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Untangling the critical success factors for blockchain adoption in supply chain: a social network analysis

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Abstract : With the advent of Industry 4.0, Blockchain is attracting Supply Chain (SC) practitioners and researchers thanks to its decentralized and trustworthy data governance features. As Blockchain adoption in SC is nascent, this article provides a Systematic Literature Review of the critical success factors for this phenomenon to help organizations meet its challenges. 56 selected articles were first thematically analyzed with NVivo to identify and conceptually categorize the factors. Then, we performed a social network analysis under VOSviewer to understand the research trends in our topic and explain the implicit ties between the identified factors. Finally, we inferred further theoretical implications of the analyzed literature in light of the 'Technology, Organization, Environment' framework. Hence, this study contributes to academic and practical knowledge by explaining the natures of the interdependent factors for Blockchain adoption in SC and of their potential links. We also propose opportunities for future research to extend our findings.

Keywords : Blockchain; Critical Success Factors; Social Network Analysis; Supply Chain; Systematic Literature Review; Technology adoption.

Distinction des facteurs critiques de succès pour l'adoption de la blockchain en supply chain : une analyse par réseaux sociaux

Résumé : Avec l'avènement de l'industrie 4.0, la Blockchain attire les praticiens et les chercheurs en Supply Chain (SC) grâce à sa gouvernance des données décentralisée et fiable. L'adoption de la Blockchain en SC étant naissante, cet article fournit une revue systématique des facteurs critiques de succès de ce phénomène pour aider les organisations à relever ses défis. 56 articles sélectionnés ont été analysés thématiquement avec NVivo pour catégoriser conceptuellement les facteurs. Ensuite, une analyse par réseaux sociaux a été effectuée sous VOSviewer pour comprendre les tendances de recherche et expliquer les liens implicites entre les facteurs. Enfin, nous avons déduit des implications théoriques supplémentaires de la littérature analysée à la lumière du cadre « Technologie, organisation, environnement ». Cette étude contribue aux connaissances académiques et pratiques en identifiant les facteurs interdépendants pour l'adoption de la Blockchain en SC et leurs liens potentiels. Des opportunités de recherches futures sont aussi proposées.

Mots clés : Blockchain ; Facteurs critiques de succès ; Analyse par réseaux sociaux ; Supply chain ; Revue systématique de la littérature ; Adoption de la technologie.

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1. INTRODUCTION

The emergence of the Industry 4.0 paradigm (Agarwal et al., 2021; Calabrese et al., 2020; Gamoura, 2021; Ivanov & Dolgui, 2020) has resulted in numerous improvements and innovations for organizations in various sectors. Although unique changes to the global scenario were brought by each industrial revolution, the speed at which the fourth revolution is affecting the businesses is unprecedented (Anand et al., 2021; Li et al., 2020a; Su et al., 2020). This revolution is induced by advanced digital technologies that empower companies to deploy data-driven strategies and develop data-processing capabilities (Li et al., 2020b). Among these technologies, Blockchain is a prominent innovation that is remodeling traditional business models and creating opportunities for improvement of transparency, trust, and for costs' reduction (Kshteri, 2018). Blockchain refers to "*a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors*" (Risius & Spohrer, 2017, p.2). This technology is particularly perceived as a solution for traceability problems in supply chain management (Lu & Xu, 2017) and a way to establish trustworthy and close relationships across the entire Supply Chain (SC) including intra-organizational units, suppliers and customers (Aste et al., 2017). Indeed, Blockchain's traceability mechanisms have the potential of preventing transactions' fraud and offer security, authenticity and legitimacy features that are crucial to supply chains (Wong et al., 2020). Also, a Blockchain-enabled smart contract induces high levels of efficiency to supply chain management along with decentralized operations (Kopyto et al., 2020). Finally, this technology can allow customers to check the goods' journey across the chain, therefore enhancing their trust (Quieroz & Fosso Wamba, 2019).

Aware of these benefits of Blockchain adoption in SC, many organizations around the globe are conducting pilot projects in order to experiment this technology and grasp its real potential. For instance, in collaboration with IBM, the Danish shipping company Maersk tested Blockchain for international logistics in order to track its shipping containers

worldwide based on attributes of temperature, GPS location, etc. (Yang, 2017). Alibaba partnered with Blackmores, AusPost, and PwC to explore Blockchain use for fighting food fraud, involving the selling of lower-quality foods usually with counterfeit ingredients (Sachdev, 2019). Blockchain startup Chronicled and LinkLab consultancy firm are working on a track and trace pilot addressing the pharmaceutical industry, with the aim to satisfy the Drug Supply Chain Security Act (Kshteri, 2018). The application of Blockchain in SC is hence still at its initial stages and is marked with the increasing emergence of such pilot projects that are crucial to resolve technical issues of Blockchain in this inter-organizational context. In addition to improving Blockchain features and adapting its use to SC, practitioners must also be aware of the critical success factors (CSFs) for this technology adoption in order to be cognitively and structurally prepared for its imminent maturity and its certain impact on business models and power relationships in SC (Biswas et al., 2017). However, while the pilot projects and most academic studies have intensively examined the functional and technical peculiarities of Blockchain in SC (Behnke & Janssen, 2020), no empirical or theoretical research has accurately characterized the contingent factors fostering its adoption in SC. Few factors have been identified in empirical studies or in prior theoretical research that investigated the trends and projections of Blockchain use in SC (e.g. Kopyto et al., 2020; Varriale et al., 2021). The question of how managers can make sure Blockchain adds value to their SCs and broadly to their organizations is still unanswered (Fosso Wamba & Quieroz, 2020).

Hence, the present study aims at covering this gap by characterizing the different CSFs that should be carefully managed to reap the benefits of Blockchain in SC and to enable managers overcome its operational and relational challenges. Moreover, given that success factors of a technology adoption are interdependent (Pankratz & Basten, 2018), our study proposes to identify potential relationships between the different categories of CSFs, thus opening-up the perspectives for future empirical research. Accordingly, we raise the following research question: *What are the inter-related*

critical success factors for Blockchain adoption in Supply Chain? To answer this question, we performed a Systematic Literature Review (SLR) that synthesizes the current academic knowledge on the CSFs for Blockchain adoption in SC. In contrast to the majority of SLR studies on Blockchain use in SC that aim at describing the global trends of this stream, our study stands out by focusing on the specific issue of CSFs for this technology adoption in SC and by striving to provide theoretical inferences explaining the natures of the factors and their potential ties. To conduct this explanatory SLR, we relied on two complementary approaches. First, a thematic analysis supported by NVivo enabled identifying and conceptually categorizing the factors proposed in a dataset of 56 articles selected for the SLR. Then, a social network analysis using VOSviewer resulted in delineating extant research in our topic under investigation and in explaining the links between the identified factors. To further emphasize the theoretical implications of this research, we analyzed our results in light of an existing theory to deconstruct the studied phenomenon as recommended for SLR studies aimed at explaining rather than at describing (Rowe, 2014). In this respect, we relied on the TOE (Technology, Organization, Environment) model (Tornatzky & Fleischer, 1990) often used for examining adoption in intra and inter-organizational contexts, in order to propose hypotheses explaining the inter-related mechanisms by which the identified CSFs impact Blockchain adoption in SC.

Thus, this study contributes to the advancement of academic knowledge and managerial practice. From a theoretical standpoint, we uncover the diverse natures of the CSFs for Blockchain adoption in SC and offer accurate description and conceptual categorization of these factors. This study also proposes an operationalization of the TOE dimensions considering the peculiarities of this technology and of this adoption context, and unveils potential direct and mediated links among the CSFs composing the dimensions. Accordingly, we provide opportunities for further research to enrich the factors, evaluate their criticality and their different contributions to the SC performance, and empirically explore their ties identified in this study.

From a practical standpoint, we raise managers' awareness of the key organizational, technological and external factors that would foster the success of Blockchain adoption for SC in their organizations. This research particularly spurs managers to rethink their project management practices, organizational capabilities, and relationships with the SC stakeholders and with the broad industrial community in order to be prepared for this digital era with Blockchain rapidly gaining ground.

This article is structured as follows. Section 2 is devoted to our theoretical foundations while Section 3 describes our research methodology. The findings are detailed in Section 4 and are further discussed in Section 5. Finally, this study concludes with its implications and future research avenues.

2. THEORETICAL FOUNDATIONS

2.1 Basics of Blockchain technology

Blockchain technology is a distributed database of records or shared public/private ledgers of all digital transactions that have been executed and shared among Blockchain participating agents (Crosby et al., 2016; Saberi et al., 2019). A main difference between the present Internet design and that of Blockchain is the fact that transactions in the Internet aim to move information, i.e. not value, and to move copies but not original information. Blockchain is additionally distinct from the most existing designs of information systems thanks to four key properties that provide a time-stamped and verifiable record of transactions (English et al., 2016): auditability, non-localization (decentralization), security, and smart execution (Baker & Steiner, 2015).

In fact, when a new transaction is created by an agent, it is broadcasted to the network for **auditing** and verification. Once the majority of the chain's nodes approve this transaction based on pre-specified consensus rules, this transaction is added to the chain as a new block associated with a generated cryptographic hash. Each block holds not only records of the transaction but also includes the hash of the preceding block. This creates a block interdependency resulting in a chain, that is the Blockchain (Hackius & Petersen, 2017). Multiple

copies of the transaction are created in a **decentralized** manner and saved in distributed nodes, hence enabling the participants to access verified records for every transaction (Crosby et al., 2016). This decentralization also fosters **security** as it makes Blockchains less susceptible to crashing, corruption or hacking (Tian, 2016). Indeed, altering a transaction would require altering the records on the devices of most networks' members, and also altering the cryptographic hash associated with every block within the chain (Hackius & Petersen, 2017). Meanwhile, a **smart contract** allows the performance of credible transactions without third parties' involvement, which helps establishing trust, accountability, and transparency among the agents (Kopyto et al., 2020). A smart contract is a software program that stores policies and rules for consensual actions and terms between a network parties (Delmolino et al., 2016). The contract automatically executes its code each time it receives a message from a network actor or another contract, and updates the registers accordingly if the contractual conditions of its network are met (Peters & Panayi, 2016).

Blockchains can therefore be used to implement an agreed set of rules that no one can break neither the users nor the system operators. They rely on a unique architecture platform for applications involving multiple parties who require little trust in each other, as is the case of fragmented supply chains (Nofer et al., 2017). This technology guarantees the system integrity in the face of idleness or dishonesty. Participants are able to view the ledgers and analyze records that are kept behind cryptography (Crosby et al., 2016), thus simultaneously ensuring transparency and anonymity (Tian, 2016). Depending on the Blockchain application, its design can form public (without authorization) or private (with authorization) networks and ledgers (Ølnes et al., 2017), which differ in terms of network actors and consensus rules. In a private or closed Blockchain, the parties know each other and there is no anonymity. In this case, there would be new roles such as certifiers, who provide certifications to network participants and keep the network private. In a public or open blockchain, to maintain trust with

several anonymous users, cryptographic methods are used to allow users to enter the network and record their transactions (Pilkington, 2016).

