Blockchain adoption in logistics and supply chain: a literature review and research agenda

Blockchain Adoption in Logistics and Supply Chain: A Literature Review and Research Agenda

Abstracts

The supply chain is an important source of knowledge that enables potential emerging technologies and, in this ecosystem, logistics are regarded as an intermediary for disseminating innovative solutions in a coordinated manner. As an emerging solution in the supply chain area, blockchain has recently been discussed as a disruptive technology and has received growing attention from academics and practitioners. Despite this interest, insufficient knowledge on the potential benefits and risks of blockchain technology causes vagueness for its successful implementation. Therefore, since effective management of logistics and supply chain operations through advanced solutions is of utmost importance, adopting an innovative approach rather than providing anectodal evidences or narrative expressions plays a critical role in blockchain adoption. Accordingly, this research aims to an in-depth analysis of the blockchain in logistics and supply chain by investigating enablers, barriers, and risks of this adoption. To this end, through employing both the Methodi Ordinatio and the narrative network analyses, the future direction of blockchain adoption is presented in light of the presented current state of knowledge. Consequently, the obtained findings offer academic and practical insights into the ambiguous, insufficiently explained, and conflicted areas in the relationship between blockchain technologies and logistics and supply chain contexts.

Keywords – Blockchain Adoption, Logistics, Smart Contracts, Supply Chain Management, Technology Implementation

1. Introduction

Blockchain has recently been proposed as a novel technology that uses peer-to-peer (P2P) networks for data verification and sharing purposes (Cole, Stevenson, and Aitken 2019). Initially introduced by Nakamoto (2008), the first blockchain technology (BT) application was bitcoin, and different cryptocurrencies emerged over time. However, the distributed ledger technology (DLT) feature provides the opportunity for registration, verification, and sharing of any contract, enabling the technology to be applied in different areas besides cryptocurrency (Tijan et al. 2019). In this respect, it is worthwhile to note that, although Bitcoin is the first application area of the blockchain system, blockchain-based applications have been developed in various domains such as logistics operations (Helo and Hao 2019).

From a technical viewpoint, it is evident that decentralized structure of BT makes this platform more reliable than centralized systems, where the whole system becomes inoperable at a single point failure (Perboli, Musso, and Rosano 2018; Saberi et al. 2019). Furthermore, the decentralized structure removes the intermediaries, freeing the partners from the need to ensure the trustworthiness and reliability of any middleman (Saberi et al. 2019). Known as a secure platform, BT becomes even more reliable and immutable against data manipulation with the addition of new blocks (Treiblmaier 2018). In addition to its reliability, the smart contracts mechanism, which enables to store agreement terms and rules and validates when these terms are met by all participants, is another prominent feature of BT (Saberi et al. 2019; Dolgui et al. 2020).

BT promises significant benefits on logistics and supply chain management (SCM), such as increased sustainability, traceability, and verification (Helo and Hao 2019; Tijan et al. 2019). The technology can be used to provide at least five different types of product-related information to the end-user, including type, location, quantity, quality, and ownership data to ensure product traceability (Saberi et al. 2019). Moreover, BT is expected to improve security besides time and cost efficiency by reducing paperwork (Hoek 2019), facilitating physical container inspections and customs procedures (Engelenburg, Janssen, and Klievink 2019). The smart contracts mechanism can further reduce costs by automating and facilitating payment systems between logistics companies and third-party organizations such as banks and other financial institutions (Wong et al. 2020b).

In addition to its enabling effects on logistics operations, BT also benefits the manufacturing supply chain; Real-time data traceability and reliability contribute to environmental and social sustainability through effective measurement of production capacity (Li et al. 2020). Furthermore, technology allows innovative product design (Rahmanzadeh, Pishvaee, and Rasouli 2020), product customization (Karamchandani, Srivastava and Srivastava 2020), agile manufacturing practices (Gunasekaran et al. 2019), flexible flow shop scheduling (Dolgui et al. 2020), and effective service composition (Aghamohammadzadeh and Valilai 2020). Shi, Yao, and Luo (2021) discuss BT as an enabler of innovative supply chain platforms such as virtual product design systems. Moreover, Zhu, Kouhizadeh, and Sarkis (2021) focus on the role of BT in product deletion to improve overall efficiency in SCM. BT can also provide information management capability to enable synchronized production and logistics (Helo and Shamsuzzoha 2020). Additionally, the benefits of technology are discussed in various fields, such as healthcare services (Yong et al. 2020) and humanitarian operations (Dubey et al. 2020; Rodríguez-Espíndola et al. 2020; Ozdemir et al. 2020).

Despite the widespread attention given to the disruptive potential of BT, there is still a gap in BT and Supply Chain (SC) integration (Wong et al. 2020a). More particularly, it is evident that the extant literature remains largely technical (Hooper and Holtbrügge 2020) or conceptual (Wong et al. 2020a) with anecdotal evidence (Dubey et al. 2020). Similar to these academic gaps, from the practical standpoint, decision-makers do not fully commit to blockchain adoption (Mathivathanan et al. 2021) since they have insufficient knowledge about how blockchain can add value to their organizations (Wamba and Queiroz 2020a). From this point forth, notwithstanding its conceptual utility, the full potential of BT in the SCM has remained underexplored (Wamba et al. 2020; Wamba, Queiroz, and Trinchera 2020) and, as such makes it indispensable to clarify the potentials of the BT (Helliar et al. 2020). Accordingly, to fill this void, we propose three main research questions based on the following rationales:

RQ1. What are the enablers and risks of integrating blockchain technology into the logistics and supply chain industry?

Since the new technologies have both positive and negative disruptions and affect the structural dynamics of the SC (Dolgui and Ivanov 2020), BT disruptions on SC also need to be investigated in detail. However, BT's enablers for SCM have not been thoroughly investigated (Helliar et al. 2020). Moreover, despite its unknown potential, technology should not be treated as a "panacea," and risks such as privacy and security remain unsolved (Chang and Chen 2020). Therefore, *RQ1* will be examined in two sub-categories: BT enablers *RQ1(a)* and risks *RQ1(b).*

The extant literature mainly focused on the benefits of BT whereas adaptation barriers are not sufficiently addressed (Kouhizadeh, Saberi, and Sarkis 2021). Accordingly, there is a research gap in examining adaptation barriers in detail. In this sense, Queiroz, Telles, and Bonilla (2019) and later, Dutta et al. (2020) similarly highlighted this research gap and indicated a detailed examination of integration challenges as a research direction. Thus, in order to contribute to the research gap underlined in these reviews and to deepen their findings, we ask the following research question:

RQ2. What are the barriers to the adaptation of blockchain technology to the logistics and supply chain industry?

Relying on its potential, BT is useful when it is largely used in the SC (Yadav and Singh 2020). This being the case, there is a need for determining whether practitioners indeed need this technology and, as such reveals a dimension of BT adoption to be examined (Wamba et al. 2020; Chang and Chen 2020). Yet, the dearth of empirical studies regarding practitioners' perception of blockchain in the SC (Karamchandani et al. 2021; Queiroz et al. 2020a) causes to ask the following research question to advance the extant literature and to reveal practitioners' perspectives on identified barriers:

RQ3. How should the convenient adaptation model be designed in light of the identified barriers?

Recent studies discussed BT in logistics and SCM and reviewed articles regarding their themes and methodologies (Chang and Chen 2020; Lim et al. 2021). For instance, Dutta et al. (2020) examined challenges, opportunities, and trends for various industries in the supply chain. Wan, Huang, and Holtskog (2020) analyzed 31 papers assuming BT-enabled information sharing increases collaboration in the SCM. Likewise, Queiroz, Telles, and Bonilla (2019) analyzed 27 papers on blockchain and SCM integration. In a similar vein, Wang, Han, and Beynon-Davies (2019) examined BT and SCM integration-related papers in the descriptive, conceptual, predictive, and prescriptive categories and developed a research agenda. From a technical perspective, Bodkhe et al. (2020) conducted a review that deals with smart applications within the scope of Industry 4.0 and BT. Finally, Cheung, Bell, and Bhattacharjya (2021) conducted a review on logistics management and BT-enabled cybersecurity. Yet, despite there are several studies focusing similarly on BT adoption in logistics and supply chain, in comparison with previous studies, our research is different in many aspects, which brings novelty. First, since prior studies have become insufficient in providing in-depth and thorough research considering BT's potential disruptions and adoption barriers on the SCM, this study enriches the literature through a detailed theoretical discussion. Second, we demonstrate potential BT disruptions in complex network structures rather than a straightforward narrative and, accordingly, we offer intellectual value through presenting a research agenda. For this purpose, we propose an integrated and novel research design from the Methodi Ordinarito and Narrative Networks (NN) analysis. In line with these novelties;

- Initially, we study the potential implications of BT on logistics and SCM and visualize the network structure to fill the research gap on this subject. Therefore, we utilize the NN analysis by Pentland and Feldman (2007), which offers an alternative approach to technology adoption and diffusion analysis.
- BT adoption barriers are also investigated in detail, and the revealed factors are discussed under four distinct categories.
- The BT phenomenon is investigated at the theoretical level and the explanatory power of existing theories to explain this phenomenon in the SCM context is scrutinized.

The remainder of this paper is organized as follows. In Section 2, the literature on blockchain and SCM is discussed under three subheadings according to the proposed research questions: BT benefits and enablers, risks and threats, and adoption challenges. While the research design is explained in detail in Section 3, analyzes described in this section are applied in Section 4. Section 4 also includes a network of BT enablers and risk factors established through narrative network analysis. In Section 5, the results of the analyzes are discussed under three subheadings. Practical and academic implications, limitations of the study, and suggestions for future research directions are also discussed in Section 5. Finally, Section 6 is devoted to conclusions.

2. Literature review

2.1 BT benefits and enablers

Explaining the motivation for digital transformation, these factors are expected to benefit the entire SC following the BT implementation. The decentralized structure and consensus mechanism eliminate the need for intermediaries within the system allowing cost reduction (Bai and Sarkis 2020). Increased and consistent information sharing improves decision synchronization among partners (Rejeb et al. 2021). Smart contracts enable flexible scheduling models to improve delivery reliability and allow shorter delivery times (Dolgui et al. 2020). Regarding the manufacturing industry, BT-enabled digitalization eliminates inspection time of end-of-life products to shorten the disassembly process (Tozanlı, Kongar, and Gupta 2020). Thus, BT promises increased delivery reliability and opportunity for mass product customization (Karamchandani et al. 2021). In this regard, Dolgui, Sgarbossa, and Simonetto (2021) more specifically discussed assembly systems from the aspect of mass customization.

