This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

IEEE Access
Multidisciplinary Rapid Review Open Access Journal

Date of publication xxxx 00, 0000, date of current version October 30, 2020.

Digital Object Identifier 10.1109/ACCESS. 2020-52946

Blockchain enablers for supply chains: how to boost implementation in industry

FABIO DELLA VALLE[1], MIQUEL OLIVER[1]
[1]Engineering Department of Information and Communication Technologies, University Pompeu Fabra, Barcelona, 08018 Spain

Corresponding author: Fabio Della Valle (fabio.dellavalle@upf.edu).

This work was partially funded by the Spanish and Catalan Governments through the projects "Plan Nacional": AEI/FEDER TEC2016-79510 and SGR2017-1739.

ABSTRACT Supply chain management is considered one of the main sectors of development for blockchain technology. This study provides solid contributions to understanding blockchain innovation and presents some main features and guidelines for how to boost blockchain implementation in industry. As explorative research, this paper presents a grounded theory analysis based on 18 expert interviews. The pool of interviewees is composed of academics and business and institutional representatives with relevant technological knowledge on blockchain and innovation management. Renowned worldwide experts provided us with powerful input to run this analysis and with a general overview of the current situation. Blockchain development of course impacts supply chains, but currently, the analysis shows that it does not seem to be a disruptive technology. In accordance with C.M. Christensen, blockchain presents all the features to be a sustaining innovation rather than disruptive. For this reason, as outcomes, we present five enablers that can foster prompt adoption in industry.

INDEX TERMS Blockchain, distributed ledger technology, innovation management, knowledge management, supply chain management, technology management.

I. INTRODUCTION

Blockchain technology is showing a rapid growth rate, both for applications and market tests [1], [2]. Additionally, interest from the scientific community has grown rapidly [3]. However, currently, such technology presents some risks and threats related to its early stage of development and novelty [4], [5]. In addition, the industry has high expectations about blockchain applications as a new enabler to shorten middleware costs and provide additional value such as trust and security. These high-expectations shown by communities on this topic represent a risk for its coming applications and how blockchain is impacting society [6], [7]. To mitigate the risks related to this blockchain surge, this study first introduces the current state of technology implementation and its position into the innovation pathway, identifying new avenues for improvements at a technological level and providing enablers for industry acquisition for supply chains.

According to the best of our knowledge, there are just preliminary studies comparing the degree of disruptiveness and radicalness of blockchain technology. This research intends to fill this gap, by utilizing the C.M. Christensen theory of disruptive innovation [8]. Taking this path allows the authors to achieve the result of delineating the features which make a blockchain system innovative.

This paper presents explorative research on blockchain expectations among experts and their current and potential applications in industry. In fact, these expectations create risks and uncertainty as to the investment plans for blockchain developments, applications and innovations [5], [9], [10]. Hence, this research conducts a critical analysis of blockchain technology disruptiveness, with special attention paid to supply chains, by interviewing a set of worldwide experts from business, academic and institutional areas.

In fact, the analysis of the interviewees allows us to explore the gaps between the current technology offered and market needs and to identify the areas in which blockchain innovations are well positioned.

A few years ago, blockchain had been tested in several sectors to find effective solutions for real-world problems [11]–[13]. Many companies, consortiums and foundations were convinced of the great impact of blockchain to be exploited in future developments. The key sectors agreed upon by worldwide organizations in which blockchain may have more impact are as follows: financial services, government services and supply chain management [14].

Thus, this research will be focused on supply chains and looking for specific answers to several questions concerning the relevance and impact of blockchain in industry, and we collected those on the following broader question: *what are the enablers for blockchain disruption in supply chains*?

Consequently, we split the previous research question into three subquestions to address specific themes, and then, we collected information on them in a comprehensive analysis:

RQ.1. *What are the present and future perspectives for blockchain in industry?*
RQ.2. *How can blockchain in industry be effectively connected to other interdependent systems?*
RQ.3. *How can blockchain in supply chains effectively foster digital enhancements?*

The research follows a similar approach to those of previous studies on blockchain-based supply chains from Y. Wang *et al.* [15], and N. Hackius *et al.* [16] but addresses the presented research gap from a different angle. To achieve this goal, we conducted qualitative analysis using ethnographic methods [17] and running expert interviews [18]–[21]. In fact, after the exploration and assessment of worldwide experts, a pool of 18 experts was interviewed in this study.

This paper is structured as follows: it starts with an overview of the literature on innovation, blockchain and supply chains. In the third part, the methodology used to collect and analyze data is presented. The fourth section presents the main findings, which are later discussed in the fifth section. Finally, the limitations and conclusions are presented.

II. LITERATURE REVIEW

In this section, we present a literature review. To the best of our knowledge, these previous publications represent a solid foundation on which we focus our efforts to achieve the goal of the research work. The main pillars that orchestrate the review are innovation, blockchain technology and blockchain for supply chains that we develop in the subsequent sections.

A. INNOVATION

Following J.A. Schumpeter [22], [23], distinguishing between innovations is extremely important for future development. This classification explains that new firms (startups) are drivers of innovation, while well-established firms have the capital needed to operate and invest in innovation processes. This framework defines two types of innovation: disruptive (for new firms) and structured (for established firms) innovations. The latter is predictable and can be planned, while the former is not.

C.M. Christensen's theory regarding "the innovator's dilemma" [24] presents a theoretical framework regarding how to individuate and manage innovations and shows that different types of innovations require different strategic approaches. According to Christensen's theory, there are specific features for identifying innovations and market trends, dividing the scenario into two possibilities: sustaining innovations vs. disruptive innovations. This framework matters for value creation because the aim of this theory is to support firms in innovating successfully [25]. In fact, adding a secondary evolution of this theory, Christensen highlights a third type of innovation: efficiency innovation [26]. These three types of innovation are able to create a closed loop that can identify innovations and their development stages.

S-curves can be adopted to assess technologies [27]–[29], as such incremental improvements will move along a given S-curve, but radically new technologies will jump from one S-curve to another [27]. S-curves identify the maturity of the technology and when and if the '*jump*' will happen. Embracing Christensen's theory can also support the development of specific metrics and criteria to track and assess potential enablers.

Disruptive technologies offer a revolutionary change in the conduct of processes or operations and provide a basis for a new competitive paradigm [30]. Disruptive technologies act completely independently from mainstream business [8]. Additionally, it is relevant that the effort of the formulation of blue-ocean spaces and the decision as to where to fit the disruptive technology, generates the major pillars for disruption [31], and the blue ocean [32] role is mainly to innovate the business model [31]. Following a three-step method, as suggested by [33], this can facilitate the prediction of disruptive innovation, defined as follows: "*an innovation with radical functionality, discontinuous technical standards, and/or new forms of ownership that redefine marketplace expectations*" [33]. For this reason, managers need to pay careful attention to potentially disruptive technologies [8].

B. BLOCKCHAIN TECHNOLOGY

Blockchain technology (BT) is a novel technology enabling new forms of distributed [34] software architectures [35] and is positioned in the early stage of development [15], [16], [36]. A blockchain is defined by [36] as "*a ledger of transactions of digital assets: of who owns what, who transacts what, of what is transacted and when.*"

The BT research stream can be considered a new field of study [4]; in fact, it started twelve years ago with a white paper describing a new form of electronic cash or digital currency [37]. Here, the first differentiation between previous digital currencies and the new cryptographic currency occurred [38]. Thus, Bitcoin was the first decentralized public ledger, and as a distributed application, the blockchain was the innovative technology characterizing the system [7], [39], [40]. This represents an innovative combination, merging peer-to-peer networking, distributed timestamping, cryptography hash functions and pointers, digital signatures and Merkle trees, among others [14], which have existed for decades [7], [39]. Then, many new blockchains emerged, changing the point of view from "*the*" blockchain to "*a*" blockchain [38]. To date, many definitions have been published. For instance, blockchain has been defined as a public history of transactions [41] and as a secure public-distributed ledger platform that is, in practice, a distributed network of computers enabling transparency and verifiability of transactions, due to cryptographic protocols. This design is characterized by asymmetric cryptographic functions that are very difficult to solve but extremely easy to verify, which allows for real-time updating for all network nodes.

The terms distributed ledger technologies (DLTs) and blockchain technologies (BTs) can often be considered interchangeable. It is important to note that blockchain has become a more colloquial name for all types of DLTs. However, blockchain is actually one type of DLT [3], [42]. The areas of application for DLTs are currencies (cryptocurrencies), contracts (smart contracts), intellectual property rights, digital identity, voting systems, banking/finance, supply/global commodity chains, property ownership, and so forth [3], [7], [10], [11], [40], [43], [44].

C. BLOCKCHAIN FOR SUPPLY CHAINS

Blockchain has been identified as a promising technology for supply chains [5], [10], [16], [45]–[51], ecosystem building [47], increasing cyber security [46], data management [45], [47], [52], [53], driving digital transformations [3], [46] and enhancing data recordkeeping and provenance [54], [55]. Additionally, it impacts new business models and operations in supply chains [4], [54], [56].

Supply chain management is the integration of all key business processes across the whole chain of processes and stakeholders [57]. In accordance with D.M. Lambert [58], supply chain management concerns relationship management and requires the involvement of all business functions [58]. Thus, having good partners is fundamental in the supply chain, and developing the right type of relationship is critical [59]. Some of the largest players in supply chains developed permissioned [60] blockchain platforms for ecosystem building and to manage partners in the chain [55].

Some of the main gains of these developments are '*building trust*'. Trust is the predominant factor driving adoption [55], and it has the power to revolutionize the concept of trust in supply chains [61].

In fact, decentralized systems allow participants, who do not trust each other, to trust in the systems themselves, in their algorithms and in their network of nodes [35]. Here, there might be a conceptual switch of trust because the technology "*removes the capacity to third parties to set what the truth is*" [62], so decentralized mechanisms will assure what trust is. In this mindset, companies need not '*trust*' their partners to the same degree since trust is prebuilt into blockchain systems [3], [39], [55].

Blockchain databases are decentralized ledgers, so provenance can be evaluated even when no one party can claim ownership over all supply chain data [63].

However, blockchains are still at the early stage of development [42], [55], and it remains unclear in which direction they will go [36]. Blockchains are enablers of innovation and disruption across multiple sectors of industry [4], [10], [12], [40], [43], most of all in supply chains [15], [16], [42]. However, not all believe that blockchain is disruptive [7], [9], [39]. A higher digital transformation of international trade, due to DLTs, might create vast efficiency gains for each actor in the supply chain [4], [51], [54], [64]. Decentralization is valuable for reducing the *cost of trust*; this is considered disruption [53], [62] but also improves performance, reduces the time required [55] and resolves the problem of mistrust.