2.2 Blockchain adoption in SC

Technology adoption refers to the decision to accept and use a new technology in order to reach performance purposes (Venkatesh & Bala, 2008). Blockchain was first adopted in the financial sector as a platform to manage the Bitcoin digital cryptocurrency (Nakamoto, 2008). Aside from the digital currency, Blockchain is a cutting-edge computing paradigm with wide opportunities and challenges for the supply chain (SC) field (Abeyratne & Monfared, 2016; Tian, 2016). SC "consists of the series of activities and organisations that materials move through on their journey from initial suppliers to final customers" (Waters, 2019, p.7). Most important SC tasks are sourcing, production, new product development, logistics, coordination, integration and demand management (Jokar et al., 2002; Vitasak, 2013), which aim at enhancing customer value and achieving a sustained competitive advantage (Handfield & Nichols, 2002). The decentralization, auditability and smart-contract enabled features of Blockchain result on its high potential for reshaping business models and improving processes in SC. Hence, this technology's application started attracting SC practitioners and scholars since 2016 (Tian, 2016). We hereby list the major implementation domains of Blockchain in SC.

First, this technology is widely used for traceability and visibility enhancements (Dujak & Sajter, 2019). It enables the verification of a product origin in terms of time, place and manufacturers, and offers information regarding its route from suppliers all the way to consumers. Providing such information is highly valuable for customers and represents a real competitive advantage for the company (Hastig & Sodhi, 2020). This application of Blockchain is particularly beneficial for retailers in fast moving consumer goods and food industries, who are compelled to inform their customers regarding the products' traceability (Fabbe-Costes & Lemaire, 2001) but hardly ever have full knowledge of the SC upstream part (George et al., 2019). Information about food journey may additionally help SC

members better prepare shipment delivery, which results in shorter lead-time to consumers and faster operations. Furthermore, consumers are more confident regarding this product and benefit from more time to enjoy its consumption.

Second, Blockchain greatly helps improving demand forecasting in SCs (Kouhizadeh et al., 2021). The latter refers to the preparation by SC members for upcoming events in the SC based on coordinated efforts for forecasting expected demand, hence jointly influencing demand and creating their supply (Dujak el al., 2017). All the upstream members should create their own demand considering the data of the independent demand, that is the product amount demanded by the SC end-use customers described in terms of location and time (Mentzer et al., 2007). This collaborative demand management allows avoiding a bullwhip effect (Lee et al., 1997) characterized with additional safety stocks on each upstream echelon of the SC that financially burden the chain and slow the material flow. The main prerequisite for this common demand forecast is the exchange of data on independent demand between all SC members; whereas the crucial problem and major barrier of supply networks is the lack of trust for information exchange between SC actors. In this respect, complete security and transparency guaranteed by Blockchain helps overcoming these issues by supporting trustworthy, secure, immutable and real-time exchange of information regarding the independent demand that is required for demand forecasting in the supply network (Kopyto et al., 2020). Additionally, final customers may connect to a Blockchain-based application, and therefore become true members of SC with the possibility to express their needs and opinions directly. These real-time feedbacks would enable more accurate forecasting, and entirely change retail and production landscape.

Third, Blockchain provides open access to information that could be available to everyone or just to specific members of the SC depending on the type of Blockchain (Helliar et al., 2020). The benefits of this open access are mainly recognized for transportation. For example, IBM and Maersk developed cargo tracking Blockchain-based

applications that provided data on containers to relevant parties (SC members, banks, and insurance companies) and created a digitized documented work flow throughout the freight journey (IBM, 2018). This helped reducing costs of insurance, decreasing the need for numerous communications between connected organizations during which many error, spoilage, waste and defects happen, and optimizing the use of empty containers through broader access to their availability on nearby ports and ships (Del Castillo, 2017). Besides, open access granted by Blockchain can contribute to establishing a more environmental-friendly behavior of consumers and companies. It decreases the need for paper form documentation and online communications and transactions. It also provides trustless information about products' lifecycle of use, which would enable more efficient re-manufacturing, recycling and leasing of existing products (Herzberg, 2015). Finally, it traces products' carbon footprints, hence allowing for giving appreciation to ecologically performing companies and products, and penalizing the opposing ones.

Fourth, Blockchain helps decreasing fraud risk and counterfeit thanks to its verification of authenticity and open access applications (Kshteri, 2018). For example, the pharmaceutical market is the world's largest fraud market with sales of counterfeit medicines ranging from 163 billion to 217 billion US dollars per year (Dujak & Sajter, 2019). Hence, pharmaceutical serialization (prescription drug labelling system for authentication through SC from manufacturer to consumer) is becoming compulsory in most developed countries. Using Blockchain as distributed ledger with records of drugs and their origin streamlines serialization and significantly reduces this fraud. Similarly, the need to prevent counterfeit is frequently expressed in the luxury jewelry industry. For instance, Everledger is a company that is striving to make the diamond SC more transparent thanks to Blockchain (Hackius & Petersen, 2017). It digitally secures records about diamonds' forty metadata points (e.g. color, carats, serial number, the cut, etc.) by using linkages to the laser inscription on the girdle of the stone. The company has uploaded 1.6 million diamonds on a

Blockchain platform (Roberts, 2017). Its services are mainly used by insurance companies, open market places and banks to authenticate the transaction process. Aside of these two sectors, the need to prevent counterfeit is becoming critical with the increased availability of technologies for additive manufacturing that allow anyone to manufacture product parts of questionable quality. Blockchain is therefore an appropriate means to help end users and producers verify quality and authenticity (Holland et al., 2017).

In sum, Blockchain possesses an enormous potential to optimize SC processes, improve performance and reshape supply business models. However, the adoption of this technology in SC is still nascent, as it requires overcoming complex challenges in terms of throughput, latency (Wang et al., 2019), energy consumption to perform the transactions (Babich & Hilary, 2020), decentralization of power, and alignment of consensus rules between the SC actors (Fosso Wamba et al., 2020). To handle these challenges, many public and private firms as well as industrial associations are conducting pilot projects, in collaboration with Blockchain labs in most prestigious universities worldwide (Dujak & Sajter, 2019). Hence, SC managers need to prepare for the imminent maturity of Blockchain and anticipate its radical transformational impact by establishing the right organizational context and managerial practices to accompany its adoption (Fosso Wamba & Quieroz, 2020). In this respect, through a systematic literature review, the present research provides a refined analysis of the inter-related critical success factors (CSFs) that affect the adoption of Blockchain in SC as explained hereafter.

3. RESEARCH METHODOLOGY

This research aims at characterizing the interdependent critical success factors (CSFs) for Blockchain adoption in Supply Chain (SC). CSFs can be defined as characteristics, factors, conditions, or variables that must go right for achieving successful results (Zhou et al., 2011). These factors need to be carefully managed, maintained, and controlled for the expected performance outcomes (Leidecker & Bruno, 1984). To answer our research question, we conducted a systematic literature review (SLR) by

following the recommendations of Kitchenham (2004) to extract the relevant academic content, analyze it and report its results. In contrast to descriptive literature reviews intending to map extant knowledge on a topic under general categories without discussing their underlying theoretical assumptions (Rowe, 2014), the present study has explanatory purposes. In fact, we aspire to delineate extant research in these factors in order to propose theoretical implications explaining their natures and their potential links (Borgatti et al., 2002). We detail hereafter our approach to scan the literature associated with our research question and analyze its insights.

3.1 Material collection for the SLR

To identify studies that examined CSFs of Blockchain adoption in SC, we relied on three leading databases in the management field namely EBSCO, Web of Science and Scopus. These reference databases are widely available for scholars and gather interdisciplinary peer-reviewed publications. Regarding the keyword protocol, inclusion and exclusion criteria were defined to evaluate the relevance of the studies according to the established research question (Anand et al., 2021; Riahi et al., 2021). In this respect, we performed a query using the keywords ("Blockchain" OR "distributed ledger") AND ("Supply Chain" OR "Logistics") AND ("success factor" OR "condition") to explore the title, abstract and keywords of the available publications. We covered English language journal articles, book chapters, and conference proceedings published since 2008, which corresponds to the emergence of Blockchain technology (Crosby et al., 2016).

After removing the duplicates, 137 matching studies were identified. We subsequently evaluated the relevance of these studies to our research question by reading their titles, abstracts and keywords, which resulted in selecting 97 publications, then by browsing the full texts of the remaining articles, therefore keeping a total of 56 studies.

3.2 Thematic coding to identify the CSFs

To determine the CSFs for Blockchain adoption in SC, we performed a thematic coding of the selected studies supported by NVivo software. Thematic

analysis is a qualitative research approach for investigating, defining, organizing, and generating themes discovered within a data corpus (Nowell et al., 2017). It is a flexible method to examining a comprehensive amount of data –in our case a sample of articles relevant for the research question - and requires from the researcher to be well structured (Braun & Clarke, 2006). Sodhi & Tang (2014) define four maturity stages in any research stream namely awareness, then framing, modelling, and finally validation. Given the nascent application of Blockchain in SC, thematic analysis as mobilized in the current study can help build awareness among practitioners and researchers of the CSFs for Blockchain adoption in SC and support the framing of their natures and links aided by existing theories and models.

We carried out our thematic coding in five steps (Braun & Clarke, 2006) that were subsequently followed by the production of the analysis report. We first got familiarized with the data corpus, generated initial codes, then searched for aggregated themes, reviewed them, and finally interpreted, defined and named these themes. These steps were performed iteratively as we progressed in the analysis of the articles selected for the SLR. Accordingly, 271 factors were identified within the selected studies and tagged with codes, which were subsequently aggregated into higher-order themes. This approach resulted in a coding grid containing 22 classes of factors, which were broadly assembled in six major categories. We henceforth refer to these 22 classes as our CSFs for Blockchain adoption in SC, since the factors that are similar are gathered in the same class, thus allowing their collective exclusivity.

3.3 Social Network Analysis to delineate the inter-related CSFs

Providing only bibliographic or keyword analysis can be insufficient for SLR in a multi-disciplinary topic as is the case of technology adoption in SC. This is even more critical for explanatory literature reviews as they are concept-centric moving away from paper-centric or author-centric perspectives (Rowe, 2014). Therefore, studying the frequency and the correlations of contents through a Social Network

Analysis (SNA) is relevant to identify word clusters and implicit ties within literature on a subject as recommended by Wang et al. (2017). SNA relies on mapping and clustering techniques to understand and discover patterns regarding a topic under investigation (Lee et al., 2018). This approach has been applied to address diverse research questions in SC and technology management (e.g. Han et al., 2020; Maruccia et al., 2020). Furthermore, the combination of quantitative outcomes of a SNA and qualitative insights of a thematic analysis results in more comprehensive and robust findings, as demonstrated in the recent study of Ullah et al. (2021).