Social manufacturing and cloud manufacturing are considered next-generation networked production technologies. With a particular emphasis on social manufacturing, Li et al. (2021) proposed a blockchain-enabled digital twin platform to contribute to heterogeneity-related issues of socialized manufacturing resources (SMRs) and tested under a 3D printing scenario. In this respect, BT primarily serves the purpose of establishing a PnP network that enables the organization of SMRs in a decentralized structure. Cloud manufacturing (CM), another form of recent networked manufacturing systems, incorporates cloud computing with various engineering applications and constitutes a joint pool of configurable production capabilities (Barenji 2021). However, as a centralized platform, CM is criticized for lacking a real-time and effective trust-based framework known as the third-party trust problem. For a BT incorporated solution, Barenji (2021) proposes a BT embedded CM architecture that involves a network of elements, including a digital certificate issue operating system (DCIOS) that provides a digital certificate for a participant firm based on its trust score. Moreover, Wang, Wang, and Tu (2021) discuss that BT can provide optimal service composition solutions for NP-hard optimization problems of CM, establishing a BT-based voting mechanism. Smart manufacturing system design (SMSD) involves various and interdisciplinary expertise and digital production concepts such as digital twins. However, extant digital twin technologies are criticized for being centralized and having traceability and security-related issues (Leng et al. 2021). Herein BT proposes a feasible solution for the known shortcomings of SMSD, as its strength lies in DLT, cryptographic validating, and consensus mechanism.

Regarding the agri-food industry, BT allows for increased food safety (Casino et al. 2020) and lower recall rates in food products (Bumblauskas et al. 2020). It is also highlighted that BT contributes food SC agility and resilience along with other disruptive technologies such as Artificial Intelligence (AI) and Machine Learning (ML) (Dora et al. 2021). Furthermore, with their game-theoretical model, Shen et al. (2021) highlight that BT can provide usefulness in an inspection-based quality management approach to induce low-quality product sellers to increase their product’s quality. Finally, BT-enabled transparency is highlighted as a driver of BT adoption in the humanitarian SC (Ozdemir et al. 2020; Dubey et al. 2020).

2.3 BT risks and threats

In addition to its benefits, BT also poses potential threats by disrupting environmental, social and functional dynamics of SC. Technology is primarily immature (Köhler and Pizzol 2020), and scalability-related issues cause performance problems and the need for new investments (Helo and

Hao 2019). The high amount of data mining and consensus protocols brings considerable energy requirements and environmental costs (Astarita et al. 2020; Esmaeilian et al. 2020; Helliar et al. 2020). In the case of erroneous data entry, the data is resistant to any correction due to the immutable nature of blockchain (Kamble, Gunasekaran, and Sharma 2020; Esmaeilian et al. 2020). Moreover, losing cryptographic keys may be resulted in blocking access to critically important data (Biswas and Gupta 2019).

Furthermore, high visibility raises questions about further data security and privacy (Ivanov, Dolgui, and Sokolov 2019; Wong et al. 2020b). It is stated that the increased level of automation due to the smart contracts mechanism causes deskilling and disemployment (Hald and Kinra 2019). Finally, it is argued that disintermediation may remove value bringing intermediaries (Tönnissen and Teuteberg 2020).

2.2 Adoption challenges and barriers

Another emerging theme in BT in SCM literature is adoption barriers. BT implementation is, first and foremost, a costly investment (Bavassano, Ferrari, and Tei 2020). Moreover, the uncertainty of return on investment remains an important challenge (Chang, Iakovou, and Shi 2020). One of the striking points is that organizational culture and business traditions significantly affect BT adoption. In business environments with strong bilateral relations, it is possible to provide some flexibility in payments and the terms of agreements. Therefore, organizations operating in such an environment can be expected to show strong resistance to the implementation of disruptive technology (Papathanasiou, Cole, and Murray 2020). It is discussed that small and medium-sized logistics companies tend to view BT as a threat rather than a benefiting factor (Helo and Hao 2019).

In addition to the role of the business environment and organizational characteristics, the managerial factor is another challenge to technology adoption (Vafadarnikjoo et al. 2021; Kouhizadeh, Saberi, and Sarkis 2021). Furthermore, Queiroz et al. (2020a) report that perceived barriers to adoption may differ depending on the geographical region.

3. Methodology

3.1 Research design

In line with the research aim and questions, the research design of this study encapsulates two consecutive steps. In the first step, a systematic literature review was employed to reveal the studies contributing to BT in the logistics and SCM literature. In this respect, as used in the systematic literature review studies, the Methodi Ordinarito, developed by Pagani, Kovaleski, and Resende (2015), was adopted to capture relevant literature. Following this, we conducted a brief bibliographic analysis of the indexed studies. The bibliographic analysis presents the distribution of articles by journals, including quartile ranks of journals.

The Methodi Ordinarito is a novel computational method to compose a scientifically relevant portfolio of high-quality papers in systematic literature review research. Therefore, we used this method to create a valid and novel research design. Following the research aim and questions the scope of the study was determined as logistics and SCM. The research protocol is listed in Table 1.

Table 1. Research Protocol.

Research	Details
Search axes	X = blockchain, Y= logistics & supply chain
Search query	(blockchain OR "digital ledger" OR "distributed ledger" OR "shared ledger" OR "smart contract") AND (logistics OR "supply chain" OR transportation)
Search fields	Titles, abstracts, and keywords
Databases	Scopus, Web of Science, ScienceDirect, ABI/INFORM, Taylor& Francis, Wiley

Time range	2008- May 2021
Inclusion	Studies published in business and management discipline and investigating blockchain themes within the logistics & SCM
Exclusion	SCM papers without any emphasis on logistics
Data analysis	The qualitative data derived from the final portfolio is analyzed by narrative network analysis.

Source: Adapted from Queiroz, Telles, and Bonilla (2019).

In the second stage of the research, indexed studies obtained from the first stage are analyzed with narrative analysis (NN). At this stage, qualitative data are derived from an in-depth reading of indexed studies, and these are used to construct meaningful and complete visual networks of BT enablers and risks. Finally, analysis is performed by interpreting the network patterns (i.e., nodes and paths). The general flow of the research design is shown in Figure 1.

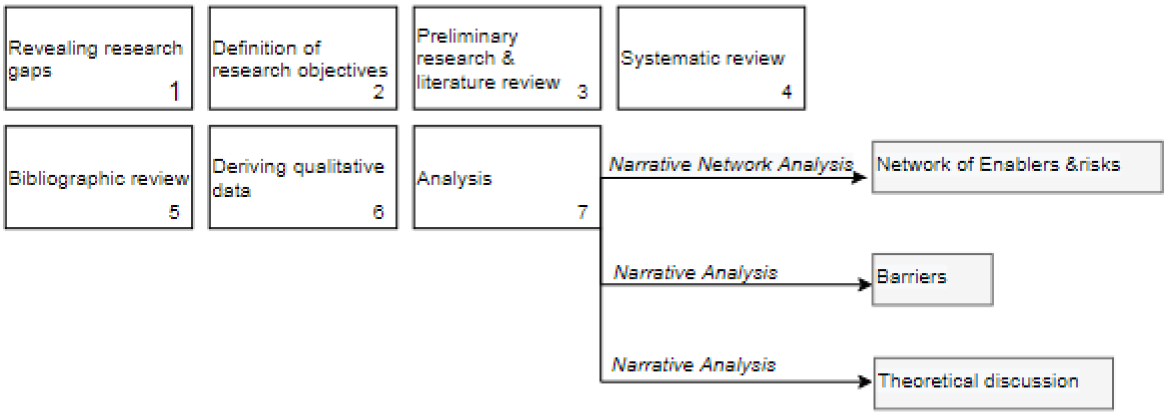


Figure 1. Research design

3.2 The Methodi Ordinatio and InOrdinarito ranking

In this study, a realistic normative approach, the Methodi Ordinatio developed by Pagani, Kovaleski, and Resende (2015), was utilized to create a bibliographic portfolio within the scope of the systematic literature review. The method is an improvement of a constructivist approach known as Knowledge Development Process-Constructivist (ProKnow-C). The Methodi Ordinatio method allows selecting and ranking of articles according to their scientific relevance by establishing a well-designed balance between impact factor, citing score, and publishing year. In Figure 2, the flow chart diagram of the Methodi Ordinarito method is presented.

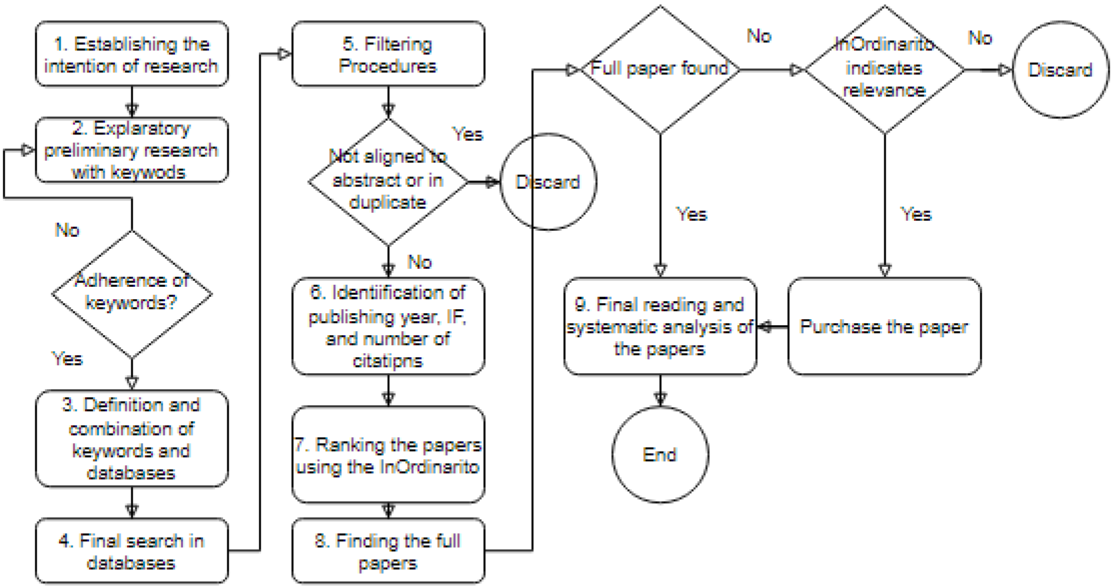


Figure 2. Flowchart of the Methodi Ordinarito. Source Pagani, Kovaleski, and Resende (2015).

The Methodi Ordinatio suggests calculating an InOrdinatio score, which includes the impact factor (IF), year of publication, number of citations (ci), and the α coefficient as given in Eq.1. Here, the α coefficient takes a value between 0 and 10 depending on the researcher's priority. The use of a value close to 10 indicates that the researcher focuses on recently published studies.

$$(IF/1000) + \alpha * [10 - (\text{Year of research} - \text{Year of publication})] + \sum ci \qquad (1)$$

The InOrdinatio score calculation is performed on the seventh of the nine-step process. Subsequently, all papers to be included in the final portfolio are ranked according to their scores (Campos et al. 2018). The most important advantage of this method is that it enables the determination of the final portfolio according to the scoring system, thus enabling more reproducible quantitative research compared to other systematic literature review methods. Hence, the required consistency for a qualitative study is provided. Due to its recognition and reliability in measuring and classifying academic journals, the SCImago journal rank indicator (SJR) was used as the impact factor value. As the alpha (α) coefficient, the maximum value of 10 was used to prioritize the most recent papers.

