigm, that is, development performed by cross-organizational and distributed teams.[12] According to Maro et al.,[29] this development paradigm complicates RT as distributed teams need to share software artifacts. These artifacts can be stored in a centralized data storage and accessed by distributed and diverse teams.[29] However, these teams cannot always trust artifacts provided by the other teams as competitors and malicious entities may be involved in the collaboration.[31] The involvement of third-party vendors raises even more significant trust concerns among the participating entities.[19] The distance produced by participating entities in interorganizational software projects has been acknowledged also by Rempel et al.[32] According to the authors, traceability may contribute to bridging this distance. However, achieving complete RT in such environments is far from being trivial, due to three main problem areas: (i) different organizational background of participating entities lead to the use of a diverse set of tools and methodologies that reside within organizational boundaries[32]; (ii) contradicting organizational objectives of entities involved in the project, for instance, each entity may create trace links that are not compatible with the other entities in terms of trace links types or granularity;[30] and (iii) organizational boundaries may lead to restricted access to artifacts created by the other participating entities, due to confidentiality constraints.[30,32] Entities may have the right to access only a small subset of the entire set of artifacts generated throughout the software development lifecycle (SDLC). This small subset of artifacts is not sufficient to enable complete RT.[32] To address these challenges, this study proposes the use of BC technology as a viable technical solution with the potential to serve as a shared, trusted, and auditable traceability knowledge base.

3 | RESEARCH METHODOLOGY

3.1 | Research approach

This study adopted a qualitative approach by conducting semi-structured interviews with BC experts. BC experts were interviewed in order to provide a comprehensive, holistic, and domain-agnostic overview of the implementation of BC technology in organizational settings. The empirical work in this phase was conducted by applying traditional GT. Although a variety of methodological genres exist, researchers seem to unanimously agree that GT is a process or method by which conceptual frameworks or theories are generated from inductive analysis of data.[33–35]

In this empirical study, GT was selected as the most suitable research methodology for three main reasons. First, factors influencing the implementation of BC in organizations go beyond technical aspects. The underlying socio-technical nature of this novel technology makes it suitable for the application of GT. Second, GT contributes to investigate a novel multifaced phenomenon in detail.[36] Despite the fact that the application of BC in various domains has been explored recently, BC research remains at an early stage in terms of theoretical and empirical grounded work and methodological diversity.[3] Lastly, GT is appropriate when researchers do not have an upfront hypothesis; instead of that, they aim to construct a theory grounded in the data. In this study, GT was adopted to derive constructs grounded in the data which will be further used to improve the initial BC-enabled RT framework.[12] In addition, the study followed the GT guidelines by focusing on a wide area such as BC rather than a specific research problem.[37]

Although GT has been used vastly in social studies, applications of this method have been noticed also in human-related aspects of SE.[38,39] Figure 1 depicts the GT stages that are used in this study, adapted from Hoda et al.[38]

3.2 | Data collection

Data collection in GT is an ongoing activity to achieve theoretical saturation that refers to the point at which no new information is being acquired.[33] The initial data collection process is aimed to identify the main concepts that are then used to decide on the data to be collected in the next stages of the process.[40] This approach is referred to as theoretical sampling by Glaser[40] and is adopted by our study. The following sections describe the experts selection and interviewing processes.

3.2.1 | Experts selection

Experts should be selected so that the most credible and accurate judgments are provided. To govern the selection process, a set of criteria was formulated by considering the recommendations of NUREG-1150 cited in Li and Smidts[41]: demonstrated experience related to the topic of interest by publications, consulting firms, laboratories, or government agencies; diverse background and affiliations; and willingness to be elicited in accordance to the designed methodology. Bearing these guidelines in mind, Fehring's[42] experts selection criteria for BC was adapted. Although Fehring's[42] criteria were initially designed to select nurses to validate nursing diagnoses, they have also been tailored to the software domain.[43] Table 1 depicts the criteria for selecting BC experts, and Table 2 presents the characterization of experts.

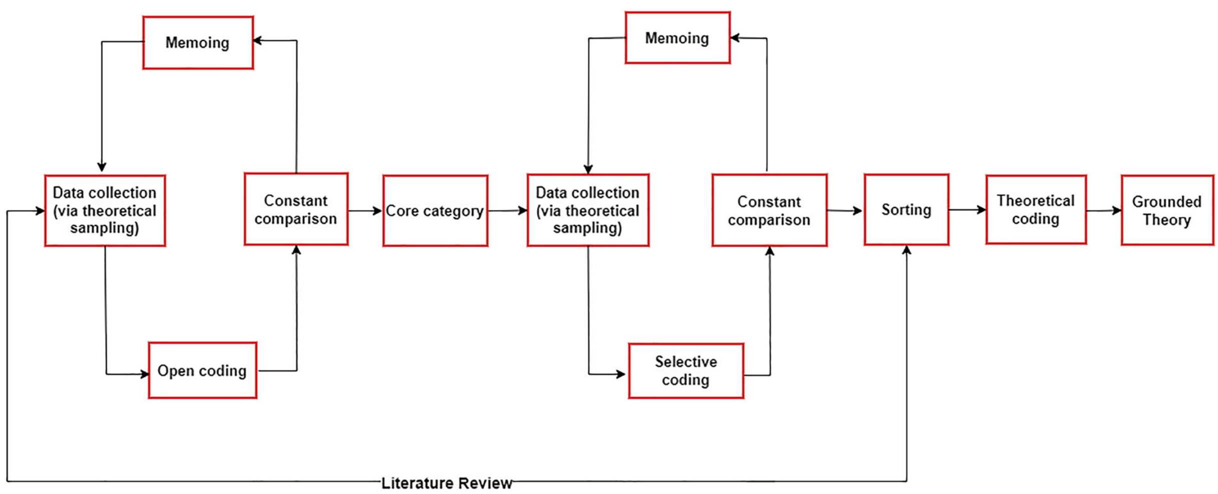

FIGURE 1 Grounded theory stages, adapted from Hoda et al.[38]

TABLE 1 Selection criteria for blockchain experts, adapted from Fehring[42]

Experts' selection criteria	Scores
C1.Over 2 years of experience in BC	04
C2.Academic experience (teaching, supervision of bachelor, master, PhD students) in BC	04
C3.PhD in BC	03
C4.Published journal articles in the field of BC	03
C5.Published conference/workshop/symposium articles/book chapters/reports in BC	02
C6.Master's degree and/or thesis in BC	01

Abbreviation: BC, blockchain.

TABLE 2 Profiling experts

Expert	+2 years of experience	Academic experience	PhD	Journal articles	Other publications	Master thesis	Score	Job position	Project domain	Country
EX1	X				X		6	Business development director	e-health, energy, supply chain	Norway
EX2	X				X		6	Solutions architect	supply chain	US
EX3	X				X		6	BC software engineer[a]	all domains	Portugal
EX4	X				X	X	7	Chief executive officer	governments, banking, e-health, energy, insurance	Norway
EX5	X				X	X	7	Researcher	marketing industry, education	Sweden
EX6		X			X		6	Associate professor	public sector	Sweden
EX7	X			X	X		9	Chief technology officer	all domains	Spain
EX8	X				X		6	Head of BC and Data strategy	banking	Norway
EX9		X	X	X	X		12	Researcher	e-health	Norway
EX10	X			X			7	Chief executive officer	all domains	Spain
N (%)	8 (80%)	2 (20%)	1 (10%)	3 (30%)	9 (90%)	2 (20%)	Avg. (7.2)			

Abbreviation: BC, blockchain.
[a]BC technical and business consultant.

The participants of this study were considered BC experts if they were evaluated with a total score of 5 or higher. Forty-five experts in the domains related to this study were identified as potential candidates by means of the personal network of the authors of this study. This sampling approach has been referred to as purposive sampling and has been mainly used in qualitative and interpretive research.[44] Purposive sampling allows the authors to exercise expert judgment.[45] To apply the selection criteria presented in Table 1, candidates' LinkedIn profiles, personal websites, and company/university webpage were thoroughly analyzed. Consequently, a set of 35 experts with a score of 5 or higher were selected and contacted by email. The final set of 10 experts was composed based on their availability and interest to participate in this study. A detailed description of the project was sent to the final set of experts prior to their participation in the study. In addition, an informed consent that outlined the implications of experts' participation in this study, their voluntariness, and anonymity rights was sent out to each of the experts (The informed consent is available online[46]). To ensure anonymity, experts of this study are referred to by IDs (EXi for i[1,10]). Table 2 presents the individual and mean scores of the final set of experts, along with other characteristics. The data indicate that the majority of the selected experts (80%) have over 2 years of practical experience with BC, although only two experts present academic experience and 90% of the experts have published conference/workshop papers, book chapters, or reports on BC-related topics.

