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Blockchain-Based Information Management for Supply Chain Data-Platforms

Fabio Della Valle * and **Miquel Oliver**

Engineering Department of Information and Communication Technologies, University Pompeu Fabra, 08018 Barcelona, Spain; miquel.oliver@upf.edu
* Correspondence: fabio.dellavalle@upf.edu

Featured Application: Results of this study identify those supply chain management processes that drive blockchain technology.

Abstract: Performance measurement and information management are vital assets for supply chain management. In this study, we analyzed the effective combination between blockchain technologies and supply chain management processes. We conducted eighteen interviews with international experts from different areas and analyzed the collected data following a grounded theory approach. We have identified five main categories in this area including accounting and administration, trust, data platform, interoperability, and disintermediation. The main findings concluded with a set of seven statements as key elements to summarize how blockchain-based supply chains fit in with supplier relationship management processes and financial business units for international trade. The seven statements also recommend future research activities and trajectories.

Keywords: blockchain; decentralized applications; information management; supply chain management

1. Introduction

In the last few decades, due to research efforts and an increasing level of digitization, supply chains have improved in terms of performance and process optimization [1]. Digital technologies allow for information sharing across supply chains [2], providing a set of benefits such as enhancing performances, implementing re-optimization procedures, and load-based optimization for sudden and unexpected events. These benefits also mitigate negative consequences and repercussions for other planned duties. In the transition to Industry 4.0, information sharing through internet of things (IoT) systems has become a strategic factor and a key component for market competitiveness [3].

Industrial IoT (IIoT) is developing new industrial management paradigms, enabling aggregations of large-scale data internally and externally to the company [4]. This progress developed new systems operating in more intelligent and interconnected platforms. Thus, the number of IoT devices is increasing every day within the industrial sectors, although this intensification of IoT devices jeopardizes several companies [5]. Moreover, an increasing number of IoT devices expose these companies to further risks, increasing their vulnerability to cyber-attacks and hacking.

Blockchain technology mitigates some of these risks [6]. Blockchain platform deployment is strengthened by cryptography and consensus protocols and acts as a detractor for cyber-attacks and hacks. Several studies [6–8] explore the leading factors of blockchain-based supply chains, assessing industrial applications that may foster digitization in operations. In this instance, the dilemma for decentralization is currently under discussion [7]. Blockchain (BC) shows a broad range of advantages but at the same time represents huge risks for companies. Blockchain platforms generate innovation for ecosystem-building among supply chain partners; however, sharing key business information on permissionless systems might expose companies to the loss of business spaces in favor to their

competitors. Other advantages, such as real-time information and trust, were identified for the implementation of this technology. Nevertheless, it is relevant to consider that they can be achieved with existing technologies. Therefore, further research is necessary to explore how blockchain platforms should be tuned for supply chain operations and to identify sufficient benefits, as well as maximize the reward. This will be fundamental in assuring a higher level of efficiency and effectiveness [8,9].

The current study addresses the aforesaid gaps, providing an identification of those processes for which blockchain platforms may benefit supply chain management (SCM) operations. In developing a cross-analysis between technological and managerial fields, this research study seeks an answer to the following research question (RQ): *how can the information flow structure affect and pilot a suitable blockchain adoption in SCM?*

We conducted interviews and collected data from a pool of eighteen experts. In analyzing data from the experts, we performed an explorative research study that provides a neutral and impartial approach. The research contribution is detailed in the discussion section, in which answers to the RQ are provided.

Following an analysis of all the interviews with international experts and by applying the grounded theory methodology, the analysis of the data allowed us to address the research question as the main contribution of our work.

The research contribution provides the following outcomes: (I) a summary of the key findings of previous research and existing work; (II) a presentation of findings emerged from the experts interviewed; and (III) seven statements as key points to drive blockchain technology in supply chain management processes.

The remainder of this paper is structured as follows: Section 2 presents the literature review of the most relevant research works for the present study; Section 3 details the grounded theory methodology and analysis of the collected data; Section 4 elaborates on the findings of the analysis; Section 5 offers a discussion and the research contributions; and Section 6 provides the conclusion.

2. Literature Review

As a distributed ledger technology, blockchain has the potential to increase certain levels of performance in terms of time and security in data platforms, but it also has limitations regarding the property of bandwidth or data storage. Blockchain, considered as a sustaining or non-disruptive innovation [10], performs a decentralized database technology recognized as a new implementation layer. This layer will shift to new communication models and support changes concerning the systems' access required for industrial communication, enabling the availability of public computers within the network.

Blockchain uses asymmetric cryptographic protocols and through a consensus model, it allows data to be acquired by the system in a pre-established logic. Concerning decentralized databases, these logics (smart contracts) use methods (tokens) to process and exchange information in the network [10,11].

Blockchain technology is an aggregate of previous existing technologies [10–12] and improves on established concepts such as smart contracts launched in the 1990s [13] or digital currencies of the 1980s [14].

2.1. Technology Definitions

Blockchain technology has its origins in the financial sector [15,16] and is in the nascent stage of development for industry [15,17–19].

However, due to its characteristics of decentralization, trustworthiness, and collective maintenance, blockchain provides a trustworthy platform to achieve a reliable peer-to-peer delivery of value without depending on a single centralized organization [20].

According to Fosso Wamba et al. [21], blockchain is defined as 'a data-management technology with 13 intrinsic characteristics: secure, shared, immutable, decentralized, distributed, authenticated, encrypted, open-source, incorruptible, integrated, publicly

visible, chronological, permanent', while Esmaeilian et al. [17] defines blockchain as 'a decentralized, distributed data structure and public digital ledger'.

Although the current business applications have designed blockchain as a platform [22], this technology can be also viewed as a replicated database that is distributed among thousands of nodes which belong to diverse parties [20].