In this respect, we performed a SNA supported by the softwares Mendeley and VOSviewer which are accessible for free. VOSviewer was used to cluster the keywords related to the CSFs and subsequently create informative infographics about their densities and relationships. This software is particularly practical as it helps synthetizing the body of knowledge on a topic and displaying research trends without advanced computer skills or profound knowledge of clustering techniques (Van Eck & Waltman, 2010). It first creates networks according to the analysis purposes, for instance networks of scientific publications, researchers, terms, etc. Items in these networks can then be connected by co-occurrence, co-authorship, bibliographic coupling, citation, or co-citation links. To construct our network of CSFs, a Mendeley file gathering the 56 articles selected for the SLR was instrumented to VOSviewer. Then, to facilitate the analysis of this content and simplify the visualization of its results, we implemented into VOSviewer a thesaurus of the 22 distinctive CSFs based on the coding grid that was built under NVivo. Accordingly, we were able to map the content of the network based on co-occurrence of CSFs and directly visualize their densities and ties (Perianes-Rodriguez et al., 2016). We chose to focus the SNA on the 22 CSFs rather than on the six major categories in order to provide a more refined reading of the literature corpus. We then confronted the SNA's results with the six global themes to infer further conclusions.

4. RESULTS

4.1 Metrics regarding the studies'distribution

Transportation Research Part E) and those on technology management (e.g. Technological Forecasting and Social Change, International Journal

Evolution of the types of studies

Number of studies per year

Types of the studies

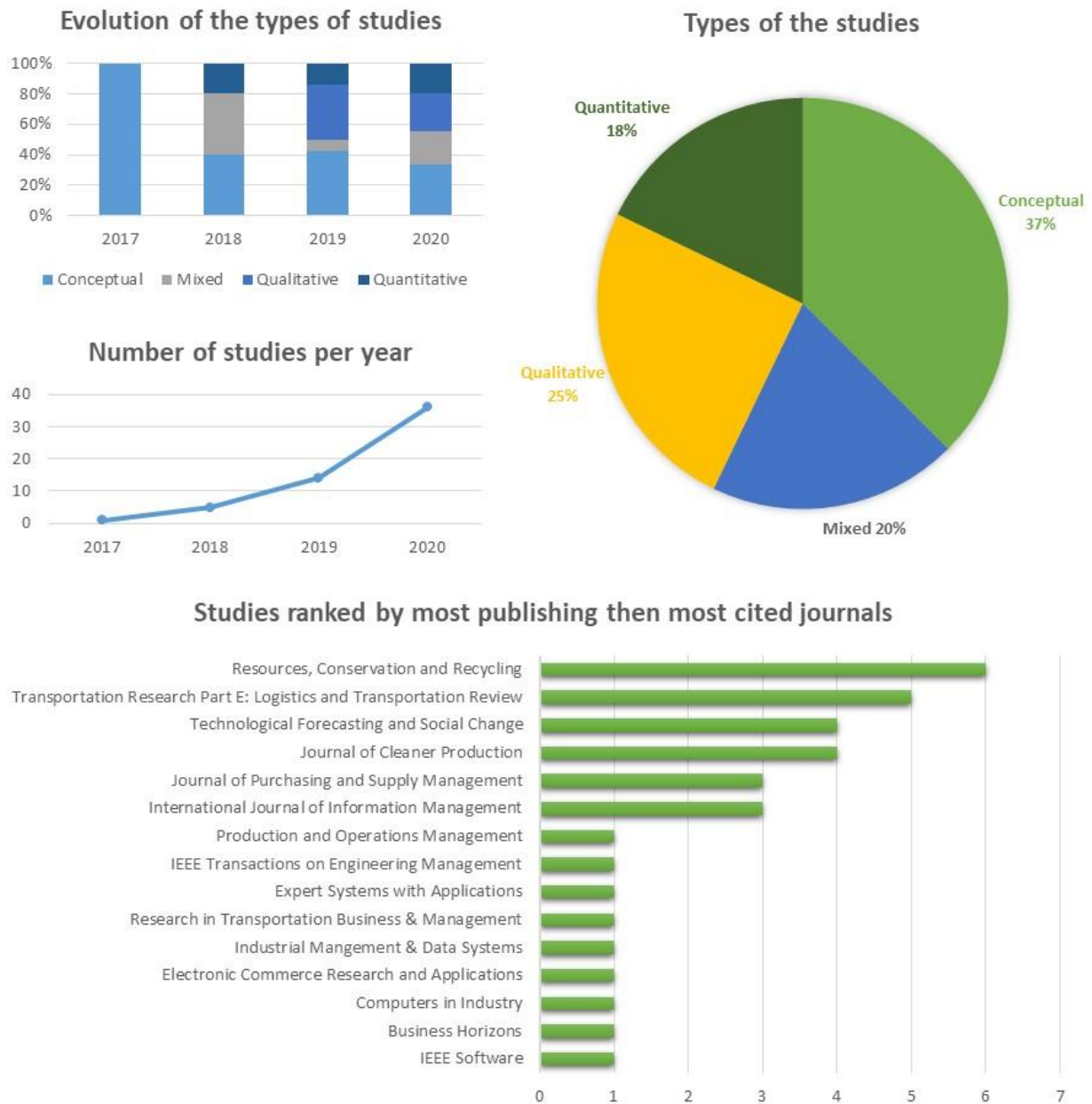### Studies ranked by most publishing then most cited journals

Figure 1: Characteristics of the publications selected for the SLR

Among the 56 selected studies for the SLR, 89% were journal articles while 9% represented conference proceedings and 2% corresponded to book chapters. Figure 1 synthesizes the metrics on this content's distribution that is detailed below.

Within the displayed top 15 most publishing and cited journals on CSFs for Blockchain adoption in SC, we notice a balance between journals on SC management (e.g. Journal of Cleaner Production,

of Information Management), thereby emphasizing the multidisciplinary feature of our research topic. The publication trend in this subject started on 2017 with an exponential growth of scholars' interest over the last three years. The nature of the studies evolved over the years from only conceptual to diverse empirical research. Overall, most selected studies are conceptual (37%) or rely on qualitative empirical approaches (25%), while 20% are purely

quantitative, hence emphasizing the infancy and exploratory nature of research in our topic.

These studies are marked by the richness of their used methodologies. The conceptual articles propose a variety of frameworks based on scientific and grey literature (e.g. Dutta et al., 2020; Schmidt & Wagner, 2019). The qualitative publications mobilize data from semi-structured interviews (e.g. Chang et al., 2020), expert panels (e.g. Hartley & Sawaya, 2019), and intakes of single case studies (e.g. Chen et al., 2019) and of multiple ones (e.g. Centobelli et al., 2020). As for the quantitative approaches, most of them rely on multi-criteria decision-making methods (e.g. Ar et al., 2020; Kumar et al., 2020; Shardeo et al. 2020; Shoaib et al., 2020) and fewer use modeling approaches (e.g. Kamble et al., 2019; Nayak & Dhaigude, 2019). Some quantitative studies are mixed with qualitative phases (18% of the analyzed corpus) performed before (e.g. Van de Kaa et al., 2020) or after (e.g. Choi, 2019) the quantitative stage.

4.2 CSFs and their categories

From the 56 publications selected for our SLR, we extracted 271 factors for successful Blockchain adoption in a SC context and categorized them iteratively as we browsed the literature content. This inductive thematic analysis performed with NVivo enabled identifying 22 exclusive classes of factors, henceforward representing our CSFs as explained in the methodology section. Based on established concepts on Information Technology and SC management literature, we assembled these CSFs into six higher-order categories to enable structured reporting of our results and their discussion in light of theoretical streams. As the thematic analysis of the publications selected for the SLR progressed, we noticed that we achieved saturation in uncovering the themes and their associated factors. We argue that these findings are likely exhaustive as our corpus was broad with content from a wide variety of scholarly sources. The outcomes of this thematic analysis are summarized in Table 1 and detailed hereafter.

We first identified three CSFs pertaining to the theme of **Data governance**. The latter refers to the practices established by organizations "*to take*

control over all aspects of their data resource from the setting of integrity constraints for data quality to the creation of enterprise-wide policies on data access and security" (Begg & Caira, 2012, p.3). The first CSF in this theme is ***Data security***, which covers the risk management practices to make it impossible to hack the system and lose the data stored in the Blockchain (Shoaib et al., 2020). These practices also concern the establishment by the SC actors of authorizations for secure access (Liu & Li, 2019) and decentralized and self-sovereign control of data (Prasad et al., 2018) within a trustless and permissioned system (Surjandy et al., 2018). Second, ***Data integrity*** includes the practices implemented among the stakeholders to ensure the authenticity, credibility, immutability (Dutta et al., 2020; Hastig & Sodhi, 2020), and quality fairness (Shoaib et al., 2020) of the data in order to make it free from bias and human error. Finally, ***Data privacy*** is related to the use of encryption methods to ensure the protection (Park et al., 2020) and the anonymity of records and users (Hastig & Sodhi, 2020; Kamble et al., 2019).

Then, a second theme that emerged from the literature analysis was seven **functional properties of Blockchain** considered as CSFs for the successful adoption of this technology in SC. In this respect, several studies emphasized the need for a ***mature platform with a credible architecture*** supporting the enacting of Smart contracts (Hastig & Sodhi, 2020; Prasad et al., 2018), the removal of intermediaries (Wang et al., 2019), the integration of Cloud and RFID technologies (Prasad et al., 2018) and the security of transactions (Dutta et al., 2020). ***Blockchain interoperability*** is also a frequently cited CSF in SC contexts. This technology should rely on standards to enable its real time integration and coexistence (Çaldağ & Gökalp, 2020) with the stakeholders' IT and legacy systems (Pautasso et al., 2020), with other cloud and trusted IoT services (Prasad et al., 2018; Surjandy et al., 2018) and between Blockchains (Wang et al., 2019). Moreover, the used Blockchain should be highly ***scalable*** with a miner incentive (Prasad et al., 2018) and a modular structure (Giustia et al., 2019) that can be extended in the long-term (Shoaib et al., 2020) with developed sidechains (Ciric et al., 2019), and can

handle a potential bloat (Prasad et al., 2018) in terms of increased size, throughput, latency and bandwidth (Ar et al., 2020). In addition, successful adoption of Blockchain in SC requires its **suitability for this context** (Hastig & Sodhi, 2020) specifically through increased practicality for multi-locations and remote suppliers (Tayal et al., 2020) and by responding to the stakeholders' constraints in terms of time behavior and resource utilization (Çaldağ & Gökalp, 2020). It also calls for its eased (Çaldağ & Gökalp, 2020) and permanent **accessibility for use** (Shoaib et al., 2020) by a wide range of actors (Dutta et al., 2020) within the SC organizations. Finally, it is fundamental for the Blockchain to be easily **auditable** with available documentation (Baldus and Hatton, 2019) and specific performance metrics to support testability and replicability (Çaldağ and Gökalp, 2020), and to be **resilient** through a sustainable and durable system (Yadav and Sigh, 2020) that is fault tolerant (Panetto et al., 2019) and recoverable to a desired state after failure (Çaldağ and Gökalp, 2020).