Furthermore, integrative use with other technologies, such as robotics, artificial intelligence (AI) and the Internet of Things (IoT) [7], [65], is a potential way forward in blockchain deployment [15]. Thus, as defined by [41], "*the combination of blockchains and IoT can be pretty powerful for industrial applications into supply chain management*". The IoT for supply chains represents some kind of access point for cyberthreats [66]. Blockchain can mitigate these cybersecurity risks, but to enhance the security level of supply chain networks, IoT systems need to ensure higher security standards, which need to be designed from the beginning [66].

Other fundamental assets of blockchain in industry are tokens [67] and smart contracts [3], [9], [68]. These functionalities might lead to a fundamental change in the way in which humans exchange value [36].

On the one hand, these assets help by removing the involvement of third parties in any transaction [48], [53] and, on the other hand, create deterministic scenarios and related benefits into a network [69]. These can generate new digital business models, according to the definition in [68]: "*Smart contracts allow us to express business logic in code. A smart contract is deterministic; the same input will always produce the same output.*"

D. BLOCKCHAIN PERSPECTIVES

According to C.M. Christensen theory for disruptive innovations [8], we consider it fundamental to understand those aspects related to the technological nature of blockchain. This can show how the technology is performing with existing systems.

As mentioned in the previous section, blockchain has been defined as a disruptive innovation—or technology—in many studies [3], [4], [12], [15], [43]. To the best of our knowledge, the identification of the degree of disruptiveness has not been based on the qualitative measures presented by Christensen theory of disruptiveness, nor have they been based on other standardized quantitative measures. Existing studies present the growth trend of blockchain [1]–[3], but without a formalized context, such as Christensen—these results may be misinterpreted by practitioners looking to use blockchain technology. This lack of standardized measure is further complicated in cases where business implementation of blockchain provides poor results. In these cases, results of different applications cannot easily be directly compared.

These aspects can generate unpredictable risks in industrial sectors where communities need proper technology assessments to forecast and set-up the technology in business processes and operations [4], [5], [29]. Thus, the research gap we want to enclose within this study is the discordance between the degree of disruptiveness and the results of real industrial implementations thus far. In fact, contributing to the current body of knowledge, this study defines evaluation criteria in order to increase the understanding of blockchain assets.

Additionally, as explorative research, the research will analyze the degree of disruptiveness correlated with the defined enablers—and their related clusters—which could foster an industry acquisition. In this context, this research provides support to those communities working in blockchain fields and gives practical guides for industrial application. Through expert interviews, we identify those enablers which will allow a rooted development in the industrial sector. As a result, this study provides a tool to assess correlated risks for industrial implementations.

III. METHODOLOGY

This study presents explorative research based on a qualitative analysis. Applying ethnographic methods as expert interviews, we collected several data, visions and opinions about blockchain technology in industry. We proceeded by analyzing the data collected with the grounded theory approach.

A. UNIQUENESS AND PREVIOUS RESEARCH

To the best of our knowledge, this research is considered unique, given the pool of experts composed of academics and business and institutional representatives with relevant technological knowledge on blockchain and innovation management. Thus, following previous studies on blockchain-enabled supply chains [15], [16], [42], [46], [70]–[74], our research goes beyond those references, more specifically reinforcing and complementing the results obtained by Y. Wang *et al.* and N. Hackius *et al*.

Some of the previous studies have chosen experts from the supply chain area, gathering their perspectives on blockchain. Their methodologies were also based on expert interviews, conducted during a very early testing phase of blockchain in industry, when there was a first change in the vision of applications, going from just finance to broader industry applications creating high expectations in terms of cost reduction and threats to existing products. Additionally, during those years, companies were too cautious to adopt such technology, but at the same time, they showed great interest because new market opportunities were arising. Thus, we designed the research work to include complementary aspects according to the evolution of the technology. In our research, we have included experts in all three key areas—management, innovation, and technology—all working in different sectors. In accordance with [19] and [75], we set up flexible guidelines to run this ethnographic research, and we found experts with a high degree of interpretive power and extensive knowledge in the field in which each expert is working.

B. DESIGNING EXPERT INTERVIEWS

In accordance with [17]–[21], we designed semistructured expert interviews, considering the interviews as a '*specialty*' approach to collecting information and keeping a collaborative, flexible, and informal character.

To the best of our knowledge, there are no previous interview formats which match blockchain technology with disruptiveness analysis. Thus, relying on C.M. Christensen theory [8], this study designed an expert interview framework taking into consideration the contrast between the level of development of this emerging technology with the high degree of complexity for the supply chain market.

Additionally, some questions were adopted from Y. Wang *et al.*[15]. Thus, we set 15 questions on 3 macro-assets: general, market, and future (see Appendix for the interview format). The 15 questions have been generated in line with the three research questions (RQs) to fulfill the scope of this explorative research.

In the following part of the paragraph, an insight about the construction of expert interview format. Based on different frameworks, this study starts analyzing and understanding blockchain disruptiveness. C.M. Christensen's theory [8], [24] allowed first for a destructuring of technological elements [general], identifying technological trajectories [market], and the maturity level [future]. According to Christensen's theory, there are specific features for identifying innovations and market trends, dividing the scenario into two possibilities: sustaining innovation vs. disruptive innovation [8]. In addition, in line with [27]–[29], S-curve positioning has been considered an important tool to be applied. Following C. Pérez's paradigms, we focus on dominant design [76]–[78], technology systems and trajectories [28], [79]. In fact, following C. Pérez's framework, it helped us to set a similar mindset for blockchain technology as an "*interrelated, interconnected and interdependent system*". However, as blockchain technology presents some characteristics still related to its infancy [15], [16], [36], we consider it worthwhile to use the S-curve for the positioning of blockchain in industry, identifying system trajectories and possible directions for future blockchain developments.

To reach these goals, we conducted 18 expert interviews and analyzed data collected following grounded theory.

C. GROUNDED THEORY

In accordance with J. Corbin and A. Strauss [80], we designed a dynamic approach for this qualitative research; this dynamic approach allows us to evolve in design as the study progresses [17]. Thus, as a form of qualitative research, grounded theory (GT) has the purpose of constructing theory grounded in data [80]–[85]. This aspect allows for the identification of general concepts and the development of theoretical explanations and offers new insights for the studied phenomena.

GT is a general method of comparative analysis in which data are systematically obtained [81], [83]–[86]. The use of GT provides modes of conceptualization to describe and to explain the current situation of blockchain in industry. In fact, considering the previous studies on blockchain-based supply chains that also used both GT and expert interviews [16], [70], [71], GT showed better results. GT is an iterative, comparative, and abductive method [85], [87], [88]. Developing a comparative analysis of the data collected, the interactive process helps reach an abstractive level of analysis [85].

D. DATA COLLECTION

A list of 52 experts was first identified and classified into three different clusters, where each interviewee presented more experience: academic, business and institutional. A second assessment of the experts allowed us to reduce the number from 52 to 29, taking into account the level of activity in terms of blockchain, innovation and close topics in the last 3 years.

The pool of 29 experts has been ranked *ex-ante* with a priority list. With the support of tables and organizational tools, the priority list allowed to fulfill specific fields of interests required for the study. It was predefined at the beginning of the interview process.

Thus, the final set of 29 experts was contacted by email to concert a first interview. The email structure followed a formal format of presentations, interest in the study and why we consider the involvement of this expert suitable.

Setting a priority list of interviewees, we collected the data between March 2019 and January 2020. Developing grounded theory, we reached saturation after 18 interviews. Finally, a pool of 18 experts was interviewed during this study, with dense interviewing activities between October and December 2019.

On average, this pool of experts provided availability for a 45-minute timeslot each to analyze and discuss the questionnaire presented. However, the average time for each expert interview was 55 minutes. Following [17]–[21], during the interview, we followed a double framework: first an informal and open discussion, followed by a semistructured interview regarding the proposed questions (see Appendix).

Additionally, according to [89], 18 interviews are a valid sample for this study.

As shown in Table 1, the experts involved were from 3 continents and 9 different countries. Some interviews were conducted in person, following a formal face-two-face meeting [8 experts], and others in virtual meetings [10 experts] using video-conference software. Nine of the experts are academics, representing 50% of the pool; 7 out of 18 are business experts, representing 39% of the pool; and 2 out of 18, are institutional experts, representing 11%. However, following a gender-based classification, 72% are male experts [13 out of 18] and 28% are female experts [5 out of 18]. This 28% female rate is disappointing for us and not as good as we hoped.

E. EXPERT BACKGROUNDS

The pool of experts is heterogeneous, interdisciplinary, and worldwide, with recognized knowledge on innovation management and blockchain technologies. They have different backgrounds in academia, business, and institutions. On average, interviewees involved were studying and/or working in blockchain technology from 2012-2016 and are equally distributed. They are also equally distributed in terms of permissioned and permissionless blockchain systems. All experts have a '*senior*' profile, and almost all of them were running activities during the "*.com*" era inside the related digital evolutions. Some of them have been involved in the ISO/TC-307 for blockchain interoperability, and most of them have deep market orientations within critical perspectives on blockchain.

Their backgrounds vary and are correlated with intellectual property rights, engineering, telecommunication and Internet of Things, mathematics and cryptology, innovation, economics and business management, supply chain management, identity and privacy, consensus protocols, cryptographic products and financial systems.

F. DATA PROCESSING

Collecting all the responses provided by experts during the interviews, we extracted the rationale from each provided answer to reduce complexity during the analysis. In accordance with the grounded theory approach, we collected memos as a source of data. Similarly, we collected a secondary source of data, attending conferences and workshops, analyzing companies' white papers and academic reports[1]. In addition, we analyzed some reports

[1] L. Hoyal, "Talking about a new revolution: blockchain.," European Patent Office, 2019.
N. Vadgama et al., "Distributed Ledger Technology in the Supply Chain," UCL Centre for Blockchain Technologies, 2019.
D. Allessie et al., "Blockchain for digital government," European Commission, Joint Research Centre, Digital Economy Unit, 2019.
D. Galen et al., "Blockchain for Social Impact," Stanford GSB Center for Social Innovation, 2018 and 2019.