3.2.2 | Interviews

The authors collected data by carrying out semi-structured interviews with BC experts. Semi-structured interviews were chosen due to their ability to provide rich contextual information, and to allow for flexibility and improvisation.[47] This technique enables two-way communication between the interviewer and interviewee, which makes the communication more personal and allows to uncover relevant information for the study.[48] The interviews were conducted via Zoom and lasted from 40 to 95 min. It is noteworthy that interviews were recorded with the interviewees' formal consent. Relying on GT principles,[40] the authors asked general questions about the implementation of BC in organizational settings in the first interviews. The transcribed data of these interviews were analyzed in an iterative fashion and used to formulate questions about specific items in the following interviews.

The interviews started with questions regarding the interviewee's experience related to BC and a brief description of the projects they participated. Next, interviewees were asked a set of questions regarding the implementation process of BC in organizational settings, implementation challenges and success factors, factors to be considered when planning to implement BC, and the selection process of the best fitting BC platform. A sample of the questions can be found in an online repository.[46] The data collected from these interviews were analyzed by using GT coding techniques as explained in Section 3.3, and the BC-enabled RT framework was updated accordingly (see Section 5.2). It is noteworthy that the BC experts were not provided with the framework beforehand to avoid potential biases.

3.3 | Data analysis

The data analysis approach adopted in this study relies on the traditional GT approach associated with Glaser.[34] Qualitative research is characterized by an abundance of data, which are difficult to be managed manually. To minimize human error when collecting and analyzing large amounts of data, qualitative researchers use Computer-Assisted Qualitative Data Analysis Software (CAQDAS). In this study, the authors used NVivo software to handle a large amount of qualitative data throughout the whole GT process. This software has been used by other GT studies in SE, for example, Javdani Gandomani and Ziaei Nafchi.[49] In what follows, the GT data analysis process is described.

i. *Open coding*. In this phase, transcripts were analyzed in order to comprehend the context under study.[40] The analysis aimed to identify key points. Once a key point was identified, a code was assigned to that specific key point.[40] Furthermore, the code was compared with previously identified codes in the same transcript and previous transcripts. This process has been referred to as constant comparison and enables high-level abstraction and the identification of concepts and categories.[40] The emergent categories will be used as the basis to generate the final theory.
ii. *Core category*. The open coding process terminates with the identification of the core category. The core category reflects the main concerns of the interviewees.[40] According to Glaser,[40] the core category should fulfill a set of criteria: being central, being related to the other categories meaningfully, and accounting for the majority of data variations. The core category can be identified by using the constant comparison technique on the categories and by identifying their relationships. After the first four interviews, the authors perceived "feasibility analysis" as the main category, as it was related to the other categories meaningfully. However, a more detailed analysis indicated that this category did not fit the following criteria: being central and account for the majority of data variations. Therefore, the authors continued the iterative constant comparison process and consequently, concluded that the core category was "BC implementation in organizations." The identification of the core category terminates the open coding process and paves the way to selective coding. Selective coding in GT entails coding only the core category, along with its related categories.[40]

iii. *Theoretical memoing*. The authors created memos in NVivo after each interview to express their ideas, thoughts, and insights related to an emergent code or category. This process is referred to as theoretical memoing, and it is crucial in ensuring quality in GT studies as it enables the authors to enhance relationships between codes.

iv. *Sorting*. Once data collection was finished, the authors started the sorting process. This process is useful in explaining each category and relationships in detail, consequently, formulating the theory grounded in data. It is noteworthy that the low number of interviews limits the generalizability of the emerging theory. In order to minimize this threat, the authors triangulated their findings with a minimal literature review which was performed at this stage of the process.

v. *Theoretical coding*. Theoretical coding is aimed to discover relationships between the core category and the related categories and formulate the hypotheses that explain the emergent theory. The authors identified the relationships between the core category "BC implementation in organizations" and the other related categories: *key activities*, *challenges*, and *success factors*, as presented in Figure 2. Glaser proposed a set of theories' structures, referred to as theoretical coding family.[40] In this study, the authors adopted the temporal/process coding family to explain the emerging theory, as illustrated in Figure 3. This coding family presents a category in terms of stages, timeliness, conditions, phases, actions, and temporal ordering of work.[49]

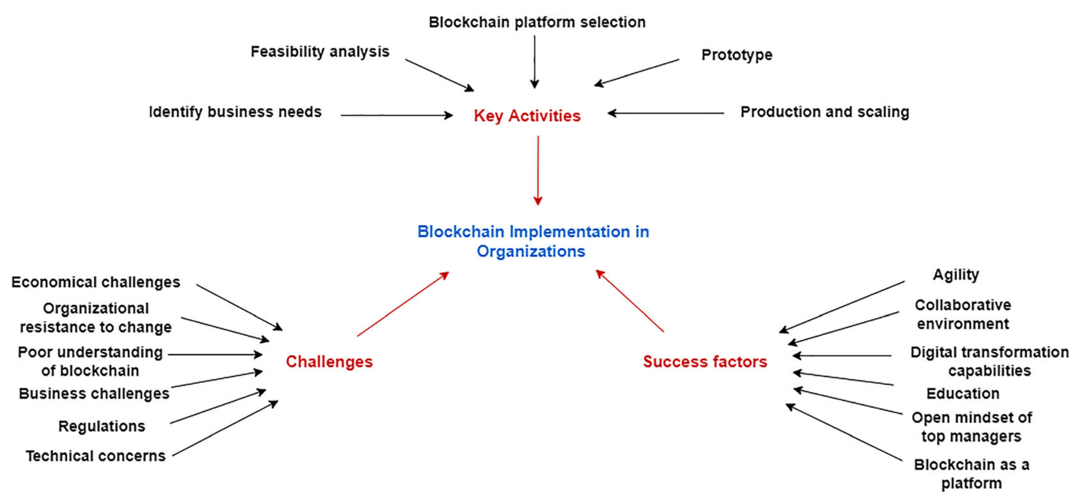

FIGURE 2 Emergence of grounded theory from the identification of categories and concepts.

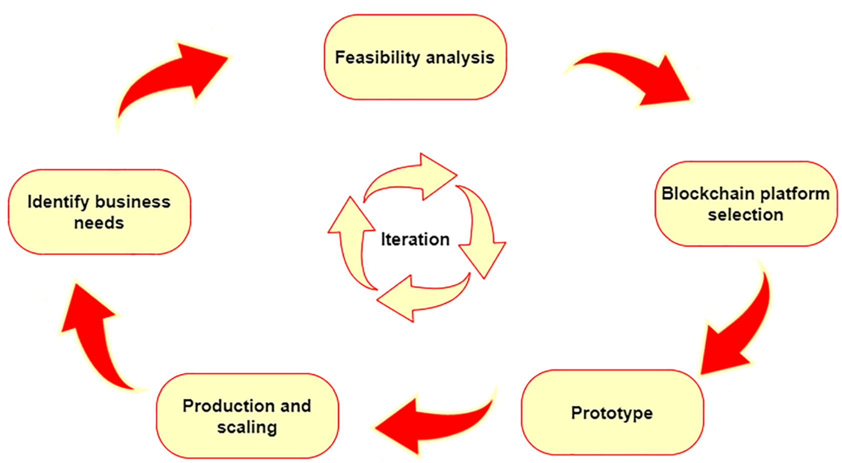

FIGURE 3 Presentation of the "key activities" category in the form of Glaser's temporal/process family

4 | RESULTS

The emergent GT in this study encompasses one core category *BC Implementation in Organizations* and three related categories: *key activities*, *challenges*, and *success factors* (see Figure 2). These categories are explained in the following sections.

4.1 | Key activities

Data analysis indicated the emergence of key activities in the implementation process of BC technology in organizational settings. These key activities are depicted in Figure 3 in the form of Glaser's temporal/process family.