Additionally, Leng et al. [23] describes blockchain as a distributed accounting system implemented by computer technology and set by distributed databases. According to Kouhizadeh et al. [24], blockchain has positive impacts on information sharing and is a data structure [25]; all transactions are easily auditable. Therefore, blockchain is a '*trust machine*', leading to a data-driven economy [26]. Unfortunately, appropriate regulations are absent in this area [10]. Caligiuri [27] provides a complete legal and regulatory framework regarding blockchain and its legal and business implications, and further provides an exhaustive overview of the correlation between blockchain and GDPR, finance, notarization, traceability, and food supply chains. In this context, Pólvora et al. [18] presents an analysis of blockchain and policy foresight for data management. At several levels, data management distinguishes itself as an essential part of blockchain deployment across sectors [18] as this technology is a secure protocol to store information [28].

2.2. Supply Chains

SCM is the integration of all key business processes across the whole chain of processes and stakeholders [29]. According to D. M. Lambert [30], SCM pertains to relationship management and requires the involvement of all business functions. Therefore, it is fundamental to have effective partners in the supply chain (SC) and crucial to develop the right types of relationships [31]. However, according to Rao and Weintraub [32], to foster innovation, enterprises often devote greater attention to resources, processes, and measuring successes that are easily quantifiable. Contrastingly, enterprises focus less on values, behaviors, and climate, which are the harder-to-measure and people-oriented determinants of innovative culture.

Performance measurement in the SC is vital [33]. In this context, it is critical to identify bottlenecks, wastage, problems, and improvement opportunities. According to Akyuz and Erkan [34], SC performance measurement needs to be addressed on the: development of partnership, collaboration, agility, flexibility, information productivity, and business excellence metrics. Furthermore, innovative performance measurement systems need to be adopted and centered on value creation, long term orientation, transversal metrics, and the monitoring of improvement [34].

The decision-support methods in SCM domains are required to be both proactive and reactive, as well as proactive and reactive simultaneously [35]. This can be achieved with robustness reserves and the speed and scale of recovery actions. Both SC robustness and resilience should be estimated to mitigate risks [35]. Risk management plays a vital role in the effective operation of SCs in the presence of a variety of uncertainties [36].

Additionally, according to Büyüközkan and Göçer [1], the digital supply chain (DSC) framework is composed of three key components, that is, digitalization, technology implementation, and SCM. There are several risks in the digitalization of SCs [22]. Advanced tracking and tracing technologies can provide real-time event identification and SC visibility; however, they have both benefits and threats that must be carefully assessed. Hence, the development of real-time coordination can mitigate certain SC risks [2].

2.3. Blockchain-Based Supply Chains

Blockchain adoption in global SC, transport, and logistics is still in its infancy [7,19,37]. Despite the immaturity of blockchain [19], it is set to transform SC activities by increasing transparency and accountability [8]. According to Hastig and Sodhi [38], transparency is a factor in the level of traceability. Alternatively, according to Bai and Sarkis [9], there are three SC transparency types: (i) range of transparency; (ii) product transparency; and (iii) participant transparency. Therefore, to boost the implementation of blockchain-based

SCs, the analysis of SC transparency factors is necessary and needs to be correlated with an opportunities and risk-perspective analysis aimed to assess the possible gains or losses [9]. Consequently, blockchain has the potential to help achieve the seven SCM objectives of cost, quality, speed, dependency, risk reduction, sustainability, and flexibility [8].

However, according to Saberi et al. [19], four barriers exist for the development of blockchain-enabled SCs: inter-organizational, intra-organizational, technical (system-related), and external barriers. Despite the prominence of technological and intra-organizational barriers [24], blockchain is a driver for digitization in the SC [39].

According to Kshetri [8], blockchain has the potential to break down data silos, offering one source of data and digitalization with a real-time data control for all (trusted) partners in the network. Trust and security can be improved with blockchain [8]. Additionally, business value exists in building trust through blockchain, improving efficiency, reputation, time-to-market, responsiveness, and material savings [16]. Thus, blockchain positively impacts SC performances [40]; however, for operation management, it provides advantages over the existing systems [6]. According to Cole et al. [15], enterprise resource planning (ERP), radio-frequency identification (RFID), and blockchain are complementary technologies, and it is fundamental to assess their best combination to maximize effects and impacts.

Given that blockchain has an emerging nature in business [41], all nine dimensions of a business model can be translated into key SC design decisions to build a viable blockchain-based SC ecosystem. However, blockchain cannot be used in isolation for SCs [41]. The challenge remains that the return on investment (ROI) for blockchain implementation is unclear [7], which makes it difficult to involve all the parties in the transition and furthermore considering that the related performance improvements are difficult to predict [9].

All the benefits stakeholders can obtain by blockchain deployment are related with immutable information and sharing; however, it is fundamental to avoid centralized platforms [11]. In a blockchain deployment, neither party would be the owner of the blockchain infrastructure [7].

According to Kshetri [8], a key element of blockchain-based models is that all transactions are auditable, which is particularly important in gaining the trust of all interested parties. Therefore, all SC stakeholders must accede for the blockchain adoption to succeed.

Finally, to support the development and understanding of blockchain technology in the SC, interdisciplinary investigations are required to build theories and designs for blockchain technology [19]. In this instance, blockchain-based social sustainability and responsibility could enable firms to extend visibility, assuring their due diligence in line with the legislations against modern slavery [15]. Moreover, there is a lack of experience, knowledge, and understanding regarding blockchain [39]. Additionally, the labor skills gap concerning the technology needs to be filled [38]. According to Pournader et al. [37], for blockchain, both technological and business limitations need to be addressed because there is an inflated expectation from blockchain, which might exacerbate the effect of the failed adoption in industry.

2.4. An Effective Combination: BC, IoT, and SCM

In this section we explore the combinations between blockchain (BC), the internet of things (IoT), and SCM. Assuming blockchain can strengthen IoT security, it can ensure SC security through IoT systems [25]. According to Kshetri [8], an IoT system in blockchain-based solutions validates the identities of individuals and assets, thereby enabling the use of blockchain in an SC to determine who is performing what actions. Additionally, these features facilitate a valid and effective measurement of outcomes and performances of key SCM processes.

Furthermore, Ben-Daya et al. [3] explored the role of IoT and its impact on SCM processes and applications. Thus, according to Ben-Daya et al. [3], IoT for SCM will affect procurement, production planning, management of inventory, quality, and maintenance.