Next, the analysis of the selected articles resulted in identifying CSFs associated with three **organizational capabilities**. An important number of studies pointed the central role of **Information System (IS) capabilities** to support the successful adoption of Blockchain in SC. IS capabilities refer to value-added combinations of infrastructure, human assets and corporate culture to effectively implement and utilize IT systems (Aydiner et al., 2019). In the context of the present study, the identified IS capabilities surround four aspects: (i) the maturity, flexibility and readiness of the IT infrastructure to deploy and leverage a Blockchain (Hastig & Sodhi, 2020; Holotiuk & Moormann, 2019), (ii) the availability of an interdisciplinary talent pool around this technology (Dwivedi et al., 2019; Prasad et al., 2018) including experts in Big data, prototyping, finance, law, software implementation and project management (Çaldağ & Gökalp, 2020; Hastig & Sodhi, 2020) -The organization should strive for creating such pool for instance through training and professional assistance (Zhou et al., 2020) -, (iii) the accessibility to applied knowledge on Blockchain mainly innovative applications, valid use cases and

advanced research (Hiskey, 2019; Thomé et al., 2020), and finally (iv) the adequacy of the organization's structure and culture to Blockchain (Hastig & Sodhi, 2020; Holotiuk & Moormann, 2019). The second CSF in this global theme is related to the **strategic alignment** between the business and the Blockchain technology. It helps a firm maximize return on IT investment, achieve competitive advantage through IS, and provides it with guidance to react to new opportunities (Avison et al., 2004). Items inherent to this alignment supporting the successful adoption of Blockchain in SC focus on top management support (Dwivedi et al., 2019), the organization's understanding of this technology's suitability and benefits for its business (Hastig & Sodhi, 2020; Holotiuk & Moormann, 2019), and the design of a well-thought business model adapted to Blockchain (Prasad et al., 2018). The third and final CSF in this category is associated with **financial capabilities** to assist the Blockchain implementation, its maturation process and its sustained use (Esmaeilian et al., 2018; Rashideh, 2020; Zhou et al., 2020).

The fourth theme that emerged from the thematic analysis is related to the **Blockchain ecosystem** that is composed of three CSFs. In the field of management of technology and innovation, an ecosystem refers to a multilayer social network consisting of actors with different attributes, decision principles, and beliefs (Tsujimoto et al., 2018). The first identified CSF within this theme corresponds to the **legal framework** that regulates cryptographic activities (Çaldağ & Gökalp, 2020). Blockchain requires an easy local legislation (Zhou et al., 2020) with a high degree of laws' clarity (Prasad et al., 2018) and political certainty (Kohler and Pizzol, 2020). The second ecosystem related CSF focuses on **community collaboration**. The technology choices and commonly agreed solutions must be established through a rich collaboration between the industry actors (Van Hoek et al., 2020), trade associations, aware customers (Rane et al., 2020), small players, academia and competitors (Hastig & Sodhi, 2020) in order to advance the technological developments and generate new projects. Finally, the third CSF in this category is related to the **multilevel acceptance** of the

Blockchain technology, with aware, motivated and engaged consumers (Hastig & Sodhi, 2020), participative users (Çaldağ & Gökalp, 2020; Prasad et al., 2018) and educated and committed employees among the SC stakeholders (Holotiuk & Moormann, 2019).

Another theme identified following the content analysis with NVivo represents the peculiarities of the **Blockchain deployment project management**, which included three CSFs. First, the involved stakeholders should perform a *cost-benefit analysis* taking into account the financial feasibility of the Blockchain implementation (Çaldağ & Gökalp, 2020) and its cost effectiveness in terms of administration cost reductions (Shoaib et al., 2020), energy efficiency (Kumar et al., 2020) and productivity (Çaldağ & Gökalp, 2020). Second, this project management should respect several *project-operating principles*. It requires an upfront planning of the deployment roadmap (Hartley & Sawaya, 2019; Holotiuk & Moormann, 2019) that ensures independence of the Blockchain project from the daily business and respects a satisfactory speed (Holotiuk & Moormann, 2019). It also necessitates clear definition of scopes, expectations (Shou et al., 2020), roles, responsibilities (Wang et al., 2019) and synergies between the project actors (Hastig & Sodhi, 2020). These actors should operate according to an incremental approach for implementation with the help of agile methods (Holotiuk & Moormann, 2019), and should closely cooperate with each other (Hastig & Sodhi, 2020) with no deadlock between the business functions and the IT units (Holotiuk & Moormann, 2019). The third CSF concerns the *customer centricity* all along the Blockchain deployment project (Holotiuk & Moormann, 2019) to foster just-in-time development of features (Shoaib et al., 2020) and improve the design of the user interface aesthetics (Çaldağ & Gökalp, 2020) by constantly integrating the customer feedback (Yadav & Sigh, 2020).

The identified final CSFs are related to three elements within the theme of **SC management**. This concept is defined as the business processes that "*span the spectrum from the raw material extractor to the end user to provide product, information, and services that add value*" (Cox et al., 2012, p.49). The first emerging CSF is associated with *information management*, which refers to the process of collecting, organizing, storing and providing information within organizations (Barmeyer et al., 2019). In the context of Blockchain adoption in SC, our analysis of the selected articles pointed out many features of information management. The stakeholders need to establish transparent exchange of information (Yang et al., 2019), that should be captured in real-time (Çaldağ & Gökalp, 2020; Hastig & Sodhi, 2020), visible to all stakeholders (Kamble et al., 2019), and decentralized while respecting the consensual privacy constraints (Hastig and Sodhi, 2020). This information capture and exchange concerns SC sourcing, maintenance, and flows (Hastig & Sodhi, 2020). It enables traceability of causes, goods' location, accidents, and fraud in the SC from the manufacturer to the end-user (Yadav & Sigh, 2020), and promotes SC's sustainability (Saikouk & Spalanzani, 2016). Then, *social capital of the SC* emerged as a second CSF, as we identified items corresponding to its dimensions namely relational, structural and cognitive capitals (Nahapiet & Ghoshal, 1998; Saikouk et al., 2021). The highlighted elements of the relational capital are trust (Çaldağ & Gökalp, 2020), communication and collaboration between the partners (Altuntaş Vural et al., 2020; Giustia et al., 2019), with truthful knowledge transfer (Surjandy et al., 2018) and open-mindedness for the development and execution of new ways of working (Çaldağ & Gökalp, 2020). The cognitive capital includes aligned business objectives among the partners (Hastig & Sodhi, 2020), and a clearly defined and shared vision and value proposition (Giustia et al., 2019). As for the structural dimension, it involves the alignment of the stakeholders' incentives and data features (Wang et al., 2019) and leadership readiness for the decentralization of management and power diffusion induced by the Blockchain (Prasad et al., 2018). As explained in Table 1, this dimension also covers the stakeholders' on-chain and off-chain power governance (Dutta et al., 2020; Kohler & Pizzol, 2020; Pautasso et al., 2020), and their accountability (Çaldağ & Gökalp, 2020).

Table 1: Categorization of CSFs for Blockchain adoption in SC

Category	CSF	Factor components	References
Data Governance	Data security	User control on data; User-centric private data management; Decentralized and self-sovereign Identity management; Authorization; Due diligence; Data access control in SC; Permission less; Near impossible loss of data; Data safety; Security protection; Risk management regarding security goals; Trustless environment; Secure for the community	*Çaldağ & Gökalp (2020); Ciric et al. (2019); Dutta et al. (2020); Esmaeilian et al. (2020); Guggenberger et al. (2020); Hastig & Sodhi (2020); Liu & Li (2019); Pautasso et al. (2020); Prasad et al. (2018); Shoaib et al. (2020); Surjandy et al. (2018); Yadav & Sigh (2020); Zhou et al. (2020)*
	Data integrity	Data credibility; Immutability; Authentic data; Data free from bias and human error; Quality fairness; Quality control	*Altuntaş Vural et al. (2020); Dutta et al. (2020); Dwivedi et al. (2019); Hastig & Sodhi (2020); Kamble et al. (2019); Pautasso et al. (2020); Shoaib et al. (2020); Yadav & Sigh (2020)*
	Data privacy	Protection; Privacy of records; Privacy encryption; User privacy; Anonymity	*Chang et al. (2020); Dutta et al. (2020); Esmaeilian et al. (2020); Hastig & Sodhi (2020); Kamble et al. (2019); Park et al. (2020); Prasad et al. (2018)*
Blockchain functional properties	Platform maturity	Platform credibility; Robust and mature Smart contracts platform; Adapted architecture; P2P Network; Software tools for smart contracts; Smart system for streamlined invoicing and inventory; Integration of cloud services; Support for RFID; Supporting disintermediation; Security of transactions	*Çaldağ & Gökalp (2020); Chang et al. (2020); Dutta et al. (2020); Guggenberger et al. (2020); Hastig & Sodhi (2020); Kohler & Pizzol (2020); Park et al. (2020); Pautasso et al. (2020); Prasad et al. (2018); Rashideh (2020); Tayal et al. (2020); Wang et al. (2019); Yadav & Sigh (2020)*
	Interoperability	Standards to enable multi-desired interoperability; Integration with stakeholders' IT infrastructure; Legacy system integration; IT system congruency; Integration with other cloud services; Integration among trusted IoT services; Interoperability between Blockchains; Service and application integration; Real time integration with other systems	*Çaldağ & Gökalp (2020); Giustia et al. (2019); Guggenberger et al. (2020); Hastig & Sodhi (2020); Kamble et al. (2019); Pautasso et al. (2020); Prasad et al. (2018); Surjandy et al. (2018); Wang et al. (2019); Yadav et al. (2020)*
	Scalability	Anticipation of increased efficiency, size, throughput, latency and bandwidth; Handling Blockchain bloat; Long-term growth; Scalability in the SC; Modularity to avoid reliance on a specific Blockchain; Extensibility; Miner incentive structure; Development of sidechains	*Ar et al. (2020); Çaldağ & Gökalp (2020); Ciric et al. (2019); Dutta et al. (2020); Giustia et al. (2019); Park et al. (2020); Prasad et al. (2018); Shoaib et al. (2020); Wang et al. (2019); Yadav et al. (2020)*
	Context suitability	Operational suitability; Functional appropriateness; Stability; Meeting the expected outcomes; Maturity meets the normal requirements for reliability; Meeting time behavior constraints; Meeting resource utilization constraints; Remote supplier practicality; Multi-location issues	*Çaldağ & Gökalp (2020); Hartley & Sawaya (2019); Hastig & Sodhi (2020); Prasad et al. (2018); Shoaib et al. (2020); Tayal et al. (2020)*
	Accessibility for use	Usability by a wide range of people; Learnability; Ease of use; Permanent availability; System's readiness for use when required	*Çaldağ & Gökalp (2020); Dutta et al. (2020); Shoaib et al. (2020); Wang et al. (2019); Yadav et al. (2020)*
	Auditability	Auditability in SC management; Available documentation; Simple system; Replicability; Testability; Specific metrics for measuring the Blockchain performance; KPIs and metrics' capturing	*Altuntaş Vural et al. (2020); Baldus & Hatton (2019); Çaldağ & Gökalp (2020); Guggenberger et al. (2020); Kohler & Pizzol (2020); Rashideh (2020); Shoaib et al. (2020); Tayal et al. (2020)*
	Resilience	Recoverability to a desired state after a failure; Fault tolerance; Attack resistance; Longevity; Durability; Environment-friendly; Sustainability	Çaldağ & Gökalp (2020); Esmaeilian et al. (2020); Kamble et al. (2019); Kumar et al. (2020); Panetto et al. (2019); Prasad et al. (2018); Rane et al. (2020); Shoaib et al. (2020); Yadav & Sigh (2020)