4.1.1 | Identify business needs

The first step of implementing BC into an organization's environment is to identify business needs. According to EX2, the main factor in any successful implementation is to define the scope, requirements, and then find the best tool to address these requirements. For instance: "the typical requirements for supply chain would be traceability. So, you have a product and you want to know who has touched it along the way, where did it origin from, has it met ethical standards throughout the value chain, has it met environmental standards … and then decide what technology you can trust to ensure traceability" (EX2). This expert strongly supported that requirements should drive the technological choice and not vice versa. Likewise, EX3 emphasized that organizations should not decide to implement BC because it is a hyped technology with intrinsic potential, but because this technology solves a problem that the organization may have. "It is not BC because it is BC, but because it solves a problem that they may have" (EX3). Likewise, previous studies have reported on the perception of BC as a solution looking for a problem.[9]

Another important aspect to consider in this phase is that BC does not fit for every use case, as agreed by our experts. In fact, BC use cases are very specific and constrained (EX6, EX7). In spite of this, the experts considered these use cases as not difficult, but they claimed that practitioners are not trained to recognize them (EX7).

4.1.2 | Feasibility analysis

After identifying the business needs and use case, it is essential to analyze if BC is the most suitable solution to address the identified business needs compared to existing alternatives. EX7 revealed that the process of investigating the right environment for the implementation of BC takes 60% of the whole implementation process. This expert suggested to consider two main dimensions in this regard:

i. *The legal dimension*. Do you need to act with other organizations or clients that may not agree with what you claim? EX7 explained this dimension further: "when you put BC in a context, it is because you need to be able to demonstrate that data is right to people who may not agree with what happened before … You need to make producers and consumers accept the data they have installed, so you need to put it in a legal context that they will accept to avoid going to trial." If this does not exist, then a shared database would be the most appropriate solution.
ii. *BC as a platform*. Do you have a market you want to join or do you intend to create an ecosystem for others to join? EX7 further stated "If you are not talking about a selling platform or to be or to put business in, you do not really need a BC. You have already the cloud for that." After identifying the need for BC in a specific organizational environment, it is important to understand the value and benefits of applying such a technology. EX6 provided an example in which BC was used to prevent double spending of the city pass vouchers and to keep track of who was using vouchers and how. Although EX6 acknowledged that this could be done with existing technologies, the expert pointed out the following benefits of using BC in this context: transparency, cost-effectiveness, and reliability. However, as concluded by the experts, benefits such as transparency and reliability might be difficult to capture and require new measurement methods.

Furthermore, the organization has to make a set of strategic considerations, for instance, where the computers will be, how to ensure their security, and how will they communicate with each other. Afterwards, the process proceeds with the identification of the number of nodes of each company, the types of tokens to be signed, and the acceptance or rejection rules for the different tokens. It is noteworthy that not every computer on the network can be considered suitable to sign specific transactions. For instance, transactions committed by providers should be checked by institutions related to the providing process, but not by providers that are related to the final consortium (EX7).

Furthermore, as pointed out by EX7, "BC is only one part of the solution you are putting into market, but it is not the whole solution." While it is true that BC is responsible for protecting the stored data and transactions, it is also true that BC is not responsible for what happens before and after. Therefore, EX7 outlined that "we need to focus on how to link the systems that go before the BC [sensors, machines, any kind of hardware] and systems that go after the BC [artificial intelligence, ERPs, any kind of software]." The last concern raised by the experts entails the delay of certification that the whole network is performing about transactions and data stored. In this regard, it is necessary to make sure that this delay is acceptable for the whole context.

4.1.3 | BC platform selection

The experts provided valuable insights into the BC platform selection process. For instance, EX8 selected the most suitable BC platforms for specific use cases in the banking domain and elaborated on the reasons behind these choices: "We decided to use IOTA because we needed an Internet of Things technology and you cannot use Ethereum, Bitcoin or Hyperledger because it is too big. We used Ethereum when it comes to buy and sell shares on the stock exchange and the reason was programmability and that the smart contracts generation is very efficient. But you cannot use Ethereum when it comes to money because you do not know who is paying and who is receiving. So, we needed to use Corda which is a private chain …."

According to EX4, foundational values of the organization should drive the underlying technological choice: "If you support the anarchistic values of Bitcoin, in a way to disrupt banking and maybe governments, then this is something you should build into … If the energy consumption is a problem for you, then you should look into a technology that uses less energy. So, I guess you should know what your values are, and from there choose a platform." According to this expert, the alignment between the organizational values and BC platforms is more important than quantitative analysis, for example, the number of transactions per second, given the emergence of new platforms and solutions such as Ethereum Layer 2 scaling solutions (EX1).

Other factors to be considered when choosing the BC platform are as follows:

i. Network accessibility which entails the selection between public and private BC platforms: "If you need a public platform, you are saying that you need the crowd saying that what you are doing is right. If you need a private platform, you are saying that you need some actors or companies to say that what you are doing is right" (EX7).
ii. Transaction fees. As EX9 stated, "transaction fees in platforms such as Ethereum are very high at the moment. So, you usually end up with an application that costs a lot of money to run. New platforms such as Avalanche and Cardano have supposedly lower transaction fees."
iii. Consensus mechanism was mentioned by two of the experts (EX1 and EX4). EX1 elaborated on this factor: "it has been recognized that proof-of-work which is the consensus mechanism of traditional BCs like Bitcoin is very energy-intensive. And that has become controversial. So, it appeals for new types of consensus. One of them is proof-of-stake. In IOTA we have developed something that is even an alternative to proof-of-stake, so it is a customized version of that."
iv. Programmability. According to EX3, it is important to consider whether the BC platform supports SC and the programming language used to build SC.
v. Community of developers. Two of the experts (EX8 and EX9) suggested considering the developers' community when selecting the best fitting BC platform. EX8 outlined the importance of this factor: "what is good with Ethereum is that if I would like to make a new project, and I am looking for a programmer, then there are hundreds or thousands of people doing Ethereum and it is very important that there is a market."

The majority of the experts confirmed that organizations face difficulties when selecting the best fitting BC platform. Two of the experts (EX3 and EX9) explained the difficulty with the fast-moving pace of BC technologies and their expansion in various domains. New platforms are emerging and as admitted by EX9: "it is difficult to follow on everything." The rapid increase of the number of BC platforms in the market has been identified as a significant challenge for organizations also in literature.[50] EX1 claimed that currently there are no standards to guide the selection process. The expert also stated that "there is a lack of clarity in the BC space, so you have lots of BCs pretending to be doing something, but in the end they do not perform as expected or do not scale towards what they claim." According to EX1, misleading indicators such as the performance of cryptocurrencies may contribute to the lack of clarity because "there is a whole domain of BC that is not reflected into these cryptocurrency trends" (EX1). Conversely, EX4 recommended the pragmatic approach of "following the stream." According to this expert, monitoring and following what BC platforms other developers, organizations, and governments are choosing is a safe and cost-effective approach. "If there is a lot of development happening, if the tooling is good, if the security audits are happening all in one BC, then you get a lot of stuff for free. But if you were to use a lower ranked BC, then you will have to use your own resources for creating development tools, testing tools, security audits …."

Furthermore, EX3 explained the difficulty in selecting BC platforms with the dependence of SC language with the underlying BC ledger. This expert pointed out that existing solutions are built with one SC language, which is bound to a specific BC platform. Consequently, "if the organization wants to then shift [into a new BC platform], a lot of rework is needed to be done" (EX3). Therefore, EX3 emphasized the importance of SC that are able to talk to different ledgers because “that makes the choice easier for decision-makers in the sense that they can build a solution using one smart contract language and they would be assured that the solution that they built can work, irrespectively of the ledger they may choose in the future” (EX3).

4.1.4 | Prototype

The experts outlined that based on their previous experience with various companies, implementing BC is rarely a decisive choice of the management. Instead, “it is more of a slow testing prototype thing, often through the innovation people or the innovation department. They test out a prototype and then, they move it slowly into the real organization, into production, which almost never happens” (EX4). EX7 refers to this process as the pilot stage, which entails creating a simulated network that covers the whole process to test whether the process is right and can work. Dozier and Montgomery[9] concluded that organizations test BC through prototypes and proof of concepts to maximize the comprehension, minimize risks, and identify the business value of this technology. Furthermore, the experts recommended carrying out a performance analysis of the BC-based solution in terms of latency, transaction throughput, and transaction speed (EX8, EX9), security analysis when dealing with sensitive data (EX8, EX9), and user-interaction analysis to evaluate how the user interacts with BC (EX9).