IoT systems offer SCM an unprecedented visibility into all aspects of the SC [3]; however, the IoT for SCM is still in its early stage of development. In this instance, there

are several risks correlated with the implementation of IoT in SCM [5]. According to Birkel and Hartmann [5], these risks are divided in three clusters: (i) environmental; (ii) network-related; and (iii) organizational. These risks impact Industry 4.0 and either the IoT for Industry 4.0 or the IIoT [3,4,42] needs an adequate level of security to mitigate environmental, network, and organizational risks.

Esmaeilian et al. [17] defines IIoT as 'connecting and monitoring industrial objects and physical devices through the internet'.

Blockchain-based access management systems can address key IoT security challenges such as those associated with internet protocol address spoofing [25]. According to Weingärtner and Camenzind [43], identity is a crucial property of IoT devices. Blockchain and decentralized identifiers (DID) can be used to trace back the origin of the device, which is especially important in security-relevant environments [43]. Consequently, blockchain may be used for the allocation and management of device identities, which will be an essential feature for future blockchain-based applications [43].

A blockchain and IoT combination facilitates the sharing of the services and resources leading the marketplace between devices, paving the way for automation and a more secure way for innovation [20]. The blockchain–IoT combination is powerful and is set to transform many industries [20,44]; for instance, IoT devices can conduct autonomous transactions through smart contracts [44], establishing machine-to-machine autonomous payments [45] and machine-to-machine autonomous communication and decision-making [3], and alter how IoT systems are used in business worldwide [20].

Therefore, the combination between blockchain, IoT, and SCs might represent a performance improvement in information management for interlocked devices.

3. Methodology

According to Saberi et al. [19], grounded theory approaches can be used to expand blockchain's features and practical implementation observations. Thus, following Corbin and Strauss [46], a dynamic approach was designed for this qualitative research. This dynamic approach enables evolution in design as the study progresses [47]. As a form of qualitative research, the grounded theory has the purpose of constructing theory grounded in data [46,48–52]. By identifying general concepts, the development of theoretical explanations offers new insights for studied phenomena.

This study maintains an investigatory character and lays the foundation for this research area. In accordance with Bogner et al. [53] and Bolger and Wright [54], we established flexible guidelines to run this ethnographic research study and identified experts with both a high degree of interpretive faculty and extensive knowledge in their respective fields.

The pool of experts (Table 1) is composed of academics (AC, eight in total), information and communication technologies professionals working in renowned companies (ICT, eight in total), and institutional representatives (WO, two in total). The international experts are from EU and non-EU countries and possess a proven knowledge of blockchain.

3.1. Data Collected

On average, the interviews were conducted for a timeframe of 45 min in which, after a first open discussion (of 10 min circa), semi-structured interviews were performed following the designed questionnaire. The questionnaire consisted of 15 open questions distributed into three sections. The first section collected general information and the expert's background; the second section was focused on market aspects of blockchain for supply chains; and the last section was tailored for future trends and perspectives from the expert's perspective.

Data were collected through memos and notes. The interviews were recorded following prior authorization and the data collected followed a screening process to develop a narrowed analysis for the study.

Table 1. Pool of experts interviewed.

#	Respondent Provenance (Anonymized)	Sector of Interest	Gender	Location
1	ICT_1_Logistics	Handling	M	Belgium
2	ICT_2_Consulting	Business models	M	New York
3	ICT_3_Consulting	Business services	M	Spain
4	ICT_4_Consulting	Financial flows	M	New York
5	ICT_5_Telecommunications	Service provider	M	Spain
6	ICT_6_Technology	Service provider	M	Ireland
7	ICT_7_Logistics	Software architecture	F	United Kingdom
8	ICT_8_Manufacturing	Industrial IoT	M	Italy
9	AC_1_Social science	Innovation	F	United Kingdom
10	AC_2_Social science	Economics	M	Australia
11	AC_3_Social science	Information flows	F	United Kingdom
12	AC_4_Engineering	Network technologies	M	Spain
13	AC_5_Engineering	Network security	M	Belgium
14	AC_6_ Engineering	Cryptography	F	Spain
15	AC_7_ Engineering	Computer science	M	Switzerland
16	AC_8_Social science	Digital economy	F	United Kingdom
17	WO_1_Law and regulation	Policies	M	Belgium
18	WO_2_Computer-implemented invention	Technicians	M	Germany

Although the 18 interviews allowed us to collect a large amount of data, other sources of knowledge (The World Economic Forum: Strategic intelligence, Transformation Map for Blockchain, and The European Blockchain Observatory and Forum: Reports) have been considered in this research study.

3.2. Grounded Theory Assessment

While conducting the grounded theory, the analysis was passed over three steps of codes iterations. The first screening process passed from more than 600 codes to 270 codes and the second iteration reduced the number of codes to 82.

With the support of tables, data were compared to generate categories. Before doing so, 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. Therefore, comparing data and codes with categories, as well as considering the major categories as concepts, we proceeded by comparing the concepts among them to validate the results.

The third screening process supported the categories' drafting and identification of the ten main concepts.

Five categories were defined and the ten concepts were segregated into categories, namely two concepts per category.

As presented in Table 2, the identified categories are: (1) accounting and administration, (2) trust, (3) data platform, (4) interoperability, and (5) disintermediation.

Table 2. Identified categories that emerged from the analysis.

Number	Categories	Main Concepts (Intermediate Data)	HP	LP	Contr.
1	Accounting and administration	Government accountability, financial reporting, and tax obligation	11	6	# Federated systems obtain collusions with blockchain
		Economic aspects, negotiation procedures, and international issues	8	9	# Many regulations are needed
2	Trust	Real time information and cost reduction	7	10	# Risk of monopolization
		Safer digitalization strategies and security	7	10	# Risk of anonymous behavior
3	Data platform	Data ownership and legacy data systems	8	10	/
		Data sharing is a digital asset and represents a value exchange	10	8	/
4	Interoperability	Blockchain platforms facilitate transactions	6	11	# The blockchain potential can be achieved only with open systems
		Smart contracts and tokens facilitate the exchange of digital assets	7	10	# High costs for energy consumption
5	Disintermediation	IoT and data capture is the link between the real–virtual world and has a relation with society	6	10	# Scalability issues # More research is needed to improve technology performances
		Smart contracts are mechanisms that define the rules set	9	7	# Scale-up factor is not affordable for SMEs # More research is needed to decompose and analyze each blockchain component

Abbreviations: HP—high priority; LP—low priority; and Contr.—controversial. Controversial notions are numbered by tags (#).