TABLE 1
POOL OF EXPERTS INTERVIEWED

#	Respondent provenance	Respondent position	Gender	Location
01	Blockchain company for Logistics	Chief technology officer; Chief product officer (co-founders)	M	Belgium
02	University – Engineering School	Associate Professor in industrial automation	M	Italy
03	University – Engineering School	Associate Professor in distributed cryptographic techniques	F	Spain
04	University – School of Economics, Marketing and Finance	Research fellow in economics and political economy of blockchain	M	Australia
05	University – School of Information Technology	Lecturer on computer science and blockchain	M	Switzerland
06	University – Business School	Research fellow in the digital economy	F	United Kingdom
07	University – Business School	Lecturer in logistics and operations management	F	United Kingdom
08	University – Engineering School	Full Professor on wireless communications and blockchain	M	Spain
09	Consulting company for innovative information technology products	Global growth advisory	M	New York
10	Management consulting company for innovation and research exploitation	Director of technologies and digital areas	M	Spain
11	University – Institute for Innovation	Honorary Professor	F	United Kingdom
12	Blockchain and frontier tech-consulting group	Managing Director (founder)	M	New York
13	European Institution	Deputy Head of the Social Security	M	Belgium
14	ICT – Multinational telecommunications company	Cohead of Blockchain Competence Center	M	Spain
15	European Institution	Director of International Co-operation; Patent examiner	M	Germany
16	ICT – Multinational technology company	Blockchain Principal Investigator/Technical Leader	M	Ireland
17	ICT – Technology provider company on blockchain-based supply chain	Chief executive officer (founder)	F	United Kingdom
18	University – Engineering School	Full Professor on cryptology	M	Belgium

from the EU Blockchain Observatory and Forum[2] and governments' guidelines[3]. These double sources of data helped us acquire a broader overview and critical thinking about the data collected.

G. DATA ANALYSIS

For the analysis, we started collecting memos and audio[4] from each expert interview. This information was analyzed and transcribed for each interview. With these transcripts, we re-assessed all the obtained information during the process, and we validated the next steps. In the end, when we reached saturation, these texts were compared and joined in a single dense text, following the questionnaire's structure. Then, starting from this full version of the compiled text, we proceeded with the data analysis and coding. With the support of tables, we compared data to generate categories, but before doing so, we ran a second iteration of code assessment, reducing the number from 448 lines of codes to 218 lines of '*cleaned*' codes. In fact, in accordance with [85], we fragmented the empirical data through coding in mode to individuate abstract categories that provide a conceptual analysis of the data collected. To identify the theoretical concepts, we iteratively compared the data collected. In fact, to test ideas and concepts, [85] suggests embracing an imaginative and creative interpretation, followed by a rigorous examination. Therefore, comparing data and codes with categories and considering the major categories as concepts, we proceeded by comparing the concepts among them to validate the results [84].

In Figure 1, we present the major outcome categories from the analysis.

However, we consider it relevant to present an insight about the analysis to develop the concepts and categories. Thus, in Table 2 is presented a brief explanation of the intermediate process that was used to reach final categories. According to the construction of this experiment, three main areas were identified as qualitative measures—as explained in section III.B: A) technological elements to obtain a general viewpoint about the technology usability and technology accessibility; B) technological trajectories to obtain a market value within trends for interrelated and interdependent systems; and C) maturity level to understand how to shape upcoming evolutions that might design future disruptions.

TABLE 2
INTERMEDIATE PROCESS OF CATEGORIES VALIDATION

Areas	A) *	B) *	C) *
Concepts	-technology features -innovation paths -maturity levels	-other technologies relations -supply chains -internet of things -Bitcoin and Ethereum -ISO standardization	-performances -needs -benefits -risks

* see section III.G

[2] T. Lyons *et al.*, "Blockchain innovation in Europe," 2018; "Building better supply chains with blockchain," 2019; "Convergence of Blockchain, AI and IoT," 2020; *European Union Blockchain Observatory & Forum*. Online at: www.eublockchainforum.eu/reports

[3] "The National Blockchain Roadmap," *Australian Government. Department of Industry, Science, Energy and Resources*, 2020.

[4] We recorded the interviews only for those experts who gave us permission.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

IV. FINDINGS

In this section, a summary of the main findings emerged from experts. The results were assessed and analyzed to create valuable outcomes that focused on making efforts to answer our research questions. Following the structure of the analysis presented above, a clear definition of major categories is as follows: features, innovation paths, digital transformation, maturity level, and industry existing-systems integration (Figure 1). In addition, in some parts, where experts presented relevant divergent opinions, we divided the paragraph into issues that generate a common consensus and other issues about which there was some controversy among experts. A brief and concise description of the main findings is provided below, while Table 3 presents a summary of the intermediate data from experts, following the abovementioned structure.

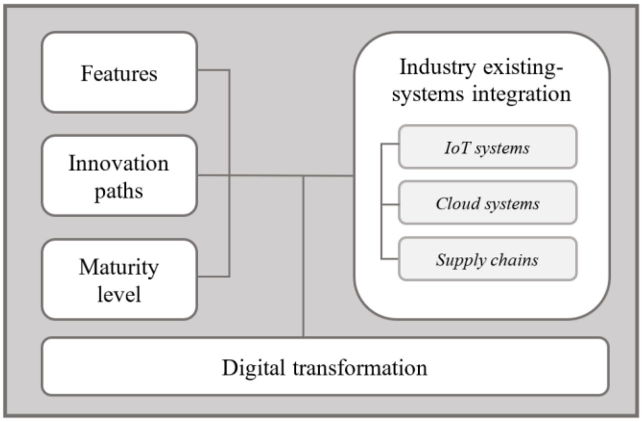

FIGURE 1. Major categories that emerged from the analysis

A. FEATURES

The evolution of certain technologies during the last 40 years has allowed for and supported blockchain creation. Thus, blockchain is a technology aggregation of several individual technologies and is defined as a new technology layer for industrial applications. It uses five assets: cryptography, protocols, software, computers and the network (see Table 4).

Blockchain shifts some of the trust in people and institutions to trust in technology. People need to trust cryptography, protocols, software, computers, and networks. People need to trust them absolutely because they are often the single points of failure.

The technology side does not need to be increased; in fact, this technology provides new access and decentralization, without the need for a central authority. Additionally, blockchain is defined as a fantastic way in which to organize information and data, and blockchain has a fundamental role in digital assets. However, it does not mean disruption; in fact, blockchain might be defined as a database technology. It is a decentralized database with the addition of consensus protocols. The consensus mechanisms are the '*plus*' that blockchain technology brings to markets, and it will be a secondary system after the primary running systems.

Permissioned blockchain systems are shared databases with shared ledgers. Thus, in these '*shaped*' platforms, customer decision making might be modeled as a vending machine (VM) that has methods (tokens) and different logics (smart contracts). Hence, blockchain is not a consumer technology but rather a software-based technology, and even if there are some limitations (lack of efficiency, high costs, and inertia due to change), all technical problems will be solved, aligning them to the other platforms/systems in use.

B. INNOVATION PATHS

Since DLTs bring into the market public computers, experts highlight that these public computers are the new paradigm. Public computers are the '*novelty*' for blockchain innovations. Thus, blockchain is not disruptive; it is a sustaining innovation that only increases performance.

Moreover, blockchain is a bottom-up innovation and, as an incremental innovation (see its definition at [79]), it brings about progressive changes and performance improvement for already existing systems. Permissioned blockchains are incremental by nature and, in several companies, innovation managers overestimate them.

Experts do not see blockchain technology as a new technology revolution but rather a technology system. The sector is highly fragmented concerning this technology-driven innovation, and the blockchain's evolutions are pushed by technology and shaped by the market. In this context, blockchain follows a bottom-up development process, where communities play a key role. Additionally, blockchain impacts business procedures, changing operational strategies. Therefore, processes will be replaced in industry.

Consequently, and according to our experts' findings, blockchain is defined as a toolkit to use, not a need; in fact, there are no needs from the market, and citizens have no need for blockchain. However, what blockchain does is change possibilities and provoke people to change their customer attitudes and behaviors.

Currently, large companies are leading blockchain development (incumbents), and these larger industry tests are centralized.

In the next few years, the blockchain market will become more competitive, and these large companies will become leaders in different blockchain applications.

C. DIGITAL TRANSFORMATION

Considering digitalization strategies, this technology might represent a '*catalyst*' for digital business implementation and transformation. In the short term, it will predominantly reduce costs before creating transformative business models. In fact, blockchain facilitates structural changes, and due to the other technologies harmonized with it, people may have the chance to change possibilities,

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

TABLE 3
SUMMARY OF INTERMEDIATE DATA FROM EXPERTS AND QUOTES

Categories	Responses from experts		
	Commonalities	Controversies	
		Academics and researchers	Business and institutional representatives
Features	-As a software-based technology, BT is just a new technology layer -BT is a secondary system alongside the primary running systems	-High risk	-High costs
		-Lack of efficiency	-Inertia due to change
		*"a fantastic way for organized information and data"	*"what BT does is shift some of the trust in people and institutions to trust in technology"
Innovation paths	-BT is not disruptive, as it is a sustaining innovation that only increase performance -Permissioned blockchains are incremental by nature -BT is a technology-driven innovation -Larger industry tests are centralized	-Power to change behaviors for administrative tasks	-Power to change business models and business processes
		-As institutional innovation, BT is a government toolkit for public administrations	-BT may represent the loss of a democratic society, and thus, it is not for digital democracy
		*"blockchain represents a sustainable innovation"	*"blockchain is a bottom-up innovation"
Maturity level	-There are no working use cases in industry -This is a learning moment for R&D, and there is no dominant design -BT will not be a product but rather a service (BaaS) -Broad communications, websites and daily news that are not informative and generate perplexity and mystification -Exit strategy from BT is an issue	-The market is not ready, and there are no parties ready to join	-Tokens have been broadly tested
		-The maturity level is low, and neither the market nor the technology is ready for adoption in industry	-The technology side is mature and ready for market implementation
Digital transformation	-BT is a structural chance, due to the other technologies harmonized with it -Bitcoin and Ethereum are only applications -The ERC-20 standard for tokens allows people and companies to launch ICOs worldwide	-For identity, digital signatures, IoT and data, AI	-For blockchain-led mobility, blockchain-led logistics, tokenization
		-BT is a 'catalyst' for digital business implementation and industry transformation	-Reducing costs before creating transformative business models
		*"simple standards can support new business models"	*"ERC-20 allows for the sharing of value in a standardized way"
Industry existing-systems integration	IoT systems		
	-IoT systems are crucial for BT in industry -IoT is a key component adding distributed consensus -IoT and BT can solve some inefficiencies	-The BT's changing point will be its integration with IoT systems	-IoT and smart contracts will enable new blockchain-based business models
		*"IoT systems are the catalyst that can enable the machine-to-machine payments by smart contracts".	*"IoT systems are the bridges to using DLTs in a real world. However, the match is worthy and risky at the same time because nobody controls IoT systems"
	Cloud systems		
	-Fair analogy between blockchain and cloud systems -BT is a database technology: decentralized databases with the addition of consensus protocols -Facilities and computational power worldwide -Accesses from local units to remote units	-New generations of databases would emerge	-Blockchain systems are shaped platforms that have methods (tokens) and logics (smart contracts)
	Supply chains		
	-The supply chain is a key area for BT applications -Blockchain-based supply chains are nondisruptive applications -Most famous projects are centralized blockchain-based platforms -Blockchain, as a service, generates frictionless operations and new negotiation procedures -BT creates and supports the redistribution of value in the value chain -BT is a solid application for ecosystem building -Higher level of transparency -Food is one of the environments that will obtain greater benefits	-No working uses cases in supply chains apply the whole BT's potential	-Blockchain-based supply chain is simple and easy to develop
		-The challenge is how to share data to create intelligence	-Difficulty in resolving the 'coopetition' paradox
		-Lost intermediary and being paperless	-BT does not have to be a 'disintermediator' to generate value
		-BT creates closest venues for/to consumers	-BT for supply chains is a small financial system
		*"the future implementations of BT into supply chains will empower customers changing their behaviors in the market"	*"BT has the ability to boost confidence in the relations between players in a network."

