

Review

# Blockchain Technology for Sustainable Supply Chain Management: A Systematic Literature Review and a Classification Framework

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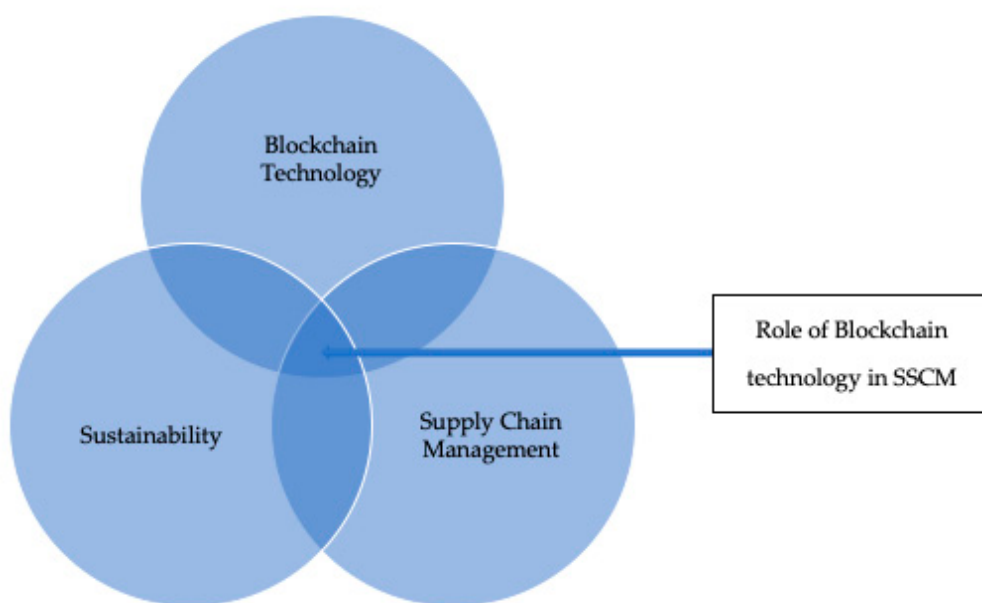


**Abstract:** Through a systematic review of publications in reputed peer-reviewed journals, this paper investigates the role of blockchain technology in sustainable supply chain management. It uses the What, Who, Where, When, How, and Why (5W+1H) pattern to formulate research objectives and questions. The review considers publications since 2015, and it includes 187 papers published in 2017, 2018, 2019, and the early part of 2020, since no significant publications were found in the year 2015 or 2016 on this subject. It proposes a reusable classification framework—emerging technology literature classification level (ETLCL) framework—based on grounded theory and the technology readiness level for conducting literature reviews in various focus areas of an emerging technology. Subsequently, the study uses ETLCL to classify the literature on our focus area. The results show traceability and transparency as the key benefits of applying blockchain technology. They also indicate a heightened interest in blockchain-based information systems for sustainable supply chain management starting since 2017. This paper offers invaluable insights for managers and leaders who envision sustainability as an essential component of their business. The findings demonstrate the disruptive power and role of blockchain-based information systems. Given the relative novelty of the topic and its scattered literature, the paper helps practitioners examining its various aspects by directing them to the right information sources.

**Keywords:** blockchain; sustainable supply chain management; information management; 5W+1H pattern; Technology Readiness Level; sustainability

## 1. Introduction

This review paper considers the three areas of research—blockchain technology, supply chain management (SCM), and sustainability. The research offers abundant resources to study each of these three topics. Previous systematic literature reviews focus on blockchain-based applications [1] and understanding the influence of blockchain technology on future supply chain practices [2]. As shown in Figure 1, the study focuses on the intersection between blockchain technology, SCM, and sustainability. While literature in this area started appearing in 2017 [3], to the best of our knowledge, this is the first systematic review of the subject. Furthermore, this study provides a systematic literature review (SLR) and a classification framework for the literature on the role of blockchain technology in sustainable SCM (SSCM).



**Figure 1.** Area of research interest.

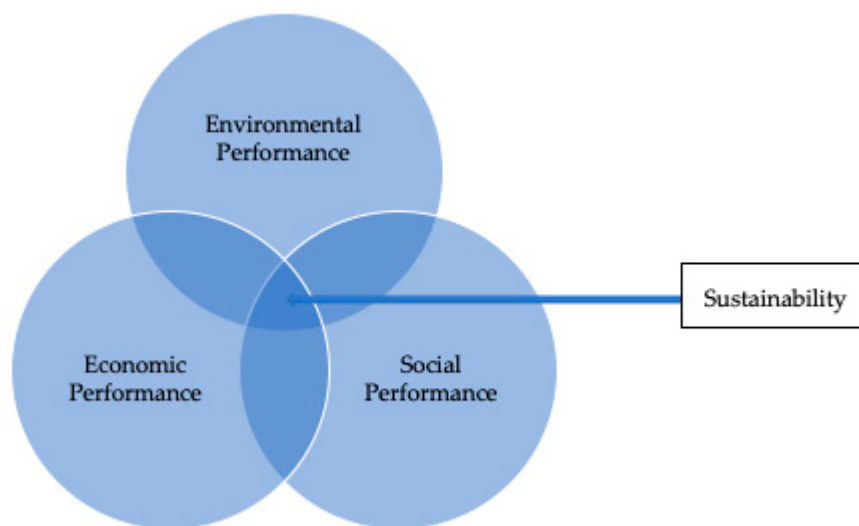
This paper begins with an introduction to blockchain technology. Subsequently, we introduce SSCM, owing to the study's focus on sustainability in the supply chain context. We also introduce how blockchain technology is relevant to SCM. With this background, we use the What, Who, Where, When, How, and Why (5W+1H) pattern to set the objectives and questions [4] that motivate the current research. This is followed by a description of the research methodology and the classification framework developed for studies on the role of blockchain in SSCM. Next, we present a discussion in terms of the aforementioned research objectives and questions. We conclude this review by highlighting our contribution and limitations.

The blockchain technology gained prominence because of its use in Bitcoin and the latter's prevalence, adoption, and rising price [5]. Today, cryptocurrencies, initial currency offerings (ICOs), and cryptocurrency exchanges have become common, with the emergence of a new cryptocurrency or an ICO becoming commonplace. Blockchain is the technology which provides foundations to develop a cryptocurrency like Bitcoin and also other cryptocurrencies, and it has been proven to be robust, efficient, and a secure means of exchanging currency. The broad use of blockchain for cryptocurrencies has led to its popularity and prompted an examination into its possible applications. Evidence shows that blockchain may revolutionize many fields, not just finance. The merits of blockchain technology for SCM and logistics have been studied for quite some time. These studies have proposed to use blockchain technology for managing the supply chains of companies in the fields of manufacturing, agriculture, food, pharmaceutical, e-commerce, airlines, hotels, and retail, as well as within the supply chains of many others sectors. The construct of smart contract has enabled the usage of blockchain technology in industries other than finance. Since 2016–17, the technology has been evolving in parallel with the development of various applications across various industries. Blockchain technology is considered an essential part of Industry 4.0, along with other technologies, like the Internet of Things (IoT) and Big Data. SCM can realize immense value with a blockchain network of supply chain participants like manufacturers, suppliers, retailers, and financial service providers. However, the inertia of existing supply chain theories and SCM business practices may be the cause behind the slow adoption of the technology in this area.

As a revolutionary technology, blockchain exerts a noticeable impact on society, law, and governance. Some of its applications, such as voting based on blockchain technology, have political implications. Blockchain has even impacted organizational design by creating the possibility of decentralized autonomous organizations. Concerning its use in cryptocurrencies, various countries have taken

different stances regarding Bitcoin, ICOs, and other blockchain applications. The positive aspect is that blockchain is not just one network, but comprises multiple networks with different consensus mechanisms and other specifications. There are multiple levels of tokenization that can help the adoption of certain blockchain networks; however, certain networks may be banned in more conservative or risk averse countries. Tokenization provides four key advantages to all investors and sellers—greater liquidity, faster and cheaper transactions, enhanced transparency, and increased accessibility. Tokenization is not an essential component of all blockchain-based applications. However, it is the key behind most of the disruptions in the financial sector, and it serves as a basis for ICOs. The role of blockchain in the supply chain is to act as an inter-organizational system; this starts with tracking the journey of products from raw materials to finished goods. Tokenization, low-energy-consuming consensus protocols, and smart contracts have added new dimensions to the potential of blockchain technology in SCM. This study provides a deeper dive into the benefits and applications of blockchain technology in SCM while reviewing the existing literature on the subject.

Economic performance, social performance, and environmental performance form the three pillars (Figure 2) of sustainability [6]. It is often a challenge for businesses to follow sustainability practices while delivering improved environmental and financial performance. The social performance calls for a democratic design where the rights and needs of all stakeholders are protected. There are long-term benefits for promoting sustainable development objectives, which are also referred to as the triple bottom line. While boosting its competitive advantage, an organization can engage in activities that have a positive environmental and societal impact [6]. This aspect must be analyzed in terms of supply chain activities. In this context, it must be noted that collaboration plays a crucial role in optimizing the flow of goods, information, and financial transactions. Very often, the supply chain participants have conflicting interests and priorities. There also exists a technological barrier of incompatible systems used by different parties to track shipments. Firms can address these challenges by integrating sustainability into their overall strategy. This will help firms to make a positive impact on the economy, society, and environment.