Organizational capabilities	IS capabilities	Mature infrastructure; Information system readiness; Sufficient IT infrastructure; Flexible infrastructure; IT deploying and leveraging capabilities; Big data capabilities; Blockchain talent pool; IT skilled people; Interdisciplinary skills including finance, law and technology; Skilled people for the development of Blockchain use cases and the implementation of Blockchain prototypes; Internal know-how; Project management skills; Software implementation skills; Staff training; Professional consultation and assistance; Adapted organizational structure; Adequate Business culture; Availability of valid use cases; Practical application examples; Research available; Innovative applications; New innovative solutions developed for complementing the product or service produced by the Blockchain; In-house/ internal development of Blockchain prototypes	Çaldağ & Gökalp (2020); Dwivedi et al. (2019); Hastig & Sodhi (2020); Hiskey (2019); Holotiuk & Moormann (2019); Prasad et al. (2018); Thomé et al. (2020); Zhou et al. (2020)
	Strategic alignment	Top management support; Support from senior management; Organization's capability to assess Blockchain suitability to the SC context; Key actor benefit awareness; Understanding of the underlying business that Blockchain is applied to; Business alignment to Blockchain capability; Adapted Business Model	Dwivedi et al. (2019); Hastig & Sodhi (2020); Holotiuk & Moormann (2019); Nayak & Dhaigude (2019); Prasad et al. (2018); Shoaib et al. (2020); Zhou et al. (2020)
	Financial support	Enough budget and resources; Availability of resources; Financial liquidity; Sufficient capital; Investment for technology maturity	Dutta et al. (2020); Esmaeilian et al. (2018); Hastig & Sodhi (2020); Holotiuk & Moormann (2019); Rashideh (2020); Zhou et al. (2020)
Blockchain ecosystem	Legal framework	Available policy and regulations for Blockchain use; Favorable legal framework for cryptographic activities; Political certainty; Regulatory clarity; Ease of local legislation	Çaldağ & Gökalp (2020); Dwivedi et al. (2019); Hastig & Sodhi (2020); Kohler & Pizzol (2020); Prasad et al. (2018); Zhou et al. (2020)
	Community collaboration	Industry collaboration; Collaboration with trading partners, academia, competitors and industry associations; Support from the industry community; NGO support; Small player involvement; Customer awareness; Rich ecosystem; Common language development	Çaldağ & Gökalp (2020); Ciric et al. (2019); Hastig & Sodhi (2020); Prasad et al. (2018); Rane et al. (2020); Van Hoek et al. (2020); Zhou et al. (2020)
	Multilevel acceptance	Educating and increasing awareness of relevant stakeholders; Stakeholder acceptance; Market leader acceptance; Minority adoption; User adoption/resistance to change; User engagement; User motivation; User participation; Consumer engagement; Acceptance across the organization; Motivation of employees	Ar et al. (2020); Çaldağ & Gökalp (2020); Ciric et al. (2019); Dwivedi et al. (2019); Esmaeilian et al. (2020); Hastig & Sodhi (2020); Hofmann & Rüsch (2017); Holotiuk & Moormann (2019); Kamble et al. (2019); Kumar et al. (2020); Prasad et al. (2018); Rane et al. (2020); Schmidt & Wagner (2019); Van Hoek et al. (2020)
Blockchain deployment project management	Cost-benefit analysis	Financial feasibility and profitability; Cost effectiveness; Cost efficiency; Energy efficiency; Administration cost reductions	Ar et al. (2020); Çaldağ & Gökalp (2020); Esmaeilian et al. (2020); Hofmann & Rüsch (2017); Kumar et al. (2020); Prasad et al. (2018); Shoaib et al. (2020)
	Project operating principles	Effective use of resources with no deadlock between business units and IT unit; Value chain cooperation; Internal cooperation between the business functions and the IT unit; Effective collaboration across the organization; Clearly defined roles and responsibilities; Intracompany synergies clarified; Clearly defined scopes and expectations; Upfront planning of the project; Road map for deployment; Staged incremental approach for implementation; Use of agile	Çaldağ & Gökalp (2020); Chang et al. (2020); Dutta et al. (2020); Dwivedi et al. (2019); Hartley & Sawaya (2019); Hastig & Sodhi (2020); Holotiuk & Moormann (2019); Nayak & Dhaigude (2019); Pautasso et al. (2020); Shou et al. (2020); Wang et al. (2019)

		methods; Independence of the Blockchain project from the daily business; Deployment speed to keep up with the environment and to satisfy the management	
	Customer centricity	User interface aesthetics; Customer satisfaction; Focus on the customer when designing use cases; Integration of customer feedback; Developing just-in-time following customer feedback	Çaldağ & Gökalp (2020); Holotiuk & Moormann (2019); Shardeo et al. (2020); Shoaib et al. (2020); Shou et al. (2020); Tayal et al. (2020); Thomé et al. (2020); Yadav & Sigh (2020)
Supply chain management	Information management in SC	Real time information capture; Timely and accurate data collection/storing/processing; Information about maintenance; Complete supply chain sourcing information; Tracing of causes, goods' location, accident, fraud happening in between the process of the SC from manufacturer to end-user with the help of IoT/ Industry4.0; Information flow and controls; Decentralization of supply chain information; Transparent governance, open communication and disclosure of information between the stakeholders by considering privacy constraints; Visibility to SC actors	Altuntaş Vural et al. (2020); Çaldağ & Gökalp (2020); Chen et al. (2019); Dutta et al. (2020); Esmaeilian et al. (2020); Hastig & Sodhi (2020); Hofmann & Rüsch (2017); Kamble et al. (2019); Shardeo et al. (2020); Shoaib et al. (2020); Tang et al. (2018); Yadav & Sigh (2020); Yang et al. (2019)
	Social capital of SC	Partnership trust; Maintaining continuous close communication among stakeholders; Collaboration between the partners; Truthful knowledge transfer; Cosmopolitanism (The actors' open-mindedness for the development and execution of new ways of working); Aligned business objectives with the partner; Clearly defined and shared vision and value proposition; Proper alignment of stakeholder incentives; Data features agreement; Leadership's readiness for decentralization and power diffusion; On-chain governance (Rules and decision-making processes encoded directly into the underlying infrastructure); Off-chain governance (Project governance, distribution of liability, IP ownership, decision-making regarding the product, the technology, the objectives and values, new members and exits); Accountability (The right of each actor to hold the other actors to a set of standards, to judge whether they have fulfilled their responsibilities in light of these standards, and to impose sanctions if they determine that these responsibilities have not been met)	Altuntaş Vural et al. (2020); Ar et al. (2020); Çaldağ & Gökalp (2020); Dutta et al. (2020); Giustia et al. (2019); Hastig & Sodhi (2020); Kamble et al. (2019); Kohler & Pizzol (2020); Pautasso et al. (2020); Prasad et al. (2018); Surjandy et al. (2018); Wang et al. (2019)
	SC operations and processes management	Common production and material stewardship standards; Demand sharing in SC; Logistics synchronization; Automation of manufacturing thanks to smart contracts; Simplicity of process standardization; Supply chain value stream mapping; Process flowcharts; Specific modelling languages	Ciric et al. (2019); Dutta et al. (2020); Hastig & Sodhi (2020); Shoaib et al. (2020)

The last CSF in this theme represents *SC operations and processes management*, namely processes of common production, material stewardship (Hastig & Sodhi, 2020), demand sharing, and logistics' synchronization (Shoaib et al., 2020), which should be automated, standardized and mapped (Dutta et al., 2020; Hastig & Sodhi, 2020).

4.3 Densities and ties of CSFs

To unveil the implicit ties of the identified 22 CSFs within the extant literature, we performed a co-occurrence social network analysis (SNA) of the 56 selected articles supported by VOSviewer. A thesaurus matching the CSFs with the articles' contents that were thematically coded with NVivo was implemented into VOSviewer to enable the direct visualization of the CSFs. Linkages among the

keywords attached to the CSFs were mapped using network analysis, and broader groups or clusters with strong internal relationship patterns were identified using clustering method (Mishra et al., 2007). This SNA resulted in three different findings as explained below and illustrated in the figures of this section. The labels of some CSFs are not clearly displayed in the figures to avoid overlapping labels, but will be addressed when relevant in the following paragraphs. The implications of these findings will be discussed in sections 5 and 6.

First, the SNA enabled identifying three distinct clusters (Figure 2) conveying how the field of research on CSFs for Blockchain adoption in SC is delineated. The color density of a cluster is associated with the number of its belonging nodes, their frequency, and the number and strength of their mutual ties. The most dominant cluster,

operating principles of the deployment project. This cluster conveys the complementarity of **capabilities at the macro (environment), meso (organization) and micro (project) levels of analysis** for the successful adoption of Blockchain in SC. The third and final cluster shows that the CSFs of customer centricity, accessibility for use, auditability and context suitability are usually examined together. The connectedness of these factors expresses that, for Blockchain in SC, **a user-focused development** is necessary to foster its usability and reliability.

Second, the software enabled determining the most recurrent CSFs (Figure 3), either through network mapping visualization (Figure 3a) or through item density visualization (Figure 3b). The former reports the CSF importance via the size of its associated circle, while the latter displays this importance through the CSF color. The colors by default range

Figure 2: Clusters portraying the boundaries of research in our topic

labeled **the socio-technical cluster**, mainly consists of the CSFs related to Data governance, most of the functional properties of Blockchain, SC information management, its operations and processes management, and its social capital. The subsequent cluster in terms of density encompasses all the organizational capabilities' CSFs, most of the factors related to the Blockchain ecosystem, and the

from blue to yellow, with yellow representing the most recurrent CSFs. As results, we identified five CSFs with marked densities compared to the other factors, which hence represent the most examined critical aspects of Blockchain adoption in SC. These factors are *Data security, IS capabilities, interoperability, information management and social capital of SC*.

