Innovative and Sustainable Logistics: Main Direction of Development

Chapter 1

Innovative and Sustainable Logistics: Main Direction of Development

Khuram Shahzad[1 2], Oskar Juszczyk[1], and Josu Takala[1]

[1] *School of Technology and Innovations, University of Vaasa, Finland*

[2] *Innovation and Entrepreneurship InnoLab*

1.1 Introduction

The current image of the supply chains appears to be increasingly complex, where multinational business entities compete to gain their share of the market (Saberi et al., 2019). The globalization of supply chains which has resulted in a "flat world" (Friedman, 2005) makes this network even more intricate because of divergent regulations as well as various customer behavioral patterns. This complexity causes difficulties in information and risk management, where fraudulent practices cause challenges in terms of trust. Therefore, there is a necessity of increasing the excellence of information distribution and transparency (Ivanov et al., 2018).

DOI: 10.4324/9781003304364-2

Such trackability of the whole production and logistics process is becoming a requirement for the growing share of environmentally conscious stakehold-ers and end customers. It can make a radical change in the competitive advan-tage of a given company, especially in the sectors of agriculture (Kamilaris et al., 2019; Kamble et al., 2020), medicine (Rotunno et al., 2014; Radanović & Likić, 2018), energy (Andoni et al., 2019; Teufel et al., 2019), or luxurious goods (Maurer, 2017).

It is challenging to achieve it in the modern supply chains, which are formed in centralized management-information systems, such as enterprise resource planning (ERP), that are imperfect in terms of reliability. Such centralized information systems rely heavily on trust given to a single authority for processing and storing valuable and sensitive data, which makes them susceptible to malfunction, cyberattacks, or even corruption (Dong et al., 2017).

Over the past few years, there has been an increasing pressure from all sectors of society on supply chains to follow the idea of sustainability. Therefore, sustainable supply chains should generate added value according to the triple-bottom-line approach that proposes harmony in consideration of economic, societal, and environmental aspects (Elkington, 1998, 2004). Following that concept, organizations perceive sustainability as a fundamental principle of smart management (Savitz & Weber, 2006), and following the triple-bottom-line strategy can not only benefit the natural environment and society but can provide long-lasting economic prosperity and a competitive advantage for the company (Carter & Rogers, 2008). However, in order to successfully achieve sustainable practices, there is a need to confirm and verify the processes, activities, and end-products that follow the specific sustainability criteria and proofs for such actions. Moreover, the triple bottom line comes with its supporting facets of sustainability that can serve companies to improve the quality of their risk management, transparency, strategy, and culture (Gladwin et al., 1995; Hart, 1995).

Hence, there is a need for better information sharing within the supply chains, which are currently not fully capable of supporting data required for the timely provenance of goods and services in a safe manner that is comprehensible and solid enough to ensure trust. Consequently, the future-oriented supply chains should improve their transparency, reliability, resilience, and operations integrity (Sivula et al., 2021). The solution that may provide such features could be blockchain technology. The application of such an innovative technology makes these improvement targets more logistically, economically, and technologically feasible (Abeyratne & Monfared, 2016). Blockchain, by being a distributed "trustless" database, is a disruptive technology that enhances global-scale transactions as well as operation decentralization amidst different supply chain actors and could make a critical—perhaps even revolutionary—impact on supply-chain management (Helo, 2020).

There have been already several applications of blockchain in different industries that have improved the transparency, integrity, and interoperability of the performed transactions. From a sustainable supply-chain-management point of view, the example of Provenance can be mentioned, which is a provider of blockchain technology in the seafood sector. In this specific supply chain, the visibility and legitimacy of sustainable standards are decisive (Steiner & Baker, 2015). The use cases show the potential applications of blockchain have been deliberated broadly in the professional, academic, and popular literature in terms of the topics related to environmental, economic, or societal performance dimensions.

Even though there is a growing number of use cases over the recent years, blockchain technology, as it is highly disruptive in nature, faces many challenges for its widespread implementation within global supply chain systems. While being in its infancy stage of development, blockchain is restricted by multifarious barriers of, for example, behavioral, structural, technological, or regulatory aspects. These numerous bottlenecks as well as measures to overcome them will be discussed more thoroughly later in this chapter.

The main goal of this chapter is to estimate the potential of blockchain technology applicability in the sustainable supply-chain-management theory and practice. In order to do so, we will introduce the main features of blockchain technology first. Then, we will discuss the possible benefits coming from its implementation by supply chains and how it could revolutionize the current outlook of supply-chain management, based on current literature. Further on, we provide a conceptual framework for blockchain-based sustainable supply chains. We will focus specifically on sustainable supply chains and how blockchains could positively impact sustainable practices. This will be followed by the presentation of various barriers to the adoption of blockchain in sustainable supply chains together with the proposition of several actions to tackle these challenges. Lastly, we will conclude the Chapter with its theoretical and practical implications as well as the direction toward future development.

1.2 Literature Review

To provide the conceptual background for this chapter, the review of the existing literature is presented to shed light on the concepts of sustainability in logistics and supply-chain management. Then, basic features of blockchain technology and its potential impact on the supply chains and more, specifically on the concept of sustainable supply-chain management, are discussed.

1.2.1 Sustainability in Logistics and Supply Chains

The most commonly used definition of sustainability is developed by Brundtland Commission: "Development that meets the needs of the present without compromising the ability of future generations to meet their needs." This broad concept includes recognizing the environmental impact of business activities all over the world (Erlich & Erlich, 1991), providing global food security (Lal et al., 2002), fulfilling basic human needs (Savitz & Weber, 2006), or enhancing the preservation of nonrenewable resources (Whiteman & Cooper, 2000). Such a macroeconomic perspective causes challenges in its understanding and application by organizations, where their specific situation affects the determination of present and future needs. Moreover, it provides limited guidance for the firms on how to decide which technological and organizational resources are necessary to meet those needs, and to efficiently balance cooperation liabilities with stakeholders within and outside of the company—including society and the natural environment (Hart, 1995; Starik & Rands, 1995). Furthermore, it is troublesome for the companies to establish their distinctive roles in such a broad concept (Stead & Stead, 1996). Therefore, a more microeconomic approach was introduced in the operations management and engineering literature by mainly considering the environmental dimension of sustainability, with limited apprehension of societal and economic aspects (Shrivastava, 1995; Starik & Rands, 1995). Still, this viewpoint continues a long-term perspective of sustainability, as Shrivastava (1995) depicts sustainability as providing the "potential for reducing long-term risks associated with resource depletion, fluctuations in energy costs, product liabilities, as well as pollution and waste management." Interestingly, the engineering literature proves more inclusive, and has directly considered all three dimensions of sustainability, claiming that organizational sustainability is "a wise balance among economic development, environmental stewardship, and social equity," (Sikdar, 2003) which includes "equal weightings for economic stability, ecological compatibility and social equilibrium" (Góncz, 2007).