3.3 Narrative Networks (NN)

In the second step of this research, we propose a NN methodology adapted from Pentland and Feldman's (2007) perspective to handle the implications of the blockchain phenomenon on logistics and SCM. The strength of this method lies in its ability to represent different scenarios and possibilities while visualizing interrelated implications on the subject (Yeow and Faraj 2011). Therefore, NN is an adequate analytical tool for outlining and visualizing the implications of BT on the SC. The notions of narrative networks are actants, actions, fragments, and ties. Actants express both human and non-human entities whilst fragments, namely nodes, represent the narrative flow between two different actants connected by an action (Pentland and Feldman 2007).

A narrative framework can be designed from different viewpoints. For instance, some papers used the method to compare the before and after work routines and organizational designs when they are performed in an alternative way (Chao 2016; Yeow and Faraj 2011). However, this study aims to obtain discrete and partial narratives from the papers that address potential implications of BT adoption and create a meaningful and compromised visual narrative flow by overlapping these narratives. The steps of the proposed NN analysis are as follows in Figure 3.

1) Considering our research questions regarding potential disruptions of BT in SC *(RQ1a, RQ1b)* authors listed all possible actants (smart contracts, DLT, immutability) and actions (improve, pose a risk, enhance). The authors provided a valid consensus on the defined actants and actions.
2) Each paper is thoroughly read for data collection, and authors manually extract fragments and discrete narrative stories from individual papers. This step involves an agreement and verification mechanism among authors without software.
3) A whole and coherent narrative network was established by overlapping previously agreed discrete narrative stories.
4) Authors add new nodes or complete missing connections to achieve a meaningful pattern. Since narratives do not necessarily need to be actual, they can be hypothetical, empirical, typical, and even fictional (Riessman 1993).
5) Finally, to provide a concrete and valid analysis, established relations between the nodes are supported by the reference source of the statement, i.e. [5]. If a missing connection is completed by the authors' consensus, in this case, it is shown by [a].
6) Analysis results are obtained by interpreting the structure of the narrative network, i.e., nodes and paths.

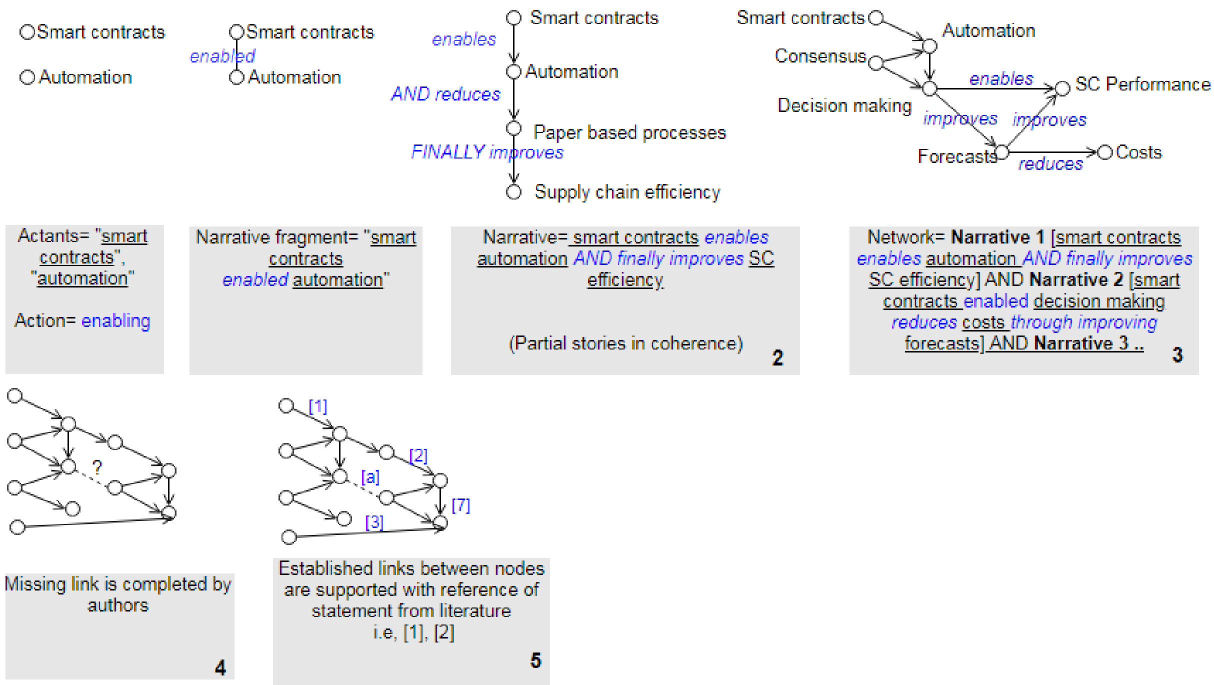


Figure 3. From actants and actions to narrative network

4. The application of integrated qualitative analysis

The steps of the Methodi Ordinarito has a nine-step research process, as shown in Figure 2. Furthermore, in this section, all steps are applied to obtain a scientifically relevant portfolio. Since the study's main objective is the current blockchain applications in logistics, the research axes are determined accordingly (x = blockchain y = logistics). After defining the research axes some articles on the subject were reviewed for preliminary research and the first keywords were determined for the x-axis: "blockchain" and for the y-axis: "logistics" and "supply chain."

Further, more comprehensive research is carried out for a final decision on keywords and databases. To ensure maximum coverage, the keywords were determined as "supply chain", "logistics", and “transportation” for the x-axis; "distributed ledger," "shared ledger," "digital ledger," "smart contracts," and "blockchain" for the y-axis. For keyword consistency, state-of-the-art literature review studies on blockchain and logistics and SCM were examined in Table 2.

Table 2. Validity, consistency, and coverage of keyword selection

Keyword	(Pournader et al. 2020)	(Wang, Han, and Beynon-Davies 2019)	(Queiroz, Telles, and Bonilla 2019)	(Gonczol et al. 2020)	Our study
Supply chain	√	√	√	√	√
Logistics	√	√	√		√
Transportation	√		√		√
Distributed ledger	√	√		√	√
Shared ledger		√			√
Digital ledger		√			√
Smart contract	√		√		√
Blockchain	√	√	√	√	√

In line with Boolean logic the search term is formed as follows: ("blockchain" OR "digital ledger" OR "distributed ledger" OR "shared ledger" OR "smart contracts") AND ("supply chain" OR logistics OR transportation). The databases chosen are Scopus, ScienceDirect, Web of Science, Wiley, Taylor & Francis, and ABI/INFORM.

Since the blockchain concept was first discussed in 2008 (Nakamoto 2008); the date range for search of the databases is set as 2008-May, 2021. The search is meticulously carried out and without the use of a reference manager. The results are sorted, compiled, and organized through a spreadsheet, simultaneously since articles are entered into the spreadsheet one by one, and only articles with a relevant title are considered. Grey literature, conference papers, and books are not included in the search due to the non-availability of the SCImago score. After the search of six databases a total of 736 articles were listed. A comparison was made between databases and 197 duplicated results were removed from the portfolio. The remaining 539 papers were evaluated for the abstract alignment and the 83 articles agreed on by all authors were subjected to InOrdinarito evaluation. A total of 77 studies with InOrdinarito scores between 91,00106 and 725,00178 were included in the final portfolio. During the revision process of the article in July 2021 and October 2021, additional 18 papers were included and the total number of articles reached to 95. With the authors' consensus, articles with an InOrdinarito value of less than 90 were excluded. This process is summarized in Table 3.

Table 3. Selection of portfolio

Databases Search term	ScienceDirect	Taylor&Francis	Scopus	Web of Science	ABI/INFORM	Wiley	No of papers
Gross papers	235	25	313	857	149	13	1592
Title Alignment	130	25	178	267	123	13	736
Duplications	197 duplicated records were removed						539
Abstract Alignment	456 papers were removed due to irrelevance						83
Score Alignment	Six papers were removed due to low score						77
Final portfolio							95

The final portfolio includes research published in peer-reviewed top-tier journals and with high InOrdinarito scores. Considering the SCImago (SJR) system, 95.78 % of papers were found in the Q1 category, supporting the validity of the final portfolio. Instead of an extensive literature review, we focused on a portfolio of the most relevant studies, with high-quality content, to ensure the validity of the research. In Table 4, it is shown how the authors ensure validation of the final portfolio.

Table 4. Validation of portfolio

SJR grouping	Citing

SJR quarter	Number of articles	% in total	Avg. # of cites per SJR group
Q1	91	95.78%	56
Q2	2	2.11%	59
Q3	-	-	-
Q4	2	2.11%	260

4.1 Bibliographic overview

The highest contribution to the BT in logistics and SCM is made by the journals International Journal of Production Research and International Journal of Information Management. Approximately 45 percent of the research in our final portfolio has been published in these journals. This situation shows that top-tier journals encourage special issues with a particular emphasis on BT in SCM. In Figure 4, the distribution of the researches by journals is presented.