Third, we were able to determine the strongest links between the CSFs, either within or across their clusters of belonging. The stronger the relationship between two CSFs, the thicker the line that is used to illustrate their link. These links are summarized in

security (6), IS capabilities (6), information management in SC (5), interoperability (4) and context suitability (4). These findings confirm the importance of the five first CSFs underlined in the frequency results in the previous paragraph and
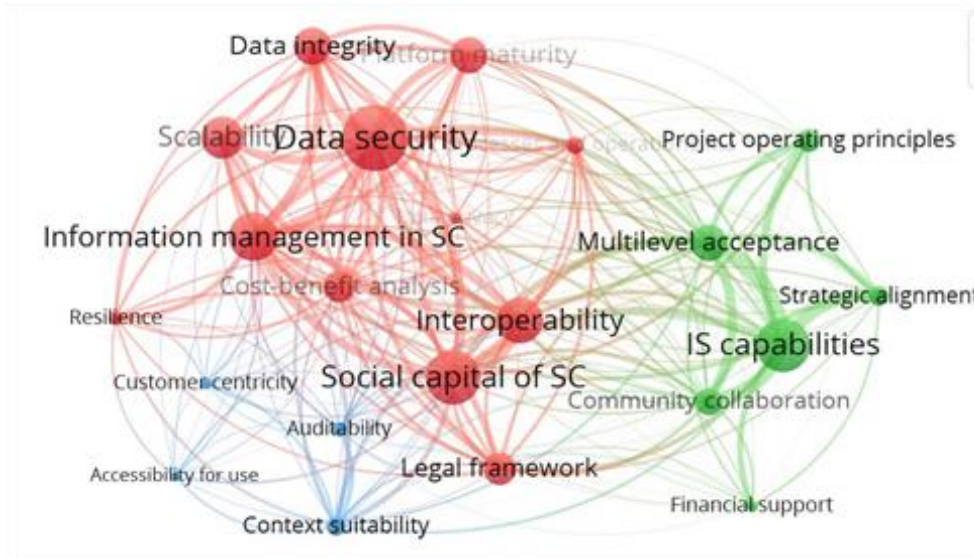

Figure 3a

Figure 3b

Figure 3 – Visualization of the most recurrent CSFs

Table 2 and displayed in the results of VOSviewer mapping (Appendix 1). This approach brings complementary insights that can be missed using only frequency based delineation of clusters and nodes. We analyzed these links from the factor then from the cluster perspectives as explained below.

• At the level of CSFs, the factors having several strong links with other factors are respectively *social capital of SC (6 links), Data*

depicted in Figure 3. They additionally demonstrate their central roles and that of Blockchain suitability to the SC context, in relation to other CSFs. Finally, seven factors were found to have no strong link with any other CSF, namely accessibility for use, cost-benefit analysis, customer centricity, Data privacy, legal framework, resilience, and SC operations and processes management.

Table 2 : Summary of the strongest links between the CSFs

CSF 1	Cluster of belonging	Theme of belonging	Co-occurring CSF	Cluster of belonging	Theme of belonging
Project operating principles	Macro/Meso/Micro capabilities	Blockchain deployment project management	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
Community collaboration	Macro/Meso/Micro capabilities	Blockchain ecosystem	Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem
Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem	Community collaboration	Macro/Meso/Micro capabilities	Blockchain ecosystem
Community collaboration	Macro/Meso/Micro capabilities	Blockchain ecosystem	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem	Social capital of SC	Socio-technical	SC management
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Project operating principles	Macro/Meso/Micro capabilities	Blockchain deployment project management
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Community collaboration	Macro/Meso/Micro capabilities	Blockchain ecosystem
Financial support	Macro/Meso/Micro capabilities	Organizational capabilities	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Financial support	Macro/Meso/Micro capabilities	Organizational capabilities
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Strategic alignment	Macro/Meso/Micro capabilities	Organizational capabilities
Strategic alignment	Macro/Meso/Micro capabilities	Organizational capabilities	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities	Social capital of SC	Socio-technical	SC management
Cost-benefit analysis	*Socio-technical*	*Blockchain deployment project management*	*None*	*None*	*None*
Legal framework	*Socio-technical*	*Blockchain ecosystem*	*None*	*None*	*None*
Resilience	*Socio-technical*	*Blockchain functional properties*	*None*	*None*	*None*
Interoperability	Socio-technical	Blockchain functional properties	Data security	Socio-technical	Data governance
Platform maturity	Socio-technical	Blockchain functional properties	Data security	Socio-technical	Data governance
Scalability	Socio-technical	Blockchain functional properties	Data security	Socio-technical	Data governance
Interoperability	Socio-technical	Blockchain functional properties	Information management in SC	Socio-technical	SC management
Interoperability	Socio-technical	Blockchain functional properties	Social capital of SC	Socio-technical	SC management
Interoperability	Socio-technical	Blockchain functional properties	Context suitability	User-focused development	Blockchain functional properties
Data privacy	*Socio-technical*	*Data governance*	*None*	*None*	*None*

Data security	Socio-technical	Data governance	Platform maturity	Socio-technical	Blockchain functional properties
Data security	Socio-technical	Data governance	Scalability	Socio-technical	Blockchain functional properties
Data security	Socio-technical	Data governance	Interoperability	Socio-technical	Blockchain functional properties
Data integrity	Socio-technical	Data governance	Data security	Socio-technical	Data governance
Data security	Socio-technical	Data governance	Data integrity	Socio-technical	Data governance
Data integrity	Socio-technical	Data governance	Information management in SC	Socio-technical	SC management
Data security	Socio-technical	Data governance	Information management in SC	Socio-technical	SC management
Data security	Socio-technical	Data governance	Social capital of SC	Socio-technical	SC management
Social capital of SC	Socio-technical	SC management	Multilevel acceptance	Macro/Meso/Micro capabilities	Blockchain ecosystem
Social capital of SC	Socio-technical	SC management	IS capabilities	Macro/Meso/Micro capabilities	Organizational capabilities
SC operations and processes management	*Socio-technical*	*SC management*	*None*	*None*	*None*
Information management in SC	Socio-technical	SC management	Interoperability	Socio-technical	Blockchain functional properties
Social capital of SC	Socio-technical	SC management	Interoperability	Socio-technical	Blockchain functional properties
Information management in SC	Socio-technical	SC management	Data integrity	Socio-technical	Data governance
Information management in SC	Socio-technical	SC management	Data security	Socio-technical	Data governance
Social capital of SC	Socio-technical	SC management	Data security	Socio-technical	Data governance
Information management in SC	Socio-technical	SC management	Social capital of SC	Socio-technical	SC management
Social capital of SC	Socio-technical	SC management	Information management in SC	Socio-technical	SC management
Information management in SC	Socio-technical	SC management	Context suitability	User-focused development	Blockchain functional properties
Social capital of SC	Socio-technical	SC management	Context suitability	User-focused development	Blockchain functional properties
Customer centricity	*User-focused development*	*Blockchain deployment project management*	*None*	*None*	*None*
Accessibility for use	*User-focused development*	*Blockchain functional properties*	*None*	*None*	*None*
Context suitability	User-focused development	Blockchain functional properties	Interoperability	Socio-technical	Blockchain functional properties
Context suitability	User-focused development	Blockchain functional properties	Information management in SC	Socio-technical	SC management
Context suitability	User-focused development	Blockchain functional properties	Social capital of SC	Socio-technical	SC management
Auditability	User-focused development	Blockchain functional properties	Context suitability	User-focused development	Blockchain functional properties
Context suitability	User-focused development	Blockchain functional properties	Auditability	User-focused development	Blockchain functional properties

CSF with no strong links

CSFs belonging to the same clusters and different themes
CSFs belonging to the same clusters and the same themes
CSFs belonging to different clusters and themes

- At the level of clusters, ***most of the strong identified connections between CSFs (34/44) are intra-cluster,*** with the socio-technical cluster representing the majority of these links followed by the Macro/Meso/Micro capabilities' cluster. These findings are aligned with the cluster density results presented in the second paragraph of this section and illustrated in Figure 2. Concerning the inter-clusters' links (Table 2), we noted the existence of strong relationships ***between the socio-technical cluster on the one hand, and the Macro/Meso/Micro capabilities and user-focused development clusters on the other hand, with no significant link between the latter two.***

To provide substantial inferences from this study, we additionally confronted the deductive mapping results of VOSviewer with the conceptual groupings that we carried out in section 4.2 using an inductive coding approach. Table 2 includes the theme of belonging of each CSF and of its connected factors. First, we note that among the 34 strong intra-cluster links, 12 are intra-theme. This finding combined with the network map (Figure 3a) suggests that the themes of ***Data governance*** and ***SC management*** entirely belong to the **socio-technical cluster**, while the theme of ***organizational capabilities*** is an integral part of the **Macro/Meso/Micro capabilities' cluster.** Second, when we examine the inter-clusters' relationships in light of the six themes that emerged from our NVivo analysis, we observe that: (i) ***Blockchain functional properties'*** theme is at the intersection of the **socio-technical** and **user-focused development** clusters, (ii) ***Blockchain ecosystem*** represents a junction between the **socio-technical** and **the Macro/Micro/Meso capabilities'** clusters, and (iii) ***Blockchain deployment project management*** is at the edge of the **three clusters**. The implications of these results are discussed in the next section.

5. DISCUSSION

The advent of Blockchain is capturing the attention and inducing opportunities and challenges for both practitioners and academics. This is particularly the case of Supply Chain management (Kshetri, 2018)

thanks to the important potential of Blockchain to provide high levels of efficiency to Supply Chain (SC) along with decentralized operations (Fosso Wamba & Queiroz, 2020). To help practitioners in this field grasp the added value of Blockchain, we performed a systematic literature review (SLR) to unveil the inter-related critical success factors (CSFs) for this technology adoption in a SC context combining two types of content analyses. On the one hand, we used NVivo to perform an inductive coding of the 56 selected articles for the SLR, which resulted in identifying 22 distinct CSFs that we interpreted and gathered in six broader themes based on theoretical concepts. On the other hand, we run a Social Network Analysis (SNA) supported by VOSviewer to deduce relationships among the 22 CSFs based on their implicit co-occurrences in the articles' database. These analyses provided complementary findings as discussed in the following paragraphs.

5.1 Blockchain adoption in SC: a nascent managerial practice and research stream

Our inspection of the publications' metrics over the years on CSFs for Blockchain adoption in SC showed that scholars have started focusing on this topic since 2017, although Blockchain technology emerged long before (Nakamoto, 2008). This result conveys that Blockchain applications in SC are still in their infancy and that a good number of managers still do not master Blockchain-related concepts (e.g., enablers, adoption, implementation, etc.) as underlined by Fosso Wamba & Queiroz (2020). This conclusion is even more corroborated by the evolution of the studies' natures, which were mostly conceptual in 2017 and have embraced different empirical approaches since then (Figure 1). Then, our bibliometric results demonstrated a balance in terms of publication between technology-oriented journals and conferences, and those focusing on managerial issues. While Yli-Huumo et al. (2016) argued that most literature on this topic has been addressing the technological challenges of peer-to-peer Blockchain usage, our results imply that, since 2017, there is an increased awareness among researchers of the detrimental organizational and project related issues that can even lead to the halting of Blockchain implementation projects. The

natures of CSFs and their links identified in this study fall within this conclusion as explained hereafter.

5.2 Socio-technical features: A catalytic role for Blockchain adoption

First, the subjects of the three clusters that emerged from the SNA along with the types of their underlying CSFs echoes a rising interest of researchers on the combined technical and managerial conditions that would foster Blockchain adoption in SC. In this respect, the high density of the socio-technical cluster shows that CSFs related to social capital are often investigated along with technical CSFs, therefore generalizing to Blockchain technology the catalytic role of this capital in shaping the decisions and structuring the capacities regarding technology adoption (Wu & Chiu, 2018). Then, the Macro/Meso/Micro capabilities' cluster was moderately dense and combined IT-related, but mostly, managerial capacities at different levels, thereby emphasizing their complementarity for successful technology adoption (Kurnia et al., 2019) especially in the case of Blockchain in SC (Kouhizadeh et al., 2019). Finally, although the user-focused development cluster was of a scant density, the natures of its CSFs suggest that the reliability of Blockchain requires elevated degrees of customer-centricity and rooting in a SC context. This result hence highlights the interdependence of technical and managerial concerns for Blockchain development (Dujak & Sajter, 2019).