3.2.1. Explanations of Categories

In this subsection we provide explanations of the categories.

The accounting and administration (1) emerging from the imperativeness of financial aspects related to blockchain and cryptocurrencies, in which financial statements and economic instruments play relevant roles, are considered.

Trust (2) is designed from the intrinsic features of blockchain and is built in both permissioned and permissionless networks. It is originated from the implementation effects that blockchain brings in ecosystem-building and information management.

With regards to the data platform (3), this category grouped several concepts from digital assets to competitive advantages. However, the implication is to retain the blockchain data infrastructure to describe the data ownership sharing process, thereby creating value.

For interoperability (4), blockchain resources, as smart contracts and tokens, emerge as a fundamental source to link different systems and ecosystems.

Finally, disintermediation (5) is introduced as an expressive form for the IoT–blockchain combination given that the combination of these two technologies may reduce the need of intermediaries and middle-men.

3.2.2. Insights on the Assessment

Before the category identification, in analyzing the 82 codes, the distribution linked with categories was grouped as follows: accounting and administration, 19.5% (16 codes); trust, 17.1% (14 codes); data platform, 19.5% (16 codes); interoperability, 18.3% (15 codes); and disintermediation, 25.6% (21 codes).

Additionally, in analyzing the 82 codes and maintaining the correlation between codes and experts' profiles, the pool of experts were impacted in the following manner: ICT for 53.7% (44 codes); AC for 34.1% (28 codes); and WO for 12.2% (10 codes). Therefore, considering the heterogeneity of the pool, composed by eight ICT (44.5%), eight AC (44.5%), and two WO (11%), it is evident that there is an alignment of data analyzed with the relevant variance of the codes gathered. This balance validates the results of the grounded theory analysis, highlighting a major influence of information and communication technologies professionals working in renowned companies.

Unfortunately, there is no gender parity in the pool of experts given that only five out of eighteen experts were women.

3.3. Data Analysis

Following data elaboration, Table 2 indicates the results of the analysis, with the five identified categories and ten intermediate concepts that emerged during the assessment. For each concept, three dimensions were set: high priority (HP), low priority (LP), and controversial (CONTR). Furthermore, the experts' views were addressed in each dimension to identify dominance. In Table 2, the values in columns HP and LP represent the numbers of experts for each dimension who agreed with the concept. Controversial notions are numbered by tags (#) and represent the experts' opinions that strongly disagreed with blockchain development for that concept. There are few experts who disagreed with most concepts, with the exception of category number three (data platform) for which no controversial opinions emerged from interviews.

Consequently, to define the priorities among categories, we applied mixing methods for explorative research [55,56], thus the qualitative data collected are analyzed by a simple quantitative framework to define priorities. Using the Likert scales [57] for the three dimensions (HP, LP, and CONTR), values were addressed to the results as follows: (1) HP—strongly agreed; (2) LP—moderate detection; and (3) CONTR—strongly disagreed. Thus, to define priorities, weights were assigned to each dimension: three for strongly agreed; minus one for moderate detection; and minus five for strongly disagreed.

Therefore, results of the concepts have been aggregated for each category and the final sum {score} highlights the priorities among categories: (1) accounting and administration {32}; (2) trust {12}; (3) data platform {36}; (4) interoperability {8}; and (5) disintermediation {8}.

At this stage, the five categories are combined in three main groups. Results define priorities and are ranked according to the obtained value {score} as follows: (i) data platform; (ii) accounting and administration; and (iii) trust, disintermediation, and interoperability.

In the following sections, the descriptions of the emerged results from the interviews are presented in the order of priority.

4. Findings

In this section, the main results of the analysis are presented in a descriptive manner. Each paragraph clearly focuses on empirical findings, retaining the explorative character of the research work; all outcomes are provided following a neutral and impartial approach.

4.1. Data Platform

Data is a crucial asset for digitalization. From the interviews, it becomes apparent that current applications of blockchain are as data platforms. These platforms support data management for shared and updated ledgers in real-time, which will be an effective key-asset for new business developments.

Interviewees explained how blockchain data-platforms have been well explored for finance and banking sectors. The development of cryptocurrencies and crypto-exchanges indicate several working solutions for currency transactions and its traceability. These aspects assure transparency regarding where the money is being invested. In this regard, data management for accountability corresponds particularly well for blockchain and a clear example is the initial coin offering (ICO) expansion that exhibited impressive results for new business investments.

Furthermore, a blockchain-based infrastructure facilitates business intelligence for analyzing data and its organization, with a pre-set of logic for gathered data. Interviewees remarked that the real business challenge is to share data to create intelligence. With blockchain as a toolkit for data integration and record keeping, it would be affordable to deploy permissioned systems to share databases into a closed business ecosystem.

Interviewees emphasized that sharing a database for a closed business ecosystem corresponds with a digital asset. This represents a value exchange and a competitive

advantage for the entire community. Therefore, it offers opportunities to real-time data platforms that can evidently increase value exchange and capture, improving performances in those processes in which the time of decision-making is relevant. Within a peer-to-peer data platform, all parties are aware of the information chain and all the key information. Interviewees relied on sharing data and how it enhances business trust between partners. Furthermore, real-time and up-to-date information are key assets for global business competitions, creating efficient data management for all stakeholders involved.

Similarly, the adoption of blockchain by the enterprise resource planning (ERP) systems is needed for future development.