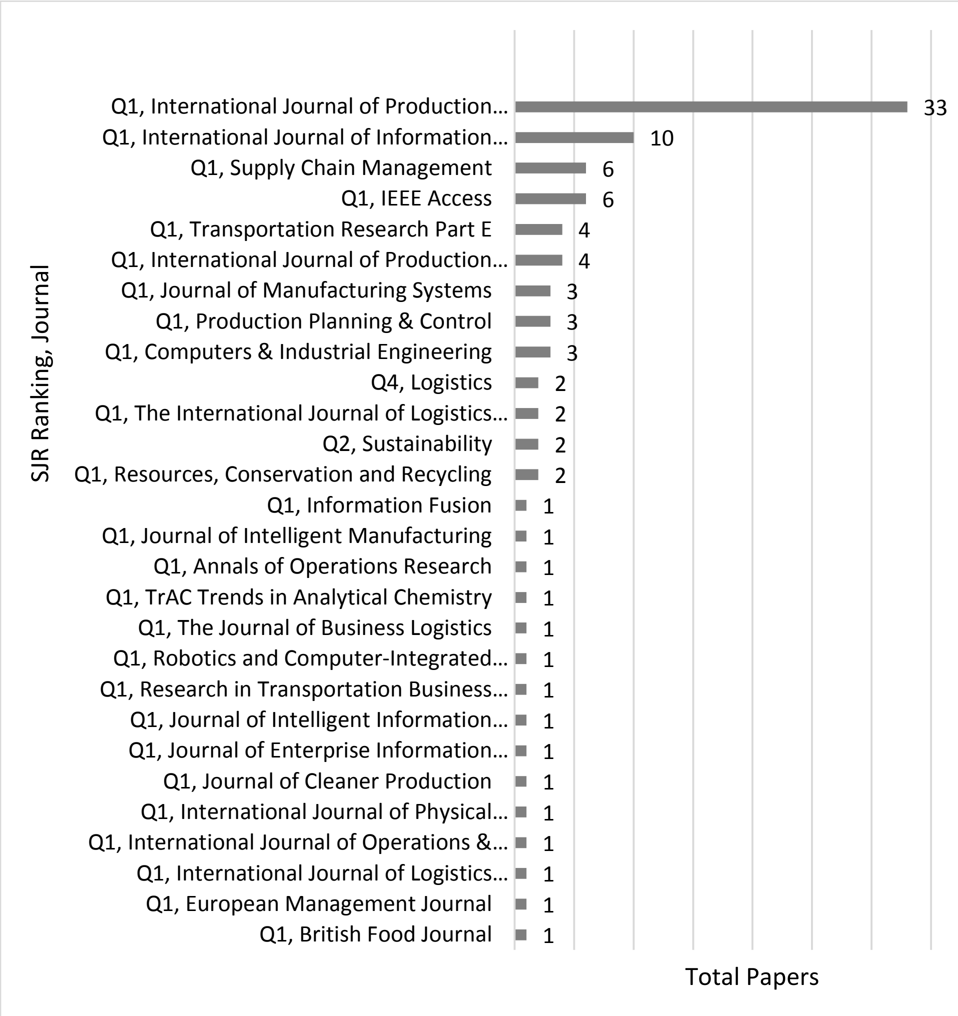


Figure 4. Distribution of journals

4.2 Literature overview

Considering the InOrdinarito score, the ranking was made among the 95 papers in the final portfolio and brief information about the first ten articles is given in Table 5. It is noteworthy that predictive research is predominant.

Table 5. InOrdinarito rankings

Papers	Industry	Concept	Theme(s)	I.o. score
(Saberi et al. 2019)	SCM	Predictive	Deals with BT adoption, sustainable SC, adoption barriers.	725,00178
(Ivanov, Dolgui, and Sokolov 2019)	SCM	Predictive	Deals with BT's role in SC risk analytics and improving ripple effect control.	477,0018
(Francisco and Swanson 2018)	SCM	Conceptual	Paper deals with revealing SC professionals' behavioral intentions regarding BT.	433,00011
(Wang, Han, and Beynon-Davies 2019)	SCM	Predictive	Deals with BT adoption drivers, barriers, and potential disruptions in SC.	326,00168
(Galvez, Mejuto, and Simal-Gandara 2018)	Agriculture SCM	Descriptive	The authors discuss BT-enabled traceability in Agriculture SC.	320,00215
(Hughes et al. 2019)	SCM	Predictive	Deals with BT adoption barriers, its potential applications, and future disruptions in SC.	294,00288
(Treiblmaier 2018)	SCM	Conceptual	The paper discusses the potential implications of BT in SC through a theoretical framework.	294,00168
(Kamble, Gunasekaran, and Arha 2019)	SCM	Conceptual	The paper discusses BT adoption in SC through three adoption theories.	265,00178
(Wang et al. 2019)	SCM	Predictive	Deals with BT adoption challenges and perceived benefits of technology.	254,00238
(Perboli, Musso, and Rosano 2018)	SCM	Prescriptive	The authors propose a solution for BT implementation at the strategic level.	238,00078

4.3 Thematic summary and narrative network analysis

4.3.1 Implementation enablers and benefits

Table 6 summarizes the data from studies highlighting the enablers of BT adoption. For simplicity and readability of the paper, the whole literature is not given here, and constructs will be expressed as interconnected stories to perform narrative network (NN) analysis. Subsequently, a conceptual network will be proposed in Figure 5 as a result of the NN.

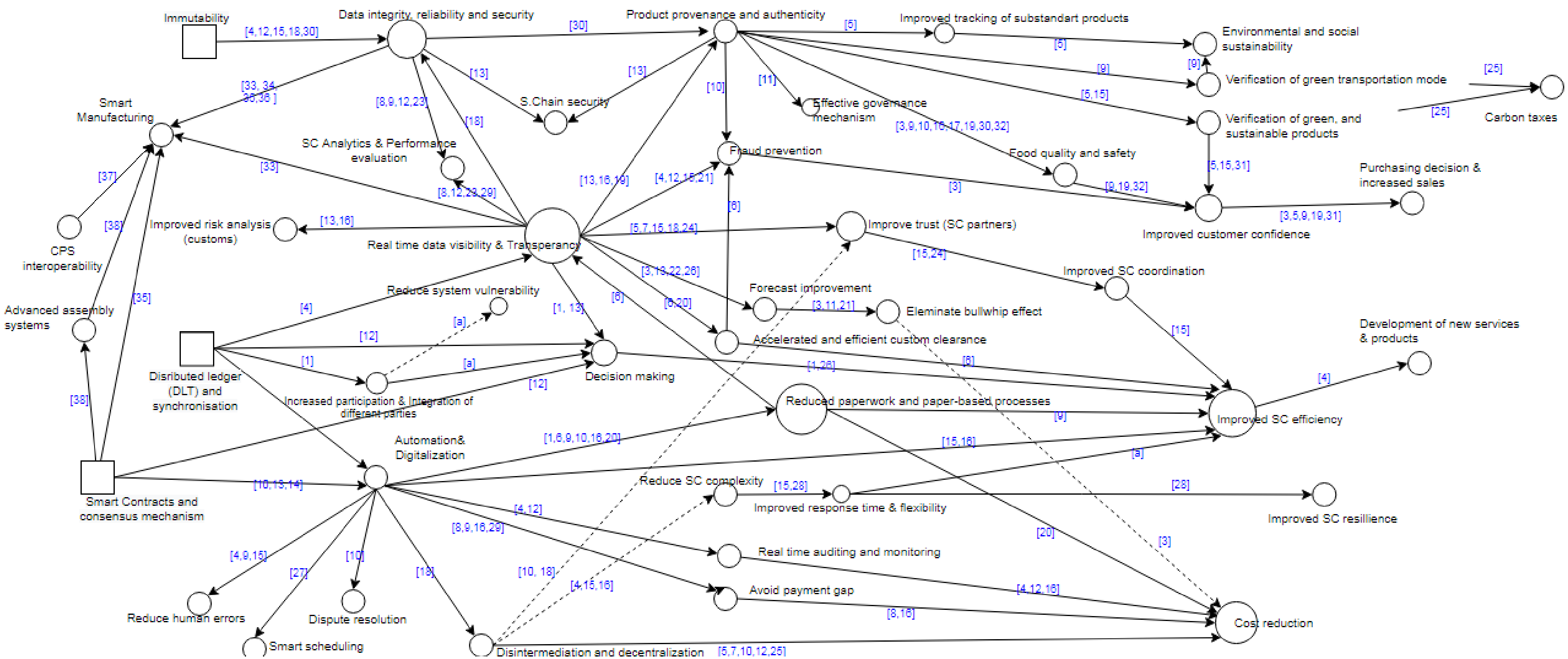
Table 6. Narrative of BT enablers

Papers	BT Enablers
(Kamble, Gunasekaran, and Sharma 2020)	While the decentralized structure allows an increase in trust among the participants, the distributed database reduces the business risks due to late or missing payments. Smart contracts mechanism and decentralized structure reduce the need for intermediaries and transaction costs. The BT-enabled timestamping provides traceability of historical data along the chain, while increased traceability and transparency allow increased trust throughout SC.
(Sander, Semeijn, and Mahr 2018)	It is stated that there is a positive correlation between transparency and traceability systems (TTs) and customers' perceptions of the quality of food products. Accordingly, a BT integration in the context of TTs is predicted to affect consumers' purchasing decisions positively.
(Papathanasiou, Cole, and Murray 2020)	Smart contract mechanisms and disintermediation reduce paper-based processes and allow time and cost-efficiency. The automation provided by the smart contracts and consensus mechanism lead to better inventory management and subsequently increased efficiency. Thanks to transparency, the customs authorities can instantly access real-time data, allowing accelerated custom clearance.
(Yang 2019)	Real-time visibility of shipment data significantly benefits the customs processes and increases efficiency in logistics. BT reduces paper-based transactions and makes some transactions completely paperless due to the digitalization of processes, contributing to improved SC visibility.
(Helo and Hao 2019)	Reducing information asymmetry through BT allows reducing capacity risk and ultimately bullwhip effect across the SC. Smart contracts enabled automation allows the effective fulfillment and verification of contract terms. Moreover, intermediary-related costs and risks arising from late payments are minimized.
(Choi et al. 2019)	The smart contracts mechanism allows automatic execution of contract terms, thereby increasing efficiency.
(Hald and Kinra 2019)	BT allows the consumer to ensure the product's origin and consider sustainability-related issues for purchasing decisions. Visibility allows users to monitor the movement of raw materials and products and increase SC's planning and coordination capacity. The smart contract mechanism increases the SC efficiency due to the standardization and automatic execution of contract rules.
(Koh, Dolgui, and Sarkis 2020)	BT-enabled provenance allows an effective governance mechanism across the SC, such as tracing the exact origin of valuable and critical goods such as diamonds and medicine. The reliable and fast information sharing, combined with optimization methodologies, enables efficient warehousing and