5.3 The most critical factors for Blockchain adoption in SC

Second, the identification of *the central CSFs* based on the analysis of occurrences and links showed a symmetry between technical factors (Data security, IS capabilities, interoperability) and managerial matters in the specific context of SC (Social Capital, Information management) with slightly more focus on the formers. Scholars' interest in these factors can be accounted for the fact that they represent specific challenges for SC management. Indeed, Data security is a fundamental precondition to mature Blockchain pilots to long-term adoption of this technology in SC (Behnke & Janssen, 2020). However, it is difficult to establish uniform authorities and definitions for generating,

accessing, and altering data in a Blockchain based SC (Kumar et al., 2020). These common agreements are necessary because suppliers would otherwise need to comply with different interface standards, therefore making Blockchain economically inefficient (Behnke & Janssen, 2020). Then IS capabilities, which convey the readiness of the organization's information system for Blockchain implementation, induce particular problems due to the scarcity of knowledge for Blockchain nascent use in SC (Fosso Wamba & Queiroz, 2020) and the difficulty of aligning traditional IS with this technology's disruptive features. In particular, SC actors put much efforts in solving the interoperability issues of Blockchain with their legacy IT infrastructures (Pautasso et al., 2020) and with other cloud-based solutions (Surjandy et al., 2018). Finally, information management in SC and its social capital emerged as dense CSFs due to the complexity of aligning their Blockchain induced properties with the peculiarities of SC. The latter factor is driven by the leadership readiness for the decentralization of management and power diffusion (Prasad et al., 2018) whereas the former requires the establishment of transparent and decentralized processes (Hastig & Sodhi, 2020; Yang et al., 2019). These features are ideologically conflicting with the power-driven nature of buyer-supplier relationships (Reimann & Ketchen, 2017).

5.4 Blockchain: a potential source of technological determinism

Third, regarding the links between the CSFs, as explained in section 4.3, most of the strong identified connections are intra-cluster, which resonates with the rationale of VOSviewer clustering algorithm that brings together close nodes (Van Eck & Waltman, 2010; 2014). As for the inter-clusters' links, we observed that the most significant ones associate the socio-technical cluster with the other two. This central position of this cluster suggests that Blockchain can be a source of technological determinism (Ostern, 2019) by forcing the SC stakeholders to align their capacities and development processes with the standards induced by the Blockchain.

5.5 Inner and outer ties resulting from the combination of inductive and deductive analysis of the literature

The confrontation of these VOSviewer results with those of our categorization using NVivo brought additional insights to the natures and roles of the 22 CSFs and the six global themes.

On the one hand, we showed that some themes represent integral parts of certain clusters, namely Data governance and SC management in the socio-technical cluster, and organizational capabilities in the Macro/Meso/Micro capabilities' cluster. Such result can provide guidance to future research that would examine the building blocks of socio-technical and multilevel capabilities in the context of Blockchain adoption in SC.

On the other hand, we found that Blockchain functional properties' theme was at the border of the socio-technical and user-focused development clusters due to the nature of the seven CSFs in this theme that relate to both clusters' topics. Also, Blockchain ecosystem interfered with the socio-technical and the Macro/Micro/Meso capabilities' clusters, thereby confirming that Blockchain adoption is subject to the influence of conditions internal and external to the SC organizations (Orji et al., 2020). Finally, the theme of Blockchain deployment project management was at the crossroads of the three clusters, although two of its three constituting factors (Cost-benefit analysis and customer-centricity) did not possess a strong link with any other CSF and the third component (Project operating principles) had a single dense relationship with IS capabilities (Table 2). This result suggests that project management plays a central role with respect to Blockchain adoption in SC that did not transpire from the sole co-occurrence analysis of the extant literature. Accordingly, scholars and practitioners should grant a specific attention to the spin-offs of deploying agile methods, focusing on customers and continuously monitoring the cost all along the Blockchain implementation projects.

In sum, our content analysis supported by NVivo unveiled an understanding of the CSFs' roles that could not have been delineated by the SNA only. We

hence show the complementarity between inductive interpretive coding and deductive analysis of the literature using an automated tool.

6. CONCLUSIONS AND RESEARCH AVENUES

This study proposes a characterization of the inter-related critical success factors for Blockchain adoption in Supply Chain. As detailed in the previous section, our results shed light on the conceptual natures of the factors and on the potential mechanisms by which they jointly foster the success of Blockchain adoption in SC. We also provide managers with guidance to reap the benefits of this technology for SC operations and foster its future adoption. First, we show that socio-technical factors play a central role with regard to factors associated with user-centricity and multi-level capabilities. Hence, Blockchain may induce technological determinism thereby requiring the SC stakeholders to be aware of the subsequent transformations that their capacities and processes should undergo in order to align with Blockchain standards and grasp its added value. Second, our findings draw the attention of SC managers to the most challenging technical factors for the future adoption of Blockchain in this interorganizational context. They include establishing uniform data security standards to make Blockchain economically efficient, and ripening IS capabilities in terms of Blockchain knowledge pool and the interoperability of legacy IT infrastructures. Finally, we identified critical factors related to SC management and Blockchain deployment project management. The former urge practitioners to adapt information management and social capital in SC contexts that are often power-driven, to the decentralization and transparency peculiarities of Blockchain. The latter are mostly associated with customer focus and the use of agile methods throughout the project. Accordingly, we stress that the future implementation of this technology in SC requires not only resolving technical issues which has long been the focus of pilot projects and scholars, but also establishing efficient project principles and a sustained SC climate conducive to this adoption and to the upcoming evolutions of Blockchain.

To identify further theoretical implications of our results and provide research perspectives, we propose to analyze this study's findings in light of the TOE (Technology Organization Environment) framework (Tornatzky & Fleischer, 1990). The TOE model suggests that technological, organizational and environmental contexts influence the process by which a firm adopts and implements a technological innovation. The Technology dimension incorporates the properties of the technological innovation. The Organization dimension corresponds to the organization's structure, resources as well as intra-firm communications. The Environment dimension refers to the characteristics of industries, markets and those of the legal environment (Kouhizadeh et al., 2021). Although an important number of studies on Blockchain adoption in SC mobilize the classical models such as the Technology Acceptance Model (TAM) (e.g. Kamble et al., 2019; Lou & Li, 2017) or the Unified Theory of Acceptance and Use of Technology (UTAUT) (e.g. Francisco & Swanson, 2018; Queiroz & Fosso Wamba, 2019), we believe that TOE can provide a more comprehensive analysis of this technology adoption determinants in SC for several reasons. TAM and its extended version in UTAUT focus on investigating the acceptance factors of new technologies from the individual organization point of view (Gokalp et al., 2020). Nevertheless, the decision to adopt a technology (Bhakoo & Choi, 2013), particularly Blockchain, in SC can also be a response to isomorphic institutional pressures and hence depends on external conditions as well as internal ones. The SC actors are required to align with the social expectations and the persistent requirements of investors and stakeholders within the sector (Orji et al., 2020). Also, government policy and support is an influential factor that entails the ability of government agencies to provide support and enact regulations that foster Blockchain adoption (Montecchi et al., 2019). Figure 4 summarizes the main findings of our content analysis and structures them according to the TOE model. The size of a CSF's font conveys its importance in terms of occurrence and ties with other CSFs. The relationships internal to a building block in each dimension are represented through circular arrows, while the

outer ties are pictured using straight-line arrows. The thicker the arrow the more important is the link based on the SNA results using VOSviewer.

The unit of analysis in this study is the SC where Blockchain is adopted following a deployment project. Therefore, the Organization dimension gathers the themes of organizational capabilities, SC management, and Blockchain deployment project management. The Technology dimension includes Blockchain properties as well as Data governance related factors. Finally, the Environment dimension corresponds to the Blockchain ecosystem theme.

Figure 4 shows that extant research examined CSFs associated with the three TOE dimensions, with a specific attention to Technology and Organization issues, either in terms of the factors' frequency or with respect to their inner ties within each dimension. The examined cross-dimensions' ties are between Organization in one side, and Technology and Environment in other sides. On the one hand, the strong relationship between the dimensions of Technology and Organization seems to be mainly driven by the SC management theme, due to the influence that Blockchain features have directly on SC processes and operations rather than on a single stakeholder's capabilities. However, the tie between the organizational capabilities' theme and that of SC management suggests the potential existence of an indirect relationship between Technology dimension and the former theme through the latter theme. Future studies can empirically investigate these direct and indirect effects and provide a better understanding of the dynamics between the Technology and Organization dimensions with respect to the success of Blockchain adoption in SC. On the other hand, the link between Organization and Environment dimensions seems to be mainly induced by the ecosystem theme, with a pronounced tie with the single organization's capabilities' theme. The links between this latter theme and those of Blockchain deployment project management and SC management indicate possible indirect effects of Blockchain ecosystem on these themes through that of organizational capabilities. Future studies can hence examine the degree to which government policies and sectorial constraints directly shape the

required capabilities for Blockchain adoption at the organizational level, and indirectly at SC and project levels. Finally, we could not find evidence of any link between the Technology and Environment dimensions, although advancing Blockchain developments requires a favorable legislation and a high involvement of different players (Hastig & Sodhi, 2020; Van Hoek et al., 2020). Therefore, further research may investigate the mediating role of the Organization dimension on the link between the other two TOE components in the case of Blockchain adoption in a SC context.