As a result of data accessibility, interviewees emphasized that tracking and tracing product origins represents receiving a true value for blockchain deployment. In this context, blockchain data-platforms foster the development of value chains, in which tracking, tracing, traceability, transparency, and trust are considered fundamental priorities for deployments. Integration and interoperability are required for data as well as for platforms, otherwise it is impossible to design scalable solutions. Thus, interoperability features and data privacy must be considered during the design phase of blockchain systems, especially in designing permissionless data-platforms to prevent and mitigate the risk of privacy issues.

Additionally, interviewees highlighted the importance of maintaining the ownership of data during the process, respecting compliances and GDPR regulations, and carefully selecting the optimal structure between permissioned and permissionless systems. Therefore, it is beneficial to integrate distributed ledger technologies (DLTs) with legacy data systems, assuring that these systems can communicate with other blockchains and guarantee trustworthiness to customers.

4.2. Accounting and Administration

Interviewees highlighted how both the shared ledgers' functionality and the peer-to-peer payments will boost the blockchain adoption for accounting and administration. Blockchain indicates advanced stages in payments and platforms for administrative tools, facilitating transactions in a global context. Furthermore, blockchain deployment impacts all recordkeeping processes, which also include the approaches used to initiate transactions as well as processing and authorization, including recording and reporting duties. Therefore, all these changes may impact business models and processes affecting the administrative activities, financial statements, and tax liability. Interviewees remarked that blockchain considerably fosters digitalization and a high degree of transparency for tax preparation and audits.

Therefore, in public administration, revenue and customs divisions may represent a key asset on which to deploy blockchain. In this application, companies and governments need to cooperate in designing a mutually beneficial toolkit platform for taxation monitoring and control. Governments will receive the higher benefit from a blockchain deployment. Additionally, tax collection agencies incur costs of intermediation and bureaucracy, which can be drastically reduced by blockchain by applying new digital tools and duties' automation, albeit initial investments are necessary.

Interviewees explained how a blockchain-based accounting system guarantees no-double spending, dispute resolution, immutability of records, lean management, accuracy, and a clear advantage in both international finance and trade.

The interviewees emphasized that for international trade, blockchain platforms assure innovative cost-effective methods for invoicing, accounting, purchases, and sales. These cost-effective methods will impact the financial business units of companies, changing the way of operation and communication with the systems involved, including public administration.

Finally, artificial intelligence (AI) plays an important role in bookkeeping. Blockchain and AI are cutting-edge technologies on their own, although they can become especially revolutionary if merged. Each of them may improve the capabilities of the other, increasing the potential for better oversight and accountability.

Contrary to what has been discussed so far in this section, a different point of view from interviewee ICT_4 is provided hereunder. Concerns about the nature of blockchain, in terms of openness and collaborative approaches, is in contrast with federated systems of public administration. There may be many risks and federal governments must not collude with lower powers regarding centralized artefacts. However, before designing strategies and action plans for blockchain in public administration, regulatory control is necessary, as governments are required to adhere by the welfare function.

4.3. Trust, Disintermediation, and Interoperability

As explained above, the five categories were divided by priority scale. The first two categories are discussed singularly above, while the other three categories grouped together and presented hereinafter.

Trust enters in the digitalization strategies and goals for business development. Interviewees emphasized that by enhancing digital trust, blockchain will be a transforming tool for many sectors. This aspect will create changes in the processes and operations of the value chains. With digital toolkits, examining, verifying, and authenticating business reports/documents with digital signatures and reporting to other parties in real-time within the network is possible.

Interviewees remarked that blockchain resolves the problem of time and real-time information with the timestamp functionality and provides assurance on the occurrence of time events. This may bring about cost reductions and benefits related to the reduction in the processing and fulfilment time of these administrative activities/tasks, thereby enhancing the performance of administrative duties.

Interviewees emphasized how blockchain enables entire ecosystems and all partners to work collectively in a reliable environment, thereby establishing mutually beneficial environments for stakeholders involved and generating distributed trust in global business ecosystems. A higher level of trust can be ensured to create fair markets and safer internet spaces, thereby improving the security and safety of data, as well as providing trustable products in the marketplace. However, security and access-controls of the blockchain design must be specified, otherwise key business information vulnerability increases. Risks might emerge in this context and business players may lose their competitive edge. Interviewees further explained that onboarding and offboarding procedures should be designed to increase trust.

Additionally, a higher level of technology trust mitigates social concerns and certain responsibility issues. Within blockchain-based trust, technology can be used to mitigate the consumption crisis for commodities, providing additional product transparency for both provenance and processes. Interviewees highlighted how a gap-of-trust appears in this context between companies that accept blockchain and those that deny it.

The interviewees stated that disintermediation is also a key discussion for future applicability. Considering blockchain is a new technology layer, it requires an intensive research effort to decompose and analyze each technology component, understanding and identifying specific links to connect other technologies, and creating value in a global perspective. Ethical considerations must be carefully considered at this stage.

Furthermore, the interviewees emphasized the intrinsic disintermediation feature of blockchain and the way this feature could generate worthy consortiums in future deployments. For instance, as blockchain is a secondary system in global markets, it equips accountability; future blockchain solutions for accountability purposes will create new needs for companies and authorities.

However, in the short-term, the focus for blockchain development will be on reducing cost, strengthening its immutable features, and strengthening its relations with society. Moreover, IoT systems play a fundamental role in future projections. IoT can open several trajectories for blockchain disintermediation in the industry, becoming the device that allows to disintermediate in businesses. In a similar manner, interviewees underlined how the IoT-data capture would be a good starting point to design new logics to organize data

and this represents another real value of blockchain data-platforms, in which data are organized by default.

Thus, IoT systems are physical devices that represent a crucial connection with real-work environments and blockchain technologies, providing the link between the real and virtual world. In addition, interviewees remarked that blockchain-enabled IoT systems can foster the development of machine-to-machine payments due to smart contract functionalities.

Blockchain platforms are tailored for digital improvements to solve inefficiencies. Functionalities related with smart contracts provide automatization of administrative duties, allowing for software creativity and linking blockchain with the real world. Thus, smart contracts are identified by interviewees as powerful computer programs for administrative automation.