	reduces the bullwhip effect.
(Tijan et al. 2019)	Visibility provides increased decision-making support to participants involved in logistics activities. The decentralized nature of BT allows the participation of all users and high SC coordination. Besides, BT-enabled allows security throughout the SC.
(Perboli, Musso, and Rosano 2018)	Thanks to increased visibility, effective stock control can be achieved with a better forecast, reducing the bullwhip effect and subsequent logistics costs. High visibility prevents product counterfeiting, positively affects customer confidence and purchasing decision.
(Cole, Stevenson, and Aitken 2019)	Product traceability reduces counterfeiting, and smart contract mechanisms reduce manual transactions and human errors. Elimination of intermediaries through the smart contract mechanism reduces SC complexity. BT-enabled automation reduces transaction costs, and automation-enabled efficiency allows the emergence of new products.
(Saberi et al. 2019)	BT-enabled visibility allows customers to ensure their purchases are green products. Thanks to improved traceability, effective detection of non-standard products reduces consumption and environmental costs caused by rework, packaging, and reverse logistics.
(Ivanov, Dolgui, and Sokolov 2019)	The authors emphasize that the application of big data on SC provides dynamic route optimization and effective inventory management. BT allows real-time monitoring of container temperature and ensures food products' safety through data visibility.
(Hughes et al. 2019)	BT significantly increases product traceability, while data visibility increases trust among SC partners. Thanks to its immutability, customer confidence is ensured by preventing counterfeiting and, at the same time, eliminating intermediates allows cost reduction.
(Dobrovnik et al. 2018)	Thanks to traceability, the customers can find information about a product's origin and its manufacturer improving customer's trust and increased profitability. Traceability of data also enables the monitoring of any vehicle's performance and maintenance records in the fleet.
(Chang, Iakovou, and Shi 2020)	The smart contracts mechanism ensures that a penalty system is automatically activated by violation of the predetermined rules, facilitating dispute resolution between SC partners. Reliable and transparent transaction records enable product provenance and the fight against counterfeiting and contribute to a sustainable SC.
(Roeck, Sternberg, and Hofmann 2020)	Immutability and consensus mechanisms prevent any manipulations; reliable and verified data contributes to the decision-making process. The BT-enabled transparency allows the users on the network to see and evaluate their partner's performance. Smart contracts-enabled automation reduces monitoring and coordination costs.
(Wang et al. 2019)	Real-time visibility enables effective demand forecast and customs controls. Together, BT-enabled reliability and product authenticity allow an increase in security throughout the SC. The smart contracts mechanism promises high automation throughout SC.
(Wang, Han, and Beynon-Davies 2019)	Operational costs are reduced through disintermediation and avoiding payment gaps through smart contract-enabled automation. Blockchain enables the transfer of consistent data to customs authorities for real-time risk analysis.
(Kamble, Gunasekaran, and Arha 2019)	The smart contract mechanism provides a solution to the costly problem of payment gaps originating from analog contracts. Transparency increases trust in the SC; additionally, data immutability and visibility enable SC analytics.
(Z. Li et al. 2020)	Particularly in manufacturing, a safe and reliable environment provides an opportunity for enterprise production capability evaluation. Such an automated performance evaluation system requires real-time data visibility, as BT provides.
(Dubey et al. 2020)	Since trust and collaboration are predictors of SC resilience, BT-enabled transparency allows for increased trust among partners and increased collaboration in the SC. Moreover, BT-enabled transparency and visibility reduce SC complexity.
(Esmaeilian et al. 2020)	BT-enabled traceability allows firms to be taxed with an appropriate carbon tax rate by tracking product carbon footprint. Additionally, disintermediation reduces verification and networking costs.
(Rejeb et al. 2021)	BT strengthens the decision-making mechanism by providing synchronization between different nodes in the SC, enabling an increase in performance. Transparency enabled uninterrupted, and accurate information data flow enables accurate forecasts.
(Dolgui et al. 2020)	In supply chains where multiple logistics service providers are involved, smart contract mechanisms can increase operational efficiency in time utilization and delivery reliability through flexible flow shop scheduling.
(Queiroz et al. 2020b)	Digitalization increases the flexibility of the SC, and especially in pandemic situations, response traceability. This is important for controlling the SC resilience and ripple effect.
(Wang, Chen, and Zghari-Sales 2020)	Automated contracts mechanism reduces late payments; moreover, it increases efficiency and cost savings within SC. In addition, visibility through tracking and tracing mechanisms enables performance management and supplier benchmarking.
(Casino et al. 2020)	Data immutability provides data security, which increases the safety of food products and ultimately enables the delivery of high-quality products to the end consumer.
(Xu et al. 2021)	The use of blockchain technologies increases consumers' awareness of green products and increases the profit of the whole SC network, especially the manufacturer.
(Wu, Fan, and Cao 2021)	BT can provide data traceability for fresh product supply chain consumers and enable companies to be assured of food quality. The consumer's confidence in product quality may influence the decision to pay a premium for such a product.

(Guo et al. 2021)	Within the scope of smart manufacturing, BT contributes the industrial dataspace concept by enabling the transmission of large amounts of data by means of security and transparency.
(Sahoo 2021)	BT can reduce the vulnerability of cyber-physical manufacturing systems (CPS) against hacking and thereby ensure social acceptance of intelligent manufacturing platforms.
(Zhang et al. 2021)	BT can resolve credibility issues of centralized cloud manufacturing architectures by providing a secure network structure that is fundamentally based on voting mechanisms and cryptographic algorithms.
(Shen et al. 2021)	BT provides a decentralized solution to the data sharing problem among untrusted parties of Digital Twin (DT) technology. Here, cloud technology is also incorporated with BT to deal with a large amount of DT data that is collected in different forms, such as physical and virtual device data.
(Pérez et al. 2021)	BT-based information systems can coordinate various autonomous CPSs and provide solutions in case of conflict between these units. In this way, BT enables the efficient implementation of mass customized productions systems, solving the interoperability problem.
(Manimuthu et al. 2021)	Smart contract mechanism and AI supported data-driven decision-making algorithms such as Federated Artificial Intelligence (FAI) framework enable industrial automation and advanced assembly systems.

All qualitative data in Table 6 is visualized by narrative network analysis, as shown in Figure 5. With an inductive approach, narrative fragments (nodes) will be separately coded for each paper, and then all patterns will be overlaid to achieve a meaningful pattern. To prove the robustness and reliability of the network the sources of nodes are specified in the graphic. While visuals expressed in a square represent BT's fundamental features, the narrative fragments are represented by circles.



[1](Tijan et al. 2019)
[3](Perboli, Musso, and Rosano 2018)
[4](Cole, Stevenson, and Aitken 2019)
[5](Saberi et al. 2019)
[6](Yang 2019)
[7](Hughes et al. 2019)
[8](Kamble, Gunasekaran, and Arha 2019)
[a] Authors' elaboration
[9](Dobrovnik et al. 2018)
[10](Chang, Iakovou, and Shi 2020)
[11](Koh, Dolgui, and Sarkis 2020)
[12](Roeck, Sternberg, and Hofmann 2020)
[13](Wang et al. 2019)
[15](Hald and Kinra 2019)
[16](Wang, Han, and Beynon-Davies 2019)
[17](Ivanov, Dolgui, and Sokolov 2019)
[18](Kamble, Gunasekaran, and Sharma 2020)
[19](Sander, Semeijn, and Mahr 2018)
[20](Papathanasiou, Cole, and Murray 2020)
[21](Helo and Hao 2019)
[22](Choi et al. 2019)
[23](Li et al. 2020)
[24](Dubey et al. 2020)
[25](Esmaeilian et al. 2020)
[26](Rejeb et al. 2021)
[27](Dolgui et al. 2020)
[28](Queiroz et al. 2020b)
[29](Wang, Chen, and Zghari-Sales 2020)
[30](Casino et al. 2020)
[31] (Xu et al. 2021)
[32] (Wu, Fan, and Cao 2021)
[33] (Guo et al. 2021)
[34] (Sahoo 2021)
[35] (Zhang et al. 2021)
[36] (Shen et al. 2021)
[37] (Pérez et al. 2021)
[38] (Manimutlu et al. 2021)

Figure 5. Narrative network of enablers

4.3.2 Potential Risks and Threats

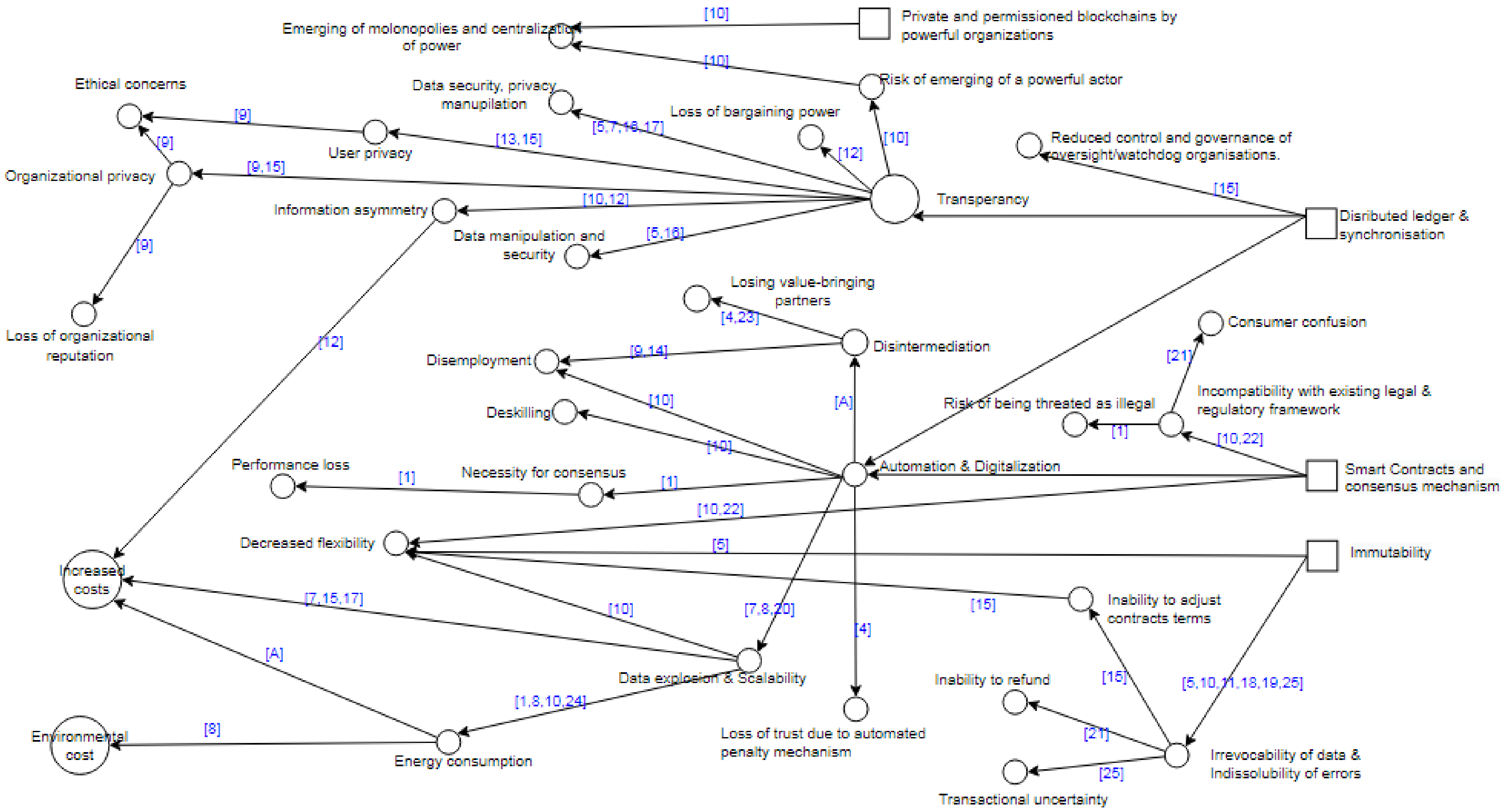
Table 7 summarizes the data from studies highlighting the risks of BT adoption. For simplicity and readability of the paper the whole literature is not given here and constructs will be expressed as interconnected stories to perform narrative network (NN) analysis. Subsequently, a conceptual network will be proposed in Figure 6 as a result of the NN.