**Figure 2.** Sustainable supply chain management.

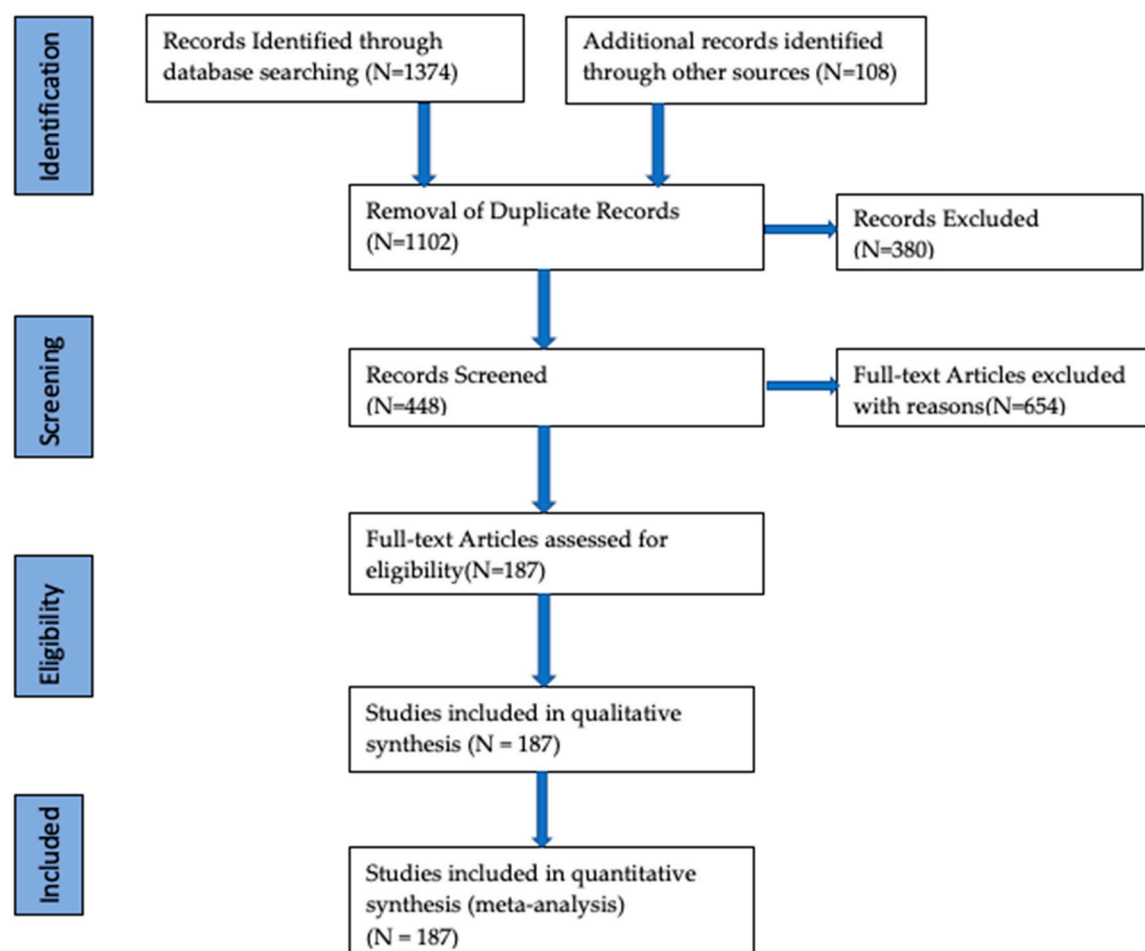
We address this aspect of sustainability through a set of research objectives and questions. The prior literature proposes a 5W+1H pattern for the formulation of research objectives and questions [4]. The 5W+1H stands for What, Who, Where, When, How, and Why. This pattern has been shown to help researchers survey a research area in a systematic manner. Using this pattern, we answer the following research questions:

1. What: What are the key findings of this literature review?

2. Who: Identify researchers in the area of our research interest and the most active researchers.
3. Where: Identify the journals that have published research in the area of our research interest.
4. When: Identify the span of time for which research has been conducted in the area of our research interest.
5. How: How is research in this area going to change the way business is conducted? Identify the new business models in this area.
6. Why: Why is it important for researchers to conduct research in this area? Why is it necessary to further examine this research area if it has already been studied in great detail? Identify the research gaps.

## 2. Research Methodology

This literature review follows the “Preferred Reporting Items for Systematic reviews and Meta-analyses” (PRISMA) checklist 2009 methodology [7]. This section clearly articulates guidelines regarding the inclusion or exclusion criteria of research papers to find relevant papers in our research area. We have also clearly mentioned how and to what extent the review was performed. The PRISMA flowchart for the research process is shown in Figure 3.



**Figure 3.** The “Preferred Reporting Items for Systematic reviews and Meta-analyses” (PRISMA) flowchart of the systematic literature review (SLR), based on PRISMA 2009 [7].

The search term used was “blockchain” + “sustainable supply chain management”. We exercised prudence while selecting the search terms. However, we acknowledge that our choice of terms and other selection criteria may have led to the exclusion of certain relevant articles from our review.

We referred to several sources while searching for relevant articles; few such sources include EBSCO Host, ProQuest, Directory of Open Access Journals, Springer Link, Emerald Open Access, Harvard Business Review, MDPI, and Science Direct. However, a search of MDPI, Science Direct, and ProQuest yielded most of the studies that satisfied our inclusion and exclusion criteria.

It is important to explain how we filtered through the numerous results. We set clear inclusion and exclusion criteria. The results were limited to “peer-reviewed” journal articles only. It was also limited to “full-text” journal articles that were available at a price or free of cost. We included “review articles” and “research articles” while excluding book chapters and other kinds of articles. Subsequently, we filtered the results by the list of journals by the MDPI list of open access journals, the Australian Business Dean Council (ABDC), the Institute for Scientific Information Clarivate, and the Association of Business School. MDPI was kept to ensure that we include high-quality open-access literature. The other lists were also included to keep the high-quality bar for the literature research, but not all of that is open access. This led to a high-quality list of about 448 journal articles. The “paid” articles were bought (whenever found to be of very high importance, based on a reading of the abstract) to make this literature review complete. Only articles published after 2015 were considered in this literature review, but relevant articles were found to appear only since 2017. This is not a strong exclusion criterion but a trend that we have witnessed. Our search on the topic of interest yielded limited results before 2017. A reading of the abstract/full text of these articles showed that they were not related to our research interest.

A preliminary examination of the manually selected papers showed the need to set some exclusion criteria because many articles were not directly related to our topic of interest. For the term sustainability, we accepted its various forms, such as “sustainable”, “sustain”, and “sustainability”. For blockchain, we accepted the term “distributed ledger technology”. However, of the 448 articles, only the author’s biographical information of some articles presented key themes like “blockchain”, “sustainability”, or “supply chain management”. While some articles supported the in-text inclusion of search keywords through citations, there is no discussion on the keywords, and the citations fail to add value to our theme. While a few articles mentioned the transformative capacity of blockchain and other emerging technologies, they did not discuss blockchain in particular. These papers were excluded from our detailed study.

We classified the literature based on a blended scheme derived from two well-known theories: Grounded Theory and Technology Readiness Level (TRL). Grounded Theory [8] is a systematic method based on reviewing the data collected, identifying repeated ideas, and tagging the concepts and elements with codes as they become apparent. These codes can then be grouped into concepts and categories. A classification of cloud computing research based on Grounded Theory is available as a case study [9]. The concept of TRL originated in the National Aeronautics and Space Administration (NASA) [10]. It was designed to track the maturity of technologies used in space missions. The European Union has created its own version of TRL for all technologies [10]. In academic circles, several authors have created variants of TRL and applied it to various assessment and classification needs. We began the process of classification with a Grounded Theory approach. However, once the concepts or subcategories were identified, we further classified them into high-level categories based on a variant of TRL, which we designed ourselves. To systematically reveal and examine insights on this relatively new topic, we developed a high-level literature classification scheme based on the TRL version used in Europe. The proposed classification scheme is termed emerging technology literature classification level (ETLCL).

A new researcher looking to begin research in an area typically wants to look at the literature which does one of the following:

- Introduces the researcher to the technology from a particular perspective;
- Introduces the researcher to the core offering or benefit of the technology;
- Raises the awareness of the researcher about early experimentation or adoption of the technology;
- Helps the researcher to assess the impact of the new technology;

- Helps the researcher or possibly a budding entrepreneur or a seasoned manager learn about the business environment in which the technology operates and how the technology may adopt to the business environment through sound business models;
- Helps the researcher/entrepreneur/manager learn about the key use cases or the applicability of the technology in the business;
- Helps the researcher/entrepreneur/manager understand how the technology is leading to sustainable development by creating sustainable practices in the business;
- Helps the researcher/entrepreneur/manager understand the state of art in research and business of the technology today;
- Helps the researcher/entrepreneur/manager understand big global success stories that have happened based on the technology.

It is very easy to understand that the abovementioned needs of the researcher are naturally very aligned to the level of technology readiness as identified by TRL. Based on the maturity level of blockchain at which a study has been conducted, we can classify it into one of the nine categories presented in Table 1. This scheme can be reused by other authors when classifying the literature on an emerging technology in any scenario.

**Table 1.** Emerging technology literature classification level (ETLCL).

Level	TRL in Europe	ETLCL
1	Observation of basic principles	INTRODUCTORY
2	Formulation of the technology concept	BENEFITS
3	Experimental proof of concept	EARLY EXPERIMENTATION AND ADOPTION
4	Validation of technology in a lab	IMPACT ASSESSMENT
5	Validation of technology in a relevant environment	BUSINESS ENVIRONMENT
6	Demonstration of technology in an operational environment	APPLICABILITY TO THE BUSINESS TODAY
7	Demonstration of system prototype in an operational environment	CREATION OF SUSTAINABLE BUSINESS
8	Completion and certification of a system complete	STATE-OF-THE-ART IN BUSINESS
9	Verification of the actual system in an operational environment	BIG GLOBAL SUCCESS STORIES

TRL = Technology Readiness Level.

Therefore, the authors have proposed this ETLCL systematic research classification framework and used in this paper as a case study. Our classification framework differs substantially from a framework that one may derive when working end-to-end, based on Grounded Theory. Our classification scheme scores over other theories or frameworks for the literature classification, as technology readiness, is one of the first aspects that one considers before beginning to review the research articles. This is especially true for emerging technologies.

The nine levels of ETLCL may be explained as follows:

- INTRODUCTORY: This level consists of introductory articles that create awareness of the various aspect of the emerging technology. It may take a look at the technology from various perspectives. It may also delve into the hype behind this new technology.



- (b) **BENEFITS:** This level consists of articles on the benefits of using blockchain. They study the primary reason the technology should be further researched and investigate the use cases. In short, this level answers the question of why blockchain technology should be given attention.
- (c) **EARLY EXPERIMENTATION AND ADOPTION:** This level consists of articles describing early experimentation and lessons learned from them. They examine the growth factors and barriers. In short, this level identifies the key use cases and the experiments conducted in this regard.
- (d) **IMPACT ASSESSMENT:** This level consists of articles assessing the long-term impact of blockchain technology. They may be based on the success and failure stories from the previous level of research articles.
- (e) **BUSINESS ENVIRONMENT:** This level consists of articles on the business environment in which blockchain technology will have to operate. They may identify legal and technical challenges. They may also identify the business models that might be successful in such a business environment.
- (f) **APPLICABILITY TO THE BUSINESS TODAY:** This level consists of articles identifying how technology is being used for influencing business in today's environment.
- (g) **CREATION OF SUSTAINABLE BUSINESS:** This level consists of articles on blockchain technology's advantages, limitations, and scope. They look at the sustainability (environmental, social, and economic performance) aspect of the businesses based on this new technology.
- (h) **STATE-OF-THE-ART IN BUSINESS:** This level comprises articles studying the current state of the evolution of blockchain technology. They examine the technology's maturity through the lens of having clear standards and policies. They also look at the performance and research gaps if any.
- (i) **BIG GLOBAL SUCCESS STORIES:** This level comprises articles on the globally relevant examples of the successful applications of this new technology.

Apart from doing classification of the research literature and presenting an overview within the classification framework, we also used 5W+1H methodology to derive our results. The research questions were formulated in the previous section, using the 5W+1H pattern. The 5W+1H pattern has been a tool of journalism for long. This method is particularly useful when doing a broad study of a relatively new research area [4]; blockchain is an emerging technology, and its application in SSCM is a relatively new research area. Therefore, this approach elegantly fits our need of a guiding research methodology for this systematic literature review.

### 3. Results: Development of a Classification Framework

The classification is based on 187 research/review articles remaining after the filtering processes. We could not find any paper on ETLCL 9. For the better presentation of and natural affinity between certain papers, we further categorized papers into one of the 39 subcategories. Table 2 shows the classification of the 187 articles in eight top-level categories (from ETLCL 1 to ETLCL 8) and 39 subcategories. This will help us to group papers with a similar theme, and thereby organize the presentation.