* quotes are provided as insight to illustrate some of the bullet points

channels and access to technologies and markets. Moreover, initial coin offerings (ICOs) showed good results in exchanging digital assets and changing customers' attitudes and behaviors, but the disruption here concerns business processes and accessibility.

Experts have highlighted that Bitcoin and Ethereum are just applications. The Bitcoin blockchain is the first successful use case for Fintech, but currently, Bitcoin is acting as a detractor for practitioners and industries. In fact, Bitcoin is not the leader at all, as blockchain has been polluted by Bitcoin's reputation. Instead, the Ethereum blockchain is the first successful use case in industry for ecosystem building, as an open system, for its collaborative approach, and for the standardization '*The ERC-20 token*'. Thus, there are currently no pioneers or leaders in terms of industrial blockchains.

Consequently, ISO standards have impacted business and society because they allow for the sharing of value in a standardized way, but ISO acquisition takes time, and the standards need to be as simple as possible to support new business models. ISO/TC-307 standards might provide better accessibility, representing a tool to disseminate innovation and to harmonize different protocols, mitigating interoperability issues. For instance, *the ERC-20* standard for tokens allows people and companies to launch ICOs worldwide. Hence, ISO/TC-307 might also represent a good tool to open new markets and increase the chances for improvements in the blockchain world.

Standards are not going to impact blockchain technological innovations. If the ISO/TC-307 is pushed, then it might have dangerous effects, converting its power into a tool to combat against technology progress for blockchain. Therefore, it is important to mitigate these risks, keeping in mind the decentralized nature of such technology.

Some controversial opinions have emerged about the future evolution of the technology in sectors where it would be more impactful. Academic experts have addressed its potential in terms of accountability, public administration and education, whereas experts from businesses and institutions have addressed its potential in terms of finance, banks and related services.

In fact, some of the interviewees defined blockchain as an institutional innovation and as a powerful governmental toolkit for public administrations. Controversially, other experts added that blockchain can achieve a better design if pushed by governments, but at the same time, some of them believe that blockchain may represent the valuable loss of a democratic society (with high social concerns), so they explain that blockchain is not useful for improving the digital democracy.

D. MATURITY LEVEL

According to the maturity levels established by [27], [28], [78], the development of blockchain in industry is positioned into the proof of concept (PoC) phase, where there is no dominant design; thus, the dominant design has not yet been reached. In fact, PoCs are not ready for massive industry implementation, and neither the market nor technology are ready for the general adoption of PoCs. Thus, the market is not ready for this technology, and there are no parties ready to join. Therefore, the interviewees point out that the real challenge is to find a working use case where blockchain is applied in industry because there are not yet working use cases in industry that allow for prompt adoption in the industrial sector. Hence, in this PoC phase, even if the maturity level is low and there is deep market confusion, the *core* technology side is considered mature and ready for market tests. However, experts do not see blockchain as a product but rather a service. In some environments, blockchain has been tested following the blockchain as a service (BaaS) model.

Currently, a learning moment for R&D exists, and more education is needed regarding blockchain. Additionally, higher confidence (*trust*) in technologies is needed, but inside the community, more clarifications as to the implications and exact meaning of *trust* are needed. Additionally, trusting open systems (OS) might help solve scaling-up issues. As a 'network language', a classification of this language must be applied in industry. Because there are high expectations for blockchain, it is not completely understood and faces the risk of being overestimated.

The interviewees also agree that blockchain in terms of social aspects is not scalable, and if pushed, unexpected risks may emerge. In fact, achieving full decentralization, data

TABLE 4
EXAMPLE OF TECHNOLOGICAL AGGREGATION THAT DEFINES THE BLOCKCHAIN INVENTION

Technologies	Features*	Activities*
The Cryptography	Hashing and asymmetric cryptology	Digital signatures/keys Simplify connections
The Protocol	Network language based on consensus	Monitoring and control
The Software	Collaborative approach for computer programs	Time stamps Transactions
The Computers	Decentralized databases with consensus protocol	Record keepers Computational power
The Network	Public computers with Internet (with open or restricted access)	Validation/deny Stream data

* not an exhaustive list

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

face the risk of privacy. This privacy issue is one of the main criticisms, critical for data integration and for data analytics, and for this reason, permissionless blockchains might represent risk.

Another problem is asymmetry in information and communications. Mass communication is not informative and generates perplexity and mystification within the community. Quite often, the daily news is untruthful and misleads communities, hampering industry acquisitions. For example, cryptocurrencies have scared practitioners in terms of financial consequences and speculations.

Additionally, the lack of an exit strategy for blockchain is an issue.

E. INDUSTRY EXISTING-SYSTEMS INTEGRATION

These findings have been split into three main areas: Internet of Things systems, cloud systems, and supply chains.

1) INTERNET OF THINGS SYSTEMS

The Internet of Things (IoT) is a key component in which adding distributed consensus methods opens up new opportunities. Hence, leveraging IoT infrastructures with blockchain will generate new working use cases, and IoT systems are identified as a crucial asset for blockchain in industry. In fact, the lack of technology enablers might be filled (partially) by the Internet of Things as a '*means*' through which smart contracts are run. However, the IoT is able to run smart contracts and tokens at the same level of application, enabling new blockchain-based business models for industrial implementation.

In the long term, experts see that smart contracts represent future power and could disrupt operations (*with new logics*), but in the short term, tokens (*new methods*) will be the nearest future with a good market space. In fact, tokens are much more mature in the market because they have been frequently tested and implemented in the banking and finance sectors with ICOs. Additionally, the '*changing point*' is identified when integration with IoT systems will happen because IoT systems might be the catalyst by which *machine-to-machine* payments can be enabled by token (*methods*) and smart contracts (*logics*).

The implementation of the IoT in blockchain-based supply chains can enable ownership of things and identification and match with the real world. These relationships with the identity of objects, ownership and sensors need to be strategically designed; otherwise, they do not make any sense. This strategic implementation is related to value capture and value proposition for application in business operations. In fact, running IoT-based data capture for DLTs might allow IoT systems to act as the '*bridge*' to use DLTs in the real world.

Here, a third party is needed because if the IoT is the '*controller*', then the third party controls the controller. Therefore, the match between blockchain and Internet of Things is worthy and risky at the same time. This implementation is critical and needs a step in between to be more secure and to mitigate this lack of control of IoT systems.

Moreover, the IoT and blockchain can solve some inefficiency. They can increase the traceability of transactions and increase security, but a differentiation between products (e.g., diamonds) and processes (e.g., oil or chemicals) is needed. For instance, in specific environments where security and safety are important (such as chemical tanks), sensors become an extremely relevant feature to be considered for blockchain applications.

2) CLOUD SYSTEMS

Experts also highlight the fair and clear analogy between blockchain and cloud systems. They provide a comparison between these two technology systems. In fact, as cited above, blockchain might also be defined as a database technology, that is, a decentralized database with the addition of consensus protocols.

The comparison between blockchain and cloud systems highlights the main aspects that are correlated with these two systems and analyzes the main aspects and characteristics distinguishing these two technology systems.

Therefore, experts have provided some additional food for thought about which progresses will be generated and what evolutions and impacts will characterize *blockchain as a service* in future applications in industry.

They infer a set of common aspects: both are designed *as a service*; both are software-based technology; deployment models are public or private; security follows cryptographic protocols; the access evolves from local units to remote units; applications are on private and public networks; and ISO standards are both in progress.

Different aspects are presented as follows: the network is centralized/decentralized for clouds (*A*), whereas the network may be decentralized/distributed for blockchain (*B*); the assets for *A* are archives and back-up keepers, whereas the assets for *B* are recordkeepers and decentralized ledgers; and the assets for *A* are centralized databases, while those for *B* are decentralized databases with consensus protocols. Thus far, the enabler technologies for *A* have been the evolution from hard disk drives [HDD] to solid-state drives [SSD], whereas for *B,* the evolution (so far) concerns the mining processing that started using the central processing units [CPUs], graphics processing unit [GPU], and then application-specific integrated circuits [ASICs]. The growing third-party capabilities were storage space worldwide for *A* and computational power worldwide for *B*; the impacts have been on remote storage for *A* and on remote computing for *B* (cloud mining).

Given this explanation, we would like to provide experts' overviews and focus on how these evolutions, such as remote access, can enable new technological '*shapes*' for database technologies in industry, open up new levels of performance

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

and change paradigms, and run operations. One of the '*impacts'* might be the opening of new business models and digital services enabling IoT devices to become increasingly powerful, externalizing (running remotely) all the '*heavy*' processing procedures.

3) SUPPLY CHAINS

Experts have agreed that blockchain-based supply chains are nondisruptive applications that add a new technology layer to software-based technological systems, and experts define supply chains as a key area in which blockchains are implemented in industry. Thus, the blockchain-based supply chain will be an added '*service',* and a *blockchain as a service* (BaaS) might generate frictionless operations and new negotiation procedures. To allow for this, three key points need to be taken into consideration: the decentralization level, scalability potential, and security clearance.

Currently, most renowned projects are centralized blockchain-based platforms that are showing solid applications for ecosystem building in the chains. This technology will be the trust keeper, impacting all recordkeeping processes and at a higher level of transparency for all stakeholders, due to updated real-time information and verifiable processes.

However, *trust* requires an '*e-ID representative*' for provenance verifiability. Experts have defined identity as a potential enabler for blockchain-based supply chains, empowering customers with product transparency and traceability that can level value chains out and boosting supply chain democracy and ethical consumption. A blockchain-based supply chain creates and supports the redistribution of value in the value chain. Thus, blockchain is suitable for the optimization and trust of food supply chain operations, making the food industry one of the first environments to obtain greater benefits from this technology implementation.