In sum, we contribute to the few studies that showed the suitability of the TOE framework as a theoretical lens to examine the determinants of Blockchain adoption in SC (e.g. Clohessy et al., 2019; Gokalp et al., 2020; Wong et al., 2020). We propose an initial understanding of the dynamics between this model's dimensions that have been rarely explored for our adoption context (Wong et al., 2020), and offer opportunities for future empirical research to assess these relationships. We particularly emphasize the relevance of examining the potential direct and mediating roles of the Organization dimension components that we unveiled in the previous paragraph. This finding suggests that, while most studies on Blockchain

adoption focus on technological issues and tend to neglect organizational matters (Yli-Huumo et al., 2016), scholars in the specific case of SC implicitly put a great emphasis on the latter subjects. Finally, this study proposes a description of the factors composing the dimensions of the TOE framework in the case of Blockchain adoption in SC. This description can be more accurate for future research on the studied adoption phenomenon than the transposition of existing operationalizations of these dimensions developed for other technologies or in other contexts. These studies can for instance adopt a critical realist perspective (Archer et al., 2013; Bhaskar, 1998) and accordingly investigate how the factors belonging to the TOE dimensions act as generative mechanisms (Henfridsson & Bygstad, 2013) of Blockchain adoption's contribution to SC performance (Fosso Wamba et al., 2020), its resilience (Min, 2019), sustainability (Saberi et al., 2019), traceability (Dong et al., 2020), transparency (Francisco & Swanson, 2018), agility and adaptability (Sheel & Nath, 2019). Further research can also assess the criticality of these factors and examine the evolution of their impacts over the post-adoption stages (Karahanna et al., 1999).
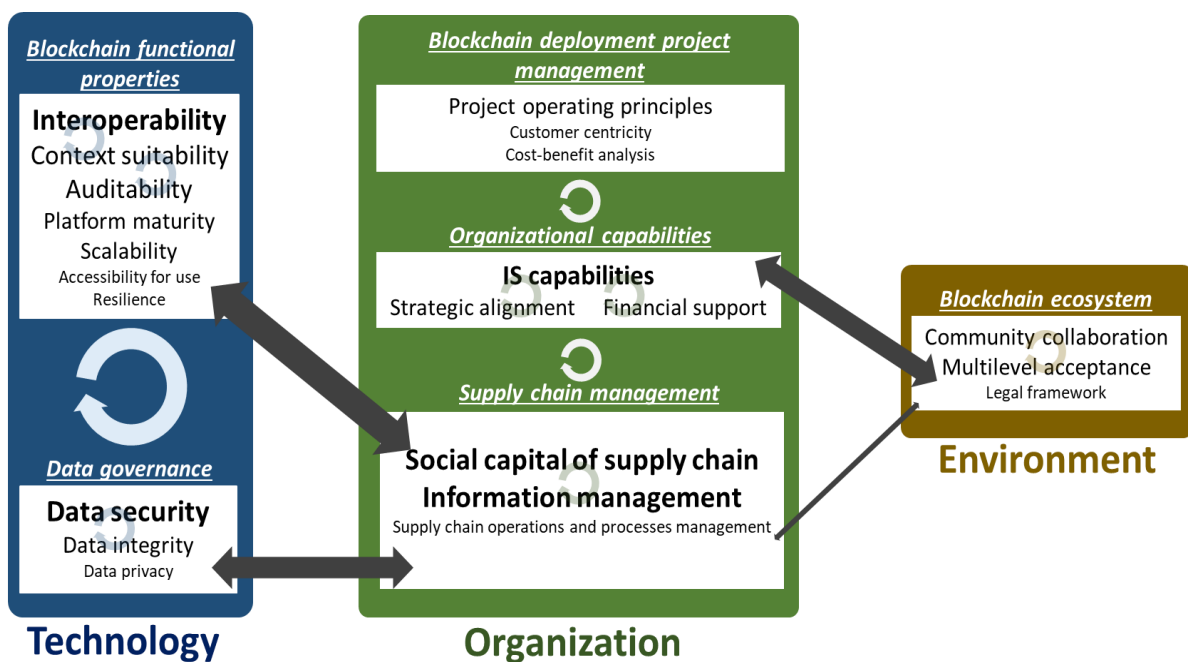

Figure 4 : Summary of study's findings in light of the TOE framework

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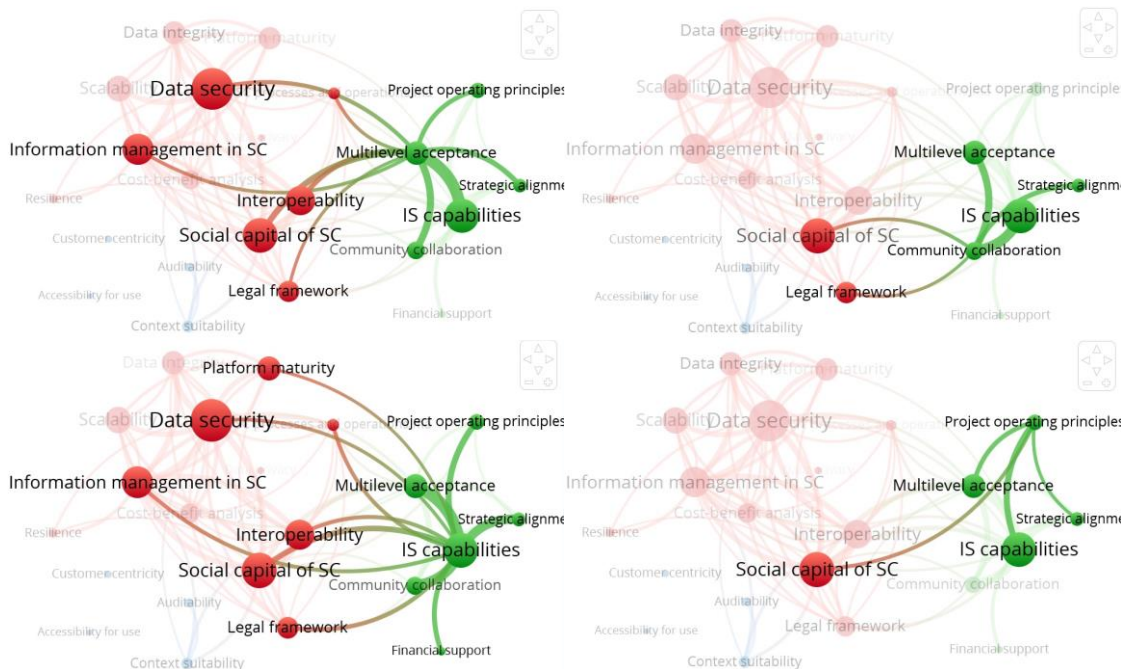https://orcid.org/0000-0001-9674-4722

9. APPENDICES

Appendix 1 - Most important links of the CSFs
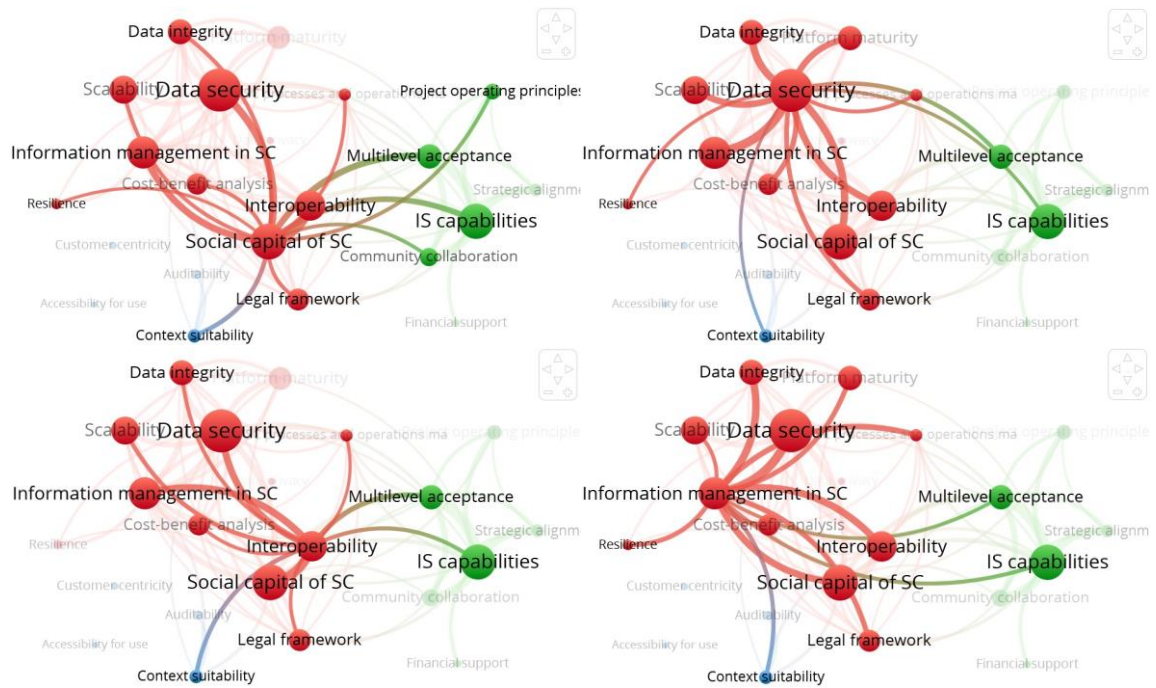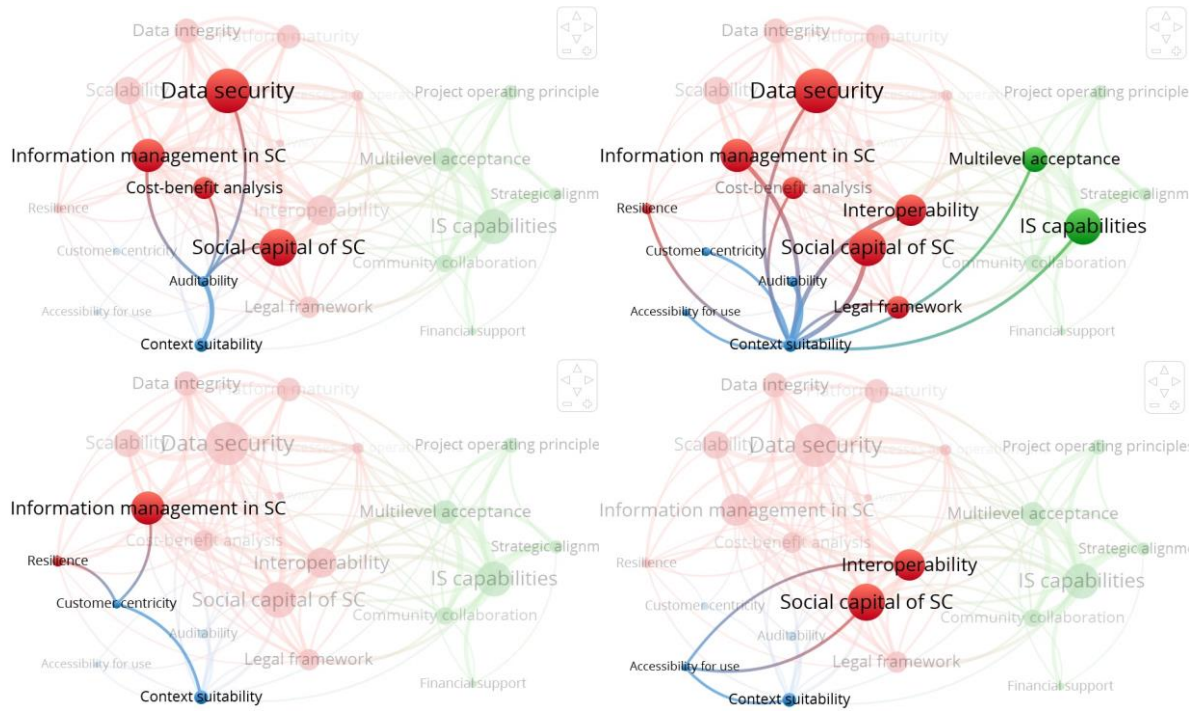

Appendix 1A : Most important links of the CSFs belonging to the socio-technical cluster

Appendix 1B: Most important links of the CSFs belonging to the Macro/Meso/Micro capabilities' cluster

Appendix 1C : Most important links of the CSFs belonging to the user-focused development cluster