**Table 2.** Classification of research literature.

Classification	Sub-Classification	Relevant References
ETLCL 1: INTRODUCTORY	Historical/Futuristic	[11–13]
	Multidisciplinary	[14–16]
	Maturity	[17]
	Socio-Technical	[18]
ETLCL 2: BENEFITS	Traceability	[19–32]
	Transparency	[33–40]
	Trust	[41–44]
	Digital Identity	[45]
	Frictionless Collaboration	[46]
	Anti-Counterfeiting	[47–51]

Table 2. Cont.

Classification	Sub-Classification	Relevant References
ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Growth Factors and/or Barriers	[52–64]
	Assessment and/or Customization	[2,65–75]
	Cryptocurrencies	[76–78]
	Review	[1]
ETLCL 4: IMPACT ASSESSMENT	Forecasting	[79]
	Disruption/Digital Transformation	[80–90]
	Industry 4.0	[91–100]
ETLCL 5: BUSINESS ENVIRONMENT	Business Model	[101–108]
	Legal and Governance	[109–114]
	Policy and Regulation	[115–117]
	Sharing Economy	[118]
	Theory	[119–122]
ETLCL 6: APPLICABILITY TO THE BUSINESS TODAY	ICO	[123,124]
	Risk Management	[125–127]
	Smart Contracts	[128–133]
	Modeling/Pilot	[134–138]
ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Advantages	[139–146]
	Limitations/Barriers	[147–154]
	Performance	[155–162]
	Environment	[163–168]
	Social Innovation/Financial Inclusion	[169–171]
	Supply Chain Finance	[172,173]
	Sustainable Development Goals	[174,175]
ETLCL 8: STATE-OF-THE-ART IN BUSINESS	Accounting/Auditing	[176,177]
	Launched Projects	[178–185]
	Research Gap	[186–188]
	Risk	[189–192]
	Standards	[193]
	Trends	[194,195]

ICO = initial currency offerings.

Table 3 shows the bi-modal distribution of the number of papers in the top-level classes. Most research articles are at ETLCL 7 or ETLCL 2. There is no article at ETLCL 9, as it does not have a prominent success story in the area of our interest. Although blockchain's application in Bitcoin has been highly successful, we do not have a notable success story of blockchain in SCM or SSCM that proves its worth in the SSCM context globally.

Table 3. Number of papers in each top-level class.

ETLCL 1	8
ETLCL 2	33
ETLCL 3	29
ETLCL 4	22
ETLCL 5	22
ETLCL 6	16
ETLCL 7	37
ETLCL 8	20
ETLCL 9	0



### 3.1. ETLCL 1: INTRODUCTORY

Table 4 shows the distribution of the research papers in this category.

**Table 4.** Subcategories at ETLCL 1.

Historical/Futuristic	3
Multidisciplinary	3
Maturity	1
Socio-Technical	1

#### 3.1.1. Historical/Futuristic

On a historical perspective, blockchain research has progressed from “Bitcoin” to “smart contract” to “proof of stake” to current research in blockchain scaling [11]. Concerning future trends, the current trend involves lowering the transaction costs for the blockchain networks [12]. It is estimated that a decline in transaction costs past certain threshold values will lead to severe disruption in business. It is predicted that the disruption will be in the form of sudden, dramatic, hard-to-predict aggregations and dis-aggregations of existing business models. Some studies also speculate that changes due to blockchain technology may be as large as the invention of the Internet. Blockchain technology has received more attention from technology focused researchers than that from information systems and information management researchers [13]. It is predicted that research in blockchain technology can contribute toward the UN sustainability development goals and disrupt industries and business practices. It is predicted that the adoption of blockchain applications will be sector-specific and not industry-wide. These sectors include finance, logistics, and supply chain.

#### 3.1.2. Multidisciplinary

Applications can combine blockchain with machine learning [14] and also artificial intelligence (AI). It is indicated that this combination of technologies would help systems to achieve continuous improvement, provide a faster and better response to disruptions, and make predictions about potential failures. Applications can combine blockchain with artificial intelligence as well [15]. In particular, blockchain can improve the quality of training data for an AI system. Given the developments in the fields of IoT, the adoption of smart products based on IoT and other technologies may require systems with high data integrity and user privacy, which can only be provided by blockchain technology [16].

#### 3.1.3. Maturity

Using the concept of Gartner’s “hype cycle” to assess the maturity of blockchain technology, it is opined that blockchain technology is currently at the peak of the “hype cycle” and anticipates that its next stop would be the “trough of disillusionment” [17]. Analysts agree that the creation of a “trust model” of the entire system is a precondition for allowing the existing platforms of any of the enterprises to reach any real level of maturity.

#### 3.1.4. Socio-Technical

Blockchain research is still at a trial stage [18]. It considers the blockchain network as a socio-technical system. It is difficult to predict how socio-technical systems evolve. Historical and lexical analyses suggest that blockchain technology can disrupt how the supply chain operates through changes in provenance and a chain-of-custody [18].

### 3.2. ETLCL 2: BENEFITS

Table 5 shows the distribution of the research papers in this category.

**Table 5.** Subcategories at ETLCL 2.

Traceability	14
Transparency	8
Trust	4
Digital Identity	1
Frictionless Collaboration	1
Anti-Counterfeiting	5

### 3.2.1. Traceability

Blockchain facilitates secure online transactions; it also shows promise in tracing unregulated fishing, right from the time it is caught to the time it reaches the consumers, and thus contributes toward fulfilling targets 14.1 to 14.5 of the sustainable development goals of the United Nations [19]. The emergence of blockchain technology appears to be a tailor-made solution for improving traceability in the supply chain [20]. From a customer perspective, product information, including origin, production, modifications, and custody, provides much-needed assurance to the customers [21]. The aspect also addresses the need for traceability in Halal food supply chains, which have highly complex to rigorous product segregation practices. Traceability as one of the key measures of operational efficiencies [22]. In this context, it must be noted that, traditionally, firms focused on quantity-oriented production. However, responding to the need for low-cost infrastructure and a scalable, flexible, and standardized solution, firms have been shifting toward quality, safety, sustainability, and functionality-oriented production. In a supply chain (SC), from a quality-assurance perspective, while it is desirable to trace each ingredient of the end product, it is difficult to ensure the same because of the varying interests and priorities of the stakeholders [23]. This aspect highlights that the successful application of blockchain technology requires the standardization of traceability processes and interfaces. Blockchain technology replicates data across all mining nodes, which could be in the thousands; hence, blockchain-based data storage is considered expensive. Therefore, it is advisable to store only essential information for an effective and energy-efficient system. Traceability and sustainability-related information would require new and innovative business models, which can create a competitive advantage. In this case, it is also essential to consider other factors influencing traceability. In the textile and clothing supply chain following factors are identified that influence traceability implementation: risk management, product authentication, and visibility [24]. Food falsification results in both economic losses and low consumer confidence [30]. Traceability is applicable in food items, also enabling us to track food from farms to shelves through blockchain technology [25,28]. Consumer preferences differ with regards to three technological systems supporting traceability, namely Near Field Communication (NFC) [32], Radio Frequency Identification (RFID), and Quick Response (QR) code particularly due to the cost impact associated with the adoption of these complementary technologies [26]. In the case of extra virgin olive oil, a complete electronic traceability prototype has been developed [27]. The integration of product attributes information and traceability information is often referred to as infotracing [29]. Blockchain technology can enable traceability of wood from a planted tree to the final user [29]. The traceability advantage of blockchain technology is an excellent enabler for smart cities with efficient supply chains and dynamic business interactions [31].

### 3.2.2. Transparency

Blockchain technology can address the question of how to enhance accuracy and transparency while moving goods through a global supply chain [33]. Blockchain and smart contracts can be applied to the price-tracing systems of SCM [34]. The potential of this application has been demonstrated in enhancing the transparency of the product distribution structure. Blockchain technology is expected to revolutionize supply chain transparency and product verification [35]. Blockchain allows us to store easily auditable provenance knowledge securely. Integration of blockchain in the supply chain architecture

can lead to a more transparent, reliable, authentic, and secure system [36]. Data-driven management, which provides transparency of crucial information like production practices, is a big issue in pig production [37]. Blockchain technology allows easy implementation of transparency features among multiple parties by compilation and verification of information [38]. Because of the benefit of real-time transparency, blockchain technology is a recommended tool for sustainability in the manufacturing industry [39]. Transparency as an extrapolation of “trust” is needed both inside and outside the government, for more participative decision-making processes in the sustainable supply chains [40].

### 3.2.3. Trust

A single version of the truth is a revolutionary concept considering how supply chains operate today [41]. The potential of blockchain to create trust resonates strongly in the supply chain world, where a lack of trust is a significant barrier for collaboration [43]. “Trust” has been identified as the blockchain’s most significant advantage, from a supply chain perspective [42]. A blockchain can replace the burden of proof that users need while exchanging information, and this could unlock huge efficiencies. Cyber-physical systems that enable modern supply chains can gather trust and security in transactions through blockchain technology [44].

### 3.2.4. Digital Identity

Blockchain networks can store various kinds of important information and provide a digital identity. Immutable document exchange networks have begun to emerge in global trade. Such a digital identity will change societal views on identity, privacy, and security. Hence, the digital identity will work as a primary construct for the stakeholders in the supply chain [45].

### 3.2.5. Frictionless Collaboration

Frictionless collaboration accelerates cycle times and enhances operational efficiency by improving internal coordination and supplier performance [46].

### 3.2.6. Anti-Counterfeiting

VeChain is designed as an anti-counterfeiting technology for the fashion industry. VeChain employs blockchain technology; it enables consumers to verify a product’s information through a mobile app that communicates with the VeChain chip placed inside the item, using the near field communication technology and public-key cryptography [47]. Any compromise to the healthcare supply chain affects the well-being of the patient [48]. Blockchain can eliminate the problem of fraudulent attacks, as records can be updated only through smart contracts. Annually, USD 200 billion is lost to counterfeit drugs, and the only blockchain is being vouched as a possible solution to bring a unified tracking system which can prevent such counterfeiting [49]. The human and financial loss due to errors in the medication supply chain can bring a fresh wave of security in the healthcare sector. Blockchain shall be central to such a strategy [50]. The sustainability of extra virgin olive oil is connected to certifications. Consumer’s behavior, however, is tied to information exchange between consumer and other supply chain participants. The development of blockchain technology-based solutions to improve this information exchange from a managerial and political point of view shall lead to the prevention of fraud [51].

## 3.3. ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION

Table 6 shows the distribution of the research papers in this category.