Additionally, before the end of this year, many patents will come out, bringing to the market more restrictions and leaders, such as IBM, which is the leader in patenting blockchain. However, experts have addressed the future evolution of supply chains in smart contracts. In fact, designing blockchain-based IoT systems linked with supply chains, logistics can humanize the boxes of a chain, moving closer to the mobility paradigm.

In addition, some controversial opinions have emerged among interviewees on supply chain applications as follows.

The current state of a blockchain-based supply chain is described according to two different views. Academics suppose that there are no working use cases in supply chains that apply the whole technology's potential because incumbents play in a centralized way, designing centralized data platforms. Rather, academics assume that blockchain for supply chains is a tool that can create closest venues for/to consumers. Business and institutional experts have described blockchain-based supply chains as simple and easy to develop, explaining how they represent a '*small financial system*' in which there are fewer and narrower problems to solve.

Additionally, the major impacts of this technology have created controversies, where academics suppose that it will impact customer behaviors, rather than others, in terms of ports and port authorities. This is because the main challenges will be how to share data to create intelligence and how difficult it would be to resolve the '*coopetition*' paradox in supply chains.

Instead, to create value, academics think about the loss of intermediaries and being paperless; other experts explain that blockchain does not have to be a '*disintermediator*' to generate value, but it can represent a changing tool for the stakeholders involved and enhance data management in the network.

V. DISCUSSION

In this section, we discuss the main findings of the study, providing answers to the proposed research questions, and present our considerations and the contributions of this research.

A. ANSWERS TO RESEARCH QUESTIONS

After this analysis, we aim to answer the main research question: *what are the enablers for blockchain disruption in supply chains*?

Thus, following the proposed framework, we proceed, answering in line with the three subquestions to address specific themes and then collecting them in a comprehensive analysis in the next paragraph.

RQ.1. *What are the present and future perspectives for blockchain in industry?*

The industrial applications for the present situation are clearly assigned to the proof of concept phase. In fact, according to [28], until the dominant design is reached, the technology system needs to be considered inside the exploration phase. Many trajectories of development could emerge from this individual technology before it reaches a clear direction on the 'S-curve'.

Thus far, for blockchain in industry, there are no working use cases that exploit the full potential of this distributed technology. Moreover, this technology is considered a bottom-up innovation where communities play a key role in the development of blockchain as a service. However, so far, they are centralized applications.

Additionally, several companies, projects and organizations are using blockchains as a marketing asset, not for applications but only to enhance their cutting-edge profiles. This aspect creates confusion and perplexity in communities approaching blockchain, creating misunderstandings about its real features and usability.

Otherwise, regarding future perspectives, the blockchain's

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

potential is clearly seen by experts. However, blockchain is not seen as a disruptive innovation because there is a lack of enablers for industrial acquisition. Hence, with a lack of key enablers, this process will take time before being fully operative in the market. Furthermore, the solving of some of the several issues affecting blockchain is needed, and it can help with the faster acquisition of blockchain in industry.

RQ.2. *How can blockchain in industry be effectively connected to other interdependent systems?*

Following [8], blockchain is not disruptive; instead, it is a sustaining technology that increases the performance of existing processes. Thus, blockchain systems need to be connected to other technological enablers that may support new business models and a possible disruption in industry.

Moreover, as has emerged, identity is not a blockchain problem, and the related issues need to be solved with other technologies. In fact, identity is considered off all the technical configurations; however, digital identity is considered one of the main sectors to explore because it represents one of the potential enablers that can facilitate acquisition in the network and provide better accessibility.

Furthermore, blending digital identity and IoT systems in blockchain structures would foster the generation of new digital business models as a key asset for the next development steps. Thus, this development needs to be designed as an open system, where communities can act and play a fundamental role in it. The Internet of Things (IoT) is also considered one of such enablers.

From experts' visions, the IoT makes sense in the future development of industrial blockchains. In addition, it will be the added technology layer that can enhance negotiation procedures and industrial trust. Otherwise, a third added layer is needed in between to be implemented into industrial systems and to assure trust and trustable data.

RQ.3. *How can blockchain in supply chains effectively foster digital enhancements?*

Since the current industrial tests are centralized, a challenge will be to improve the decentralization level in blockchain-based supply chains. Running applications are a good tool for ecosystem building and achieving higher levels of trust in business networks. Thus, this can fairly support the resolution of the '*coopetition*' paradox in supply chains and in the designing of new processes that are mutually beneficial for the stakeholders involved. In fact, there is a growing necessity of engaging stakeholders to understand their needs, in order to deal with the '*coopetition*' paradox [90]. Hence, breaking down trustable operations can help to create value for the whole supply chain, fostering technology scalability and overall decentralization.

As a first identified solution, considering the technological gap between research and industry, it might be required to define a fair tradeoff between distinguishing features—decentralization level, scalability potential and security clearance—as this tradeoff may also play a relevant role in contributing to both industry and understanding.

However, blockchain will be a *service* for supply chain stakeholders. These new services can support the restructuring of value chains, with new information flows and new responsibility duties. In addition, food supply chains are considered the field in which it makes more sense to apply (step-by-step) these technology improvements. In addition, trust (or *chain-of-trust*) could be set as a new service for customers that can bring about more ethical consumption in the market and then strengthen the community of informed customers.

Therefore, merging existing systems, such as digital identity and IoT systems, with smart contracts and tokens can generate '*killer*' applications for supply chains. Enabling business networks to move toward a higher level of digitalization and automatization of administrative duties.

This can be designed as a deterministic virtual machine for industrial operations, following an accurate definition of processes, procedures, responsibilities, and duties. Additionally, extraordinary or emergency situations can be defined, but this digital enhancement directly address autonomous payments, autonomous maintenance, and machine-to-machine transactions for frictionless business negotiations.

Hence, concerning digitalization strategies, a key asset for industrial automation is addressed as to how the cryptographic identity of IoT devices can replicate the asymmetric cryptography used on blockchains to generate randomness in devices' identities, enhancing security and control.

Finally, some kind of artificial intelligence ought to be blended with these solutions to spread the potential for new business model generation and new industrial viable solutions.

B. CONTRIBUTIONS OF THE STUDY

Due to the interview sessions, several data points were collected, assessed and analyzed to reach the aim of the study. With these obtained results, we identified key enablers where communities need to focus more efforts to foster blockchain adoption in industry.

Identifying enablers will guide practitioners during the risk assessment related with blockchain deployment. Given that implementation risks are still high for blockchain, isolating specific features would be relevant to define the required steps for development.

Therefore, considering this as exploratory research, we present possibilities to identify specific acquisition steps that can allow for frictionless blockchain developments in industry. This means the identification of those enablers that bring about new technology improvements in the technology system.

In this section, we present our consideration for future possibilities. We have identified four main areas: 1)

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

positioning, 2) timing, 3) change management and 4) enablers.

From these following four paragraphs, we lay the foundation for improving management of blockchain innovations. Approaching new levels of developments, it is critical to take into consideration relevant risks, intended function, and the ability to design and assess the benefits—where they exist—of technology acquisition.

1) POSITIONING ON THE "S-CURVE"

Blockchain per se is not disruptive; experts see it as a sustaining innovation/technology that brings about new performance in a new technological layer. As an aggregation of several technologies, the innovative step lies in the combination of activities and in how individual technologies are aggregated and blended. Therefore, we can say that the *novelty* aspect of blockchain has no technical features (see Table 4), whereas such *novelty* is present in public computer networks and the access thereof.

Blockchain is a technology system; as such, blockchain innovations are opening new trajectories of development in several industrial sectors, impacting them in different manners. Given that there are no working use cases in industry but only proof of concepts (PoCs), we can assign blockchain models into the explorative phase of the 'S-curve' graph [28]. In fact, there is no dominant design; according to C. Pérez, the design is still open to new industrial '*shapes*.' These new shapes will play a part in new digital business models and in new ways in which to manage processes. However, this process takes time and is not predictable right now. According to this, we provide an example in Table 5 to assign this unpredictable process to some events that occurred during the development path.

2) TIMING FOR ADOPTION

Since a dominant design is missing, after the analysis of collected information, we can expect a minimum period of three years before blockchain enters industry, contributing to value creation and value exchange. However, there are still many issues to take into account and resolve before this acquisition; in fact, the interviewees consider this prediction optimistic.

In addition, as experts remarked, several regulations are still missing, and this progress will take time to be operative and acquired in the business world. Governments and institutions, who are imagining blockchain development for public procedures and for public administration, still have a long path to run. We can optimistically presume a period of five years.

However, we can suppose that in the next five years, blockchain will achieve robust development and interoperability with other systems and will assure feasibility at scale. This will be possible due to the growing focus institutions and business communities are placing on the technology, and the growing investments they are exploiting.

3) CHANGE MANAGEMENT FOR TECHNOLOGY TRUST

For centuries, the common meaning of '*trust*' was allocated to people, institutions or third parties. In recent decades, technological development has added a further level of '*trust*', switching some elements of trust to technology trust. Blockchain technology is part of these changes, and managers need to consider it in advance because these changes will impact common ways in which to operate and processes. Hence, new different paradigms of management will emerge to set up new lean procedures to assign technology trust.

For example, considering a blockchain-based food supply chain, the word '*trust'* for companies means transparency, traceability, tracking and tracing. These four aspects together impact the whole system, allowing for real-time information systems, digital identities of approved parties, ethical attitudes/behaviors for stakeholders involved, and a closest avenue to/for customers. However, these '*4Ts*' of trust require an effort by the management team in companies to solve related problems coming from new business models, new/higher technical applications, and higher expectations from customers on controlling the net. Therefore, trusting technology will be a business advantage, but it needs to follow a rigid management procedure; otherwise, it will be considered a risk for the companies involved, causing them to lose their market position.

In addition, to properly manage a blockchain core business, the management team needs to mitigate the missing technical-knowledgeable people inside companies. This is an aspect that cannot be excluded or underestimated for blockchain businesses, or otherwise, it may generate unpredictable risks. In fact, technical people cannot be a third-party or an externalized service; they need to be inside and completely part of the team. If the technical aspects are the *core*, then the core technology cannot be externalized to mitigate, monitor and control all security management

TABLE 5
EXAMPLE OF AN INNOVATION PATHWAY

To provide an example regarding the positioning into the 'S-curve' graph and trying to represent the "*dilemma zone"* for blockchain in industry, the following can be true: "considering Hyperledger as the leader in designing *Blockchain as a Service* and providing several tools for companies in narrowed market niches, considering Bitcoin as a use case for banks and financial procedures to solve double-spending problems, and considering Ethereum as a use case that allows for the transfer of ownership, we can follow the evolutionary progresses on these three large networks and imagine this flow as three common steps of development: STEP_1) in 2008, Bitcoin launched blockchain for fintech and banks applying new '*methods*' to manage and exchange money – cryptocoins; STEP_2) in 2014, Ethereum created a new language (solidity) and new '*logics*' to manage the ownership of money – smart contracts; STEP_3) in 2016, Hyperledger created a network where these '*methods*' and these '*logics*' might be applied in industry. These new models, patterns and structures have been implemented '*as a service*', capitalizing the ownership of money for interested companies (still in proof of concepts). However, it created new blockchain-based services (or *BaaS*) that are following the '*methods*' and '*logics*' used before.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

procedures.