In the context of supply-chain management from the logistics perspective, authors have scrutinized particular societal and environmental issues, such as environmental-logistics strategies, environmental purchasing, improvement of fuel efficiency, limiting greenhouse gas (GHG) emissions in transport, the safety of various means of transportation, etc. More lately, Carter and Jennings (2002) have provided a conceptual framework for integrating environmental and social issues within a theory of Logistics Social Responsibility (LSR), which relates to the issues discussed previously, such as natural environment, human rights, safety, etc., to the logistics management field. They follow their research by including purchasing impact of LSR, which they call Purchasing Social Responsibility (PSR). According to their definition, PSR is a second-tier concept composed of first-tier dimensions discussed earlier, which are: Environment, safety, diversity, philanthropy, and human rights (Carter & Jennings, 2004). Although there are numerous definitions of sustainable logistics, the foundations have always focused mainly on environmental and/or social aspects, leaving the economic dimension unconsidered.

Having that in mind, the triple-bottom-line concept emerged including three components of environmental, societal, and economic value creation, where each of them is considered simultaneously from the microeconomic perspective (Elkington, 1998, 2004). This seminal theory has shed new light on the theory of sustainability and is still present in the literature as a foundation for future concepts.

Next, we are going to discuss the notion of supply-chain management, which was described by Mentzer et al. (2002) as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses with the supply chains, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole," whereas Lambert (2006) perceives it as "the integration of key business processes from end-user through original suppliers that provides products, services, and information that add value for customers and other stakeholders." Basing on these classifications and by including the elements of sustainability discussed above, Carter and Rogers (2008) define sustainable supply-chain management (SSCM) as "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains." This definition also strictly relates to the triple-bottom-line concept and the previously mentioned supporting features of sustainability—risk management, transparency, strategy, and culture.

1.2.2 Blockchain Technology

Blockchain (or distributed ledger technology—DLT) is a technology that ensures digital information distribution in a shared database that contains a continuously expanding log of transactions and their chronological order. In other words, it is a ledger that may contain digital transactions, data records, and executables that are shared among blockchain participating agents (Nakamoto, 2008; Andoni, 2019). Blockchain technology is distinct from other previously known information systems by its four main features: Non-localization (decentralization), security, auditability, and smart execution (Teufel et al., 2019). It is a highly innovative technology that is the result of a decade's efforts from "an elite group of computer scientists, cryptographers, and mathematicians" (Tucker, 2019).

The basic process within blockchains is structured as follows. First, the agent creates a new transaction to be included in the blockchain. This freshly created transaction is shared with the network for verification and auditing. When the transaction is approved by the majority of nodes based on predetermined and multilaterally established rules, this activity can be transferred to the chain as a new block. A record of that transaction is stored in several distributed nodes to ensure security. In the meantime, the smart contract, as a crucial component of blockchain, facilitates trustworthy transactions to be conducted without third parties' involvement (Cong & He, 2019; Saberi et al., 2019).

To show the substantial change in current information systems, a comparison with the Internet could help the readers to realize the potential impact of blockchain technology on existing structures. Principally, the Internet (as opposed to blockchain), was designed to transfer information (not value) as well as to process and relocate copies of things (not original information). Therefore, in blockchains, value is generated through transactions recorded in a distributed ledger which is secured by arranging a verifiable, time-stamped record of transactions, which results in secure and auditable information

(Arora & Arora, 2018). These digital transactions go through a verification process that is agreed upon by the network consensus rules. When the new record passes this whole process, it is verified and included in the blockchain, and then multiple copies are generated in a distributed way to form a trustworthy chain.

One of the most essential features of blockchain is decentralization, which significantly increases information validity. Adding, updating, or removing information in the centralized information systems is not only inefficient and costly, but such systems are more vulnerable to hacking, corruption, or critical errors (Casino, 2019). Blockchain, by providing decentralized information sharing systems, significantly improves trust of the performed transactions, as there is no longer a need to estimate the credibility of the middlemen (who are removed) or of any parts of transactions in that network, and this information is easily accessible and verified. This results in another substantial benefit coming from blockchain utilization, which is the transparency of information whilst protecting the anonymity of participants, e.g., through cryptographic systems (Wang et al., 2019). Moreover, this structure allows limiting any human or behavioral misconduct such as dishonesty or sluggishness, ensuring the integrity of the system.

Determined by a specific technology application, blockchain construction can be contrasting when forming public (permissionless) or private (permissioned) information systems and ledgers. Both public and private blockchain networks are decentralized and distributed between their users to track all peer-to-peer transactions without the intermediary customarily trusted to authorize them (Yang et al., 2020). However, in private or closed blockchains, the partners know each other and there is no anonymity, which creates a need to introduce certifiers who are responsible for certifying network participants and maintaining these private networks. In public or open blockchains, cryptographic methods are applied to ensure trust among many anonymous users to allow them to access the network and perform operations inside of it. To continue this comparison, let us discuss a few key differentiating aspects. Private blockchains have higher transaction processing rates with fewer authorized participants. Therefore, a shorter time is needed to achieve the network consensus and more transactions can be processed within a second. By contrast, public blockchains have a significantly limited transaction processing rate. The consensus mechanisms such as Bitcoin's Proof-of-Work (PoW) in public blockchains require the entire network to reach a consensus on the state of transactions. Moreover, public blockchains' information privacy is more prone to risk due to their inherent nature. Alternatively, private blockchains have stronger data security foundations where any modification can be made basically when all nodes agree that the data can be transformed by the consensus mechanism (Yang et al., 2020).

In the meantime, the innovative transactional applications that enhance trust, transparency, and auditability are possible through blockchain applications, and these applications are ruled by smart contracts. Smart contracts are software solutions for storing principles and regulations during the negotiation of terms and actions between participants. It serves to automatically verify if preestablished rules and conditions have been fulfilled, and then executes transactions. Smart contracts could mitigate informational asymmetry and expand welfare and consumer surplus through enhanced access and competition, yet distributing information during consensus generation might encourage larger complicity (Cong & He, 2019).

Blockchain has gained popularity as a trading platform for Bitcoin, which is a digital cryptocurrency (Nakamoto, 2008). However, it has been spread across different industries as a tool for improvement in computing and information-flow aspects, also with numerous implications for innovative supply chains and logistics (Abeyratne & Monfared, 2016; Maurer, 2017; Cole et al., 2019, Pournader et al., 2020). Therefore, we will discuss the applications of blockchain in supply chains and possible multidimensional benefits coming from blockchain technology implementation.