**Table 6.** Subcategories at ETLCL 3.

Growth Factors and/or Barriers	13
Assessment and/or Customization	12
Cryptocurrencies	3
Review	1

### 3.3.1. Growth Factors and/or Barriers

The rapid internationalization of blockchain start-ups is based on three factors—network effects, solving the chicken-and-egg problem, and building an ecosystem around the evolving technology [52]. The effects of various variables on blockchain adoption for SCM of small and medium enterprises (SMEs) in Malaysia have been investigated [53]. Competitive pressure, complexity, cost, and relative advantage were found to be significant variables. On the other hand, variables that were found to be insignificant include market dynamics, regulatory support, and upper management support. The features of immutability and transparency make blockchain technology essential for SMEs' sustainability. The industry-wide adoption of blockchain occurs either via the ICO route or as an immutable ledger. Similar to any new technology, blockchain faces adoption barriers owing to entrenched interests and other technical factors like scalability, energy consumption, and trust [54]. Investment in server infrastructure and the addition of specialized resources for development and governance keeps companies from adopting blockchain after the proof-of-concept stage [55]. However, it must be noted that the adoption is expected to increase subsequent to the introduction of blockchain-as-a-service (BaaS) offerings by the large cloud providers. BaaS eliminates the need for investment in supporting infrastructure and blockchain developers. The various factors that determine the cost of setting up a blockchain infrastructure are as follows: the number of transactions that are processed, the required transaction speed, and the costs incurred to deploy IoT sensors to track physical goods and environmental conditions [55]. Concerning adoption behavior, a study reveals different behaviors between India- and US-based professionals in adopting blockchain for SCM [56]. The study concludes that more countries and contexts should be investigated before making generalizations on the adoption behavior. Blockchain will result in an integrated system comprising enterprises, logistics partners, and banks, and hence will facilitate a reduction in delayed and costly payment gaps [57]. It will also impact variables that can increase the supply chain sustainability, like reduction in the working capital requirements and simplified financial operations. In industries already impacted by blockchain, SCM practitioners will face competitive pressure to use this technology [58]. However, in industries where costs and risks outweigh the benefits, the adoption will be delayed. The following barriers to blockchain adoption in SCM have been identified: governance, collaboration, interoperability across private and public blockchains, legal and scalability challenges, market-based risks, high sustainability costs, and poor economic behavior [60]. However, the development of the distributed ledger technology (DLT) has addressed the aforementioned scalability challenges. Many DLTs are likely to coexist, and blockchain exchanges facilitate cross-DLT transactions. Many corporations and start-ups are attempting to apply blockchain throughout the global supply chain [59]. The most critical use cases seem to be the transfer of titles, recording permissions, and logging activities for tracking. Global supply chains have always influenced the adoption and development of financial instruments [61]. Blockchain technology is already being adopted to finance items in supply and to settle financial claims. Improved transparency in the supply chain is a major growth factor for adoption of blockchain technology [62]. In a study of the Norwegian offshore industry, main drivers for blockchain innovation discovered were (a) cost reduction, (b) high regulation, (c) large amount of data to process, and (d) intention to work more effectively [63]. The same study notes the barriers as (a) high cost of blockchain technology implementation, (b) poor quality Internet at site, (c) low technology diffusion, and (d) aversion to risky investments [63]. The motivations behind adoption of blockchain technology are both economic and social [64].

### 3.3.2. Assessment and/or Customization

Blockchain will gradually revolutionize businesses [65]. This is because blockchain is a foundational technology that requires technological, regulatory, and social coordination for implementation. Organizations can develop their blockchain capabilities by starting with single-use applications and gradually progressing toward more complex, novel, and transformative applications. While designing a blockchain-based supply chain system, key activities are selecting a blockchain's entry point in the SC, building a blockchain ecosystem, articulating the platform value, establishing the governance model, exploring legal implications, and scaling up a blockchain-enabled supply chain network [2]. Blockchain platforms aim to achieve decentralized governance [66]. While smart contracts and tokens digitize all points of conflict, collaboration is required to arrive at a consensus regarding the rules that need to be digitized. Blockchain-based disruption in supply chain transactions can be attributed to cost and dependency reduction [67]. However, blockchain changes the power distribution, which might come with disadvantages. Hence, firms should use empirical evidence to improve the assessment of blockchain usage in the supply chain. Determining what kind of blockchain to use and how to customize it poses the most significant barriers to the initiation of a blockchain project [68]. In the context of a luxury SC, the usefulness of a BT-supported certification platform for diamond authentication and certification need to be emphasized [69]. Businesses also face choices about which of their applications are a better fit for public or private blockchains. The adoption of private blockchains is gaining momentum due to the business risks associated with public blockchains [70]. Public blockchains are open for all participants ("permission-less") and completely decentralized, while the private blockchains are closed ("permissioned") with elements of centralized control [73]. Private blockchains are especially useful when multiple parties who do not fully trust one another operate together in one supply chain [70]. When adopting the technology, some of the questions that demand planners should answer are as follows: (a) What are the products that can benefit from blockchain technology? (b) Is there a need to employ smart contracts? (c) How to identify rules for creating a digital chain of command? Similar to other technologies, blockchain should be adopted based on its ability to satisfy a need [72]. The choice and implementation of features and functionalities should be linked to such a need. This should also coincide with the identification or creation of an appropriate variant of the technology. When adopted along with value drivers, blockchain can multiply advantages across the business. Blockchains provide information on planning replenishment and order-promise dates, thereby contributing to supply chain efficiency [71]. Engagement, technology novelty, local context, alternative technologies, and technology alteration are five essential principles to make appropriate use of blockchain technology [75]. It is vital to find what to adopt with regards to blockchain technology and identify the right business opportunity [74].

### 3.3.3. Cryptocurrencies

Most use cases of blockchain in SCM require the use of a token/cryptocurrency [76]. These findings show SCM to be the critical area promoting the accelerated adoption of blockchain. New consensus protocols like proof of stake have emerged in recent years [77]. It is predicted that mining would be loss-making in the future due to the consensus mechanism of the Bitcoin protocol, which incurs higher hardware and energy costs for the miners. Higher payments for miners are needed for financial sustainability. Moreover, more energy-efficient algorithms are required for consensus for environmental sustainability. Therefore, the tokens/cryptocurrencies should be carefully designed before Bitcoin or some other cryptocurrency is adopted in supply chain finance. The use of the latest technologies has created new jobs and business models within the consumer and supply chain finance domains [78]. Many hedge funds, angel investors, and venture capitalists are having stakes in blockchain companies and ICOs or pre-token sales. These findings show the financial sector has been slow to realize the potential of blockchain; similarly, the blockchain industry has also been slow in understanding the power of being inclusive.

### 3.3.4. Review

Systematic literature reviews of blockchain-based and blockchain-enabled applications review a selection of applications ranging across diverse sectors of business, including the supply chain [1].

### 3.4. ETLCL 4: IMPACT ASSESSMENT

Table 7 shows the distribution of the research papers in this category.

**Table 7.** Subcategories at ETLCL 4.

Forecasting	1
Disruption / Digital Transformation	11
Industry 4.0	10

#### 3.4.1. Forecasting

Supply chain members can improve the demand forecasting by making use of the transaction data stored in the blockchain in the fashion industry [79].

#### 3.4.2. Disruption/Digital Transformation

Digital technologies disrupt markets by multiple means—combining/recombining existing products and services, lowering barriers to entry, and hindering the sustainability of the competitive advantage of incumbent players [80]. By using technologies like AI and blockchain, a firm can transform its cost structure by optimizing logistic streams and reducing the length of its supply chain [81]. For example, a car-sharing lending platform can rely on blockchain, smart contracts, and global positioning systems [82]. A blockchain-enabled car rental ecosystem can allow platform users to rent their cars and determine the terms and conditions of use independently. It is expected to result in a more competitive market. Blockchain will transform business and management by eliminating transaction costs and promoting the use of both internal and external resources [83]. Multiple surveys of supply chain professionals conducted on a 10-year horizon found that one-third of the respondents believed in the potential of blockchain to create a competitive advantage and that about 10% of the respondents viewed blockchain as a potential disruptor of their industry [84]. In a short-term horizon, 7% of respondents said they would surely invest in blockchain, while under 50% of respondents were unsure. Blockchain technologies can address Physical Internet obstacles [85]. Blockchain technologies pose direct threats of disruption to organizations acting as intermediaries between transaction parties [86]. Blockchain will also disrupt the SCM sector when it is combined with IoT. Given this, blockchain facilitates collaboration between businesses, thereby strengthening and extending supply chains [86]. Blockchain technology creates a secure and visible chain of custody for all members of the supply chain [87]. It is recommended for organizations to adopt the following disruption prevention mechanisms: appointing a visionary leader for technological decisions, creating a technology roadmap that is aligned with the organization's supply chain processes, and updating all information systems, even those at a foundational level [88]. Blockchain, together with Big Data and cognitive computing, has a significant potential to disrupt many of the current practices in routine disease surveillance systems and the strengthening of healthcare research [89]. Physical Internet is a comprehensive framework that provides the opportunity to change design, structure, and management of modern supply chains impacting triple bottom line sustainability [90].

#### 3.4.3. Industry 4.0

The collaboration mechanism of the SCM information system is expected to be impacted by blockchain technology [92]. Blockchain will change the process and consensus collaborative management mechanism. This is expected to optimize transaction process management, blockchain system consensus, and accounting, among others. The paper discusses a platform architecture design



of a data transaction system that is integrated with a new collaboration mechanism based on the blockchain [92]. Concerning the literature on Industry 4.0, the textual and google trends data from 2010 to 2018 show Industry 4.0 trending in SCM [95]. Industry 4.0 comprises technologies that facilitate connectivity and communication between numerous devices; this aspect raises concern for sustainability [93]. The prospect of digitalization overlaps with the design principles of Industry 4.0 and impacts procurement and supply digitalization [94]. Blockchain technology is the part of Industry 4.0 that ensures traceability, transparency, trust, fault tolerance, immutability, tamper prevention, and data integrity; these fundamental benefits are reaped by a supply chain that uses a blockchain-based solution [91]. Blockchain secures transactions and increases the efficiency and transparency of supply chains. Blockchain ensures the same version of the ledger for everyone, thereby preventing any disputes [96]. Blockchain technologies can change the actor structure within supply chains. Synergies exist between information management and SCM for designing a modern supply chain for Industry 4.0 [97]. In Industry 4.0, blockchain can operate as the ledger and provide cryptocurrencies for fast and frictionless financial transactions between different components of smart factories, suppliers, and even customers [98]. The blockchain can coordinate data flow between distinct systems of the company, which may be based on IoT and AI. This will change the strategic role of Chief Financial Officer (CFO) of the company and hence competency of the CFO will be a prerequisite for adoption of blockchain-based information systems [99]. Blockchain is set to reshape business models when integrated with Industry 4.0 [100].

### 3.5. ETLCL 5: BUSINESS ENVIRONMENT

Table 8 shows the distribution of the research papers in this category.