Therefore, risk mitigation and risk management need to be structured and defined before starting a blockchain project.

4) ENABLERS

As mentioned above, blockchain is not disruptive for industrial applications. It is a sustaining innovation that increases the performance of processes and operations. However, following the examples provided by [25], neither Uber nor Netflix use fully disruptive technologies, but they are considered disruptive due to the enablers applied in a specific market sector (see Table 6). Thus, we would like to discuss our findings in terms of blockchain's potential enablers.

As has emerged, we present a proposal of the potential enablers of blockchain in industry. In accordance with this study's research findings, based on expert interviews. To the best of our knowledge, these enablers have the potential to turn future blockchains into disruptive applications.

As mentioned, disruption is not predictable, but within this study we lay the foundation for the identification of enablers, following the Christensen theory. This identification might guide practitioners during the assessment of risks related with blockchain developments. In such cases, this guide would help isolating specific blockchain functions/activities. Isolating specific functions, practitioners can test if blockchain makes sense for the analyzed operations, and if the solution is exploiting the whole technology potential.

Furthermore, as explained above, these enablers not only increase performance but also can foster new ways in which to operate, new processes and the generation of new digital business models (see Table 6). In fact, due to these enablers, new *blue ocean opportunities* [31] might succeed in industrial sectors, so that they would be likely exploited to achieve disruptive innovations.

Hence, as listed and explained below, we conclude by highlighting our main contribution of answering the broader research question we pointed out in the section I: *what are the enablers for blockchain disruption in supply chains*? Thus, the identified enablers are gathered in five categories (Figure 2): a) access enabler: *identity and digital signatures*; b) value-creation enabler: *artificial intelligence and data*; c) interoperability enabler: *tokenization*; d) remote enabler: *Internet of Things*; and e) social enabler: *blockchain-based mobility and blockchain-based logistics*.

a) Identity and digital signatures

Identity and digital signatures are not technical problems that may be solved just by blockchain. Identity requires other technologies, and these technologies are already deployed in industry, presenting good levels of performance and security. Otherwise, considering the outcomes of this research, identity is considered the '*access enabler*' for blockchain development. In fact, identity, in the broad spectrum for people, companies, robots, objects, etc., is considered the first key step in gaining access to a blockchain network. This proof of access can lead to new technical opportunities for blockchain in industry.

b) Artificial intelligence and data

The match between blockchain and *artificial intelligence and data*, as has emerged, offers opportunities for better oversight and accountability. The match between them can be the enabler to solve interoperability issues, impacting recordkeeping processes, including the way in which transactions are initiated, processed, authorized, recorded and reported. In fact, this '*value-creation enabler*' creates changes in business models and business processes and may impact back-office activities, such as financial reporting and tax preparation, especially given that blockchain has been defined as "*a fantastic way to organize data*". Hence, while blockchain can help industry track, understand and explain the decisions made by artificial intelligence (AI), inversely, AI can manage blockchains more efficiently. Since the blockchain technology layer must relate to other technology levels, AI needs to be taken into account for industrial development. Moreover, regarding distributed implementations, determining how a distributed ledger will be managed falls to a single third party in charge of key considerations, such as that who has access and can invite new members into the ledger. In this sense, AI may set basic rules about onboarding new users, likely addressing the offboarding process, keeping the "*exit*" issue as one future problem to assign for industry.

c) Tokenization

Tokenization may represent '*a first step*' for systematic interoperability. Considering Ethereum's standardization of tokens (*ERC-20*) as the enabler that allowed for a new kind of crowdfunding and interoperability, this tokenization impacted new forms of practices and accessibilities for fintech. As a result, the ERC-20 created some frictionless procedures on investments and trading, reducing barriers, and empowering users by allowing everybody to take part in the system.

Furthermore, this digital transformation designed a new business model, known as an initial coin offering (ICO), instead of the common initial public offering (IPO). Thus, since 2017, the ICO concept has brought about potential for

TABLE 6
EXAMPLE OF A DISRUPTIVE IMPLEMENTATION

As an introduction, the Uber example is explained as follow. Uber is a new taxi service, and the application per se is not disruptive because it only digitalizes the calls for a taxi ride. This digitalization is a performance improvement, so it is assigned as a sustaining innovation. Otherwise, this new digitalization of calls for taxi rides would become disruptive due to the smartphone app. In fact, the app is considered *the enabler*, providing a tool for customers that allows for a peer-to-peer connection with taxi drivers. The match between these two aspects—the digitalization plus the connection—converts Uber into a disruptive innovation [25].

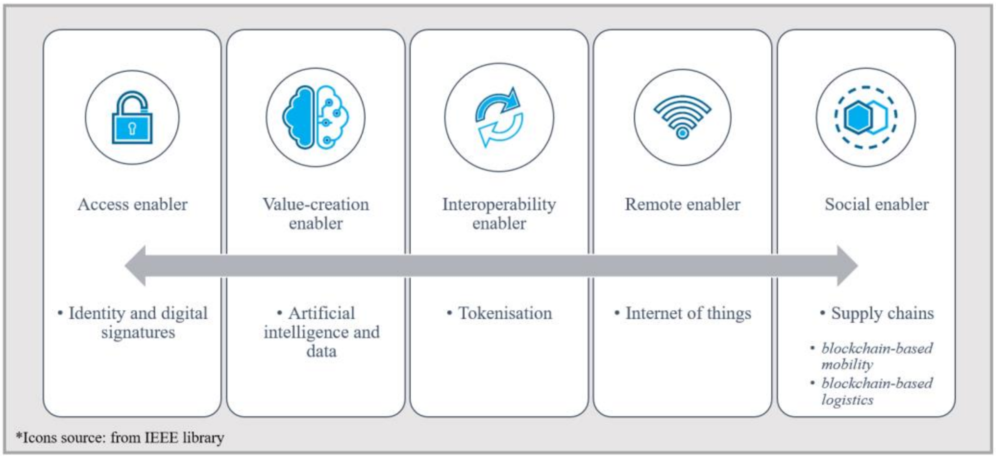

FIGURE 2. **Identified enablers in a conceptual framework with a 5-step implementation process**

new dominant designs in cryptobusinesses, bringing new digital access and perceptions to the market. Hence, we could affirm that this '*interoperability enabler*' may represent an enhancement to digitalization procedures, even if many regulations are in progress to define the positive consequences and to mitigate the negative impacts. A delineation of a potential interoperable token may be the potential enabler for widespread acquisition in industry.

d) Internet of things

The *Internet of Things* is considered the '*killer*' application or catalyst for frictionless negotiation procedures where machine-to-machine transactions may emerge [15]. In fact, due to smart contracting and autonomous contracting, this machine-to-machine procedure is a software program deployed following specific requirements depending on the goals to achieve. Therefore, blockchain-based IoT for robotic devices may support chain-of-trust and managing data and act as a new service for data optimization.

In addition, the business intelligence applied to this chain of trust would organize it in a better framework using blockchain. As such, considering the blockchain as a decentralized database technology with a consensus protocol, remote computing can allow IoT systems to propose new business models, foster new access, design new device architectures, and empower a new level of performance.

However, this '*killer*' implementation would need a third party to control it because considering the IoT system only, they will not be able to assure the data gathering in a trustable framework. Thus, this third party may be considered the basic enabler for IoT developments in this implementation; this '*remote enabler*' can be reached with existing technologies.

e) Blockchain-based mobility and blockchain-based logistics

Regarding supply chains, *blockchain-based mobility* and *blockchain-based logistics* are considered two enablement sectors where blockchain may have a higher impact on society. In fact, as has emerged, new types of data management platforms have been implemented and have shown good results so far, but these data platforms are only a first step of development for blockchains that increase industrial performance. Therefore, to exploit the whole potential of blockchain technology, these data platforms need to reach an advanced stage of development, and to reach this progressive evolution, they need enablers.

In this case, for logistics and mobility, enablement factors may be new types of engagement with society, empowering customers with new forms of decision-making toolkits, redistributing value into the economic paradigm, or providing metrics for social responsibility (e.g., value chains and sharing economy). All these potential enablers will not be related to key performance indicators (KPIs) as one of the standard ways in which to manage decisions inside companies , reducing costs and improving performance, but these enablers will be related to social behaviors, social attitudes and hyperengagements. Thus, we can affirm that these enablers have the power to change people' behaviors, to educate urban and rural communities, and to create a more aware society with higher impacts on environmental issues, healthcare, and climate urgency[5].

Therefore, considering logistics and mobility as two similar models, we would like to consider these '*social enablers*' as good food for thought for the sustainable development of blockchain and to mitigate some of the many issues and concerns that present in the discussion on blockchain. Furthermore, considering the interoperability of

[5] R. Born, "DLT for Climate Action Assessment", *EIT Climate-KIC* and *ETH Zurich*, 2018. Online at: https://www.climate-kic.org/in-detail/dlt-for-climate-action-assessment/

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

different technological layers, these social enablers may be the '*vector*' for new value propositions in industry, mixing and blending all the enablers cited above.

VI. LIMITATIONS

The explorative research carried out has some limitations that we state in this section. The selection of experts may miss several of the renowned representatives working in blockchain, who might have brought valuable further data to the study. Additionally, as a qualitative approach, data collection and data analysis might be affected by our personal judgments. However, we applied grounded theory in a meticulous manner to assure the mitigation of possible misleading results and respecting the defined criteria. Additionally, as we collected a flourishing range of results, the presented outcomes are not fully comprehensive but are focused on answering the research questions. Moreover, as the expert interviews were applied to technology-oriented people working on innovation and blockchain in different sectors, some insight for supply chain areas might be missed. In addition, we provided some development steps for acquisition in industry but with a low level of details and keeping a macro-overview for the implementation.

VII. CONCLUSIONS AND FUTURE RESEARCH

In this paper, we explored experts' opinions about blockchain disruption in supply chains and industrial applications. Applying an explorative research approach, we designed 18 semistructured interviews that allowed us to run an analysis on the current situation of blockchain (S-curve positioning), on the interconnections and interdependences, and on what industry needs to understand to identify how blockchain may affect supply chains.