Table 7. Narratives of BT risks

Papers	Potential Risk and Threats
(Lin et al. 2019)	Processing and storing large amounts of data may cause scalability issues, an increase in operating costs, with significant performance loss. The need for data sharing between indirect partners (e.g., manufacturer and retailer) poses a privacy risk.
(Biswas and Gupta 2019)	Inconsistency due to software updates may cause technology risks. A significant technology risk is the loss or theft of cryptographic keys, in which case the data in the blocks becomes unrecoverable.
(Helo and Hao 2019)	The BT transactions require high-capacity physical infrastructure. Ultimately, such a scalability problem can significantly increase operating costs. As another BT risk, existing BT applications cannot provide sufficient data privacy, and sensitive information can be transmitted to a node outside the network.
(Hald and Kinra 2019)	Permissioned and private blockchain structures can lead to a monopoly, strengthening the network's hierarchy. The inflexibility of the smart contracts mechanism and non-compliance with the existing legal infrastructure are other SC risks. Smart contracts-enabled automation results in deskilling and disemployment.
(Koh, Dolgui, and Sarkis 2020)	Privacy emerges as an ethical issue with its different dimensions, such as organizational and individual privacy. It is also argued that BT-enabled digitalization may cause disemployment for low-skilled workers.
(Tijan et al. 2019)	BT requires a large amount of energy to function due to the required processing capacity. Every transaction on the system requires acknowledgment by all users and causes slowdown and performance loss throughout the SC. The lack of legal and regulatory infrastructure regarding the smart contract mechanism may cause its users to fall into illegal status.
(Saberi et al. 2019)	In addition to the scalability risk, an effective solution has not yet been proposed for data manipulation, security, and privacy problems. Although BT provides data security through immutability, this also means that erroneous data permanently remains in the system where any is erroneously recorded.
(Ivanov, Dolgui, and Sokolov 2019)	Besides the advantages they provide, advanced track and trace systems may cause data security problems.
(Astarita et al. 2020)	Implementing BT technologies can be environmentally costly, as performing the necessary computing requires large amounts of energy. Additionally, the fact that large amounts of data will be stored brings scalability problems.
(Wong et al. 2020b)	Data security and privacy issues are considered BT risks by SC professionals. Moreover, immutability causes erroneous data to remain in the system and poses a threat to data integrity.
(Chang, Iakovou, and Shi 2020)	The scalability problem caused by the limited processing capacity of existing digital ledger technologies emerges as a post-implementation risk.
(Kamble, Gunasekaran, and Sharma 2020)	The authors express the immutability-based irrevocability of any data in the blockchain system, and security threats arising from selfish mining pose significant BT risks.
(Roeck, Sternberg, and Hofmann 2020)	BT-enabled transparency may reveal some partner's incompetencies and reduce their bargaining power within the network. Additionally, one-way traceability (upstream or downstream) may cause information asymmetry between users.
(Cole, Stevenson, and Aitken 2019)	The disintermediation may cause value-creating partners to lose their current positions. Moreover, automated penalty mechanisms can undermine business relationships and a loss of trust between organizations. Firms have to rely on a penalty mechanism with complicated algorithms.
(Wang, Han, and Beynon-Davies 2019)	As well as its technical risks, the smart contracts mechanism also poses social risks as it removes intermediaries or reduces their numbers, which will result in disemployment.
(Hughes et al. 2019)	Every node on the network separately keeps a record of all transactions and creates a privacy risk while increasing the computational cost. Additionally, immutability prevents any changes and corrections of the data, such as adjusting contractual terms, leading to decreased flexibility.
(Dutta et al. 2020)	Lack and inadequacy of legal and regulatory mechanisms may lead to consumer confusion. Another issue arises in repayment: immutability does not allow for adjustment in the existing transaction, and a refund requires a new transaction.

(Esmaeilian et al. 2020)	Defining the rules and terms of smart contracts by software developers creates incompatibility problems with legal regulations. Moreover, smart contract mechanism-related inflexibility brings along the problem of not adapting to the expectations of different partners and different scenarios.
(Tönnissen and Teuteberg 2020)	Although different partners in the SC produce benefits as intermediaries, BT-based disintermediation may cause valuable partners to be excluded from the system.
(Helliar et al. 2020)	Especially in permissionless systems, performing the necessary calculations to solve the algorithms requires a high amount of energy.
(Liu, Zhang, and Zhen 2021)	Irrecoverability of the BT data poses the risk that if the system blocks any data, any information and value associated with this data may be completely lost, ultimately resulting in transactional uncertainty.

All qualitative data in Table 7 is visualized by narrative network analysis, as shown in Figure 6. With an inductive approach, narrative fragments (nodes) will be separately coded for each paper, and then all patterns will be overlaid to achieve a meaningful pattern.



[1](Tijan et al. 2019)
[4](Cole, Stevenson, and Aitken 2019)
[5](Saberi et al. 2019)
[7](Lin et al. 2019)
[8](Astarita et al. 2020)
[9] (Koh, Dolgui, and Sarkis 2020)
[10](Hald and Kinra 2019)
[11](Biswas and Gupta 2019)
[12](Roeck, Sternberg, and Hofmann 2020)
[14](Wang, Han, and Beynon-Davies 2019)
[15](Hughes et al. 2019)
[16](Ivanov, Dolgui, and Sokolov 2019)
[17](Helo and Hao 2019)
[18](Wong et al. 2020b)
[19](Kamble, Gunasekaran, and Sharma 2020)
[20](Chang, Iakovou, and Shi 2020)
[21](Dutta et al. 2020)
[22](Esmaeilian et al. 2020)
[23](Tönnissen and Teuteberg 2020)
[24](Helliar et al. 2020)
[25] (Liu, Zhang, and Zhen 2021)
[A] Authors' elaboration

Figure 6. Narrative network of BT risks

4.3.3 Implementation Barriers and Challenges

The barriers to BT adoption are increasingly investigated in the literature. These include investment costs, lack of skilled labor, and lack of a legal and regulatory framework. BT adoption barriers compiled from the literature are shown in Table 8.

Table 8. Implementation challenges

Papers	Implementation Barriers and Challenges
(Kamble, Gunasekaran, and Sharma 2020)	The technical inadequacy of the organizations and an inadequate legal and regulatory framework stand as obstacles to BT adoption.
(Papathanasiou, Cole, and Murray 2020)	A qualified and technical workforce is required for the integration of the maritime industry into BT. The uncertainty caused by the lack of a standard legal infrastructure is another barrier. Additionally, before blockchain integration, trading partners must be integrated through existing systems such as ERP.
(Yang 2019)	The lack of globally viable and consistent technical standards and regulatory frameworks is an obstacle to BT integration. Another finding of the study is that senior-level managers have a sceptical view of new technologies.
(Helo and Hao 2019)	The very long implementation process and the requirement of highly qualified personnel are expressed as adaptation barriers.
(Koh, Dolgui, and Sarkis 2020)	BT-enabled transparency may not be accepted in SC networks where information asymmetry is common. Additionally, the integration of legacy systems, investment requirements, and the necessity for inter-organizational change management are other barriers.
(Di Vaio and Varriale 2020)	Particularly in the airport industry, the lack of expert staff with coding skills and the high setup fee are considered integration barriers.
(Cole, Stevenson, and Aitken 2019)	Given the required investment costs, the authors point out BT adaptation may not be attractive for local and small supply chains.
(Saberi et al. 2019)	Authors suggest BT adoption barriers into different categories: Intra-organizational barriers, inter-organizational barriers, system-related barriers, and external barriers.
(Dobrovnik et al. 2018)	The costs of transition to the new system and the necessity to develop new standards for BT compliance in the logistics infrastructure are significant barriers.
(Bavassano, Ferrari, and Tei 2020)	The major obstacle to BT adoption is the lack of interest from authorities and regulators to make the necessary investment. The need to set up a clear implementation strategy, the absence of overarching standards for complete SC integration and high investment costs, are other obstacles.
(Wong et al. 2020b)	The lack of trust and sufficient knowledge of SC professionals about BT is a challenge against integration. Additionally, technical standards are required to integrate different users who provide services in a wide range of specialties within the SC.
(Chang, Iakovou, and Shi 2020)	The uncertainty of return on investment is an obstacle to BT implementation. The lack of technological knowledge, and the requirement for standardization that will provide interoperability between SC players, emerges as another challenge.
(Yang 2019)	The requirement of determining technical standards for maritime SC and uncertainty regarding regulatory governance are expressed as implementation barriers.
(Sternberg, Hofmann, and Roeck 2021)	Insufficient knowledge about BT's functionality and benefits, lack of standards developed for SC, conflicting stakeholder expectations, and existing corporate culture are challenges to adaptation.
(Kouhizadeh, Saberi, and Sarkis 2021)	There is a distinct difference between academics and practitioners regarding BT adaptation barriers. While practitioners' approach to the issue is more technologically oriented, academics evaluate adaptation barriers within the SC, technology, and sustainability with a more holistic perspective.
(Wan, Huang, and Holtskog 2020)	Users may be reluctant to share data due to conflicts of interest and the highly competitive environment, which appears as a barrier to adoption. The lack of awareness towards digitization across the industry and the need for investment and time cost are other barriers.
(Mathivathanan et al. 2021)	The business owner's reluctance to use new technologies such as blockchain is an important barrier. In addition to the unwillingness of companies to share commercial data with their partners, regulatory uncertainty, insufficient digitalization, and uncertain benefits of technology are other barriers.
(Vafadarnikjoo et al. 2021)	The use of blockchain in the "underground economy" for illegal purposes such as gambling and money laundering is an adoption barrier. Moreover, management's commitment and transactional level uncertainties are identified as other adoption barriers.
(Yadav et al. 2020)	The authors examined ten adaptation barriers for Agri-food SC; the lack of regulatory infrastructure and regulatory uncertainty and lack of trust among stakeholders are the most significant challenges for BT adoption. The complexity of system design and the user's negative perception of system use are other significant barriers.

(Queiroz et al. 2020a)	Facilitating conditions such as organizational infrastructure and IT capabilities are significantly affect behavioral intention to adopt the technology. Moreover, individuals' perception of performance expectancy from BT is considered a significant barrier.

4.3.4 Theorization of BT and SCM relationship

Theorization is crucial to thoroughly investigate any implications of BT on SC and address the adaptation phenomenon on a solid basis. However, criticism is brought to the existing literature for the small number of theory-based studies conducted so far (Sternberg, Hofmann, and Roeck 2021; Acar and Kucukaltan 2021). In this section, we discuss five theories, namely Dynamic Capability View (DCV), Information Processing Theory (IPT), Resource Orchestration Theory (ROT), Institutional Theory (IT), and Upper Echelon Theory (UET), for addressing the blockchain phenomenon in the SC.