1.3 Conceptual Framework

In this section, we will present a conceptual foundation for the chapter. Based on the literature review, we provide insight into blockchain-based sustainable supply chains. The whole process of building the framework is depicted in Figure 1.1.

In order to perform deductive reasoning, we will start with the applications of blockchain technology in supply chains. Next, we will apply blockchain technology into the context of sustainability, which will strongly support and directly lead us to the central concept of sustainable supply-chain management implementing blockchain. Because of its automation and decentralization, we will discuss the idea of blockchain as a governance mechanism as well.

Lastly, as it is an emerging technology in its early stages of development and practical application, we will examine the main barriers and challenges

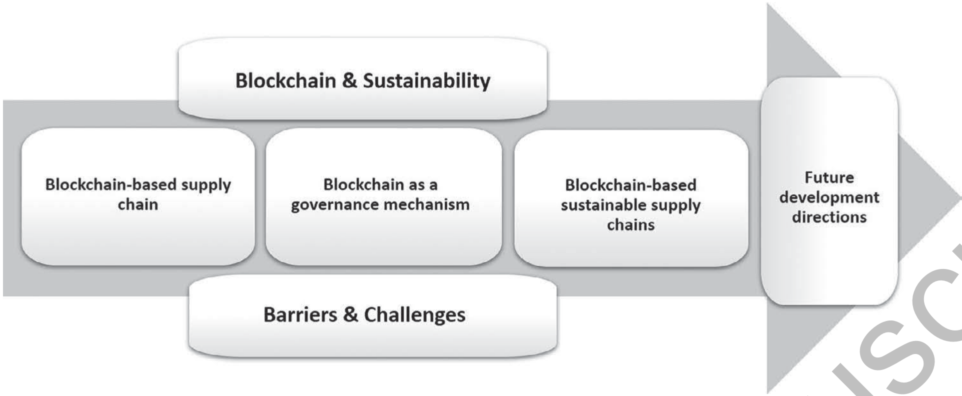

Figure 1.1 A Conceptual Framework for Blockchain-Based Sustainable Supply Chains.

Source: Own elaboration.

to a widespread blockchain implementation in supply chains. This whole process will help us to critically review the pros and cons of deploying blockchain in sustainable supply chains as well as limitations in the recent literature which will allow us to propose future directions for research and further development of that concept in theory and practice.

1.3.1 Blockchain-Based Supply Chains

Blockchain, as a highly innovative technology, can provide new solutions for the structure, operations, and management of supply chains. Its capability of ensuring dependability, traceability, and validity of information, as well as connection with smart contracts creating a trustless environment for transactions could result in major alterations in the current image and understanding of modern and future supply chains. This possibly revolutionary impact can be seen in Figure 1.2.

Dissimilar to certain public blockchain applications like Bitcoin or Ethereum, blockchain-based supply chains might require a closed, private, permissioned blockchain with multiple participants. However, the possibility of open, public, permissionless blockchains may still be possible and thus, the determination of privacy level will be one of the key initial decisions (Saberi, 2019).

Primarily, new actors' groups might appear to support blockchain integration into supply chains. According to Abeyratne and Monfared (2016), there would be a need to include:

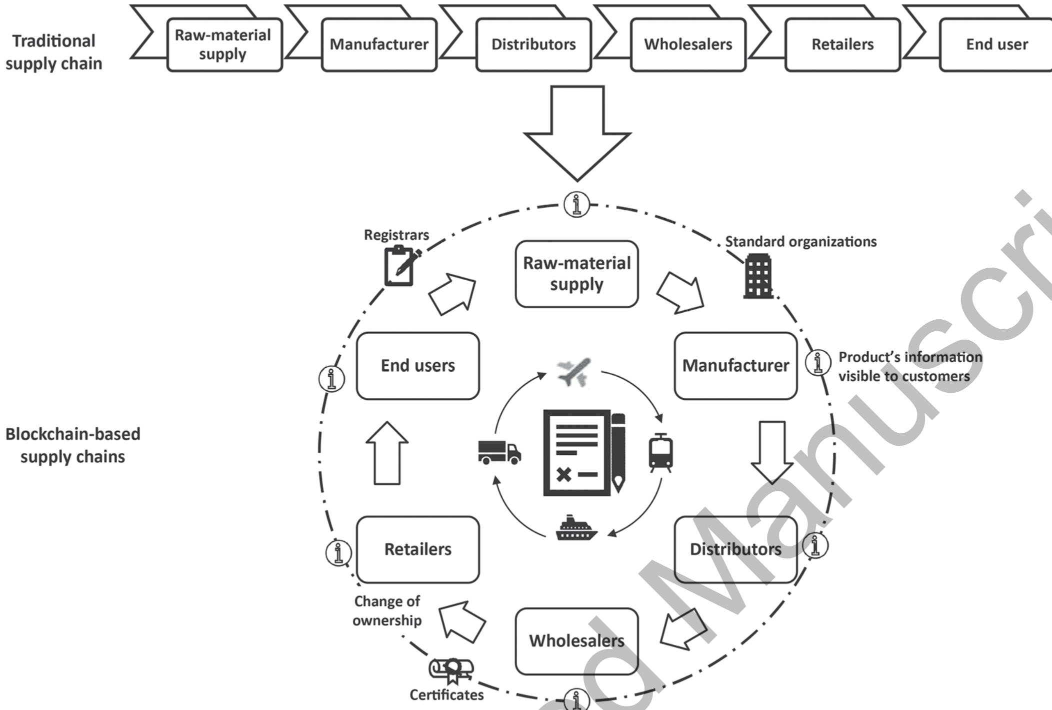

Figure 1.2 Supply Chain Transformation.

Source: Adapted from Saberi et al., 2019.

1) *registrars*, who form unique identities to network participants,
2) *standards organizations*, which develop standards frameworks, policies, and technological criteria,
3) *certifiers*, who give certifications to supply chain network participants, and
4) *actors*, containing producers, retailers, or end-customers, that need to be certified by an authorized auditor or certifier to ensure the system's trust.

Moreover, the influence of blockchain on supply-chain material and product flows can be observed as well. Each product could have a digital blockchain existence so that all interested participants would have direct access to product details. For security measures, only authorized users of blockchain would have that access through the digital key. The information about the materials or products could be of a different nature, such as their ownership and localization status, type, origin, or quality. Each product would have a digital information tag that connects the physical compound with its virtual identity in blockchain (Pournader et al., 2020).