Due to the grounded theory approach, we identify five categories that make an effort toward and explore this research line in more detail. As the main result, we individuate that blockchain is not disruptive; instead, it is a sustaining innovation. Thus, it is worth identifying some enablers that can allow for its prompt acquisition in industry. A simple conceptual framework of 5-step implementation has been presented to underline the milestones that the industry needs to develop before starting a blockchain project: a) access enabler, b) value-creation enabler, c) interoperability enabler, d) remote enabler, and e) social enabler.

This study lays the foundation for the identification and assessment of risks related with blockchain developments. This study could help isolating specific blockchain functions and activities. With this isolation, practitioners can test if blockchain makes sense for their operations, and if their solution is exploiting the whole blockchain potential.

In addition, we understand that this process will take time, approximately three years, and we can suppose that in the next five years, blockchain will experience robust development and interoperability with other systems and will assure feasibility at scale.

Regarding change management, blockchain shifts the trust in people and institutions to trust in technology. This change needs to be carefully taken into account by managers before starting a blockchain project, and if the blockchain is a *core* activity, then know-how needs to be inside company, not externalized. Therefore, the '*4Ts*' of trust are not enough, and managers need to add new layers to create and exchange value.

After this analysis, we will focus our future efforts on studying in-depth some of the findings presented in this paper. These findings have been recognized as enablers for potential improvements of blockchain systems in industry. As presented above, these themes will be analyzed in future research studies: 1) randomness identity for IoT systems, 2) machine-to-machine transactions, and 3) strategically distributed ledgers for food supply chains.

Furthermore, as has emerged in the study, more education is needed about blockchain. Hence, in addition to research activities following the lines presented above, we will be committed to designing, preparing and editing blockchain educational materials. With these materials, we believe that we will contribute to fulfilling some lack of knowledge that brings about perplexities and mystifications regarding this topic. Therefore, we would like to contribute to increasing the awareness and understanding of providing educational materials for students, practitioners, and representatives.

ACKNOWLEDGMENT

We are glad about the outcomes achieved in this research study. Thus, we thank all experts for their kind collaboration and for the time given to conduct this exploration. We believe that this time interviewees provided us with will impact future studies and future research communities. This will provide a greater understanding of blockchain technology in industry, and we clearly believe that this achieved knowledge is due to the availability of experts interviewed, their worthy overviews and the feedback they provided.

APPENDIX

INTERVIEW FORMAT

RQ related	Questions
	Expert's intro: *background and related digital application interests* Short introduction, how familiar he/she is with blockchain applications
	General viewpoint: *technology usability and accessibility*
RQ1	- What is your opinion about the current research and developments in the utilization of blockchain? *
RQ1	- What are your main concerns about the adaptation of blockchains at a wider scale in your sector/industry or in others? *
RQ1	- Which criticisms or drawbacks do you think might drive practitioners away from blockchain technology? *

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

RQ1	- Are there any current or potential applications (or use cases) of blockchain in your sector that you find disruptive? Why? Which is the most impacting? *
RQ3	- Which benefits of the technology's implementation do you think would be most attractive to supply chain businesses? *
	Market value: *trends for interrelated and interdependent systems*
RQ2	- Radical vs. incremental changes – Which enhancements do blockchain bring to the marketplace?
RQ2	- Which existing technologies could be replaced by blockchain and which blockchain's functionality will boost its market adoption?
RQ2	- Market demand rate vs. technology improvement rate – What do you think is the higher growing rate for blockchain?
RQ2	- Blue ocean opportunities – Which products would be generated by merging blockchain with other technologies?
RQ3	- Critical performance – Which changes or new markets will be generated by blockchain for supply chain sectors?
	Shape evolutions: *future disruption*
RQ1	- Pioneer vs. leader – Who is the pioneer and who is the leader of blockchain technology in your sector?
RQ2	- Smart contracts vs. tokens – Where is the real disruptive innovation if so?
RQ3	- Satisfying customer needs – Which needs are citizens and companies showing currently that can be satisfied by blockchain?
RQ3	- Which business units will be killed off/deeply restructured by established companies? What will the organizational change be inside companies?
RQ3	- Are international standards for blockchain going to make a difference? Have you heard about the coming standardization ISO/TC-307? Any opinion on that?

* source Y. Wang *et al.*[15]

REFERENCES

[1] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "Blockchain challenges and opportunities: a survey," *Int. J. Web Grid Serv.*, vol. 14, no. 4, pp. 352–375, 2018.

[2] J. Yli-Huumo, D. Ko, S. Choi, S. Park, and K. Smolander, "Where is current research on Blockchain technology? - A systematic review," *PLoS One*, vol. 11, no. 10, 2016.

[3] S. Chang and Y. Chen, "When blockchain meets supply chain: A systematic literature review on current development and potential applications," *IEEE Access*, 2020.

[4] M. M. Queiroz, R. Telles, and S. H. Bonilla, "Blockchain and supply chain management integration: a systematic review of the literature," *Supply Chain Manag.*, vol. 25, no. 2, pp. 241–254, 2019.

[5] H. Treiblmaier, "The impact of the blockchain on the supply chain: a theory-based research framework and a call for action," *Supply Chain Manag.*, vol. 23, no. 6, pp. 545–559, 2018.

[6] M. Swan, *Blockchain: Blueprint for a new economy*. O'Reilly Media Inc, 2015.

[7] P. Tasca and C. J. Tessone, "A Taxonomy of Blockchain Technologies: Principles of Identification and Classification," *Ledger*, 2017.

[8] J. Bower and C. M. Christensen, "Disruptive Technologies: Catching the Wave," *Harv. Bus. Rev.*, vol. 73, pp. 43–55, 1995.

[9] M. Iansiti and K. Lakhani, "The Truth about blockchain," *Harvard Business Review*, vol. 1, pp. 3–11, 2017.

[10] J. Al-Jaroodi and N. Mohamed, "Blockchain in industries: A survey," *IEEE Access*, 2019.

[11] S. Nascimento, A. Pólvora, and J. Lourenço, "Blockchain4EU: blockchain for industrial transformations," *European Commission, Joint Research Centre*. 2018.

[12] F. Casino, T. K. Dasaklis, and C. Patsakis, "A systematic literature review of blockchain-based applications: current status, classification and open issues," *Telemat. Informatics*, vol. 36, pp. 55–81, 2019.

[13] M. Walport, "Distributed Ledger Technology: beyond Blockchain," *UK Government Chief Scientific Adviser*. 2015.

[14] N. Hewett, W. Lehmacher, and Y. Wang, "Inclusive deployment of blockchain for supply chains," *World Economic Forum*. 2019.

[15] Y. Wang, M. Singgih, J. Wang, and M. Rit, "Making sense of blockchain technology: How will it transform supply chains?," *Int. J. Prod. Econ.*, vol. 211, pp. 221–236, 2019.

[16] N. Hackius and Petersen M, "Translating High Hopes Into Tangible Benefits: How Incumbents in Supply Chain and Logistics Approach Blockchain," *IEEE access*, 2020.

[17] K. O'reilly, *Ethnographic methods*. Routledge, 2012.

[18] J. Magenheim, W. Nelles, T. Rhode, N. Schaper, and S. Schubert, "Competencies for Informatics Systems and Modeling: Results of Qualitative Content Analysis of Expert Interviews," *IEEE EDUCON Educ. Eng.*, pp. 513–521, 2010.

[19] A. Bogner, B. Littig, and W. Menz, *Interviewing experts*. Springer, 2009.

[20] M. Muskat, D. Blackman, and B. Muskat, "Mixed methods: Combining expert interviews, cross-impact analysis and scenario development.," *Electron. J. Bus. Res. Methods*, vol. 10, pp. 9–21, 2012.

[21] S. Schensul, J. Schensul, and M. LeCompte, *Essential ethnographic methods: Observations, interviews, and questionnaires*. AltaMira Press, 1999.

[22] J. A. Schumpeter, *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Transaction Publishers, 1982.

[23] J. A. Schumpeter, *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process.* New York: McGraw-Hill, 1939.

[24] C. M. Christensen, *The Innovator's Dilemma: when new technologies cause great firms to fail*. Boston: Harvard Business School Press, 1997.

[25] C. M. Christensen, M. Raynor, and R. Mcdonald, "What Is Disruptive Innovation?," *Harvard Business Review*, 2015.

[26] S. Denning, "Christensen updates disruption theory," *Strateg. Leadersh.*, vol. 44, no. 2, pp. 10–16, 2016.

[27] C. M. Christensen, "Exploring the limits of the technology S-curve. PART I: COMPONENT TECHNOLOGIES," in *Production and Operations Management Society*, vol. 4, Wiley Online Library, 1992.

[28] C. Perez, "Technological revolutions and techno-economic paradigms," *Cambridge J. Econ.*, vol. 34, no. 1, pp. 185–202, 2010.

[29] R. Apreda, A. Bonaccorsi, F. Dell'Orletta, and G. Fantoni, "Functional technology foresight. A novel methodology to identify emerging technologies," *Eur. J. Futur. Res.*, vol. 4, no. 1, 2016.

[30] R. Kostoff, R. Boylan, and G. Simons, "Disruptive technology roadmaps," *Technol. Forecast. Soc. Change*, vol. 71, no. 1–2, pp. 141–159, 2004.

[31] S. Brad, M. Murar, and E. Brad, "Methodology for lean design of disruptive innovations," *Procedia CIRP*, vol. 50, pp. 153–159, 2016.

[32] W. Kim and R. Mauborgne, "Value innovation: A leap into the blue ocean," *J. Bus. Strategy*, vol. 26, no. 4, pp. 22–28, 2005.

[33] D. Nagy, J. Schuessler, and A. Dubinsky, "Defining and identifying disruptive innovations," *Ind. Mark. Manag.*, vol. 57, pp. 119–126, 2016.

[34] P. Baran, "On distributed communications networks," *IEEE Trans. Commun. Syst.*, vol. 12, no. 1, pp. 1–9, 1964.

[35] M. L. Marsal-Llacuna and M. Oliver-Riera, "The standards revolution: Who will first put this new kid on the blockchain?," *2017 ITU Kaleidosc. Challenges a Data-Driven Soc. (ITU K) (pp. 1-7). IEEE.*, pp. 1–7, 2017.

[36] R. Adams, B. Kewell, and G. Parry, "Blockchain for Good? Digital Ledger Technology and Sustainable Development Goals," in *World Sustainability Series*, Springer, 2018, pp. 127–140.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

[37] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system." 2008.

[38] A. Greenfield, *Radical technologies: The design of everyday life*. VERSO, 2017.