Alternatively, regarding interoperability, interviewees believed that it is fundamental to consider both public and private blockchains and define how these systems communicate with each other. Given that DLTs are public computers, interviewees explained that identity toolkits are a necessary step in obtaining access to networks and facilities. In future technological developments, several different blockchain platforms will coexist, implying that blockchain platforms will represent several separate products and/or services. Thus, for international interoperability, relevant standards are necessary for a broad implementation.

Interviewees further highlighted that additional research on privacy-preserving technologies and integration between different blockchains is required. The main sources of developments are in alternating consensus methods and energy performances; however, research communities must endeavor to define and understand how some problems can be solved, regarding what is '*in*' or what is '*out*' from blockchain issues.

Furthermore, interviewees remarked that there are several missing spaces in which enabled technologies can play a fundamental role in blockchain systems. For instance, both tokenization and smart contracting enable interoperability in sectors such as creative industries, logistics or automotive industry—that is, music and film, port management, or manufacturing (robotics), respectively—providing a broad range of advantages from the implementation of blockchain solutions parallel to other (existing) technologies.

Contrastingly, the controversial opinions (CONTR) emerged from the trust, disintermediation, and interoperability categories are grouped and presented hereinafter.

The concerns relating trust feature around the centralized aspects that are characterizing the blockchain development for business and institutions currently. Certain solutions provided by the interviewees explain that centralized platforms need to be managed by a central entity. Interviewee AC_8 explained that if this aspect is not mitigated, future development might be under the risk of creating a monopoly of information for specific sectors/applications. Another concern revolves around ensuring a fully transparent source of information and mitigating the risk of anonymous behavior in the network.

As far as disintermediation is concerned, a cost–benefit analysis is essential to relieve scalability issues that blockchain has exhibited in industry deployments. In this context, interviewees ICT_8 and WO_2 underlined that it would be fundamental to compare future blockchain-based solutions with existing technologies and ascertain the optimal technology '*mix*' for each specific application. Some priorities are regarding academic research efforts, as it has been discussed, as more research is needed to decompose and analyze each blockchain feature that creates the puzzle for the entire blockchain scenario. Specific insights would be set on improving the technology performances and on designing new business models.

Regarding the interoperability, there are concerns about permissioned and permissionless blockchain systems. A strong remark focused on the real technology potential. Interviewee AC_5 pointed out that blockchain was created as an open system for distributed applications and this distributed dominance cannot be achieved with permissioned or centralized systems.

5. Discussion

In this section the main considerations emerging from this study are discussed. This section provides an identification of those key fields in which blockchain platforms may benefit SCM operations and, answering the RQ, the contribution of the study attempts to bridge the gap in the existing body of knowledge.

Firstly, we recognize certain limitations of the study. In the selection process for experts, we may have overlooked several renowned experts who may have brought a valuable perspective into the analysis. In this context, the experts interviewed are from Western Europe, Australia, and the United States. We recognize that in recent years, blockchain has also shown impressive practices in Asian countries such as China, Japan, and South Korea, and this may represent a limitation of this study.

In a similar manner, as a qualitative approach, the data collection and assessment might have been influenced by our personal judgments. However, the grounded theory was applied in a meticulous manner to assure the mitigation of possible misleading outcomes, respecting defined criteria. Furthermore, in the data analysis during priorities' definition, weights were assigned to each dimension: three for strongly agreed; minus one for moderate detection; and minus five for strongly disagreed. This definition was a critical step to score priorities of the five categories and the impacts of this definition may have leveraged some research perspectives.

Additionally, as we collected a large variety of results, the presented results are not fully comprehensive but focus on answering the given RQ.

5.1. Contextualized Outcomes from the Experts

In this subsection, a set of seven elements are presented.

(1) Blockchain-based SC is not yet a mature technology and the return on investment (ROI) for its deployment is unclear. Thus far, this technology has been implemented and tested in several areas, although SCs appear to be one of the most prominent fields of application for blockchain. Several use cases and companies have already tested the technology in this area; however, performances are still low and there are many concerns about privacy and competitive advantages. Sharing data on a public ledger does not seem to be an appealing feature for companies and consequently they would need to design permissioned blockchain solutions to protect data and businesses.

Statement 1: *hybrid solutions are needed between permissioned and permissionless blockchains.*

(2) Blockchain has its origins in the financial sector with the Bitcoin protocol and it made several improvements regarding cryptocurrencies, payments, and new decentralized financial solutions. If we consider SC as a tiny/small financial system, it becomes clearer how the blockchain may benefit current industrial ecosystems, improving traceability and transparency for many parties involved. However, most of this technology deployment is used as a data platform rather than for its whole distributed potential.

This opens new trajectories for data and information management, as blockchain allows for pre-setting the logic on data organization and real-time information, demonstrating a performing feature about sharing data on the blockchain data-platform. These data are validated by the network's nodes and added to the chain, respecting the timestamps of when processes are run.

Statement 2: *information management is one of the drivers for blockchain in SCs.*

(3) Despite the low performances, the many barriers, risks, and security concerns related with its implementation, blockchain data sharing is a digital asset and may represent a value exchange in the stakeholders' network. Several technological gaps are wide open between research and industry, and it may be necessary to define a fair trade-off among

them, with distinguishing features such as the decentralization level, scalability potential, and security clearance.

In this context, applications such as accounting, financial statements, and tax obligations are consolidated duties in business management, and they might be automatized by blockchain-based solutions. Thus, by creating links between the blockchain-based information management platforms, all bookkeeping processes can be automatized and shared in a business ecosystem, for which governments can play the crucial role of due diligence compliance assessment.

Statement 3: *blockchain-enabled autonomous audits and lean administrative procedures for financial statements.*

(4) Regarding operation management and optimization, smart contracts can be applied, designing a deterministic virtual machine. Application steps may be set by analyzing industrial operations, defining processes, identifying procedures, and assigning responsibilities about '*who does what*' in the whole SC. These aspects would lead a digital enhancement of SCM, directly addressing all the data in a one-source platform. Thus, the combination between smart contracts, IoT, and SC promise to afford a new level of corporate liability for industrial management.