**Table 8.** Subcategories at ETLCL 5.

Business Model	8
Legal and Governance	6
Policy and Regulation	3
Sharing Economy	1
Theory	4

#### 3.5.1. Business Model

Supply chain is the most important non-finance application of blockchain [101]. Blockchain solutions can be integrated into existing value networks. In order to assure a single version of the truth, it is essential to facilitate interoperability between Enterprise Resource Planning (ERP) systems of all participants in the blockchain solution. A service provider can offer an integrated system of IoT devices and blockchain network. The critical challenge is to integrate every participant's ERP systems with the blockchain solution, thereby assuring a single version of the truth. A blockchain-enabled business platform highlights the trend of peer-to-peer collaborative consumption, analytically proving its benefit for the platform and the consumer [102]. From the platform perspective, the revenue sharing scheme is found to be better than fixed service charging. In the blockchain technology era, a change in the service SC's information structure affects operations efficiency, thereby creating the possibility of new business models and disruptions [103]. For both start-ups and incumbents, DLTs can enable new business and operating models. The ability to track provenance can add value by reducing the amount of inefficiency and lack of clarity in supply chains [104]. A case study on five Chinese companies that have started blockchain initiatives offers insights into their value creation logic and value capturing mechanism [105]. It also highlights the challenges that can threaten the long-term viability of these companies. SYNCHRO-NET is a Horizon 2020 European research project which aims to remove the vulnerability of international supply chains. It utilizes the benefits of smart-streaming and synchro-modality transportation strategies together with the related business

models. BIC (Blockchain-Internet of Things-Cloud) technology layer is an opportunity to upgrade the SYNCHRO-NET system [106]. A study of logistics and manufacturing companies in Finland and Russia found blockchain as an immature technology to base business models upon [107]. Adoption of blockchain technology requires businesses to rethink and redesign the full business model of agriculture and food supply chain, especially in the Covid-19 scenario [108].

### 3.5.2. Legal and Governance

Lawmakers should consider legal and illegal practices while leaving room for experimentation. Both excessive and limited legal intervention can adversely affect the blockchain revolution [109]. From a legal standpoint, blockchain improves data reliability and eliminates fraudulent activities. However, this can be realized only through effective governance and legal frameworks [110]. In this context, it should be noted that laws about blockchain technology are still at an evolutionary stage. However, developed legal frameworks are expected to influence operational and production practices [111]. Providing stakeholders with access to verified information during the product's life cycle can also contribute to improving the firm's social performance. Concerning challenges, the governance of a blockchain network is decentralized, and therefore it is likely to encounter political pressure and regulatory intervention [112]. Users will also find it difficult to trust the "code" instead of their government. It is also difficult to get stakeholders' consensus on changing network rules. However, technology has been able to address challenges in the area of copyright enforcement. Blockchains and blockchain-based smart contracts are expected to help in the administration and enforcement of copyright [113]. There are three governance strategies that countries may use: (a) industry-driven, (b) precautionary and preemptive, and (c) active surveillance [114]. The governance strategies influence and differentiate the response to digitalization sustainability threats.

### 3.5.3. Policy and Regulation

Blockchain is more than a disruptive technology, as it changes people's relationship with the state and can significantly transform economic, legal, and political systems [115]. The adoption of blockchains to larger scenarios and its ability to disrupt can lead to unintended consequences, attracting regulatory intervention. Various aspects of regulation have been studied by using both public-value theory and stakeholder theory [117]. Token exchanges on blockchain to be regulated to prevent money laundering and terrorist financing. Regarding policy, we focus on consumer policy. Prosumerism considers consumers who are also involved in the design and production of products. In this regard, the United Nations Guidelines on Consumer Protection highlights the duty of consumers to act responsibly by promoting sustainable consumption patterns. Information provision can assist consumers in consuming sustainably [116]. Blockchain can help consumers fulfill the aforementioned objective of consumer policy.

### 3.5.4. Sharing Economy

The algorithmic management of sharing-economy platforms has led to information asymmetry [118]. Labor platforms like Uber present more evidence of the negative consequences of reliance on algorithms. However, capital platforms, like Airbnb, showcase positive results. Uber is facing several lawsuits in which its drivers claim to be employees. Although Uber refers to drivers as partners or customers, it controls their working conditions. Blockchain technology can change this power imbalance through blockchain applications that allow individuals to coordinate without a third party [118]. ArcadeCity is one example of a decentralized carpooling platform. Blockchain technology can contribute toward the creation of organizations that would facilitate equal distribution of value in the sharing economy [118].

### 3.5.5. Theory

In the absence of the sensemaking process, supply chain organizations would have been less proactive in reacting to changes and responding to challenges accompanying disruption, the implementation of blockchain initiatives, and strategic growth at an organizational level [119]. Sensemaking theory drives them to design blockchain systems that are more suitable for their supply chains. To understand the role of blockchain in SCM, the network theory, principal-agent theory, resource-based view, and transaction cost analysis have been applied [120]. Transaction cost theory has been utilized to understand how blockchain might influence transaction costs and governance decisions [121]. It is argued that blockchain in SCM could enable truly sustainable Supply chains. The literature of blockchain in SCM and logistics is found to be based on six organizational theories: (a) agency theory, (b) information theory, (c) institutional theory, (d) network theory, (e) resource-based view, and (f) transaction cost analysis [122].

### 3.6. ETLCL 6: APPLICABILITY TO THE CURRENT BUSINESS SCENARIO

Table 9 shows the distribution of the research papers in this category.

**Table 9.** Subcategories at ETLCL 6.

ICO	2
Risk Management	3
Smart Contracts	6
Modeling/Pilot	5

#### 3.6.1. ICO

ICOs can create a new source of funding for entrepreneurs [123]. They can allow entrepreneurs to raise funds from small and big investors across the globe. They can also a source of social finance by providing blockchain-based tokens; the tokens are expected to either exercise governance rights or be immediately tradeable [124].

#### 3.6.2. Risk Management

Blockchain is the key technology to improve transaction security in the financial/banking industry [125]. Blockchain can contribute toward overcoming information symmetry and reducing the risk management capability of enterprises [126]. It also provides a basis for the application of blockchain technology to mega projects for supply chain risk management. Based on the transparency attribute of blockchain technology, the mean conditional value at risk is used to describe the risk-aversion behavior of retailers [127].

#### 3.6.3. Smart Contracts

Smart contracts are a piece of software code that contains instructions for executing agreements among stakeholders. While this offers numerous advantages and applications, it comes with the problem of fitting with the traditional contract law [133]. The use of blockchain technology in conjunction with manufacturing plants that implement cyber-physics systems has been suggested [128]. In such scenarios, the system can automatically process an order for equipment replacement, thereby automating supplier selection, among others. Coding conditions in the smart contract can also trigger the payments. Smart contracts can be effectively used for creating synchro modality in logistics, thereby facilitating highly efficient, reliable, flexible, and sustainable services [129]. With smart contracts, stakeholders' liabilities can be defined clearly and transparently. The legal nature and reliability of smart contracts and argue that they offer a much better solution than traditional contract law for facilitating trade [130]. A blockchain-enabled smart-contracts-based framework can derive the possible benefits of the supply chain process design [131]. TransICE, an open platform, applies smart contracts

to (a) shipment pricing and scheduling process, and (b) pickup, shipping, and delivery process in the Integrated Casinos and Entertainment industry [132].

### 3.6.4. Modeling/Pilot

Blockchain, as a service, can be developed by software professionals, particularly by the ERP and cloud-computing companies [134]. Concerning its implementation, traceability is the most significant reason for blockchain technology's implementation in agricultural SC, followed by auditability, immutability, and provenance [135]. It helps the practitioners to design the strategies for blockchain technology-based projects' execution and implementation in agriculture, thereby ensuring food safety and sustainable agriculture supply chains. Permissioned blockchains can contribute to increasing an organization's profitability [136]. It is important to classify the applications of blockchain technology in the scope of operations and SCM [137]. IBM is using blockchain as a next-generation supply chain tool [138]. Three profitable pilot projects have been done by IBM in its supply chain. In the first pilot project, IBM worked with hard drive supplier Seagate to guard against counterfeits. In the second project, it focused on collecting real-time visibility and other asset data about shipments and individual parts in the IBM supply chain. Blockchain significantly improved parts traceability. In the third project, IBM applied blockchain technology to enhance and expedite customs clearance.

### 3.7. ETLCL 7: CREATION OF SUSTAINABLE BUSINESS

Table 10 shows the distribution of the research papers in this category.

**Table 10.** Subcategories at ETLCL 7.

Advantages	8
Limitations/Barriers	8
Performance	8
Environment	6
Social Innovation/Financial Inclusion	3
Supply Chain Finance	2
Sustainable Development Goals	2

#### 3.7.1. Advantages

Blockchain has the following advantages: accessibility, data management, data safety and decentralization, documentation, laws and policy, and quality [139]. They demonstrate that these advantages drive blockchain adoption in supply chain and promote sustainability. An extensive research is called for into the sustainability of blockchain-related transactions [140]. Blockchain can be used to develop a framework which enhances sustainability by providing accurate provenance information and enforcing representations through blockchain-based smart contracts [141]. Conceptually, blockchain technology can be used to create a SSCM model for SMEs [142]. By illustrating blockchain technology-based mechanisms, SCM objectives, such as cost, flexibility, dependability, quality, risk reduction, speed, and sustainability, can be studied [143]. Studies show that blockchains increase transparency and accountability of supply chain activities [143]. Blockchain technology has the potential to address the challenges of SSCM [144]. It suggests that blockchain technology can enhance performance and improve collaboration, thereby generating economic benefits and achieving socio-environmental goals. Achieving transparency through blockchain technology is crucial for presenting the added value from sufficiency-oriented offerings [145]. The integration of blockchain technology with smart city concepts, like smart home and smart building, is recommended to improve the sustainability of the building construction sector [146].

### 3.7.2. Limitations/Barriers

Blockchain encounters the limitation of trusted intermediaries at the last mile between a digital record and an individual [147]. A comparison of the cost for computation and storage on blockchain versus a cloud service show that the former suffers from scalability limits of throughput [149]. A tradeoff exists between cost and other non-functional qualities in the design of blockchain-based systems. The issue of trust cannot be completely addressed with technical solutions like blockchain technology [150]. In this regard, the author focuses on ascertaining the economic incentives of relevant parties correctly. Blockchain networks duplicate all records across all the mining nodes, which causes performance to deteriorate exponentially in terms of the size of the network [151]. This puts scalability restrictions on the blockchain network. During the implementation of blockchain technology in enterprises, it is identified that non-conventional limitations such as an external policy system, the human capital structure, and the nature or opinion of the manager are prevalent [152]. Technical limitations of blockchain technology include the area of interoperability with other systems [153]. Management challenges are identified, given the need to integrate blockchain applications with legacy systems. There are also limitations related to scalability and performance [153]. The data-quality problems in emerging markets affect the sustainability of fashion supply chains' operations [154]. Situations occur when the application of blockchain technology causes tradeoffs between social welfare and supply chain profitability [154]. These disadvantages lead to blockchain technology adoption barriers. There are four major blockchain technology adoption barrier categories in the context of supply chain sustainability—inter-organizational, intra-organizational, technical, and external barriers [148].