[39] T. Aste, P. Tasca, and T. Di Matteo, "Blockchain Technologies: foreseeable impact on industry and society," *Computer (Long. Beach. Calif).*, vol. 50, no. 9, pp. 18–28, 2017.

[40] A. L. Tsilidou and G. Foroglou, "Further applications of the blockchain," *12th student Conf. Manag. Sci. Technol.*, 2015.

[41] D. Wörner and T. Von Bomhard, "When your sensor earns money: Exchanging data for cash with Bitcoin," in *UbiComp 2014 - Adjunct Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 2014, pp. 295–298.

[42] H. Treiblmaier and U. J. Umlauff, "Blockchain and the future of work: a self-determination theory approach," in *Blockchain Economics: Implications of Distributed Ledger Technology*, World Scientific, 2019, pp. 105–124.

[43] M. Pilkington, "Blockchain Technology: Principles and Applications," in *Research handbook on digital transformations*, E. E. Publishing, Ed. 2016.

[44] M. Faioli, "Blockchain, contratti e lavoro. La ri-rivoluzione del digitale nel mondo produttivo e nella PA," *rivisteweb.it*, vol. 50, no. 2, pp. 139–157, 2016.

[45] D. Dujak and D. Sajter, "Blockchain Applications in Supply Chain," in *SMART supply network*, Springer, 2019, pp. 21–46.

[46] K. Korpela, J. Hallikas, and T. Dahlberg, "Digital Supply Chain Transformation toward Blockchain Integration," in *50th Hawaii international conference on system sciences*, 2017.

[47] H. Min, "Blockchain technology for enhancing supply chain resilience," *Bus. Horiz.*, vol. 62, no. 1, pp. 35–45, 2019.

[48] G. Nair and S. Sebastian, "Blockchain Technology; Centralised Ledger to Distributed Ledger," *Int. Res. J. Eng. Technol.*, vol. 4, no. 3, pp. 2823–2827, 2017.

[49] L. Ge, C. Brewster, J. Spek, A. Smeenk, and J. Top, *Findings from the pilot study Blockchain for Agriculture and Food*. 2017.

[50] A. Shahid, A. Almogren, N. Javaid, F. A. Al-zahrani, M. Zuair, and M. Alam, "Blockchain-based Agri-Food Supply Chain: A Complete Solution," *IEEE Access*, 2020.

[51] R. Azzi, R. K. Chamoun, and M. Sokhn, "The power of a blockchain-based supply chain," *Comput. Ind. Eng.*, vol. 135, pp. 582–592, 2019.

[52] M. J. Casey and P. Wong, "Global supply chains are about to get better, thanks to blockchain," *Harv. Bus. Rev.*, vol. 13, pp. 1–6, 2017.

[53] D. Tapscott and A. Tapscott, "How blockchain will change organizations," *MIT Sloan Manag. Rev.*, vol. 58, no. 2, p. 10, 2017.

[54] T. Felin and K. Lakhani, "What problems will you solve with blockchain?," *MIT Sloan Manag. Rev.*, vol. 60, no. 1, pp. 32–38, 2018.

[55] Y. Wang, J. H. Han, and P. Beynon-Davies, "Understanding blockchain technology for future supply chains: a systematic literature review and research agenda," *Supply Chain Manag.*, vol. 24, no. 1, pp. 62–84, 2019.

[56] M. Du, Q. Chen, J. Xiao, H. Yang, and X. Ma, "Supply Chain Finance Innovation Using Blockchain," *IEEE Trans. Eng. Manag.*, 2020.

[57] M. C. Cooper, D. M. Lambert, and J. D. Pagh, "Supply Chain Management: More Than a New Name for Logistics," *Int. J. Logist. Manag.*, vol. 8, no. 1, pp. 1–14, 1997.

[58] D. M. Lambert, *Supply chain management: processes, partnerships, performance*. Supply Chain Management Inst., 2008.

[59] D. Kane, "A Global View of Supply Chain Management," *Univ. Auckl. Bus. Rev.*, vol. 10, no. 2, p. 30, 2008.

[60] G. Hileman and M. Rauchs, "Global blockchain benchmarking study," *Cambrige Centre for Alternative Finance*, 2017.

[61] P. Reyes, J. Visich, and P. Jaska, "Managing the dynamics of new technologies in the global supply chain," *IEEE Eng. Manag. Rev.*, 2020.

[62] R. Linke, "Blockchain's applications reach further than you think," *MIT Sloan Management Review*, 2018.

[63] H. M. Kim and M. Laskowski, "Toward an ontology-driven blockchain design for supply-chain provenance," *Intell. Syst. Accounting, Financ. Manag.*, vol. 25, no. 1, pp. 18–27, 2018.

[64] M. Tripoli and J. Schmidhuber, "Issue Paper Emerging Opportunities for the Application of Blockchain in the Agri-food Industry Agriculture," *Food and Agriculture Organization of the United Nations (FAO) and ICTSD*. 2018.

[65] M. Conoscenti, A. Vetro, and J. C. De Martin, "Blockchain for the Internet of Things: A systematic literature review," *IEEE/ACS 13th Int. Conf. Comput. Syst. Appl.*, pp. 1–6, 2016.

[66] T. Relihan, "These are the cyberthreats lurking in your supply chain," *MIT Sloan School of Management*, 2019.

[67] M. Di Angelo and G. Salzer, "Tokens, Types, and Standards: Identification and Utilization in Ethereum," *Intl. Conf. Decentralized Appl. Infrastructures*, 2020.

[68] K. Christidis and M. Devetsikiotis, "Blockchains and smart contracts for the internet of things," *IEEE Access*, 2016.

[69] G. Bigi, A. Bracciali, G. Meacci, and E. Tuosto, "Validation of decentralised smart contracts through game theory and formal methods," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 9465, Springer Verlag, 2015, pp. 142–161.

[70] R. Beck and C. Müller-Bloch, "Blockchain as Radical Innovation: A Framework for Engaging with Distributed Ledgers," *50th Hawaii Int. Conf. Syst. Sci.*, 2017.

[71] R. Post, K. Smit, and M. Zoet, "Identifying Factors Affecting Blockchain Technology Diffusion Completed Research," *AIS eLibrary*, 2018.

[72] S. Kurpjuweit, C. G. Schmidt, M. Klöckner, and S. M. Wagner, "Blockchain in Additive Manufacturing and its Impact on Supply Chains," *J. Bus. Logist.*, 2019.

[73] M. L. Jochumsen and A. Chaudhuri, "Blockchain's impact on supply chain of a pharmaceutical company," *EUROMA Conf. 2018*, 2018.

[74] R. Ziolkowski Geetha Parangi Gianluca Miscione Gerhard Schwabe, "Examining Gentle Rivalry: Decision-Making in Blockchain Systems," *52nd Hawaii Int. Conf. Syst. Sci.*, 2019.

[75] F. Bolger and G. Wright, "Use of expert knowledge to anticipate the future: Issues, analysis and directions," *Int. J. Forecast.*, vol. 33, no. 1, 2017.

[76] J. M. Utterback and W. J. Abernathy, "A dynamic model of process and product innovation," *Omega*, vol. 3, no. 6, pp. 639–656, 1975.

[77] F. Suárez and J. M. Utterback, "Dominant designs and the survival of firms," *Strateg. Manag. J.*, vol. 16, no. 6, pp. 415–430, 1995.

[78] W. B. Arthur, "Competing technologies: an overview," in *Technical change and economic theory*, G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete, Eds. London: Printer, 1988.

[79] C. Freeman and C. Perez, "Structural crises of adjustment, business cycles and investment behaviour," in *Technical Change and Economic Theory*, G. Dosi, C. Freeman, R. Nelson, G. Silverbeg, and L. Soete, Eds. London: Pinter, 1988.

[80] J. Corbin and A. Strauss, *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications, 2014.

[81] B. Glaser and A. Strauss, *Discovery of grounded theory: Strategies for qualitative research*. Routledge, 2017.

[82] A. Strauss and J. Corbin, "Grounded theory methodology," in *Handbook of qualitative research*, N. K. Denzin and Y. S. Lincoln, Eds. Sage Publications, 1994, pp. 273–85.

[83] K. Locke, "Rewriting the discovery of grounded theory after 25 years?," *J. Manag. Inq.*, vol. 5, no. 3, pp. 239–245, 1996.

[84] R. Suddaby, "From the editors: What grounded theory is not," *Acad. Manag. J.*, vol. 49, no. 4, pp. 633–642, 2006.

[85] K. Charmaz, *Constructing grounded theory: A practical guide through qualitative analysis*. Sage publications, 2006.

[86] J. Corbin and A. Strauss, "Grounded theory research: Procedures, canons, and evaluative criteria," *Qual. Sociol.*, vol. 13, no. 1, pp. 3–21, 1990.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2020.3038463, IEEE Access

[87] K. Charmaz, “The search for Meanings–Grounded Theory,” in *Rethinking Methods in Psychology*, J. Smith, R. Harre, and Van Langenhove L., Eds. London: Sage Publications, 1996, pp. 27–49.

[88] K. Charmaz and L. L. Belgrave, “Grounded Theory,” in *The Blackwell Encyclopedia of Sociology*, Oxford, UK: John Wiley & Sons, Ltd, 2015.

[89] S. Baker, R. Edwards, and M. Doidge, “How many qualitative interviews is enough?: expert voices and early career reflections on sampling and cases in qualitative research,” *NCRM*, 2012.

[90] G. Perboli, S. Musso, and M. Rosano, “Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases,” doi: 10.1109/ACCESS.2018.2875782.

Fabio Della Valle is pursuing a Ph.D. at the University Pompeu Fabra. In the engineering department, he is conducting research on blockchain technology and IoT systems for supply chains. He obtained an MSc in Industrial Engineering and Management at the University of Pisa and worked more than five years in different technology transfer offices in Europe. He has worked on the exploitation of research, innovation management, IP rights, entrepreneurship education and supporting academic-based start-ups during business growth. Fabio started his first investigation on blockchain technology and DLTs in 2015 at the Centre for the Digital Economy at University of Surrey.

Miquel Oliver is Full Professor in the Department of Information and Communication Technologies of the Universitat Pompeu Fabra. He received his Ph.D. from Universitat Politècnica de Catalunya in 1999, a degree in Business Administration (UOC, 2009) and GloColl Executive Education (Harvard, 2011-12). Before joining UPF, he was an Associate Professor at the UPC and Visiting Scholar at Rutgers University (US, 1999). He has led the multidisciplinary Networking and Strategies Research Group (NeTS) since its foundation. He has been Visiting Scholar at Cardiff University (2019), Southampton (2018), MIT (2013-14) and Columbia University (2011). His research is on wireless communications, with a multidisciplinary view including regulation, telecom policies and economic impact.