Especially important in the context of ownership, access to the trading platforms granted to certified actors may be an important rule, whereas getting that access might require smart contract agreements and consensus mechanisms. Before the ownership is changed (by a sale or transfer), both sides would sign a digital contract or meet the standards of the smart contract to validate the transaction. After performing this exchange, its details are updating the blockchain register. Blockchain provides the automatic update of transactional data once the transaction is performed, which leads us to another important feature of blockchain—cost- and time-efficient automation of processes within supply chains (Abeyratne & Monfared, 2016).

As already mentioned, blockchain can provide detailed information on key product characteristics, such as the nature (what it is), the quality (how good it is), the quantity (how many units are available), the location (where it is) and the ownership (who owns it at any time). In that context, blockchain removes the need for a trusted central organization in these processes and provides the access to direct, verifiable, and constantly updated information about the product across its life cycle.

Blockchain, by providing reliability and transparency, facilitates material and information flow across the supply chain, with distributed and automated governance exigencies. This may cause an essential alteration from an industrial, product-oriented economy to an information and customization-centered economy. It is claimed that products will be more dependent on knowledge and information sharing rather than on components' features (Pazaitis et al., 2017). This can also result in increased customers' trust, as they could verify all the necessary information about the given product.

Smart contracts, being a set of pre-agreed rules, facilitates information flow between the participants of a blockchain-based supply chain. A smart contract can manage actors' certification, by providing precise and up-to-date information on access statutes, requirements, and limitations for a particular participant. The current state of rules cannot be changed without consensus mechanisms. Smart contracts can be useful in procurement as well, because of their ability to legally update the automated record of the transactions between trading partners. Therefore, smart contracts have a huge potential to provide substantial business process improvements in supply chains (Saberi, 2019).

To conclude this section, blockchains could bring many benefits to the supply-chain management, by impacting process and product management as well as financial transactions between supply-chain participants. A main possible utility of blockchain in supply chains is the removal of the middlemen from the transaction processes, and providing new trading possibilities which would boost the efficiency of trading processes between business partners and allow cost reduction of the end product, which could result in substantial savings (Fanning & Centers, 2016; Kamilaris, 2019). Lastly, the automation of financial transactions through smart contracts would facilitate their security, interoperability, and integrity as preestablished financial management mechanisms would allocate the funds to specific projects and departments in a well-timed and cost-effective manner, through their ability to mix currencies and resources in the optimized way (Tapscott & Tapscott, 2017).

1.3.2 Blockchain and Sustainability

As part of increasing environmental awareness in general on a global scale, organizations are heading towards sustainability which, besides environmental goals such as pollution reduction, also involves care for economic and social sectors as part of an overall strategy to improve organizational operations and their performance in the supply chain. Thus, sustainable supply-chain management offers several benefits to all participants by adopting more efficient production and transportation means, and reducing delays and costs. However, achieving sustainability has been limited due to inherent inefficiencies in traditionally oriented processing involving data and material flows such as inaccurate data, material waste, and the inability to meet requirements involving supply and demand in terms of quality, quantity, and timing, in particular for those of end-customers. This has resulted in the centralized nature of supply chains, with a lack of transparency and traceability across organizations. Therefore, as a technological solution, blockchain can be leveraged to deliver benefits, for example, tracking the origin of raw materials, production locations, product carriers, storage, and retailers which can be done using IoT combined solutions (Juszczyk & Shahzad, 2022). It allows to hold employees and ultimately businesses with their supply chains accountable by providing visibility into its tamper-resistant ledger. Such solutions enable decentralized systems, peer-to-peer trading of natural resources and permits, supply-chain monitoring and origin tracking, new financing models such as democratizing investment, and realization of nonfinancial value such as natural capital (Dorri et al., 2017; Tian, 2017).

Blockchain enables efficient tracking and transparency of defective and substandard goods (Saberi et al., 2019). It also helps to verify the provenance of a product and related sustainability practices, that is, if there are any fraudulent and unethical labor practices involved (Nyman, 2019). Such possibility of efficient tracking also helps to track the sustainability of supply chains, for example by calculating the carbon footprints of the products (Saberi et al., 2019). The verifiable and transparent management of resources enables an increase in the environmental sustainability of the supply chain. This could be maintained and even increased by using a tokenized ecosystem where resources, materials, and shipments are linked to tokens that in turn are verifiable and traceable. When a supply chain's practices are ideal from an environmental standpoint and verified through the blockchain, the organization would be rewarded with tokens. This ecosystem could draw more organizations into the ecosystem which would turn their supply chains more environmentally sustainable.

Blockchain can promote circular economy practices which include reducing materials and waste, reusing products, and recycling. The traceability and transparency features mean that operating costs decrease, and so can waste decrease. Blockchain can be used to incentivize new behaviors by verifying social sustainability claims, tokenizing sustainable purchases, and creating new systems for pricing and trading. Each step and transaction of the supply chain can be traced and its sustainability can be evaluated. While Köhler and Pizzol (2020) stated that there is no strong evidence as such that blockchain would increase sustainability, if we think about the main advantages of blockchain, i.e., transparency, traceability, authenticity, and trust, it can support a sustainable supply chain in various ways (Saberi et al., 2019). For example, having better information available about product freshness can help reduce food waste. Another example is how blockchain can enable certifications, including sustainability certifications, to be easily issued and tracked in a trustworthy way. In that sense, it can also help tackle human rights issues. Nevertheless, the design of the blockchain solution has a great influence on achieving specific sustainability objectives; it enables more efficient tracking of social and environmental conditions of supply chains (Saberi et al., 2019; Köhler & Pizzol, 2020).

Blockchain helps organizations in ensuring an environmentally green and sustainable supply chain. It is often difficult to verify that products are produced in an environmentally friendly way. If there is proof available that the products are manufactured with the use of renewable energy and sustainable material sources, consumers are more willing to buy the products. For example, in the furniture industry, Ikea has a table in their catalog claiming that it is made from a sustainable woodcut in Indonesia. Ikea must have an efficient tracking system to ensure that the product is indeed made from a specific material. It is a difficult process but can be accomplished with the use of blockchain technology and the origins of the product can be tracked through the whole supply chain (Saberi et al., 2019). Another aspect that blockchain can help to achieve is social sustainability. Saberi et al. (2019) stated that the food and beverage industries are just a few examples that face a lot of pressure from consumers related to sustainability nowadays. Blockchain can help organizations to ensure that only suppliers that provide proof of sustainable practices are allowed, which can be validated as product, ingredient information, and certificates need to be recorded in the blockchain. Varriale et al. (2021) stated that blockchain can also help in preventing the violation of human rights. This is necessary, especially in luxury products such as diamonds where corruption and illegal practices are common. The transparency offered by blockchain can help in achieving better sustainability, and control suppliers to avoid human rights violations, child labor, inhuman working conditions, and corruption.