### 3.7.3. Performance

There is a need for collaboration between managers and policymakers while using blockchain technology to create an environment of mutual trust to improve the effectiveness, efficiency, and sustainability of the supply chain [155]. Blockchain technology is an indispensable tool for SSCM [157]. To solve the issue of information asymmetry, firms can apply the recent developments in blockchain technology; these applications provide mechanisms that simultaneously create a trust culture and preserve competitive identity [156]. An application framework based on emerging technologies, including blockchain for the agri-food supply chain can guide sustainable supply chain practitioners in building a robust data-driven agri-food supply chain [158]. The positive effects of blockchain technology on partnership growth are highly significant, while the effect is only marginal on partnership efficiency [159]. Based on a contingent resource-based view theory, it is found that product complexity shapes the relationship between upstream supply chain visibility and the social, environmental, and economic performance dimensions [160]. Due to the evolution of modern supply chain networks into highly complex value networks, technologies like IoT, when used in combination with blockchain, have the potential to increase both the effectiveness and the efficiency of supply chains [161]. Findings of a study in B2B e-commerce demonstrate that the use of blockchain technology translates into an improvement in logistics and digital documentation maintenance of 74% and 75%, respectively [162].

### 3.7.4. Environment

There are multiple use cases where green supply chains can benefit from blockchain technology [163]. In 2017, to manage its operations, blockchain consumed more electrical power than that consumed by 159 individual nations [164]. Blockchains that use a proof of stake system are less energy-intensive than those using evidence of the work system. Greener decisions will make blockchain technologies more environmentally sustainable in the future. Issues such as waste information management have been identified in conjunction with the concept of “circular economy” [165]. Physical documents are still commonplace in maritime transport. Blockchain technology can help control the discharge of wastewater from commercial ships, with the intended outcome being

environmental preservation by guiding ships to the best discharge areas [166]. A blockchain-based framework can establish a feature to reduce the carbon emissions of the clothing manufacturing life cycle [167]. Frameworks can be developed for green logistics based on blockchain fundamentally but also incorporating other technologies like IoT and Big Data [168].

### 3.7.5. Social Innovation/Financial Inclusion

The limited reach of financial services, such as electronic payments, among rural Indians, hinders connectivity to supply chain networks. Blockchain technology can potentially resolve challenges in financial inclusion [169]. Akshay Patra showcases an inspiring example of social innovation by providing midday meals to 1.6 million children every day. The company has significantly improved its operations management by employing a solution integrating blockchain, IoT, and AI technologies; this solution has been developed in collaboration with Accenture Labs [170]. The trade-in agriculture and food domain have a profound impact on social stability and sustainable development. FTSCON is a food-trading system that helps eliminate information asymmetry, which results in the creation of a credible trading environment with enhanced security features [171].

### 3.7.6. Supply Chain Finance

The application of Fintech technologies like blockchain is enabling the integration of the value chain of the global e-commerce industry [172]. The application of blockchain technology in finance is a potential paradigm shift [173]. Blockchain technology is expected to disrupt legacy finance procedures.

### 3.7.7. Sustainable Development Goals

An Ethereum-based blockchain application for solid waste management is expected to improve multiple areas of sustainable development goals (SDGs) like health, environment, and social inclusion [174]. Blockchain is an enabling technology for “Traceability for Sustainability” [175]. The United Nations has acknowledged the significance of supply chain for the fulfillment of multiple SDGs, including the following: SDG 8, inclusive and sustainable growth; SDG 9, resilient and sustainable infrastructures, industrialization, and innovation; and SDG 12, sustainable consumption and production patterns.

## 3.8. ETLCL 8: STATE-OF-THE-ART IN BUSINESS

Table 11 shows the distribution of the research papers in this category.

**Table 11.** Subcategories at ETLCL 8.

Accounting/Auditing	2
Launched Projects	8
Research Gap	3
Risk	4
Standards	1
Trends	2

### 3.8.1. Accounting/Auditing

Blockchain technology is an enabler of a real-time, verifiable, and transparent accounting ecosystem; it can also improve auditing practices, and thereby reduce trading costs, increase transaction settlement speed, reduce fraud risk, improve the auditability of transactions, and increase the effectiveness of monitoring [176]. There is an opinion about the infeasibility in using blockchain as a more secure alternative to current accounting ledgers. A study identifies multiple flaws in both public and private blockchains which hinder the implementation of the blockchain as a financial reporting tool. It also



notes that interoperability problems arising due to incompatible blockchains would present a significant hurdle to adoption [177].

### 3.8.2. Launched Projects

The global and widespread adoption of modern data-driven technologies is a necessity for shipping companies [178]. In early 2017, Maersk and IBM utilized blockchain technology to track and digitize their complex paper trail. In order to build open standards and platforms to facilitate the application of blockchain technology, IBM is collaborating with companies involving retailers, banks, and shippers [179]. IBM's new blockchain cloud-based services provide international verification services, which ease the transfer of goods along the supply chain [179]. In December 2017, Osell launched blockchain for its cross-border e-commerce operations. The blockchain records the credit certificate. Osell has collaborated with the SilkChain, which is a digital chain of international trade [180]. The use of the Gcoin blockchain to store the data flow of drugs is expected to bring transparency to drug-transaction data [181]. A strategic assessment of the prospects of using a distributed ledger like Hyperledger Fabric, which is a permissioned blockchain implementation, found it to be one of the best blockchain implementations [182]. Blockchain is a costly storage medium, and hence the set of benefits it brings to the business should more than offset its overhead costs. Platforms like Ositrade and Agri Marketplace are targeting international implementations of "farm to fork" concept, which provides complete traceability together with also value added features like price transparency and automated contracts [183]. BCautoSCF has emerged as a successful player in supply chain financing by providing reliable and efficient financing platform for auto retail industry in China [184]. Sensorica is a post-blockchain model which introduces a socio-technical configuration [185]. The configuration illustrates openness and sharing but also highlights contradictions and limitations. Sensorica's economic model is under reconfiguration. Institutional support shall be necessary for it to be fully deployed and replicated [185].

### 3.8.3. Research Gap

Research gaps identified in producing open externalities information call for examining the use of blockchain ledgers for accounting for externalities data and compiling full cost accounts by organizations in the various stages of supply chain operations [186]. An explanatory model for interactions between various stakeholders of supply chain identify some intermediary tasks that can be replaced by blockchain technology [187]. A research agenda across the themes of development of blockchain technology for operations and SCM, adoption of blockchain technology in supply chain networks, evolution of supply chain relationships, etc. is called for [188].

### 3.8.4. Risk

Blockchain technology alone is not enough for creating an effective cyber security strategy [189]. It is possible to calculate the amount of computing power needed by an attacker [190]. Additionally, mining is sustainable only when it is profitable. Sudden drops in prices can result in fall in participating miners and can therefore make a majority attack more likely. The shadow payment system imitates the functioning of banks, but it is not subject to regulatory oversight [191]. This system does not benefit from the prudential regulatory strategies, thereby causing greater risk to customers and economic stability. The effectiveness of various strategies to address these risks has been examined [191]. Cryptocurrencies based business ecosystems are frail because the blockchain technology is an evolving technology. Moreover, competitive market pressures eye an opportunity of exponential returns in the cryptocurrency market. Novel ways need to be found to protect blockchain-based economies and for them to coexist with competitive markets at a global scale [192].

### 3.8.5. Standards

Market regulators need standardized transactional data. The lack of interoperability is reducing the effectiveness of new blockchain technologies [193]. The study proposes that a partnership between the global industry and governments can contribute toward the development of data identification standards and a secure financial-sector DLT protocol standard, among others.

### 3.8.6. Trends

In a paper about blockchain-technology-based decentralized data storage in relation to the development of sustainable logistics and SCM [194], the authors present a comprehensive review of the current and rising trends in this area. Blockchain is gaining momentum in supply chain finance by supporting transactions around the globe [195].

## 4. Discussion in Context of Research Questions

### 4.1. Research Question 1: WHAT

Table 12 shows authors who have published articles that have gathered more than 100 citations.

**Table 12.** Most cited articles.

Citations	Authors (Year)	Title	Journal	Classification	Sub-Classification
326	Kshetri, Nir (2018)	Blockchain's roles in meeting key supply chain management objectives	International Journal of Information Management	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Advantages
202	Francisco, Kristoffer (2018)	The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply	Logistics	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Growth Factors and/or Barriers
193	Saberi, Sara (2019)	Blockchain technology and its relationships to sustainable supply chain management	International Journal of Production Research	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Limitations or Barriers
179	Casino, Fran (2019)	A systematic literature review of blockchain-based applications: Current status, classification and open issues	Telematics and Informatics	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Review
171	Dai, Jun (2017)	Towards Blockchain-based accounting and assurance	Journal of Information Systems	ETLCL 8: STATE OF ART IN BUSINESS	Accounting or Auditing
170	Tapscott, Don (2017)	How Blockchain will change Organizations	MIT Sloan Management Review	ETLCL 4: IMPACT ASSESSMENT	Disruption or Digital Transformation
150	Ghobakhloo, Morteza (2018)	The future of manufacturing industry: a strategic roadmap toward Industry 4.0	Journal of Manufacturing Technology Management	ETLCL 4: IMPACT ASSESSMENT	Industry 4.0
104	Werbach, Kevin (2018)	Trust, but verify: Why Blockchain needs the law	Berkeley Technology Law Journal	ETLCL 5: BUSINESS ENVIRONMENT	Legal and Governance
104	Casey, Michael J. (2017)	Global Supply Chains are about to get better, Thanks to blockchain	Harvard Business Review	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Growth Factors and/or Barriers

Nir Kshetri has received the highest number of citations for his paper titled “Blockchain’s roles in meeting key supply chain management objectives” [143]. This paper by Nir Kshetri, published in 2018, addresses the fundamental question of the applicability of blockchain technology in fulfilling the objectives of SCM. On the dimension of cost alone, multiple use cases make it economically sensible to have blockchain tokens for smaller transactions as well. Like all digital technology, blockchain helps eliminate paper records, thereby reducing the cost of regulatory compliance. Cost-related benefits also accrue from proper handling of a crisis involving the defective products and total collapse of mechanisms for partners engaged in low-quality and counterfeit ingredients. There are also benefits that come in the dimensions of speed and dependability. Digitizing the physical process reduces the number of human interactions involved bringing in speed. Digital certification based on blockchain technology implies increase trust or dependability. Risk reduction in another supply chain performance dimension where blockchain technology-based solutions score over other solutions. It is important to note that blockchain technology makes it possible to verify sustainability, i.e., the indicators related to sustainability can become more quantifiable and meaningful. Blockchain solutions are more flexible than traditional IT solutions.

Kristoffer Francisco and David Swanson wrote a seminal article [62], “The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency”. This paper emphasizes that each and every product that goes through the supply chain has a long history. However, much of this history is not captured in the form of data anywhere in the current scenario. Moreover, the data that may exist in silos are not transparent. Many unethical practices often happen in the supply chain. These negative practices often create financially crippling situations. Some examples of negative practices are the use of child labor or the unethical use of natural resources. The adoption of blockchain technology as a foundational framework for supply chain traceability has been studied by using the well-known Unified Theory of Acceptance and Use of Technology (UTAUT) [62]. In the age of information technology revolution where customers are empowered, it is essential to provide more and more information about the products purchased. Blockchain technology can easily provide a high level of supply chain transparency, which cannot only help answer customer queries but also gain substantive competitive advantage.