While BC applications have become more available and easier to develop with time (EX3, EX4), three of the experts (EX1, EX3, EX7) agreed that the most difficult part of the implementation process is designing the right BC-oriented solution. EX1 claimed that “a lot of the bottlenecks are in the development phase, rather than scaling or implementation. Developing the solution means to design it. A lot of people have a problem understanding BC and how to design a solution that utilizes it.” Likewise, EX4 confirmed the difficulty of the design phase: “I think having the right design for the client is the hardest part because our minds are not really thinking the BC way. We are thinking the services way, we are thinking that we have fast service on the cloud, that we can query and get answers. In the case of BC, you can query but to get answers you need to accomplish some rules and these rules must be consensual among all parties having the infrastructure”

4.1.5 | Production and scaling

The pilot stage is followed by the production and scaling stage that aims to support the increasing volume of transactions and data. Previous studies have reported on limited production implementations of BC systems[6,9] and scarce empirical studies investigating the reasons.[6] The experts confirmed that most of the projects stop at the pilot stage and provided three main reasons. According to EX6, this may occur because the solution did not deliver the expected value. On the other hand, EX4 perceived this as a strategic problem rather than a technical problem. Furthermore, EX4 elaborated on this perception: “I guess the bottleneck in organization is often that the receivers or the people working in production, or with real life products when they are faced with taking over the project from the innovation team, moving from prototyping into production show a lot of resistance, because maybe they hadn't been included or maybe they hadn't included themselves in the process” (EX4). The organizational resistance to change barrier has been explained in detail in Section 4.2.2.

Finally, EX3 who is specialized in building prototypes and proof of concepts for different customers considered the scaling of these solutions challenging: “We provide MVPs, proofs of concepts for different customers, but then when the scaling of the solutions does come forward, it is much harder because it goes back to this business discussion so it starts to involve other parties, and then the doubts from these different parties starting being raised on who controls what, what are the benefits for my side to actually onboard such system.” According to EX3, one of the easiest ways of putting a BC system into a full-scale operation is when there is one central party that has a lot of market power to push the other parties into the system.

4.2 | Challenges

4.2.1 | Economic challenges

All the experts discussed the costs related to the implementation of BC in organizations. As EX7 pointed out, “having a decentralized network with different machines, working in different places that need to be protected and secured is not the cheapest thing you can think.”

The experts mentioned five types of costs: (i) transaction fees, which are significant when building on public BC platforms (EX1, EX3, and EX9). EX1 referred to these fees as “not only substantial, but also unpredictable”; (ii) legal costs “when you try to live in that gray area, in the brink of something illegal, then you have to use a lot of money on lawyers making sure you do not end up in jail” (EX4); (iii) cost of shifting into another BC platform (EX3, EX4); and (iv) development and infrastructure costs (EX7) which EX7 categorized into three groups:

i. *Application for providers*. These costs vary depending on whether you have to update existing software, find a standard application that can work or develop a new application for providers. EX7 outlined challenges faced in each of the aforementioned options: "there is no standard application, so you have to pick different solutions," "No one wants to expand their applications to let them work with BC, because no one wants to pay," "the problem is that you have a lot of companies having their own vision on what should be done. In the end, you need to make everyone happy and this is not easy."
ii. *Applications for consumers*. Consumers are not always the same entities as providers; hence, they do not use the same applications. In fact, consumers may vary a lot. EX7 illustrated the difference between consumers and producers with the following example: "producers in a market for selling shoes, they all make shoes. So, their software can be similar or maybe they use a standard software … And consumers could be stores, parties in the middle, consumers could be the same providers. So, the ecosystem of applications you have may vary more." The most cost-effective solution in this scenario would be to create the same application for providers and consumers. Otherwise, the cost of each application may vary from \$20,000 to \$100,000–\$300,000 depending on the complexity of the application, according to EX7.
iii. *Infrastructure costs* entail *data storage*, *network communication*, and *hardware*. The *data storage* depends on the type of data transferred and the amount of data. However, it is noteworthy that storage costs are much lower compared with those from 20 years ago (EX7). Regarding *communication*, there is a lot of information that moves from providers to the network, inside the network to reach synchronicity of machines, and information going out. Therefore, it is important to determine the number of clients and providers and enable machines to avoid data movement redundancy. Finally, it is important to determine *hardware costs* that depend on the number of nodes.

EX7 presented the whole picture of costs involved in BC projects: "If we are talking about a small network of 3–4 nodes having one kind of provider, I do not really care if they are 3 or 5 companies but they act if they were just one, they use the same software and they are putting the same kind of data inside. And when it happens something in the same way with the clients, then you can start pricing the whole solution, maybe \$250,000. But when you have a complex scenario, when you have a lot of companies, a lot of providers, a lot of consumers, prices go really high compared to that." Indeed, financial stability of the organization is necessary in order to support the implementation of BC.[51] Therefore, our results suggested that the decision on whether to implement BC given the associated costs also depends on the economic environment of the organization. As stated by EX8, "if an organization has a lot of money, then there is tolerance … if there is not so much money, the organization is cautious about what to implement."

4.2.2 | Organizational resistance to change

The experts considered the organizational resistance to change as a core challenge when implementing disruptive technologies such as BC. This is in line with previous research on the topic.[52] Walsh et al.[52] attributed the resistance to the lack of standards and regulatory backing. Our results suggested that the resistance to change and skepticism is related to the hype of the technology: "people will be against it [BC], even if it would make some sense, but they would be for it even if it would not make a lot of sense to implement it" (EX6). Moreover, three main factors that contribute to organizational resistance to change emerged from data analysis:

i. *Innovation–production gap*. As EX4 outlined "BC is a technological choice, which is pushed through by innovation people who are often business people." The pressure to implement BC solutions does not come from the top, but from the innovation department. Therefore, technicians working in production or with real-life products are resistant when they take over the project from the innovation team. EX4 explained that this may occur due to their lack of participation in the process (they have not been included or they have not included themselves) or their unwillingness to utilize this technology.
ii. *Conservative management*. EX1 raised the concern of conservative managers or decision makers that challenges the implementation of BC in organizations: "they are thinking operationally how to maximize the performance of the organization and when you bring BC you need to divert from the usual course of action." Two of the experts (EX8 and EX9) referred to specific domains that are conservative: healthcare and banking. EX9 raised the following concern: "to make changes in the healthcare industry takes a lot of time and I think a lot of people in the decision-making positions are quite reluctant to disruptive changes and if you look at electronic health records, they are controlled by a few very large actors that supply these systems and they have not adopted blockchain." EX8 stated that banks are slow in adopting new technologies, especially when it comes to cryptocurrencies: "they do not like cryptocurrencies and the reason is financial authority. They have to know who is paying and who is receiving … However, when it comes to using BC as a technology for sharing information, they are very much looking into it, at least in Norway."
iii. *Centralized mentality*. EX3 reported on having worked with different entities with a centralized mentality. According to EX3, *"this is their modulus operandi, but it defies the purpose of using distributed ledger technology or BC, if an entity wants to control everything."* In order to change this mentality, education is essential.

4.2.3 | Poor understanding of BC

All experts acknowledged the issue of poor understanding of BC. This challenge has been also confirmed in the existing literature.[6,51–53] EX1 reported on the confusion between the concepts of SC and BC and the tendency to overuse SC in any context. In this regard, EX1 clarified: "you can use BC without an association with SCs and smart contracts is just a layer on top of it …." In addition, EX1 outlined the difficulty in designing solutions that utilize BC due to the poor understanding of this technology. On the other hand, EX3 acknowledged that BC solutions have become more available and easier to develop, but there is a gap from most companies in understanding the potential. In the same line, EX10 reported that decision makers have difficulties in understanding the technology and its potential: "they think the implementation of BC can be similar to implementing CRM [customer relationship management] or ERP [enterprise resource planning]." These difficulties have been confirmed also by EX9: "a lot of people have trouble wrapping their head around the decentralized governance part of the technology since this is quite new." Four of the experts (EX2, EX3, EX4, and EX8) asserted that BC is immature and companies fail to understand the appropriate application of such a technology.