1.3.3 Blockchain as a Governance Mechanism

Unlike traditional organizational governance where rules and conditions are enforced through economic governance, i.e., contractual governance or through sociological governance, i.e., relational governance (Shahzad et al., 2018), blockchain functions as an autonomous system of formal rules—a self-automated governance mechanism, relying on a set of protocols and code-based rules that are inevitably applied by the underlying blockchain-based network (Lumineau et al., 2021). Since blockchain does not directly depend on the enforceability of external legal obligations, smart contracts are placed in a blockchain-based network that facilitates the enforcement of rules by their embedded codes and algorithms (Catalini & Boslego, 2019). Blockchain also negates the concept of dependence, expectations of partner's behavior, and/or judgment based on their history, as it facilitates collaboration beyond these notions of expectations in behaviors and integrity is established without any direct contact between parties but through the system's immutability. In this vein, scholars such as Lumineau et al. (2021) comprehensively differentiated blockchain governance with contractual and relational governance based on defining features, regulatory principles, modes of enforcement, and form. They argued that, in blockchain, the identity of collaborating parties is less important and blockchain governance is distinct from both contractual and relational governance which facilitates hindering opportunism and boosting cooperation.

Thus, a holistic understanding of blockchain governance, its processes, implementation, and practices in the industrial ecosystem is required for further research in order to produce a clear understanding for both research and practice. It necessitates exploring and mapping the usage of blockchain technology by firms to automate transactions as well as revising and renewing their business model in order to achieve a successful innovation-management process. Blockchain can help in breaking silos among different actors in the supply chain and has the potential to make it an integrated ecosystem that is fully transparent to all the players involved.

1.3.4 Challenges and Barriers to Adopting Blockchain in the Supply Chain

Kshetri (2021) mentioned that blockchain has several challenges on its way before entering mass adoption. One major issue is the lack of standards, regulations, and laws. Global supply chains operate in an environment where different countries have different regulations and standards on how to operate, and most of the processes are managed by human beings in an old-fashioned way with lots of documents. Data in the blockchain needs to follow different regulatory requirements, and it is not yet clear what can be recorded in the blockchain and how the data needs to be managed in a secure way that is aligned with the requirements. Kshetri (2021) further identified common barriers to blockchain adoption including lack of institutional capacities, low degree of digitization, lack of technological expertise and absorptive capacity, and rank effect and barriers faced by small companies. The lack of institutional capacities relates to a lack of consistent societal, political, and economic operational context involving environments with diverse laws, regulations, and institutions where supply chains operate across the globe. Also, in developing countries, for instance, person-dependent patron-client relationships, which are often informal, reach from the state structures to local levels and determine which path will be taken in practice with respect to official laws and regulations. A low degree of digitization is another issue typical in developing countries as high-degree computerization is a core requirement for blockchain and the digitalization of supply chains overall. This means a lack of digital devices as well as Internet access, which together inhibit the introduction of the solutions.

Furthermore, since blockchain is in its infancy and developing in several industrial sectors, the available use cases are limited and industry-specific, and it becomes difficult to generalize its value for everyone by only looking at some pilot projects. In such a scenario, several concerns regarding its scalability and operability in the context of the supply chain arise, as there exist chain limitations with the ever-increasing number of transactions and a huge amount of information in blocks. A lack of technological maturity also hinders the blockchain to run efficiently as this has to do with the scalability aspect of the technology (Hackius & Petersen, 2017). The concern of the cost of developing, maintaining, and implementing blockchain in the supply chain is another factor that triggers an uncertainty as it is not just a question of developing in-house but acquiring or outsourcing from external sources to fit with the requirements of a firm's supply chain. Queiroz and Wamba (2019) highlighted that replacing a mature system to implement blockchain can pose several infrastructural challenges along with the cost of such changes. The ability to connect blockchains with the existing infrastructure of the companies, in order to function effectively, creates uncertainty as the technological usability remains low. Thus, it becomes unclear whether the technology will develop in the future and if so, how it will happen (Hackius & Petersen, 2020). Similarly, for small companies, it might be challenging to implement blockchain as it requires infrastructural changes and investments (Queiroz & Wamba, 2019), which small companies usually lack.

As traditional supply-chain operations face several challenges such as damage, erroneous data entry, order mismanagement, etc., the effective implementation and smooth functioning of blockchain in supply-chain systems requires the integration of various supply-chain players. As blockchain requires every transaction to be processed and validated through each node, weak infrastructure and political and institutional arrangements in developing countries restrict flawless implementation (Kshetri, 2021; Min, 2019). Although the transparency, visibility, and immutability of blockchain are great advantages in supply chains, data duplication in certain nodes or individual tampering might hurt the whole chain (Queiroz & Wamba, 2019). Furthermore, the mass adoption of blockchain technology is considered to be a challenge at the moment as the technology itself is not ready yet. Since the size of supply networks has grown massively, the capacity of blockchains to deal with a huge number of transactions seems to prevent scaling up. As several alternative solutions exist and excel in dealing with such large sets of data in the supply chain, the suitability of blockchain with legacy systems can pose several challenges for firms. For example, global supply chains are complex; one cannot just employ blockchain in operations to solve a certain supply-chain problem as it requires the whole supply-chain parties to integrate and comply with diverse laws, regulations, and institutions (Hackius et al., 2020; Kshetri, 2021). This might also slow down the development of blockchain in supply-chain operations because of the large number of participants involved. Also, each participant would want to have their own ways of working applied and many participants will have to change their existing way of working.

Regulating disruptive technologies is one of the main barriers when organizations want to implement blockchain. For blockchain, there are only a few standards placed while requiring more standards to execute the system efficiently and securely. Also, the legislation is changing at a rapid pace and questions remain as to whether the solutions will comply with the future laws (Hackius et al., 2020). In addition to that, the lack of support from governments in the form of regulatory frameworks and policies promoting standards restricts the adoption of the blockchain (Choi et al., 2020). The legality of smart contracts is still unclear because of the nature of encrypted code that courts may not be able to recognize. Even cryptocurrencies are still being monitored and policies are in the process of being established.

Another barrier that is restricting the adoption of blockchain into supply chains is the lack of understanding of the technology that stakeholders have (Jabbar et al., 2021). Currently, there is a low level of understanding that exists among both industry leaders and consumers. Blockchain technology contains complex elements that are sometimes difficult to understand, and several people stamp it as illegitimate due to the recent frauds and scandals reported. Furthermore, lagging to adopt technology is not an unknown phenomenon and is often studied by scholars. Costs, complexity, and skills are existing barriers to technology adoption. Walsh et al. (2021) studied the resistance to a blockchain system by assessing managers' resistance to the change. In short, perceived benefits decrease resistance, however there are challenges in understanding the full benefits because of a lack of knowledge about blockchain technology (Walsh et al., 2021).