Sara Saberi, Mahtab Kouhizadeh, Joseph Sarkis, and Lejia Shen are among the few authors who have discussed blockchain technology’s relationship to SSCM in a paper [148] published in 2019. Despite its recent publication, it is the third most cited paper. It investigates the question of how blockchain can address and aid sustainability in the supply chain. It concludes by identifying four major adoption barrier categories for blockchain technologies. These are as follows: (a) inter-organizational barriers, (b) intra-organizational barriers, (c) technical or system-related barriers, and (d) external barriers. Table 13 summarizes the key adoption barriers.

Fran Casino provides a comprehensive classification of applications developed using blockchain technology in diverse sectors [1]. Most prior literature classifies the blockchain applications into financial and non-financial applications. However, Fran Casino uses the application-oriented classification. The various classes of blockchain applications include: (a) financial applications, (b) integrity verification, (c) governance, (d) Internet of Things, (e) healthcare management, (f) privacy and security, (g) business and industrial applications, (h) education, (i) data management, and (j) miscellaneous applications. Blockchain applications in the area of supply chain management are covered in the “business and industrial applications” category.

Jun Dai and Miklos A. Vasarhelyi have studied the underexplored area of blockchain-enabled accounting system [176]. Such a system is expected to work in real-time, be verifiable, and also provide transparency in transactions. It looks at the potential of blockchain technology to radically transform auditing practices. Technology has changed the world a lot in the last decade and last century, but accounting is still based on centuries-old principles. Similar is the case with auditing practices. However, blockchain technology is set to change this. The difficulties in further developing the technology and its complex implementation of such a radical change should not be ignored.

The development of new algorithms and approaches on the technological side will significantly influence how the accounting and assurance applications of blockchain technology will evolve.

**Table 13.** Adoption barriers.

Barrier Category	Adoption Barrier
Inter-organizational Barriers	Customer's level of awareness and tendency with regard to the blockchain technology and the sustainability aspects
	Collaboration-, communication-, and coordination-related problems in a supply chain which needs to be digitized
	Lack of information disclosure policy or policy-implementation challenges between partners in the supply chain
	Barriers in integrating sustainable practices based on a new technology like blockchain technology across all partners of the supply chain
	Cultural differences inherent in big, medium, and small supply chain partners
Intra-organizational Barriers	Constraints of financial nature
	Absence of top-level management's commitment and support
	The flexibility to introduce new organizational policies for using the blockchain technology which may have no relevant policies in place to begin with
	Absence of knowledge and expertise in current workforce
	Challenges associated with bringing a transformation in the organizational culture
	Inertia of legacy systems causing unwillingness to adapt to new systems
	Lack of technological tools for implementation of new solutions in the sustainable supply chains
System-Related Barriers	Security and related issues
	Blockchain technology may not be easily accessible
	Negative public perception can lead to lower adoption intention for blockchain technology
	Immutability property of blockchain technology may be viewed as both a virtue and a vice
	Blockchain technology is an evolving technology, so blockchain based solutions as they exist till today are immature
External Barriers	Absence of a regulatory framework and governmental policies in most geographies
	Amidst the market competition, blockchain technology adds to the uncertainty of doing business
	Absence of external stakeholders in the onboarding process for the blockchain technology
	Commitment of the industry in ethical and safe practices may be lacking or be limited
	The rewards and encouragement programs associated with using blockchain technology may not be substantial

Don Tapscott and Alex Tapscott examine how blockchain will change organizations [83]. They predict that the blockchain technology will impact many organizational functions and business processes. These functions and processes include human resources and procurement, finance and accounting, sales and marketing, legal affairs, and raising capital.

Morteza Ghobakhloo states that blockchain is critical to Industry 4.0 [98]. Their reasons lie in frictionless financial transactions that blockchain enables through cryptocurrencies. These transactions can also be automated through smart contracts. These transactions are believed to be transparent, secure, fast, and frictionless. Extending the use of blockchain technology to any kind of digitized transfer of information, Industry 4.0 can develop trusted and autonomous relationships between its various components.

Werbach presents an extensive study of why blockchain would need the law [109]. It makes a very counter-intuitive point that while blockchain solves the age-old problem of trust, blockchain-enabled applications may be counterproductive or dangerous if they are used outside the legal framework. There is a compelling need to use the blockchain technology as a supplement, complement, or substitute for legal enforcement in some cases. One should be forewarned that rigid legal provisions related to the technology may kill innovation, and many opportunities may be lost. The need of the hour is for blockchain developers and architects to work together with legal institutions.

Michael J. Casey and Pindar Wong take a look at how the global supply chains can be improvised by using the new technology of blockchain [59]. Existing corporations and start-ups have begun to explore the use of blockchain in multiple use cases, leveraging the fundamental advantages that blockchain bring. In the context of the supply chain, the most significant advantage of blockchain is that it resolves the problems of disclosure and accountability between the stakeholders whose commercial interests differ. Governance, interoperability, and legal challenges can act as potential barriers to the quick adoption of this wonderful new technology.

#### 4.2. Research Question 2: WHO

Researchers from across the globe have contributed to this subject. Table 14 lists the authors who have more than one article as the first author in our selected list of 187 publications.

**Table 14.** Authors with more than one publication.

First Author	Title	Journal	Classification	Sub-Classification
Choi, Tsan-Ming	Blockchain-technology-supported platforms for diamond authentication and certification, in luxury supply chains	Transportation Research Part E	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Assessment and or customization
	Data quality challenges for sustainable fashion supply chain operations in emerging markets: Roles of blockchain, government sponsors and environment taxes	Transportation Research Part E	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Limitations and Barriers
	Information disclosure structure in supply chains with rental service platforms in the blockchain technology era	International Journal of Production Economics	ETLCL 5: BUSINESS ENVIRONMENT	Business Model
	Peer-to-peer collaborative consumption for fashion products in the sharing economy: Platform Operations	Transportation Research Part E	ETLCL 5: BUSINESS ENVIRONMENT	Business Model
Kamble, Sachin	Modeling the blockchain-enabled traceability in agriculture supply chain	International Journal of Information Management	ETLCL 6: APPLICABILITY TO THE BUSINESS TODAY	Modeling or Pilot
	Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications	International Journal of Production Economics	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Performance
	Understanding the blockchain technology adoption in supply chains-Indian context	International Journal of Production Research	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Growth factors and or barriers

Table 14. Cont.

First Author	Title	Journal	Classification	Sub-Classification
Treiblmaier, Horst	The impact of the blockchain on the supply chain: A theory based research framework and a call for action	Supply Chain Management: An International Journal	ETLCL 5: BUSINESS ENVIRONMENT	Theory
	Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management	Logistics	ETLCL 4: IMPACT ASSESSMENT	Disruption/ Digital Transformation
	Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda	Smart Cities	ETLCL 2: BENEFITS	Traceability
Chang, Shuchih Ernest	Supply chain re-engineering using blockchain technology: A case of smart contract-based tracking process	Technological Forecasting and Social Change	ETLCL 6: APPLICABILITY TO THE BUSINESS TODAY	Smart Contracts
	Blockchain-enabled trade finance innovation: A potential paradigm shift on using letter of credit	Sustainability	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Supply Chain Finance
Cottrill, Ken	Can we trust the “trust machine?”	Supply Chain Management Review	ETLCL2: BENEFITS	Trust
	The Benefits of Blockchain: Fact or wishful thinking	Supply Chain Management Review	ETLCL2: BENEFITS	Trust
Giusti, Riccardo	Sustainable and De-Stressed International Supply-Chains Through the SYNCHRO-NET Approach	Sustainability	ETLCL 5: BUSINESS ENVIRONMENT	Business Model
	Synchromodal logistics: An overview of critical success factors, enabling technologies, and open research issues	Transportation Research Part E	ETLCL 6: APPLICABILITY TO THE BUSINESS TODAY	Smart Contracts
Kouhizadeh, Mahtab	Blockchain Practices, Potentials, and Perspectives in Greening Supply Chains	Sustainability	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Environment
	At the Nexus of Blockchain Technology, the Circular Economy, and Product Deletion	Applied Sciences	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Environment
Ramirez-Pena, Magdalena	Shipbuilding 4.0 Index Approaching Supply Chain	Materials	ETLCL 2: BENEFITS	Transparency
	Achieving a sustainable shipbuilding supply chain under 14.0 perspective	Journal of Cleaner Production	ETLCL 4: IMPACT ASSESSMENT	Industry 4.0
Tapscott, Don	Blockchain and the Internet of Value	Research-Technology Management	ETLCL2: BENEFITS	Trust
	How Blockchain will change organizations	MIT Sloan Management Review	ETLCL 4: IMPACT ASSESSMENT	Disruption or Digital Transformation



Table 14. Cont.

First Author	Title	Journal	Classification	Sub-Classification
Vaio, Assunta Di	Artificial Intelligence in the Agri-Food System: Rethinking Sustainable Business Models in the COVID-19 Scenario	Sustainability	ETLCL 5: BUSINESS ENVIRONMENT	Business Model
	Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry	International Journal of Information Management	ETLCL 7: CREATION OF SUSTAINABLE BUSINESS	Performance
Violino, Simona	Are the Innovative Electronic Labels for Extra Virgin Olive Oil Sustainable, Traceable, and Accepted by Consumers?	Foods	ETLCL 2: BENEFITS	Traceability
	A Full Technological Traceability System For Extra Virgin Olive Oil	Foods	ETLCL 2: BENEFITS	Traceability
Wang, Yingli	Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda	Supply Chain Management: an International Journal	ETLCL 3: EARLY EXPERIMENTATION AND ADOPTION	Assessment and or customization
	Making sense of blockchain technology: How will it transform supply chains	International Journal of Production Economics	ETLCL 5: BUSINESS ENVIRONMENT	Theory

Tsan-Ming Choi is the most active researcher in this area, with four publications included in this literature review. He has studied fashion and luxury goods supply chains and examined the role of blockchain technology in these niche areas. He has also discussed the topic in relation to other fundamental concepts like “authentication and certification”, “data quality challenges”, “information disclosure structure”, “peer-to-peer collaborative consumption”, and “sharing economy”. His four publications included in this literature review are published in A\* rated journals—the highest rating in the ABDC Journal Quality List. Another researcher, Sachin Kamble, has investigated blockchain technology in the context of agriculture SC and has also discussed the adoption of blockchain in the supply chain in the context of the Indian market. Horst Treiblmaier has developed a research framework for blockchain technology in supply chain management. He has also explored the relation of the subject with “Triple Bottom Line Sustainability” and “Smart Cities”.

#### 4.3. Research Question 3: WHERE

Table 15 shows the prominent journals featuring most of the articles. There are 80 research journals that feature the shortlisted 187 articles. Table 15 shows the full diagram of all the journals and the number of articles together with the h5-index and the h5-median [196] of the journals. There are nine journals with five or more research articles.