In a future trajectory, IoT systems will lead the automation of physical devices with data-coordination of real-world environments, whereas smart contracts will lead the automation and accountability of virtual environments. In this context, statement four is presented.

Statement 4: *an appropriate technology mix can enable and leverage future blockchain implementations.*

(5) Blockchain technology finds its foundations in asymmetric cryptographic protocols and consensus algorithms. These foundations allow to structure a reliable and secure digital transition for SCs through which all processes could be potentially digitized. The expert interviews indicate that a development of data platforms would allow for key information sharing within a network of companies and third parties operating in the SC. However, it is relevant to define the recording of such information in the blockchain to not lose competitive advantage in the market. An implementation of blockchain on information management duties can offer administrative improvements regarding the reduction of time, quality of information exchanged, and increased security.

Consequently, blockchain can be part of the digital transition, contributing to a reliable adoption by companies; however, it will be necessary to develop an extremely precise design for the tasks blockchain would have to include [11]. Blockchain can be considered as a service for SC stakeholders, providing enhancements on existing processes [10]. However, considering the recent industrial tests are centralized, the future challenge will be to improve the decentralization degree in blockchain-based SCs. Although existing deployments are tools for ecosystem-building, they have had positive impacts on the stakeholders involved, achieving higher levels of trust in the business networks they operate in.

Statement 5: *blockchain enhances trust in (digital) ecosystem-building for SC stakeholders.*

(6) According to Cooper et al. [29], D. M. Lambert [30], and Kane [31], SCM is composed of eight macro processes: customer relationship management, supplier relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, product development and commercialization, and returns management.

Current blockchain-based solutions such as ecosystem-building and stakeholder engagement are appropriately placed in the process of supplier relationship management. The identification of criteria for segmenting suppliers is essential in this process. Assuming the validity of the main findings of Lambert and Schwieterman [58], in SCM '*it is necessary*

to have the capability of measuring the performance of the supplier relationship management in terms of their impact on incremental revenues, costs and investment'. Understanding suppliers' capabilities permits, then, to develop detailed programs aimed at improving SC performance. Additionally, this knowledge allows to negotiate the sharing of benefits and costs such that all the involved players have the incentive to participate [58].

Statement 6: *blockchain fits in the supplier relationship management process.*

(7) Although a process has been identified for blockchain pertinence, other areas of development may be described, for instance, the finance business units. As shown by the grounded theory analysis (Figure 1), accounting and administration is one of the most relevant categories discussed, which becomes especially revolutionary when complemented with Industrial IoT and automation.
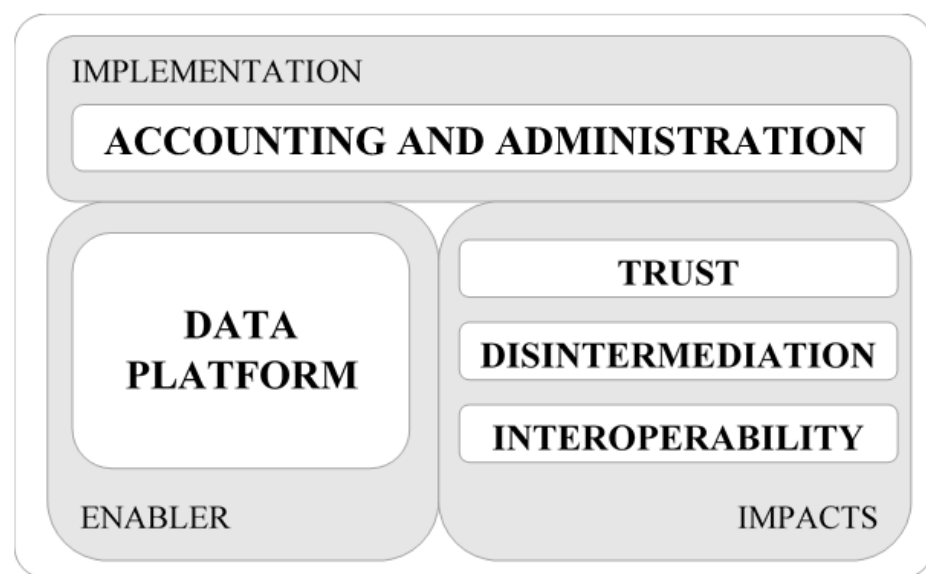

Figure 1. Major categories emerged and functional factors.

In this instance, as an additional outcome of the grounded theory assessment, we identified a further distinction among functional factors, which characterizes categories. What emerged refers to a higher degree of automation for financial duties (i.e., machine-to-machine autonomous payments).

Figure 1 presents a conceptual map of the five categories, which are assigned in three sections as functional factors: (i) implementation, (ii) enabler, and (iii) impacts. The former is composed of the accounting and administration category, considered as a vertical implementation for SCM that could be related to almost all the eight processes of SCM mentioned above. The enabler is identified as the new data platform blockchain frames, given that it allows for new improvements for data and information management. This aspect may also be related to the automation and Industrial IoT for future innovative applications. Consequently, trust, disintermediation, and interoperability are the resulting impacts for business ecosystems in which this architecture links all the systems and stakeholders involved into one source of liability.

Statement 7: *blockchain-based SC data-platforms are lean data-driven solutions and become even more revolutionary for future Industrial IoT systems.*

Table 3 summarizes the seven statements presented in this section.

Table 3. Precautions for applying blockchain to SCM.

#	Statements
1	Hybrid solutions are needed between permissioned and permissionless blockchains.
2	Information management is one of the drivers for blockchain in SCs.
3	Blockchain-enabled autonomous audits and lean administrative procedures for financial statements.
4	An appropriate technology mix can enable and leverage future blockchain implementations.
5	Blockchain enhances trust in (digital) ecosystem-building for SC stakeholders.
6	Blockchain fits in the supplier relationship management process.
7	Blockchain-based SC data-platforms are lean data-driven solutions and become even more revolutionary for future Industrial IoT systems.