On the other hand, EX6 perceived the hype around the technology as the problem, rather than the poor knowledge: "people have polarizing views on how beneficial it [BC] is, so they either are completely against it without knowing much about it, or they are strongly supporting it even though they know some of the drawbacks and some of the use cases they are pushing will not be possible to implement." This expert strongly believed that the hype that has been raised around this technology will never be matched regardless of the improved BC platforms that will emerge in the future.

4.2.4 | Business challenges

EX7 considered BC a "business technology," which is pushed into an organization's environment by business people who identify the need for new markets: "A technician will never think of BC. The technician will think of the cloud that (s)he can manage and can make it grow in an easy way and have a lot of techniques that are really prepared to do that. When you put BC inside companies is because the business part of the company says, we need new markets. We need to create incomes from collateral activities, and we need to join the rest of our clients." However, experience has revealed that business people are not committed to understanding the potential of BC (EX7). This expert described how subject matter experts assist business people in understanding BC "When we go to a new company that is interested in BC, we say to them, we do not want to talk with your tech people. We need to talk to business people and tell them you are losing clients because your clients are going to that market that they have created. Well, you need to join that, but you need to understand first, what the internet of value is, and how you can use it in your organization to grow your business and to create new businesses around. So, it is 50% working with business people, 50% working with legal people. When everything is fine, tech people enter the equation."

The implementation of BC-based solutions requires the willingness of organizations to take a step forward and be ready to digitally transform their businesses into new business models (EX3). According to EX1, "BC-based solutions are not just plugins to enhance cost efficiency. Most of the time, they bring some sort of business model transformation." Organizations need to make strategic considerations either by moving into a new market or by creating new products from their old products. EX4 illustrated this with an example: "you cannot do lending as you do today, but you will have to look into decentralized finance … If you are utilizing kind of ecosystem building, opening up your data, that would mean that your product will be something new, but you will still do lending in a way. And that could of course change how your whole business is built."

4.2.5 | Regulations

While it is true that regulations may reduce the level of experimentation because of associated risks, it is also true that regulations ensure that what gets experimented with is well-thought and less risky (EX3). Hence, EX1 outlined the importance of being aware of regulations in the market in which the organization operates and being willing to engage in regulatory discussions. This expert has dealt with different regulators in various industries and revealed that these parties set up sandboxes to allow innovation to get observed and understood. Therefore, the organization that aims to implement BC needs to be ready to be exposed to this type of environment. Interestingly, EX1 encouraged those who believe in the potential of the technology to stand in front and push to the reshaping of regulatory frameworks. However, EX3 admitted that working with public BCs is unlikely to happen in a realistic way, at least for regulated industries, due to the need to be approved by regulators. Some entities may, however, sidestep regulations and experiment anyway, given that public BCs offer this capability.

On the other hand, EX4 and EX9 believed that the problem is not regulation per se. EX9 considered the fear of regulation and confusion related to whether the BC is aligned with current regulations as the crucial issues: "mainly when I talk about this [BC] technology with people within the health domain, I usually get that question. Can we implement this with the current regulation and I do not see any reason why not …

There are gray areas, but there is no sort of regulation that really put sort of a break towards it. But I think, the fear of regulation and maybe a little bit of confusion if it is suitable with the current regulation or not."

In addition, EX4 raised concerns about ethical issues introduced by entities who try to bend regulations: "It is very challenging because what these companies will try to do is often in a gray area of the law or regulation and that is not the fault of the regulation, it is because people will try to bend the rules because it is the BC." Furthermore, EX8 acknowledged the importance of regulations but claimed that regulators are slow: "If the regulators were faster and they could regulate the market, then you could trust the market and more money comes into the market." Likewise, EX7 argued that technology moves to a faster pace compared with regulations which means that what is being regulated risks to become outdated: "they are trying to regulate the picture of how Bitcoin and Ethereum were two years ago. That is so far from where we are now." This expert introduced another problem which entails the need for an invitation to join BC ecosystems. Once an entity joins, the BC assures that all the data and transactions are protected mathematically and shared among all entities. However, BC does not take responsibility for what happens outside the platform. As EX7 stated: "this makes BC a private club … We have to require that the government is invited to every private network and why should they be …."

One of the most critical problems discussed by the experts is the General Data Protection Regulation (GDPR). The immutability nature of BC goes against the right to be forgotten enforced by GDPR. EX4 elaborated on this issue: "you will need to always put one part of private data on BC, which can be the Ethereum address or Bitcoin address which is not erasable … But it is a challenge to store private data on BC forever, which goes directly against GDPR." In addition, EX6 reflected upon storing data on BC in relation to GDPR: "according to GDPR, you are only allowed to gather what you specifically need or must have. BC of course collects a lot more usually …." The absence of compulsion to comply with data privacy regulations such as GDPR has been considered a barrier also by previous studies.[3,54]

4.2.6 | Technical concerns

Interoperability is an important concern that has captured the attention of BC researchers.[55] Organizations may choose different BCs that do not communicate with each other. This defies BC's purpose of sharing information by creating additional silos. EX3 explained this technical limitation, as follows: "interoperability is definitely a concern that may impact the implementation of such systems, because as people start to see that different [BC] platforms are popping up, and they decided to use one instead of the other. So, different organizations may see that it ends up being similar to centralized systems, because different organizations are in different systems, so siloed and these silos do not communicate with each other …." EX3 outlined the need for SC languages that are able to talk to various ledgers. The idea is to build solutions that work, irrespectively of the ledger that organizations choose in the future. Furthermore, this expert elaborated on this issue: "right now, if you choose to go with Ethereum, it bounds to solidity. If you go with Hyperledger Fabric, you are bound to the chain code. If you are going for R3 Corda, SCs are developed through Java and Kotlin … If for instance, you have a SC language that can talk to all these, you kind of separate this aspect from the underlying ledger." Currently, EX3 is working with a technology that enables an SC language that is independent of the underlying ledger. EX2 emphasized the importance of abstraction and encouraged discussions regarding abstraction rather than BC itself. This expert quoted one of the customers who is the head of US Homeland Security's Silicon Valley Innovation Program: "We want to stop talking about BC … We want to abstract that so far away that we never need to talk about it at all." Currently, EX2 is working with decentralized identifiers and verifiable credentials as an abstraction that sits on top of distributed ledger technologies.

Furthermore, the experts mentioned other technical concerns. One of the concerns is scalability, which is the capability to process transactions to the same degree of efficiency if the network grows and the number of transactions increases (EX1). Another concern is security, that is, organizations need to host BC systems and guarantee that they are secure against attacks that may deny the service and are inaccessible by unauthorized users (EX3). Security issues are even more severe in safety-critical domains. EX6 claimed that "some of the blockchain applications have not been very good at that [ensuring security in safety-critical domains]." This expert supported this claim with several attacks against cryptocurrencies that have led to significant financial losses. On the other hand, EX7 perceived BC as "the best technology we have created thinking about security" and supported this perception by claiming that "in 10 years working with Bitcoin, no one could break it, and we are talking about something that a lot of people would like to break to pick the money. So, it makes it really stable, and really secure." Paradoxically, this expert considered BC as "the most vulnerable technology we have put into market" because "all computers have the whole storage." EX7 elaborated on this concern: "your network is as secure as the least secure computer on the network, because if I am a hacker, and I can enter one node, I can steal the whole information on the system. So, instead of having one computer in the cloud that I have to attack, I have thousands of machines that I can attack. So, we have created a lot of points of attack for hackers." This is in line with other studies that identified security as both a benefit and a challenge of BC systems.[3] Although the increased security built into the design of BC is a benefit for enabling peer-to-peer transactions, several attacks such as account-take over, 51% attack, hacking, and digital identity theft are theoretically possible.[3] However, Bitcoin, the first BC application, has not been successfully attacked.[2]

4.3 | Success factors

4.3.1 | Agility

In order to implement BC successfully, organizations should be agile, meaning that they need to be ready to experiment in an iterative fashion and to learn from mistakes quickly (EX1). Likewise, EX5 encouraged small iterations in order to understand problems quickly and prioritize them. According to this expert, "one of the biggest mistakes organizations are doing is that they start out big, they do it too fast, and then they do not understand what they are doing." According to EX1, many practitioners are not knowledgeable in this regard; therefore, this expert recommended "setting up dedicated teams working as a task force to actually do these developments, rather than starting from the existing teams and operations." Moreover, EX3 stressed the importance of close collaboration between subject matter experts or startups that offer their BC expertise and customers by involving customers in all the meetings and sessions that are carried out internally. In this way, customers can be aware of the different tasks that need to be developed.