Table 15. Publication outlet with number of publications and key indexes.

h5 Index	h5 Median	Journal	Number of Papers
78	113	Sustainability	26
67	113	International Journal of Information management	13
6	11	Supply Chain Management Review	11
61	104	Harvard Business Review	8
53	99	Business Horizons	7

Table 15. Cont.

h5 Index	h5 Median	Journal	Number of Papers
89	126	International Journal of Production Economics	6
63	90	International Journal of Production Research	6
132	166	Journal of Cleaner Production	5
53	72	Transportation Research Part E	5
27	41	Electronic Markets	4
NA	NA	Logistics	4
46	77	Supply Chain Management: an international journal	4
58	77	Computers and Industrial Engineering	3
27	39	Future Internet	3
85	117	International Journal of Environment Research and Public Health	3
74	96	Technological Forecasting and Social Change	3
46	68	Annals of Operations Research	2
26	41	Computer Law and Security Review	2
35	59	Electronic Commerce Research and Applications	2
NA	NA	Foods	2
66	94	Industrial Marketing Management	2
42	57	Information Systems Frontiers	2
96	131	Journal of Business Research	2
31	49	Journal of Purchasing and Supply Management	2
35	63	Journal of the Association for Information Systems	2
22	54	MIS Quarterly Executive	2
37	64	MIT Sloan Management Review	2
104	151	Sensors	2
45	84	Academy of Management Perspectives	1
27	41	Accounting and Business Research	1
29	40	Agriculture	1
29	51	Agronomy	1
30	43	Animals	1
53	68	Applied Sciences	1
24	35	Berkeley Technology Law Journal	1
NA	NA	Big Data and Cognitive Computing	1
51	70	Cities	1
16	24	Cogent Economics and Finance	1
70	130	Communications of ACM	1
45	79	Computers in Industry	1
NA	NA	Cryptography	1
26	34	Decision Sciences	1
NA	NA	Delaware Journal of Corporate Law	1
58	84	Entropy	1
12	16	European Business Organization Law Review	1
58	107	Government Information Quarterly	1
12	15	International Review of Intellectual Property and Competition Law	1
NA	NA	Informatics	1
NA	NA	Information	1
19	29	Information Economics and Policy	1
26	40	Information Systems and e-Business Management	1
73	102	International Journal of Environmental Research and Public Health	1
44	65	International Journal of Forecasting	1
68	93	International Journal of Hospitality Management	1
38	54	International Journal of Physical Distribution and Logistics Management	1
21	32	Journal of Consumer Policy	1
NA	NA	Journal of Emerging Technologies in Accounting	1
11	14	Journal of Financial Regulation and Compliance	1
23	31	Journal of Information Systems	1
41	56	Journal of Intelligent Manufacturing	1
10	14	Journal of International Technology and Information Management	1
34	42	Journal of Manufacturing Technology Management	1
23	27	Journal of Marine Science and Engineering	1
18	24	Journal of Risk and Financial Management	1
11	14	Journal of Risk Management in Financial Institutions	1
19	26	Journal of Sensor and Actuator Networks	1
35	57	Journal of Strategic Information Systems	1
49	73	Marine Policy	1
NA	NA	Materials	1

**Table 15.** *Cont.*

h5 Index	h5 Median	Journal	Number of Papers
8	9	Philosophy of Management	1
35	47	Research in International Business and Finance	1
87	128	Research Policy	1
25	57	Research-Technology Management	1
61	86	Resources, Conservation and Recycling	1
NA	NA	Review of International Business and Strategy	1
57	84	Scientometrics	1
NA	NA	Smart Cities	1
52	88	Telematics and Informatics	1
12	17	The Journal of Alternative Investments	1
18	29	The Journal of Corporation Law	1

#### 4.4. Research Question 4: WHEN

The research conducted from 2015 to early 2020 was examined. The relevant research literature on this subject started appearing in 2017. There has been a rapid increase in the number of papers in these high-quality journals. It shows the growing interest in the applications of blockchain technology in SCM. The literature review was concluded in the early part of 2020, and hence we have only a few articles published in 2020. We expect an increase in the number of research publications in 2020 than that in the previous year. There is a visible trend, starting in 2017, of heightened interest in this domain as visible from Table 16.

**Table 16.** Number of publications (by year).

Year	Number of publications
2015	0
2016	0
2017	16
2018	41
2019	78
Early 2020	52

#### 4.5. Research Question 5: HOW

Success stories of early blockchain experimentation should lead to more extensive adoption. However, blockchain adoption will occur if the value added by the blockchain technology overcomes any cost incurred when creating the blockchain infrastructure. Multiple business models have been applied in regard to blockchain implementation. We list a few of the value-creation opportunities [105] that can be exploited to build successful business models:

- Creation of a blockchain architecture that can be used by others to develop applications. It will work by promoting itself as a technical or market standard over which innovations can be developed.
- Displacement of incumbents from value chains, such as blockchain-based car rental platform that may displace companies like Uber and Ola.
- Creating firm-specific value for all partners of the value chain by enhancing value-chain efficiency.
- Address and resolve long-standing issues of contemporary business practices like traceability issues.
- Development of blockchain solutions for pre-existing business practices.

#### 4.6. Research Question 6: WHY

Despite extensive research in this area, multiple research gaps exist which give ample reasons to continue research in this area. The advantages of blockchain technologies are compelling. However, the decision to use or integrate them with existing systems comes with its own set of challenges. Some of the research gaps that need to be addressed are as follows:

- (a) How to theoretically evaluate the benefits of blockchain technology-based applications in SSCM?
- (b) What tradeoff considerations must be evaluated while reflecting on the adoption of blockchain technology for SSCM?
- (c) What changes in accounting practices would ensure that they account for externalities?
- (a) What activities are necessary to integrate existing legacy systems into the blockchain networks?
- (b) How can blockchain service providers gain traction from multiple actors of the supply chain?
- (c) Is the lack of governance structure a barrier to the evolution of blockchain-based supply chains?
- (d) How will SCM theories evolve to account for blockchain-based supply chains? Will it require new theories? Will it essentially require multidisciplinary teams to come up with a new theory?
- (e) How does stakeholder behavior change when blockchain-based information management systems manage data?
- (f) Can blockchain technology help build information management systems that address all three pillars of sustainability simultaneously?
- (g) How to determine the need to use blockchain for an SSCM project? What are the information management systems for which a firm should use blockchain-based distributed ledgers? Which systems should remain in silos of individual organizations (traditional databases)?

## 5. Conclusions

### 5.1. Theoretical Implications

This paper makes a theoretical contribution by providing a classification framework (ETLCL) based on the widely used TRL and Grounded Theory. ETLCL framework can be applied for surveying other emerging technologies in any context. ETLCL framework may be applied only to create top-level categories or to a created double deep-level classification scheme. ETLCL stands parallel to NASA's TRL, which is a compelling concept [10]. Several concepts have been developed based on NASA's TRL or other variants of TRL (Inc., 2020), such as manufacturing readiness levels (MRLs), interface readiness levels (IRLs), system readiness levels (SRLs), and people readiness levels (PRLs). The ETLCL framework can be used for determining the level of maturity at which the research literature addresses the concerning emerging technology. It may also be used directly or adapted to create classification frameworks for already established technologies. However, the ETLCL framework may not be the best guide when applied to established technologies. These established technologies can be best studied by learning the technical standards created at a technical level, learning the best practices at a management level, and examining global success stories. However, there is a long list of technologies that can be classified as emerging technologies. Hence, this theoretical development has substantial applicability, besides the domain this research article considers. This is our original contribution to the body of knowledge that examines different ways of conducting literature reviews on technical topics. This study also demonstrates how TRL can be combined with the classical Grounded Theory to arrive at a deep double-level classification scheme. Additionally, it shows the potential of the 5W+1H pattern to help frame research questions and objectives. The relevance of these research objectives and questions become evident in Section 4, which discusses the findings based on these questions. In addition, to study a new research area it is advisable that one uses the ETLCL framework and Grounded Theory together with 5W+1H, as both of these methodologies are particularly suited to review new emerging research areas. While the ETLCL framework is recommended for classification of the literature, the 5W+1H pattern is recommended to make key findings. Both the classification framework and key findings are important artifacts of a systematic literature review. Therefore, it can be said that these methodologies nicely complement each other. Hence, we suggest that using ETLCL + Grounded Theory together with 5W+1H for researching a new area is a theoretical contribution from our end.

## 5.2. Practical Implications

This paper captures a strong trend ongoing since 2017 and growing exponentially; therefore, this paper raises awareness about the discussed niche area among the practitioners. The choice of journals contributes toward a high-quality literature review. Thus, this review paper also helps practitioners examining specific aspects of this study area by directing them to the right information sources. With 39 subcategories, the classification of literature proves to be substantial.

From a new learner's perspective, ETLCL 1 to 3 may be the right set of resources to start with. From the perspective of a firm manager looking to initiate a project in this area, ETLCL 4 to 6 may be recommended. From a policymaker's perspective, one may allow experimentation at smaller levels, and then focus on ETLCL 7 to 9 and provide the right set of policies and regulations that could be available to decision-makers at all levels. However, since our overall classification scheme is much deeper than the nine levels and runs into 39 subcategories, one may choose to refer studies based on the detailed classification. Moreover, the ETLCL framework allows other authors to choose suitable subcategories from their own research domain. This allows for a substantial amount of freedom, while still operating within the structure of the nine levels of ETLCL.

## 5.3. Limitations and Scope for Future Research

One of the limitations of this research is that this research area has been drawing increased academic attention; in a few years, the body of literature is expected to double. However, our contribution to presenting a classification framework helps transcend this limitation to some extent. Therefore, this paper focuses on offering a summary of the literature reviewed and organized by the novel classification framework and discovering and creating subcategories.

Another limitation is that we have used the number of citations for identifying the most relevant or popular research articles. However, more recent articles, especially those in 2020, have had a lower chance of being cited at the time of the research. This limitation can be partially transcended by adopting the following metric: sorting criteria = number of citations/(2021—the year of publication); it can also be addressed by employing some measure of popularity. Instead of creating a metric or measure of popularity, we present the top nine most cited papers in 2017, 2018, and 2019; these papers were presented in Table 12 in Section 4.1 which lists papers by the number of citations. Since this literature review was conducted in the first quarter of 2020, only 52 papers from 2020 could be included; since this period concluded the review, it was not possible to present papers that received a significant number of citations during the period. Moreover, the number of citations is a very fast-changing statistic.

This paper introduces a number of new concepts; hence, research can substantially gather many directions from this paper. From a methodology perspective, future researchers can base their studies on ETLCL framework. Future studies may also evaluate, alter, or extend the ETLCL framework. Moreover, future work can be theoretical, empirical, or entrepreneurial, based on what is the key takeaway for the researcher. It is recommended that ETLCL is used to arrive at a complete double-deep classification. This will help capture both technology readiness and research area related constructs. Moreover, it is recommended to use 5W+1H together with this combination as these two methodologies nicely complement each other. Finally, it is recommended to use this theoretical framework mainly for new emerging areas where the literature is scattered and developing along multiple directions.

The “Why” section of this paper provides various research gaps where the researchers may concentrate their efforts. The benefits of blockchain technology in SSCM can be realized by developing trust, transparency, and traceability in the information flow across supply chain actors and efficiently managing supply chain finance. To address the issue of sustainability in SC, research will have to consider all the three pillars of economic, social, and environmental performance.

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