Kshetri (2021) states that another issue is that there is a relatively low level of digitalization in the supply chain and the technical requirements to start using blockchain. To adopt blockchain, a high degree of computerization is required from the participants and many of them are in developing countries. In such countries, there are challenges related to digitalization, and simply not enough resources to implement blockchain in their operations. In addition to this, the overall level of skills regarding blockchain is still rather low. As of 2018, there were approximately 20 million software developers in the world, but only 0.1% of them knew about blockchain codes. It requires a lot to implement a high-quality blockchain ecosystem that includes a wide network consisting of different countries and operations. Similarly, Chang et al.

(2020) state that one of the main barriers to the larger adoption of blockchain in supply-chain management is that most organizations are too suspicious of the technology. Blockchain is easily considered a synonym for cryptocurrencies, and organizations are suspicious about the safety of the system and the actual benefits that can be gained when implementing it in real-life projects. For now, not many users see the benefits clearly as there are too many threats such as fear of unintentional data compromise because the regulations and standards are not implemented yet.

One notable challenge related to blockchain adoption is also that it is unclear whether it is needed and how beneficial it is compared to the current centralized data-sharing and management models. It costs a lot to set up a blockchain network as it needs to be integrated with the existing systems. In addition to the costs, and complexity, it remains unclear whether it is scalable enough to handle all the transactions and whether the performance and level of costs are sufficient to replace the old systems.

1.3.5 Overcoming the Challenges

Overcoming these challenges boils down to recognizing the limitations of implementing blockchain solutions, particularly on a large scale. Blockchain could be leveraged in improving operational efficiency by optimizing existing business processes to recognize its benefits, if any. As blockchain technology is young and future research is required to develop new traceability applications, small-scale experimentations can be performed to quantitatively stress the need for blockchains in the supply chain (Sunny et al., 2020). Moreover, as experiments are conducted and relevant experience is acquired, technological enablers become more applicable and available. With better capabilities combined with lower prices as well as the establishment of a more comprehensive digital infrastructure across the globe, implementation of blockchain solutions on a wider scale can be achieved for the benefit of all. The issue of ensuring appropriate inputs into blockchain remains among the main concerns, which requires the establishment and application of comprehensive governance based on the decentralization principles for input validation in blockchain to minimize the incentives to act based on adverse motivations when participating in blockchain-based cooperation.

Moreover, there is still a lot of work to do with the features and operations of smart contracts, and those developments are expensive and troublesome. The programmed codes with bugs can cost a lot to organizations, so they must be precise, but also simple and cost-efficient. Regarding key management, in a smart contract every user has public and private keys, which are used for authentications; it can be challenging to store the private keys. Further, a smart contract platform to keep up with the growth of organizations must be scalable. However, current platforms are not capable and scalable enough and have different limitations, such as time intervals and block sizes required to generate new blocks (Omar et al., 2020). Similarly, these platforms are not equipped to prepare and handle unseen future events, such as natural disasters or any unexpected change of circumstances. This obstacle could be handled by combining the smart contract with artificial intelligence, big data, or machine learning, however, the combined technologies are not mature enough (Omar et al., 2020). People can resist when a new platform or technology is set to be implemented in an organizational setting. Similarly, Omar et al. (2020) argued that people are used to the old technologies and ways to work and are afraid of the risks, and do not want to try new possibilities. Also, the privacy of data plays a role, as each country has its own laws and legal requirements which make it difficult for smart contracts to be implemented effectively (Khan et al., 2021). Also, due to the fact that the supply chain involves various entities in different stages, having multiple decision makers complicates the management and therefore leads to information inequality. Lack of information sharing and traceability makes the process, collaboration among parties, sense, and response events more difficult to chart.

In order to ensure product safety and quality, there is a need for greater transparency throughout the entire supply chain. As the customers have more knowledge in different fields, they demand to know the provenance of the product before they commit to buying it. It is vital to build trust and strong relationships with the customers and all of the partners throughout the supply-chain process.

Data loss is one challenge that the implementation of smart contracts has, due to the fact that the systems are mainly heterogeneous and categorized under different administrative domains. One challenge is the governance-related issues, where it is important to know how governments should regulate such contracts and how such heterogeneous regulations will be emerged. For example, it is important to know how certain transactions will be taxed and how the privacy and anonymity of data will be addressed as it can be challenged. When a large number of transactions takes place simultaneously and a hacker gains unauthorized access to the blockchain, they can create false contracts that might be left unnoticed and accepted, which can lead to many types of losses, of which the financial losses are the most obvious (Rouhani & Deters, 2019).

1.4 Conclusions and Future Development Directions

In this opening chapter, we have gone straight to the future to suggest an innovative technology solution that may revolutionize the whole supply chain. In response to the global changes in the environment, society and business areas, it is imperative for all of the actors in the supply chain to follow the sustainable path of operations.

Therefore, in the literature review, we have introduced the concept of sustainability and linked its development all the way to sustainable supply-chain management. Next, we have shed some light on the principles and basic features of blockchain technology, as it is still an emerging technology with relatively low levels of common understanding by society.

This theoretical foundation has led us to present a conceptual framework for blockchain application in sustainable supply chains. We have achieved it by mixing the concepts of blockchain-based supply chains together with blockchain utilization in sustainability. The supporting element of our framework was blockchain as a governance mechanism, which can drastically change the current administration of supply chains. As blockchain is still in its infancy stage of development, we have identified major barriers to its widespread implementation within supply chains and proposed practical measures to overcome these numerous challenges. Therefore, this conceptual framework provides both theoretical and practical implications by analyzing extant seminal literature in the field of sustainable supply-chain management together with proposing future research directions. Practitioners from the logistics, blockchain technology, digitalization, and supply-chain areas can utilize this framework as a guide toward the successful implementation of blockchain in future-oriented sustainable supply chains.

As it is claimed that blockchain could revolutionize the current approach toward supply-chain management, future research should further investigate the impact of blockchain and its long-lasting benefits (Pournader et al., 2020). By providing disintermediation and supply-chain transparency, blockchain can support a trust-free environment for conducting business, which could dramatically change the interrelations between producers and end customers and cause the rethinking of the current trust-based theories in the supply chain (Saberi et al., 2019). As it is claimed that blockchain-based systems may require business model innovation, an interesting area of future research is the influence of blockchain's application on the current business models (Nowiński & Kozma, 2017; Shahzad, 2020). Moreover, as shown in the chapter, blockchain would provide new governance mechanisms, which will put the existent supply-chain governance structures into question. Furthermore, as the main feature of blockchain is to improve information sharing, a more advanced information processing theory would help to better understand technical nuances related to the blockchain-based supply chains.