A well-established and excessively employed theory, the Resource-Based View (RBV), explains how specific organizational capabilities and resources can lead to competitive advantage (Ketchen Jr and Hult 2007). However, as a static theory, it falls short of explaining how firms develop their resources and abilities in dynamic environments (Gupta et al. 2020b). Derived from RBV, DSV can successfully explain the transformation of traditional SC's into digitally enabled and agile structures by uniting, building, and reconfiguring a firm's ability to adapt to dynamic environments (Teece, Pisano, and Shuen 1997). Dynamic capabilities improve organizations' agility, allowing them to generate increased profits during uncertainty (Dolgui, Ivanov, and Sokolov 2020), enhancing social and environmental sustainability (Dubey et al. 2019c) and SC resilience (Altay et al. 2018). Martinez et al. (2019) emphasize that BT is transforming organizations' standard core capabilities into new and dynamic core capabilities, such as data analytics. The authors further argue that analyzing and using data on customers' changing consumption habits to gain competitive advantage is a dynamic core capability.

IPT is currently a popular tool for explaining SC-related phenomena, especially for post-covid scenarios (Yang et al. 2021). The theory addresses the relationship between information processing, environmental uncertainty, and organizations' adaptation requirements (Saberi et al. 2019). The theory can adequately explain how organizations gain a competitive advantage through information flow in high uncertainty (Jia et al. 2020). Accordingly, investing in information processing capability is considered an effective strategy (Dubey et al. 2019a). BT-based data management prevents opportunistic behaviors in the SC through accession to reliable and visible data (Karamchandani et al. 2021). As the relationship between big data processing capability and swift-trust is proved (Dubey et al. 2019a), BT's big data analytics capability reduces behavioral uncertainty through increased data sharing among members. Further, transparency enables swift-trust building and improves SC collaboration (Dubey et al. 2020).

Another criticism of RBV is that, while trying to explain firm performance and competitive advantage through acquiring and developing strategic resources, it is insufficient to explain how similar firms with similar outputs can differentiate in outputs (Sirmon et al. 2011). At this point, ROT is introduced; the theory derived from RBV is based on the efficient management of capabilities and resources to generate value (Sirmon et al. 2011). The theory strongly emphasizes the orchestrator's role and ability to structure and bundle a firm's resources to maximize the output (Plasch et al. 2020; Chavez et al. 2020). So far, little contribution has been made to the theory in SC studies (Craighead, Ketchen Jr, and Darby 2020). Drawing from the ROT, Plasch and colleagues (2020) discuss the central orchestrators' role in utilizing the logistics network through physical internet. Chavez et al. (2020) discussed the relationship between competitive advantage and the organization's environment, economic and social performance (three bottom lines -TBL) through ROT. Accordingly, internal lean practices orchestrate resources as a manufacturing system and improve TBL performance.

The Institutional Theory (IT), which explains organizations' tendency to isomorphism with coercive, normative, and mimetic mechanisms, can adequately explain how firms respond and adapt to substantial environmental changes to earn legitimacy (Wamba and Queiroz 2020b). Throughout the Covid-19 pandemic, large manufacturers and distributors (e.g., General Motors and Amazon) have faced challenging environmental pressures such as devoting part of their production and distribution capacity to medical products (Craighead, Ketchen Jr, and Darby 2020). However, institutional pressure can also be a driving force for organizations to develop new capabilities (Wamba and Queiroz 2020b). And at this point, the integration of the institutional theory with the DSV can explain the role of environmental pressure in developing the organization's dynamic internal resources (Gupta et al. 2020a). As the fundamental promise of BT lies in big data processing capacity and data analytics, institutional pressure impacts developing a big data culture through skilled workforce development and appropriate resource selection (Dubey et al. 2019b). Moreover, drawing on IT, researchers argue that the BT-enabled transparency provides social legitimacy within the scope of food certification (Hew et al. 2020; Tan, Gligor, and Ngah 2020).

Upper Echelon Theory (UET) assumes that factors related to top management, such as experience, age, and even personality traits impact organizational success (Hambrick and Mason 1984). Accordingly, top management plays a crucial role in solving the organization's problems. As a successful BT adoption requires a highly skilled technical workforce (Kouhizadeh, Saberi, and Sarkis 2021), the theory can explain the top management's role in hiring, training, coaching, and empowering such skilled workers (Potter 2021). It is also discussed that organizational leaders have a role in ensuring the compliance of targets and processes amongst the firms and their suppliers (Potter 2021). In this respect, UET can address the interoperability issue, one of the obstacles to BT adoption. The UET has the potential to establish a theoretical basis for studies using technology acceptance models that aim to explain the intention of system users to accept and use new technologies. In this case, logistics and SC managers' perspectives on BT adoption can be analyzed in a solid theoretical framework.

5. Discussion

In this section the research results are discussed under three headings following the analysis level. First, BT enablers and risks are interpreted as indicated in Figure 5 and Figure 6, which include visualized narrative networks. Then, the barriers to blockchain adaptation from Table 8 are interpreted and categorized. Finally, the relationship between BT and the SC is discussed on the theoretical level.

5.1 Enablers and risks

In Figure 5, we proposed a narrative network framework to reveal BT enablers in detail and provide a concrete answer to *RQ1 (a)* to contribute extant literature. Our main finding is that BT adoption ultimately is resultant in increased efficiency across the SC through direct and indirect enablers. The digitalization of paper-based processes (1), efficient decision-making mechanisms (2), improved SC coordination (3), and flexibility (4) are prominent driving factors of SC efficiency. As an indirect effect, transparency enabled real-time visibility improves the efficiency of custom processes. This outcome supports and enhances previous studies' findings predicting that blockchain adaptation will increase SC efficiency and performance (Wamba, Queiroz, and Trinchera 2020). Second, research shows that there is a strong clue for interconnectedness among BT enablers. This finding can explain the vagueness and confusion about the full potential of BT in the SC (Wamba et al. 2020), providing an answer to our *RQ1(a)*. Our finding is consistent with recent studies that focus on interconnectedness among BT constructs such as barriers and enablers (Yadav and Singh 2020; Ozdemir et al. 2020).

Another finding is BT's most significant impacts on SC are environmental and social sustainability (Saberi et al. 2019). However, there is a limited contribution to BT adoption in terms of sustainability (Lim et al. 2021). In a limited number of studies, sustainability is mainly contributed through traceability and product provenance (e.g., Dobrovnik et al. 2018); thus, we could not find any evidence for an attempt to establish a link between sustainability and indirect BT enablers such as dispute resolution, disintermediation, or risk analysis. Köhler and Pizzol (2020) similarly emphasize that the impact of BT on sustainability has not yet been conclusively proven. The potential consequences of disintermediation are addressed by scholars (Tozanlı, Kongar, and Gupta 2020; Tönnissen and Teuteberg 2020); however, it is not adequately discussed in terms of environmental and social sustainability. To enhance extant literature, we bring the following research proposal:

RP1. What is the relationship between smart contract enabled disintermediation and supply chain sustainability in the environmental and social sphere?

Another finding of our study is that the connection between customs processes and SC sustainability has not yet been established. Referring to Figure 5, the existing argument on customs-based risk analysis does not address its contribution to social and environmental sustainability. Considering customs processes have a vital role in maintaining an efficient SCM, and there is increasing emphasis on sustainability (Wamba and Queiroz 2020a; Khan et al. 2021), the intellectual value of investigating the relationship between these concepts in detail emerges. To take Tian et al.'s (2021) research question on the development of specific applications of BT in sustainable SCM one step further and to contribute extant literature, we bring the following research proposal:

RP2. What is the relationship between transparency-based risk analysis (customs) and supply chain sustainability in the environmental and social sphere?

BT promises prominent advantages regarding manufacturing systems, particularly for smart-intelligent production techniques. As an enabler of cloud manufacturing (CM), BT provides a trustless mechanism for secure and reliable data sharing and addresses CM's well-known vulnerability known as the third-party trust problem. In this case, BT can be used to establish an integrated architecture to provide trust score-based digital certificates (Barenji 2021) and resolve credibility-related issues of centralized CM systems (Zhang et al. 2021). Again, BT-based voting mechanisms can provide an adequate solution for NP-hard optimization problems of CM architectures (Wang, Wang, and Tu 2021). Moreover, BT can function as a data-sharing layer to enable communication and coordination of various decentralized cyber-physical objects. In spite of all the promises of BT-integrated solutions, the main drawback of such applications is excessive resource utilization, delay time, and low throughput due to inefficient consensus algorithms. Despite the recent efforts (e.g., Zhang et al. 2021), further research is required to exploit enabling effect of BT on advanced production methods, and particularly for CM architectures. Therefore, to enhance extant literature, we bring the following research proposal:

RP3. What should be a well-optimized consensus algorithm for BT to enable cloud-based manufacturing?

Regarding *RQ1 (b),* we established a narrative network to reveal the blockchain risks in logistics and SCM to enhance the findings of prior research (Figure 6). The structural dynamics of the SCs are discussed from different perspectives, such as social, economic, functional, and technical (Dolgui and Ivanov 2020). Regarding BT's disruptive effect on functional dynamics, we found that inflexibility emerges as a technology risk resulting in the cooperation of the consensus mechanism, automated contracts, and immutability; it may ultimately result in business risks such as loss of opportunity to update contractual terms. To some degree, our findings are in line with papers that discuss the inflexibility of the technology (e.g., Esmaeilian et al. 2020). Unlike our research, these studies associate BT-related inflexibility non-holistically and either with only smart contracts or immutability.

This finding reveals that further research is needed to empirically investigate the inflexibility issue by considering three features of BT.

Transparency is seen as the most crucial feature of BT and promises various enablers unlikely to be claimed otherwise, such as fraud prevention (Roeck, Sternberg, and Hofmann 2020) and increased trust (Kamble, Gunasekaran, and Sharma 2020). Our findings show that transparency may also lead to problems ranging from privacy breaches to loss of organizational reputation and even monopolies within the SC. Although the BT-enabled transparency has been intensely addressed (e.g., Bai and Sarkis 2020), the risks arising from transparency have not yet been adequately explained on theoretical grounds. Therefore, the following research is proposed for a detailed investigation in the light of management theories:

RP4. On what theoretical basis does BT-based traceability lead to monopolies within the supply chain?

5.2 Adoption barriers

To provide a concrete answer to the *RQ2* regarding BT adoption barriers, we evaluated the literature findings from Table 8. As a result, adoption barriers are divided into four distinct categories: governance and regulatory, economic, technical, and business ecosystems. To clarify our findings we break down these categories into individual adaption factors. First, we found that investing in high-tech human capital to improve an organization's technical knowledge is the most crucial issue in the "technical" category. This finding confirms the emphasis in the literature that the lack of technical knowledge of the organization is one of the most crucial adaptation barriers (Mathivathanan et al. 2021; Orji et al. 2020). Similarly, Kouhizadeh, Saberi, and Sarkis (2021) emphasize the importance of technical expertise. Another finding is that developing technical standards to integrate different SC actors emerges as a challenge. This finding is in line with Yadav et al.'s (2020) emphasis on interoperability, and standardization stands out as a significant challenge against adoption. From a business ecosystem perspective, we found that the structure of the SC network (i.e., traditional and reactive or data-driven) is crucial through external stakeholders' support.