4.3.2 | Collaborative environment

BC aims to break the silos between different types of organizations. A crucial requirement to fully leverage this technology is the collaboration not only on an intra-organizational level but also on an inter-organizational level.[8] As EX1 stated, "It is not enough to apply it downwards into your own organization; it is about how you collaborate with the other parties, so you need to have collaborative environment." Likewise, EX5 claimed that the main benefits of using BC do not come by just applying it in your organization, but by creating the "network effect." Frizzo-Barker et al.[3] define the network effect as the concept that the value of a product or service is based on the total number of users. In addition, EX1 highlighted the importance of creating new value streams in collaboration with other parties and referred to this as innovation ecosystems. This collaboration can take the form of alliance structures in which all the parties can define together how the solution will be orchestrated and governed by the different parties (EX1). Moreover, collaborations can also be in the format of public–private partnerships. EX1 illustrated this with the IOTA case: "IOTA technology can be utilized for public sector level, as part of the digital infrastructure and you will have the private sector on top, leveraging that technology and using it."

Furthermore, EX4 pointed out that collaboration is essential in a BC ecosystem; however, it has taken a new decoupled form. This means that there is no need to know the other parties or have bilateral agreements; instead, you just need to integrate with them and leverage their SC or services in your service. Finally, EX9 mentioned the importance of collaboration between industry and academia. According to this expert, most of the developments within the BC sphere are carried out by startups in the sector. Although the development is faster in the private sector than in the academic sector, EX9 reported that in the healthcare domain, executives are very interested in academic research to support their decision to implement BC.

4.3.3 | Digital transformation capabilities

The experts had different views on the importance of digital capabilities of organizations that intend to implement BC. EX1 raised the concern that "companies that are not techie are going to struggle a bit" and suggested companies "to be ready to hire some talent, probably people that are of younger generation who know how to manipulate those technologies." Similarly, EX3 acknowledged the importance of hiring talents in order to bring a different vision, but outlined the need to be balanced with the business knowledge that experienced people have. However, three of the experts (EX3, EX5, and EX6) did not perceive this factor as critical for most organizations, given the possibility to leverage BC startups and consultants. Despite leveraged expertise, it is still important for an organization to understand what can be done with BC and what value it can bring. In addition, EX7 strongly recommended organizations to invest in training existing personnel and getting BC knowledge in-house, due to the scarce market of BC experts, which has also been confirmed by other studies.[3,53]

4.3.4 | Education

The experts confirmed the need for education in three perspectives: (i) education on how to recognize BC use cases because "BC is not a solve everything solution"(EX4) or "BC does not fit for everything" (EX7). According to EX6, many people treat BC as a *silver bullet* that enables you to do a variety of things. In fact, there are very specific and constrained use cases that may yield benefits from using BC, (ii) to educate managers regarding the business value of implementing such a technology (EX5) and to change their centralized mindset (EX3, EX9); (iii) education from a technical perspective in order to develop expertise on how to build BC-based systems (EX3). However, understanding what knowledge is required to implement BC in organizational settings is not trivial because "BC is not a technology that was created in a university environment or laboratory … So we cannot say this is the standard and this is what everyone should know to put the technology into real work … Universities try to do that but technology evolves in an uncontrolled way" (EX7).

4.3.5 | Open mindset of top managers

One of the key success factors of implementing BC in organizational settings is to approach it with an open mindset as innovators and be willing to take some degree of risk, which is inherently associated with innovation (EX1). EX1 outlined the importance of being open to change: "When you bring BC, you need to divert from the usual course of action." In the same line, EX4 considered BC a new way of doing things, and therefore advocated "openness to change and new way of thinking."

4.3.6 | BC as a platform

The experts suggested interested organizations to think of BC as a platform. EX7 encouraged organizations to consider implementing BC if there is a market they want to join or if they intend to create a market for others to join (see Section 4.1.2). EX4 reported on previous communications with different organizations and discovered that "they want to leverage data in a way that benefits them and not their competitors. However, that does not make much sense in the BC world. It is important to create the platform which other parties are using and thereby giving away a lot of power and data for free to get people into your platform, to get people to build on top of your data, to leverage your ecosystem." EX3 revealed that getting new organizations or entities into your platform is not a trivial process: "When you want to invite new organizations to join your consortium or join your efforts to build a system where you interact with multiple parties on a certain topic, that is where the conversations just keep going and going. Agreements are not always easy and quick."

In addition, according to EX4, it is important to think big, and not try to digitize only a part of a process or put it on BC because it will not make sense from the business perspective. In such a case, existing technologies would be more suitable. The efficiency of BC can be perceived in the case of a larger chunk of the process that includes many parties. EX4 illustrated this with an example: "working with the Norwegian Business Registry, I see that the value for them is not kind of tokenizing shares and just creating a digital representation of the company's stocks, but it is building the ecosystem so when they deliver the foundation which is a tokenized stock, then any company can come in and expand on that revenue stream with functionality and businesses, so that could be crowdfunding, lending, it could be new kind of portfolio systems either for viewing or for doing index funds."

The main findings are summarized in Table 3.

5 | DISCUSSION

5.1 | Results evaluation

Glaser[40] introduced four criteria to evaluate the validity of the emergent categories that compose the theory: fit, workability, relevance, and modifiability. These criteria are explained in the following section:

i. *Fit* refers to codes, categories, and a theory that emerge from data, rather than preconceived perceptions, views, and biases of researchers. The authors of this study did not perform an extensive literature review in the initial phases to prevent preconceived perceptions, views, and biases from influencing the data. In fact, data only emerged from the interaction between the researchers and participants. In addition, the authors selected a diverse set of participants in terms of job positions, project domains, and countries (see Table 2) to ensure different perspectives on the emerged concepts and categories and fulfill the *fit* criterion.
ii. *Workability* refers to the extent the core category is integrated with related categories and the extent the theory explains the area under study.
iii. *Relevance* refers to the extent the theory enables the emergence of core problems and processes in the area under study. In order to assess the *workability* and *relevance* criteria, the authors provided participants with a preliminary report of the results. BC experts were asked to provide feedback on the results. In what follows, the authors present the feedback provided by a few experts: "I do think results provided are valid and relevant," "There is always a bias in all implementations, but I can figure out real situations behind the rationale depicted. Maybe it is not covering all cases, also true …," "some of the most important challenges can be derived from results provided. It paves the way towards better and clearer challenges, and opportunities can be seen there," "very interesting results."

TABLE 3 Summary of the main findings

Categories		Main findings
Key activities	Identify business needs	• Requirements should drive the technological choice, not vice versa. • BC does not fit for every use case.
	Feasibility analysis	• The process of investigating the right environment for BC implementation takes 60% of the whole implementation process. • Organizations should consider two dimensions that influence the decision on whether to use BC: the legal dimension and BC as a platform.
	BC platform selection	• Foundational values should drive the BC platform selection process. • The following factors should be considered when selecting the suitable BC platform: network accessibility, transaction fees, consensus mechanisms, programmability, and community of developers.
	Prototype	• The most difficult part of the implementation process is designing the right BC-based solution. • The decision to implement BC comes from the innovation department because of testing out a prototype, rather than the management.
	Production and scaling	• Most BC projects stop at the pilot stage.
Challenges	Economic challenges	• Findings reveal the following costs associated with implementation of BC projects: transaction fees, legal costs, costs of shifting into another BC platform, development and infrastructure costs (costs for providers' applications, consumers' applications, data storage, network communication, and hardware).
	Organizational resistance to change	• Three main factors contribute to organizational resistance to change: (i) innovation–production gap (ii) conservative management (iii) centralized mentality.
	Poor understanding of BC	• Decision makers have difficulties in understanding BC and its potential.
	Business challenges	• BC is a business technology that is pushed into organizations by business people.
	Regulations	• Technology moves at a faster pace than regulations. • Absence of compulsion to comply with GDPR • The main issue is not regulation per se, but the fear of regulation and confusion whether BC is aligned with current regulations.
	Technical concerns	• Main technical issues to be considered are interoperability, scalability, and security. • Lack of interoperability leads to the creation of silos that do not communicate with each other, like centralized systems. • The need for smart contract languages that are independent of the underlying ledger. • BC can be considered the best technology created considering security, but at the same time the most vulnerable technology.
Success factors	Agility	• Organizations should be agile, use small iterations to identify problems quickly and prioritize them. • Close collaboration between BC experts and customers
	Collaborative environment	• Importance of establishing innovation ecosystems in collaboration with other parties to create new value streams