Importantly, as we have discussed sustainability in supply chains, further research is recommended to analyze the blockchain-enabled sustainable supply chains from the environmental, economic, and societal aspects and to measure each performance accordingly (Kshetri, 2021).

Lastly, blockchains, through providing decentralization, transparency, and smart contracts, might bring a very open and dynamic approach to performance systems which would allow more operational relationships while decreasing the importance of strategic alliances. It will strongly stimulate the supply-chain risk management as well, by bringing efficiency improvements which would serve to reduce delays and overall risk levels across the supply chain (Fu & Zhu, 2019). Hence, such a possible significant influence of blockchain on current structures requires deeper investigation.

Acknowledgments

This research is a part of the BizPub research project funded by the foundation for Economic Education (Liikesivistysrahasto) under the grant number 200264.

References

Abeyratne, S. A., & Monfared, R. P. (2016). Blockchain ready manufacturing supply chain using distributed ledger. *International Journal of Research in Engineering and Technology*, *5*(9), 1–10.

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., & Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *100*, 143–174.

Arora, A., & Arora, M. (2018). Digital-information tracking framework using blockchain. *Journal of Supply Chain Management Systems*, *7*(2), 1.

Carter, C. R., & Jennings, M. M. (2002). Logistics social responsibility: An integrative framework. *Journal of Business Logistics*, *23*(1), 145–180.
Carter, C. R., & Jennings, M. M. (2004). The role of purchasing in the socially responsible management of the supply chain: A structural equation analysis. *Journal of Business Logistics*, *25*(1), 145–186.
Carter, C. R., & Rogers D. S. (2008). A framework of sustainable supply chain management: Moving toward new theory. *International Journal of Physical Distribution & Logistics Management*, *38*(5), 360–387.
Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification, and open issues. *Telematics and Informatics*, *36*, 55–81.
Catalini, C., & Boslego, J. (2019). *Blockchain Technology and Organization Science: Decentralization Theatre or Novel Organizational Form?* Working Paper, Massachusetts Institute of Technology, Cambridge.
Chang, Y., Iakovou, E., & Shi, W. (2020). Blockchain in global supply chains and cross border trade: A critical synthesis of the state-of-the-art, challenges and opportunities. *International Journal of Production Research*, *58*(7), 2082–2099.
Choi, T. M., Guo, S., & Luo, S. (2020). When blockchain meets social media: Will the result benefit social media analytics for supply chain operations management? *Transportation Research Part E: Logistics and Transportation Review*, *135*, 101860.
Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: Implications for operations and supply chain management. *Supply Chain Management: An International Journal*, *24*(4), 469–483.
Cong, L. W., & He, Z. (2019). Blockchain disruption and smart contracts. *The Review of Financial Studies*, *32*(5), 1754–1797.
Dong, F., Zhou, P., Liu, Z., Shen, D., Xu, Z., & Luo, J. (2017). Towards a fast and secure design for enterprise-oriented cloud storage systems. *Concurrency and Computation: Practice and Experience*, *29*(19), 4177.
Dorri, A., Kanhere, S. S., Jurdak, R., & Gauravaram, P. (2017). *Blockchain for IoT Security and Privacy: The Case Study of a Smart Home*. 2017 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops) (pp. 618–623). IEEE. DOI: 10.1109/PERCOMW.2017.7917634; https://www.ieee.org/about/index.html?utm_source=dhtml_footer&utm_medium=hp&utm_campaign=learn-more
Elkington, J. (1998). *Cannibals with Forks: The Triple Bottom Line of the 21st Century.* Stoney Creek, CT: New Society Publishers.
Elkington, J. (2004). Enter the triple bottom line. In A. Henriques & J. Richardson (eds.), *The Triple Bottom Line: Does It All Add Up?* (pp. 1–16) London: Earthscan.
Erlich, P. R., & Erlich, A. H. (1991). *The Population Explosion.* New York, NY: Touchstone.
Fanning, K., & Centers, D. P. (2016). Blockchain and its coming impact on financial services. *Journal of Corporate Accounting & Finance*, *27*(5), 53–57.
Friedman, T. L. (2005). *The World Is Flat.* New York, NY: Farrar, Strauss and Giroux.
Fu, Y., & Zhu, J. (2019). Big production enterprise supply chain endogenous risk management based on blockchain. *IEEE Access*, *7*, 15310–15319.

Gladwin, T. N., Kennelly, J. J., & Krause, T. (1995). Shifting paradigms for sustainable development: Implications for management theory and research. *Academy of Management Review*, *20*(4), 874–907.

Góncz, E., Skirke, U., Kleizen, H., & Barber, M. (2007). Increasing the rate of sustainable change: A call for a redefinition of the concept and the model for its implementation. *Journal of Cleaner Production*, *15*(6), 525–537.

Hackius, N., & Petersen, M. (2017). *Blockchain in Logistics and Supply Chain: Trick or Treat? In Digitalization in Supply Chain Management and Logistics: Smart and Digital Solutions for an Industry 4.0 Environment*. Proceedings of the Hamburg International Conference of Logistics (HICL), Vol. 23 (pp. 3–18). Berlin: epubli GmbH.

Hackius, N., & Petersen, M. (2020). *Translating High Hopes into Tangible Benefits: How Incumbents in Supply Chain and Logistics Approach Blockchain*. IEEE Access, 8, 34993–35003.

Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of Management Review*, *20*(4), 986–1014.

Helo, P., & Shamsuzzoha, A. (2020). Real-time supply chain: A blockchain architecture for project deliveries. *Robotics and Computer-Integrated Manufacturing*, *63*, 101909.

Ivanov, D., Dolgui, A., & Sokolov, B. (2018). The impact of digital technology and industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, *57*(3), 1–18.

Jabbar, S., Lloyd, H., Hammoudeh, M., Adebisi, B., & Raza, U. (2021). Blockchain-enabled supply chain: Analysis, challenges, and future directions. *Multimedia Systems*, *27*(4), 787–806.

Juszczyk, O., & Shahzad, K. (2022). Blockchain Technology for Renewable Energy: Principles, Applications and Prospects. *Energies*, *15*(13), 4603.

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management*, *52*, 101967.

Kamilaris, A., Fonts, A., & Prenafeta-Boldύ, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, *91*, 640–652.