5.2. Drive the Blockchain Adoption in SCM

This section is aimed to respond to the presented RQ: *how can the information flow structure affect and pilot a suitable blockchain adoption in SCM?*

As shown in Figure 2, the connection between two major processes identified highlights a segment in which blockchain may fit into SCM. This segment may help to reduce complexities and drive blockchain adoption in future technologies' deployments.
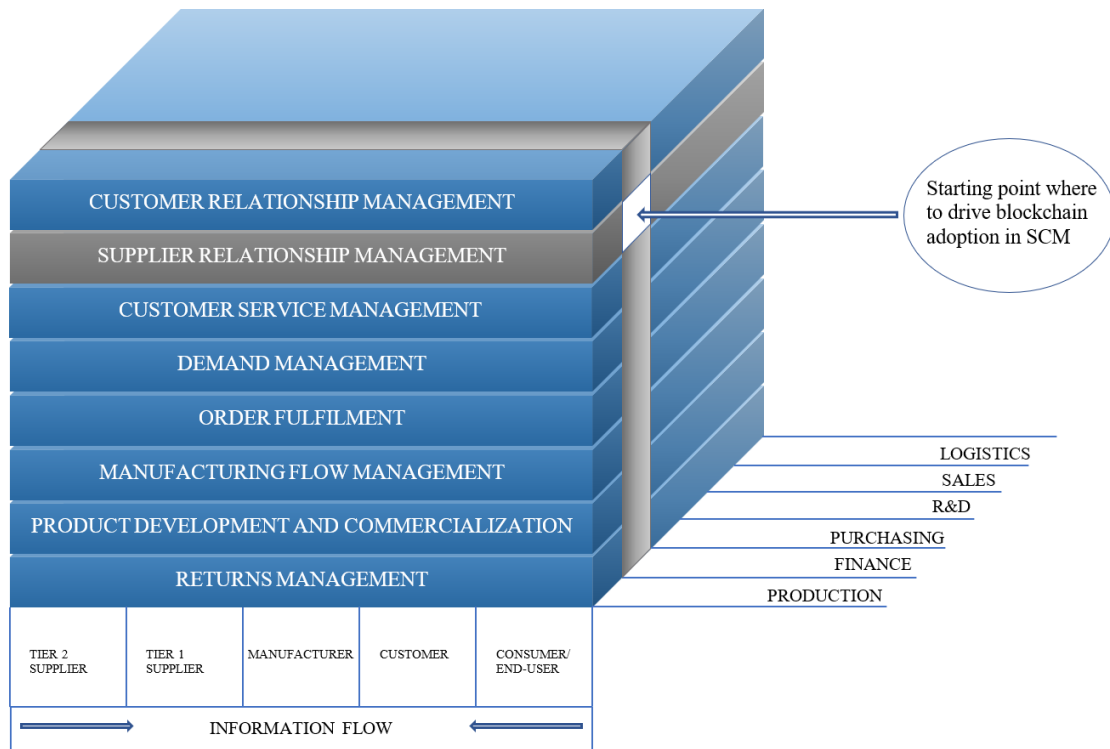

Figure 2. The eight macro business processes: integrating and managing business processes across the SC (adapted from [58]).

This macro representation may support the analysis of the internal resources, links, and stakeholders involved that compose the business ecosystem. By downscaling the segment, the appropriate level of details may be found for those digital implementations in which blockchain may mitigate SC risks and enhance the added value in operations.

As an example, following the literature reviewed, for the SC micro risk factors identified by Ho et al. [36], 15 out of 110 risk factors can be mitigated by a blockchain solution (13% circa) in which information management, smart contracts, dispute resolutions, and real-time data-sharing would play a relevant role. Additionally, in detailing the enhancements of SCM in the segment, it would be relevant to assess partners' cooperation, competitive advantages, SC information flow, and partnership governance [38].

At this stage, it is essential to keep focus of the two major processes identified. In fact, those processes are purposed with managing the information flow for supplier relationship management and the financial aspects related to it.

Moreover, considering further digital deployments and industrial improvements that may bring added values in operations, distributed data-platforms will perform innovative roles in SCM. Therefore, data are replicated as many times as the nodes of the network warrant. Thus, it is fundamental to identify those key-data to be shared in the distributed ledger and provide an infrastructure capable of obtaining the best value from a consensus protocol deployment. Once the ecosystem identifies the data to be shared, a blockchain platform can make it available for each stakeholder involved, improving security and reducing time for the information management process. At this layer, the information flow can be set internally to reduce complexities and delays, aligning it to internal software that organizations use to manage day-to-day business activities (ERP, for instance) [15].

To the best of our knowledge and after the presented study, we believe that these results may guide practitioners in identifying an effective information flow structure to deploy blockchain in SCM. However, we recognized some limitations of this research study and further direction is needed to consolidate these results for a broader adoption.

6. Conclusions

In this study, experts' opinions on blockchain-based SC are explored. Using an explorative research approach, 18 interviews were conducted with international experts from different countries.

Applying the grounded theory methodology, the data collected were analyzed and five categories were identified. These categories were grouped into three main clusters to present the findings: (i) data platform; (ii) accounting and administration; and (iii) trust, disintermediation, and interoperability.

Each cluster presents the main findings in detailed descriptions and each is a valuable input for research contributions and final statements. As one of the main results, seven statements are provided and explained in the earlier section.

This study lays the foundation for the identification and assessment of blockchain developments for SCM processes. In bridging this gap, the proposed research has an original character and contributes to the body of knowledge, addressing future research needs to the best of our knowledge.

Two major processes are identified for blockchain applications. One focuses on the supplier relationship management process, enhancing performances in terms of their impact on revenues, costs, and investments in complex SCs, suggesting a second process which is more suitable for a lean SCM. Using a data-driven approach, this can lead to leaner financial procedures, the deployment of higher levels of automation and Industrial IoT that are capable of providing a single liability source, and additional feature-related advantages.

However, blockchain for SC is still an emerging technology necessitating further research. It will be prudent to further explore how blockchain-based platforms may transform risk management and corporate liability in future deployments.

Our future investigations may follow quantitative approaches (i.e., [59]) to merge outcomes and generate comprehensive results.

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