TABLE 3 (Continued)

Categories		Main findings
		• Collaboration can take the form of alliance structures or public-private partnerships. • In the BC ecosystem, collaboration has taken a new decoupled form. • Most of developments are carried out by BC startups. • Development within the BC sphere is faster in the private sector than in academic settings.
	Digital transformation capabilities	• Organizations should not rely solely on BC startups and consultants, but train existing personnel and get BC knowledge in-house.
	Education	• There is a need for education in three dimensions: (i) on how to recognize BC use cases (ii) educate managers regarding the business value of implementing BC (iii) technical education on how to develop BC-based solutions.
	Open mindset of top managers	• Approach the implementation process of BC with an open mindset, openness to change and risk, and new ways of thinking.
	BC as a platform	• Think big and do not digitize only a part of the process. • The efficiency of BC can be perceived when digitizing a larger chunk of the process that involves many parties.

Abbreviation: BC, blockchain.

Based on the feedback received, the authors confirm that the emergent categories work because they explain the reality of the area under study and are relevant because they allow core problems and processes in the BC sphere to emerge.

iv. *Modifiability* refers to the ability of the theory for continual modification and development with the occurrence of new data. The categories that emerged in this study went through different modifications over time due to the constant comparison techniques that were followed. The authors compared new data with existing codes, concepts, and categories until the theoretical saturation point was identified. Because this process allows the results to be modifiable, future work may focus on evolving the categories upon receipt of new and more diverse data.

5.2 | Implementing BC for RT using the emerged concepts

In this section, the authors aim to improve the initial BC-enabled RT framework presented in their previous study[12] using the emerged concepts (see Section 4). Such an initial framework consisted of four elements: strategic layer, BC proposal, implementation, and assessment. The improved framework (depicted in Figure 4) keeps the BC proposal at the core and integrates the other three elements into the core categories as follows.

5.2.1 | Identify the need for distributed RT

As recommended by the experts, the first phase should commence with determining the scope, identifying business needs and requirements, and then choosing the best tool to address these requirements. The focus of our case study is on RT in interorganizational software projects. First, it is important for organizations to identify the need for RT in such projects. Rempel et al.[32] provided a good overview of the importance of RT in distributed software projects, as a proof-of-quality and correctness of the end product to avoid costly disputes. In addition, traceability is needed to track the project's progress to determine if the project can finish in time, within budget and with the expected output, and to verify the compliance of the project execution with legal regulation. In spite of the importance of sharing traceability information among participating entities, previous studies revealed that this information is not always disclosed and relied upon due to organizational boundaries and conflicting objectives.[32] For instance, the organizational goal of one project partner may be to keep technical knowledge confidential, and this may contradict the need of

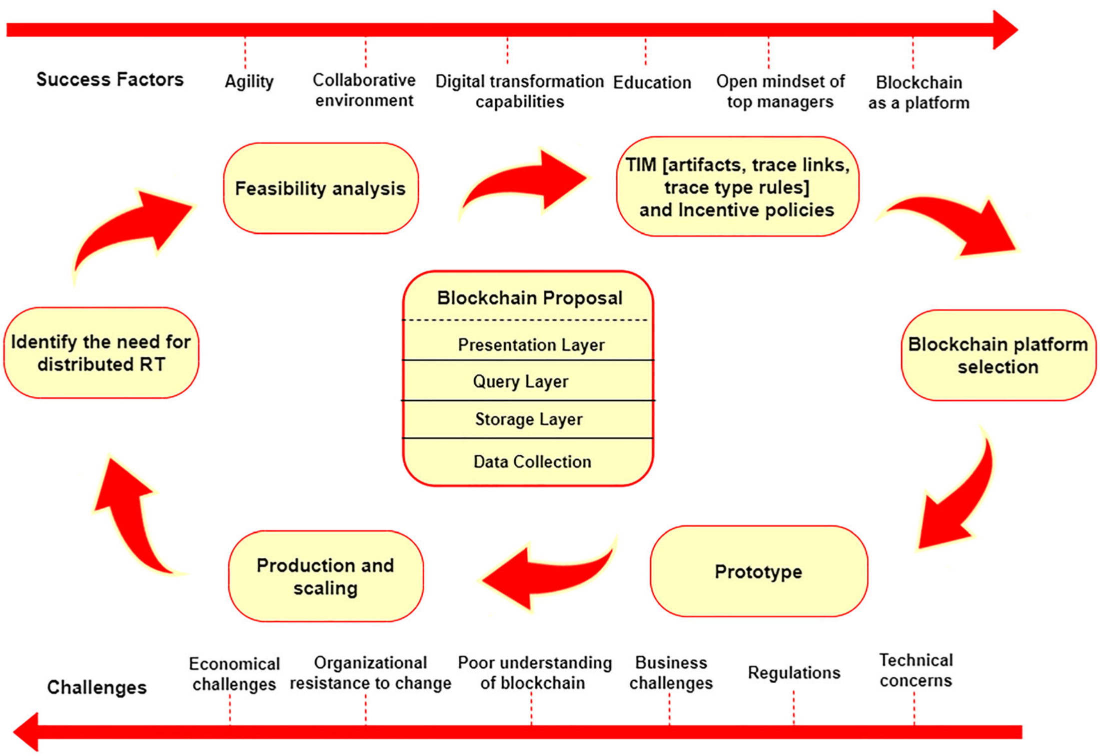

FIGURE 4 An implementation framework for BC-enabled RT

the other entity to gain product knowledge, which could be used for further release planning.[32] These problems enable us to deduce the following requirements for traceability information: available, shared, reliable, and trusted. Organizations should identify a suitable solution that addresses these requirements and the ultimate scope of enabling a shared, reliable, and available traceability knowledge base that ensures visibility to all the participating entities regarding what/how/when trace links were created and by whom.

5.2.2 | Feasibility analysis

In this phase, organizations should decide on the most suitable technology to address the identified needs. BC can be a viable technical solution to ensure reliability and availability of traceability information in interorganizational software projects.[23] This technology needs to be compared with existing solutions for the storage and representation of trace links such as cross-reference tables, traceability matrices, relational databases, and graph traceability repositories.[56] Our results suggest that the assessment of whether BC is required for RT should consider two dimensions: (i) *The legal dimension*. In interorganizational software projects, clients may claim the product was not delivered with the expected quality, and they may raise bugs even if the software is working in accordance to client's specifications.[32] In order to avoid expensive disputes, the supplier should prove the correctness of the software and this can only be done by tracing the requirements specified by the clients with implementation/verification artifacts of suppliers.[32] (ii) *BC as a platform*. An ecosystem for developing complex and large-scale software systems can be created among different parties that want to join and participate in any of the SDLC phases, such as customers, distributed teams composed of requirements engineers, developers, testers, third party vendors, crowd-workers, and regulators. Furthermore, our results indicate the need to make a set of decisions (see Section 4.1.2), for instance, how to link tools used throughout the SDLC with BC, and how to ensure that the delay of certification for transactions and data stored on the distributed ledger does not impact the quality and time-to-market of the software under development.