Khan, S. N., Loukil, F., Ghedira-Guegan, C., Benkhelifa, E., & Bani-Hani, A. (2021). Blockchain smart contracts: Applications, challenges, and future trends. *Peer-to-Peer Networking and Applications*, 1–25.

Köhler, S., & Pizzol, M. (2020). Technology assessment of blockchain-based technologies in the food supply chain. *Journal of Cleaner Production*, *269*, 122193.

Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. *International Journal of Information Management*, *60*, 102376.

Lal, R., Hansen, D. O., & Uphoff, N. (2002), *Food Security and Environmental Quality in the Developing World*. Boca Raton, FL: CRC Press.

Lambert, D. M. (2006). *Supply Chain Management: Processes, Partnerships, Performance* (2nd ed.). Sarasota, FL: Supply Chain Management Institute.

Lumineau, F., Wang, W., & Schilke, O. (2021). Blockchain governance: A new way of organizing collaborations? *Organization Science*, *32*(2), 500–521.

Maurer, B. (2017). *Blockchains Are a Diamond's Best Friend: Zelizer for the Bitcoinmoment*. In: F. F. W. Nina Bandelj & Viviana A. Zelizer (eds.), *Money Talks: Explaining How Money Really Works* (pp. 215–230). Princeton: Princeton University Press.

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2002). Defining supply chain management. *Journal of Business Logistics*, *22*(2), 1–25.

Min, H. (2019). Blockchain technology for enhancing supply chain resilience. *Business Horizons*, *62*(1), 35–45.

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. Retrieved from: https://bitcoin.org/bitcoin.pdf Available [April 4, 2022].

Nowiński, W., & Kozma, M. (2017). How can blockchain technology disrupt the existing business models? *Entrepreneurial Business and Economics Review*, *5*(3), 173–188.

Nyman, T. (2019). *Increased Transparency and Prevention of Unethical Actions in the Textile Industry's Supply Chain through Blockchain*. Aalto University. Retrieved from: https://aaltodoc.aalto.fi/handle/123456789/39341 Available [April 1, 2022].

Omar, I. A., Jayaraman, R., Salah, K., Simsekler, M. C. E., Yaqoob, I., & Ellahham, S. (2020). Ensuring protocol compliance and data transparency in clinical trials using Blockchain smart contracts. *BMC Medical Research Methodology*, *20*(1), 1–17.

Pazaitis, A., De Filippi, P., & Kostakis, V. (2017). Blockchain and value systems in the sharing economy: The illustrative case of backfeed. *Technological Forecasting and Social Change*, *125*, 105–115.

Pournader, M., Shi, Y., Seuring, S., & Koh, S. L. (2020). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *International Journal of Production Research*, *58*(7), 2063–2081.

Queiroz, M. M., & Wamba, S. F. (2019). Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management*, *46*, 70–82.

Radanović, I., & Likić, R. (2018). Opportunities for use of blockchain technology in medicine. *Applied Health Economics and Health Policy*, *16*(5), 583–590.

Rotunno, R., Cesarotti, V., Bellman, A. Introna, V., & Benedetti, M. (2014). Impact of track and trace integration on pharmaceutical production systems. *International Journal of Engineering Business Management*, *6*(25). DOI: 10.5772/58934.

Rouhani, S., & Deters, R. (2019). Security, performance, and applications of smart contracts: A systematic survey. *IEEE Access*, *7*, 50759–50779.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135.

Savitz, A. W., & Weber, K. (2006). *The Triple Bottom Line*. San Francisco, CA: Jossey-Bass.

Shahzad, K., Ali, T., Takala, J., Helo, P., & Zaefarian, G. (2018). The varying roles of governance mechanisms on ex-post transaction costs and relationship commitment in buyer-supplier relationships. *Industrial Marketing Management*, *71*, 135–146.

Shahzad, K. (2020, July). Blockchain and organizational characteristics: towards business model innovation. In *International Conference on Applied Human Factors and Ergonomics* (pp. 80–86). Springer, Cham.

Shrivastava, P. (1995). The role of corporations in achieving ecological sustainability. *Academy of Management Review*, *20*(4), 936–960.

Sikdar, S. K. (2003). Sustainable development and sustainability metrics. *AIChE Journal*, *49*(8), 1928–1932.

Sivula, A., Shamsuzzoha, A., & Helo, P. (2021). Requirements for blockchain technology in supply chain management: An exploratory case study. *Operations and Supply Chain Management: An International Journal*, *14*(1), 39–50.

Starik, M., & Rands, G. P. (1995). Weaving an integrated web: Multilevel and multisystem perspectives of ecologically sustainable organizations. *Academy of Management Review*, *20*(4), 908–935.

Stead, E., & Stead, J. G. (1996). *Management for a Small Planet: Strategic Decision Making and the Environment* (2nd ed.). Thousand Oaks, CA: Sage.

Steiner, J., & Baker, J. (2015). *Blockchain: The Solution for Transparency in Product Supply Chains*. Retrieved from: www.provenance.org/whitepaper Available [February 10, 2022].

Sunny, J., Undralla, N., & Pillai, V. M. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering*, *150*, 106895.

Tapscott, A., & Tapscott, D. (2017). How blockchain is changing finance. *Harvard Business Review*, *1*(9), 2–5.

Teufel, B., Sentic, A., & Barmet, M. (2019). Blockchain energy: Blockchain in future energy systems. *Journal of Electronic Science and Technology*, 100011.

Tian, F. (2017). *A Supply Chain Traceability System for Food Safety Based on HACCP, Blockchain & Internet of Things*. 2017 International Conference on Service Systems and Service Management (pp. 1–6). IEEE, June.

Tucker, C. (ed.) (2019). *Blockchain: The Insights You Need from Harvard Business Review*, HBR Insights Series. Brighton, MA: Harvard Business Press.

Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2021). Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management. *Sustainability*, *13*(11), 6372.

Walsh, C., O'Reilly, P., Gleasure, R., McAvoy, J., & O'Leary, K. (2021). Understanding manager resistance to blockchain systems. *European Management Journal*, *39*(3), 353–365.

Wang, L., Shen, X., Li, J., Shao, J., & Yang, Y. (2019). Cryptographic primitives in blockchains. *Journal of Network and Computer Applications*, *127*, 43–58.

Whiteman, G., & Cooper, W. H. (2000). Ecological embeddedness. *Academy of Management Journal*, *43*(6), pp. 1265–1282.

Yang, R., Wakefield, R., Lyu, S., Jayasuriya, S., Han, F., Yi, X., & Chen, S. (2020). Public and private blockchain in construction business process and information integration. *Automation in Construction*, *118*, 103276.