From a governance and regulatory perspective, we have few findings. First, the lack of legal and regulatory infrastructure stands out as a significant external barrier. This corresponds with Yadav et al.'s (2020) findings on the impact of governmental guidance on BT adoption. Second, from firm governance, organizations' commitment to digital transformation emerges as an intra-organizational barrier, which is in line with previous studies' findings (Kouhizadeh, Saberi, and Sarkis 2021). Most strikingly, the managerial factor is found to be the least highlighted among all adaptation barriers. However, adaptation is affected by the individual decision-making mechanism, which may vary according to the characteristics of the decision-maker (Bai and Sarkis 2020). Similarly, consistent with our findings, Wamba, Queiroz, and Trinchera (2020) report that managers' efforts to understand the BT and SCM relationship are not sufficient. It is further reported that empirical studies to measure individual adoption behavior in the SCM are scarce (Queiroz et al. 2020a).

For a detailed investigation on managerial perspective on BT adoption and to provide a comprehensive answer to the *RQ3*, we are bringing the following research proposal to the agenda by referring to the integrated Technology Acceptance Model (TAM) and Upper Echelon Theory (UET) considering four categories of blockchain adoption. While the TAM model is a popular tool for measuring adaptation to new technologies (Yang 2019), UET explains the management's role in the organizational success (Hambrick and Mason 1984).

RP 5. What are the effects of adoption barriers in governance and regulatory, economic, technical, and business ecosystems categories on the perceived usefulness (1) and perceived ease of use (2) of logistics managers regarding BT technologies?

5.3 *Theoretical lens*

There is increasing interest in BT studies within the academic community, while few studies discuss the subject on a theoretical level. Our finding at this point is that the theoretical grounds of the BT and SCM relationship were not contributed to in two respects. First, ROT has not received enough attention from SCM studies (Craighead, Ketchen Jr, and Darby 2020); there is no evidence of any effort to explain the BT phenomenon in the SCM through ROT. The subjects of disintermediation and the emergence of blockchain service providers as new intermediaries have recently been discussed (Tönnissen and Teuteberg 2020); herewith, ROT can adequately explain the BT service provider's role as a central orchestrator to increase efficiency across the SC. Further, the theory can also explain the BT service provider's role as a neutral orchestrator in ensuring interoperability between different team members in the SC. Due to the theory's potential to explain the BT phenomenon within the SC, the subject needs to be paid attention by researchers. In this context, the following research question is proposed:

RP6. As a new player in the supply chain, how can the BT service provider's role in improving efficiency be explained within the scope of ROT?

Second, although it is argued that new products and services will emerge due to the BT integration in SCM, while these possible innovations have not been discussed in a theoretical framework yet. In this context, the following research agenda is proposed:

RP 7. Based on Porter (1985)'s competitive advantage strategies, which new products and services will result in a competitive advantage due to the adoption of blockchain technologies to the supply chain?

5.4 *Academic implications*

The research dissimilarly offers several academic contributions through methodological novelty and theoretical contribution. From the methodological aspect, the Methodi Ordinarito is used as a systematic literature review technique for the first time in the BT research domain. More particularly, since the method allows to index high-quality papers considering their scientific relevance, the findings thus created a convenient portfolio of relevant papers, 95.78 % of which are included in the top-tier journals indexed in the SJR Q1 category.

Second, although the NN has been used to compare the before and after work routines and test new organizational designs, in this study, the NN analysis was used for the first time in BT research. The proposed framework differs this study from extant reviews as it is capable to visually present the story flow between BT constructs and potential interconnections in the wake of providing clues about the missing parts of the story. Consequently, we were able to go deeper into different constructs of the BT phenomenon, such as disintermediation and transparency, and proposed a research agenda to shed light on future research.

In terms of the theoretical contribution, this study initially set out to advance blockchain adoption in logistics and SCM literature through a detailed theoretical discussion, including dynamic capability view (DSV), information processing theory (IPT), resource orchestration theory (ROT), institutional theory (IT), and upper echelon theory (UET). By doing so, we have proposed a research agenda that significantly contributed to the theoretical grounds of future blockchain and SCM research. In a nutshell, the ROT has recently been acknowledged as a poorly employed theory in SCM studies (Craighead, Ketchen Jr, and Darby 2020). Therefore, to provide a concrete contribution to the issue, we brought a new discussion that the theory could explain the BT service provider’s role, as a neutral orchestrator, in solving the interoperability issues among SC members and achieving resource efficiency throughout the network.

In addition, the UET emerges as another theory capable of explaining BT-related interoperability through its approach to organizational leaders. Moreover, the UET has proven its potential to contribute to the theoretical groundings of leader-oriented technology adoption models. Nevertheless, UET remained underexplored in BT research. In this respect, we have enhanced our RP5 with UET to explore organizational leaders' adoption behavior and to contribute the theoretical discussion in BT and SCM research. To sum up, we suggested that BT in SCM research can significantly benefit from ROT and UET to understand the roles of top management and service provider in BT adoption.

5.5 Practical implications

One of the prominent practical contributions of the research is that BT implications on logistics and SCM are illustrated as a visualized network structure. Unlike traditional narrative inferences of the extant literature, the proposed framework is a powerful tool for visually demonstrating the evolving story of BT disruptions. Therefore, it is ensured that industry practitioners can evaluate the potential disruptions of the technology more clearly. At this point, the investigation of narrative networks based on a systematic and valid methodology is quite suitable for industry-oriented applications and can be used by practitioners.

Another practical contribution of the research is that adaptation barriers are determined in four distinct and well-designed categories, which provides a significant response to the *RQ3*. Therefore, by considering these four categories, firms can develop software-embedded analytical tools and evaluate their readiness for adaptation. In the transition to this new technology, to reveal and measure organizational readiness, a detailed mapping can include various factors. Accordingly, the proposed framework and adaption categories can be used by the firms implementing business process re-engineering (BPR) for BT adoption. Besides, the proposed research model provides a clear demonstration that managers should consider the potential risks of the technology and, above all, have a digital transformation strategy.

From an engineering point of view, the proposed framework provides significant guidance to engineers in production lines of the certain supply chain to demonstrate BT's enabling effect on intelligent manufacturing applications encompassing cloud manufacturing, cyber-physical systems, and digital twins. In this direction, BT is emerging as a crucial technology to resolve the credibility and security-related issues of the centralized production methods, particularly digital twins and cloud manufacturing applications. However, it has also been revealed that technical drawbacks originating from the consensus mechanism must be eliminated for BT to be fully implemented within the scope of smart production techniques and to provide its promised benefits. Therefore, it can be beneficial to develop efficient consensus algorithms such as Proof of Service Power (PoSP) proposed by Zhang et al. (2021).

5.6 Limitations and future research direction

This study evaluated BT adoption barriers in four categories: governance and regulatory, economic, technical, and business ecosystems; however, these categories require statistical validation. We suggest the statistical validation of these categories and their subsequent integration into the technology adaptation modeling methods in future studies. Second, NN analysis has been applied for the first time to analyze the structured literature review. For this purpose, the authors manually performed the data collection and extraction, but for practicality, UCINet and similar software may be preferred for future studies.

As another limitation of this study, since some theories were not sufficient to address the focus and scope of the study (e.g., force field theory of change), we just dealt with the limited number of suitable theories. Although this study is the first approach revealing that the NN analysis is capable of exhaustively disclosing both drivers and resisting forces of BT adoption in SC, it can further incorporate Lewin's force field theory (Lewin 1951), which emphasizes the equilibrium between forces to and against change. At this point, we suggest that examining the TOE and force field framework, previously proposed by Kouhizadeh, Saberi, and Sarkis (2021), can be enhanced by means of the NN methodology and, thus, a holistic decision mechanism can be established.

6. Conclusion

Blockchain promises substantial benefits for logistics and SCM, while industry pioneers have already started adopting the technology. For instance, IBM and Walmart established a BT partnership to improve food safety through a distributed contract platform (Dolgui et al. 2020); IBM further joined a partnership with Maersk for ocean transportation applications (Tönnissen and Teuteberg 2020). Deloitte in the agri-food business (Kayikci et al. 2020) and Everledger in the luxury supply chain (Bai and Sarkis 2020) are other examples of industrial initiatives of BT adoption. Nonprofit organizations also use blockchain for humanitarian purposes; the Building Blocks application of the World Food Program and the Blockchain Open-Loop Payments Pilot Project are two successful examples in practice (Ozdemir et al. 2020).

BT promises significant utility for manufacturing industries as the modern production systems are become shared, decentralized, and encompass the cooperation of various Industrial Internet of Things (IIoT) objects. Although advanced technologies such as cloud manufacturing, digital twins, and IIoT enabled cyber-physical systems to promise imminent operational efficiency, stand-alone use of such technologies has limited applicability to production lines due to data security or interoperability-related issues. At this point, BT is increasingly highlighted as a prominent information sharing layer and coordination mechanism to enable advanced production systems and methodologies. Herewith, this study addresses BT as an enabler of intelligent production and contributes to supply chain research.

In line with our results on recent intelligent manufacturing practices, we draw a major conclusion that manufacturers can consider an integrated BT and cloud manufacturing framework to deal with untrusted parties. Furthermore, such an integrated solution allows overcoming the disadvantages associated with the transmission of large amounts of digital twin data collected from various sources. However, the aforementioned integrated framework is required to be supported with efficient consensus algorithms to avoid excessive use of resources. In this point, this study provides a research proposal to contribute extant literature with a particular focus on BT in cloud manufacturing. Furthermore, BT-based information systems can reduce the vulnerability of cyber-physical systems, provide interoperability between different autonomous cyber-physical system objects, and be used within customized production. Today, IIoT, AI, and smart contracts incorporate customized intelligent innovations such as federated learning – AI algorithms are sought to be adopted by manufacturing industries to improve overall efficiency (Manimuthu et al. 2021).

However, despite all the efforts and enthusiasm shown in academics and practice, BT integration into the SCM has progressed slowly. To contribute to the extant literature and practitioners' efforts on integration, this research sets out to present the progress of integrating blockchain with logistics and SCM in three sub-categories: enablers, threats, and adoption barriers. In addition, the theorization of the blockchain and SCM relationship was also investigated in detail. Following our research aim, we adopted an integrated novel research design. The proposed research design allows an in-depth analysis of the BT disruptions and potentials in SCM as it provides a visual interpretation ability, including BT-enabled advanced manufacturing. At this point, we have interpreted BT's potential disruptions in SCM in detail and suggested a future research direction.

The proposed visual framework provides substantial clues to interconnectivity among the different constructs of BT that will result in positive and negative disruptions to SCM. Therefore, to adequately analyze the potential disruptions of BT, these interconnected relations should be considered, especially at the statistical analysis level. Concerning adoption barriers, more research is needed in order to evaluate BT adoption from a managerial perspective; UET theory can provide a sufficient theoretical basis in this regard. Finally, although not enough effort has been put into contributing to BT research on a theoretical level, ROT theory can contribute to this relationship on different grounds.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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