After identifying the need for BC in interorganizational software projects, the organization should determine the benefits along with the challenges associated with the implementation of this technology. Due to its inherent features, BC is expected to provide a holistic and reliable view of artifacts and trace links to all distributed stakeholders, incentivize software practitioners to create quality trace links, increase the use of traceability to support SDLC tasks and consequently, improve the performance of practitioners in addressing SDLC tasks. The increased quality and completeness of traceability may lead to increased software quality, consequently, less need for software maintenance and cost savings.[12]

Despite these benefits, organizations should be aware of the challenges associated with the implementation of this technology into their organizational environment. Our results revealed economic challenges in particular costs for the infrastructure (storage, network communication, and hardware) and for the development of applications for practitioners who participate in SDLC activities, and also for entities such as customers and regulators who need to access the data stored on the distributed ledger to verify requirements coverage, monitor project's progress and assess compliance to regulations. In addition, the results revealed that the implementation of BC in organizational settings is prone to organizational resistance to change, which is caused by three main factors: innovation–production gap, conservative management, and centralized mentality. These factors are related to the poor understanding of BC; therefore, education has been outlined as a critical success factor that can minimize the organizational resistance to change by changing the centralized mindset, improving the understanding of BC business values, and enhancing BC technical skills. To address the innovation–production gap, the findings suggest involving technicians working in production in the prototype testing process, which is led by the innovation team. In addition, the experts mentioned business, regulation, and technical concerns such as interoperability, security, and scalability issues. Although the category of business challenges emerged, the authors perceive this factor as not critical when applying BC for RT because they do not expect business transformation or new business models. As EX4 stated, "if you are trying to only achieve a kind of track and trace database, do not have high hopes of amazing transformative stuff …." Furthermore, the experts encouraged organizations to continuously monitor the compliance of BC solutions with domain-specific regulations. A particular focus needs to be paid to the (mis)alignment between GDPR principles and inherent BC features.

The experts also recommended organizations to be agile, to experiment in an iterative fashion, and to set up dedicated teams working as a task force for the development and implementation of BC solutions. Given the globally distributed nature of organizations that may be interested in implementing BC technology, scaling agile is important.[57] Therefore, frameworks for scaling agile, such as Scaled Agile Framework (SAFe) can be adopted.[57] Principles of SAFe concepts, in particular, agile release trains (ART) are aligned with BC principle of breaking silos that exist within an organization or across organizational boundaries. In the case of BC-based SE solutions, ARTs should consist of dedicated teams with all the capabilities (e.g., SE, RT, and BC expertise) necessary to define, deliver and operate BC solutions. The experts also advocated creating a collaborative environment among different parties such as organizations interested to join the BC ecosystem, collaboration with BC startups, BC experts, and academic researchers who may guide the implementation process. However, due to the scarce market of BC experts, it is highly recommended to upskill existing personnel and acquire BC knowledge in-house.

5.2.3 | Traceability information model and incentive policies

This phase consists of defining the traceability information model (TIM), which has been advocated as a best practice by traceability researchers.[58,59] The main utility of TIM lies in guiding the setup of traceability and enabling the validation of changes.[58] In addition, implementing traceability in an agreed manner ensures the consistency of results in multi-stakeholder projects.[58] A basic TIM defines types of artifacts to be traced and their metadata, trace links based on source artifact ID and destination artifact ID, and trace type rules to generate the semantics of trace links.[56] SC can be used to register only the artifacts and trace links that are defined in TIM and identify the semantics of trace links automatically. Further, organizations interested in implementing BC to enhance the motivation of practitioners to engage in traceability tasks need to define incentive policies that focus on the eligibility to create trace links, the validation of trace links quality and the amount of incentive that goes for the creation of quality trace links according to their priority.[12]

5.2.4 | BC platform selection

The experts provided guidance to the BC platform selection process that can be useful for organizations interested in implementing BC for RT. The results indicate network accessibility and programmability as critical elements that need to be considered. The selection between private and public BC platforms depends on the type of software under development. For instance, public platforms may be suitable in the case of open-source software with diverse and unknown contributors, while private platforms are more aligned with complex and large-scale software being developed by known organizations or distributed teams. The latter is the main focus of the BC proposal in Figure 4. Furthermore, programmability is another important factor to consider because the BC proposal makes use of SC to enable a set of functions. Therefore, it is necessary to choose a platform that supports SC execution.

The results suggested other factors to be considered, such as the alignment between foundational organizational values and BC platforms, transaction fees, consensus mechanism, and community of developers. Additionally, concerns were raised by the experts regarding the difficulty in selecting the best fitting BC platform due to the emergence of new platforms. A cost-effective practice advocated by the experts to facilitate the selection process is to continuously monitor what BC platforms other organizations or developers are choosing and "follow the stream."

5.2.5 | Prototype

Our findings revealed that the innovation team of the interested organization is expected to test out a BC-enabled RT prototype. However, according to the experts, designing the right BC solution is not trivial. Figure 4 depicts a BC-enabled solution for RT, which entails four main components: (i) *Data collection*. The SDLC is composed of a variety of tools that generate artifacts that need to be traced, according to TIM. Data ingestion tools/plugins can be used to capture these artifacts. In addition, eligible stakeholders can create trace links and register these links on BC by means of SC. (ii) *Storage layer and smart contracts*. In this proposal, SC enable the following functions: register artifacts (id, type, name, description, priority, and parent_id), register trace links (source_artifact_id and dest_artifact_id), validate the quality of trace links, and reward the creators of quality trace links by means of digitized tokens based on incentive policies that are encoded into SC. (iii) *Query layer*. This layer enables traceability-related queries that comprise primitive links between adjacent artifact types in TIM and composite links between non-adjacent artifact types. (iv) *Presentation layer*. This layer enables the visualization of traceability information in an interactive and hierarchical manner to facilitate the comprehension of the overall system. For a more detailed description of the proposal, the authors refer to their previous study.[12]

Finally, based on the recommendations of our BC experts, organizations need to perform a performance analysis of the solution (latency, transaction throughout, and transaction speed), security analysis if the software is built for safety-critical systems, and user-interaction analysis to evaluate how stakeholders of the SDLC interact with BC.

5.2.6 | Production and scaling

In this phase, the prototype shifts into production. However, as confirmed by the experts, most of BC projects stop at the pilot phase. The interested organization should be aware that the main problem lies in the resistance of practitioners working in production because they have not been included in the pilot phase carried out by the innovation team or they have decided to not participate. Therefore, our results suggested close collaboration between the innovation and production teams during all the phases of the BC project. The inclusion of the production team in the early stages of the project may minimize their resistance and bridge the innovation–production gap, as referred to in this study.

5.3 | Limitations

The main limitation of this study is limited generalizability. This study does not claim that its results are generalizable due to the low number of interviews. The authors noticed that after eight interviews, no new concepts emerged; however, they decided to perform two more interviews to validate the theoretical saturation point. Although the theoretical saturation point was reached, it does not ensure generalizability. To address this, the authors selected a diverse set of participants in terms of job positions, projects domains and countries (see Table 2). Nonetheless, limited generalizability is a known limitation of qualitative research because qualitative research aims to enable a contextualized understanding of human experience.[60] While it is true that GT ensures the discovery of high-level concepts that are not specific to a subject or setting,[61] it is also true that any qualitative inquiry method may be subject to external validity threats.[60] Furthermore, Myers[62] claimed that novice researchers may find the coding process to be time-consuming and tiring. Consequently, they are prone to feeling lost in the coding process and unable to unveil concepts and categories grounded in data. As recommended by Annells[63] and Chun Tie et al.,[34] the first author of this study was assisted in her journey of inquiry by the other more experienced authors.

6 | CONCLUSION AND FUTURE WORK

This study adopted a GT approach to unveil the BC implementation process in organizational settings by performing semi-structured and in-depth interviews with BC experts. BC experts were selected through a rigorous selection process that put an emphasis on their diversity in terms of job positions, projects domains, and countries. The results revealed key activities, success factors, and core challenges, along with 17 concepts to explain the phenomenon under study.

The authors used the emerged concepts to improve a BC-enabled framework for RT in interorganizational software projects. The results suggested that the implementation process follows the following phases in an iterative manner: identify the need for distributed RT, perform a feasibility analysis, define the TIM and incentive policies, select the best fitting BC platform, test through prototypes, and shift from prototyping to production and scaling. These results may enhance the knowledge regarding this publicized technology and may encourage the collaboration between BC experts and requirements engineers towards developing more prototypes and proof-of-concepts.

Future efforts can be devoted to the following dimensions: (i) evolving the categories and concepts by collecting new data from a larger set of BC experts and other data collection techniques, such as observation; (ii) focusing on one of the emerged categories in-depth and using GT techniques to provide an explanatory theory, given that this study takes a general perspective on the implementation process of BC; and (iii) applying the results of this study in different domains and identifying similarities and discrepancies of the implementation process. Our main priority will be the development of the proposed BC-enabled RT prototype and the validation of the improved framework by requirements engineering experts.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in figshare at https://doi.org/10.6084/m9.figshare.19078079.

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