sustainability

MDPI

Article

Blockchain Technology and Its Role in Enhancing Supply Chain Integration Capability and Reducing Carbon Emission: A Conceptual Framework

Michael Wang [1], **Bill Wang** [2] **and Ahmad Abareshi** [3,*]

1 Faculty of Engineering Technology & Science, Higher Colleges of Technology, Abu Dhabi, UAE; michael.wang@hct.ac.ae
2 Department of Business Information System, Auckland University of Technology, Auckland 1010, New Zealand; bill.wang@aut.ac.nz
3 The School of Accounting, Information Systems and Supply Chain, RMIT University, Melbourne VIC 3000, Australia
* Correspondence: ahmad.abareshi@rmit.edu.au

Received: 23 September 2020; Accepted: 12 December 2020; Published: 17 December 2020

check for updates

Abstract: Most current blockchain and carbon emission studies are from engineering and sciences disciplines. By incorporating blockchain technology into supply chain integration capabilities, the firms are be able to work collaboratively with each other to enhance the supply chain integration and simultaneously reduce the carbon emission in a supply chain. This paper presents a conceptual framework to understand the role of blockchain in a low carbon supply chain management. Applying the Socio-Technical Theory and Resource-Based View, the research propositions between blockchain, supply chain integration capability and carbon emission are proposed in the research framework. The results indicate that the blockchain technology may be viewed as a strategic management approach to enhance supply chain integration and reduce the carbon emissions. In addition, it may be adopted as an operational tool to track carbon footprint, streamline processes and improve efficiency of carbon management to minimize the overall emissions in supply chains. The paper contributes to the blockchain literature and its applications in low carbon supply chain management and provides recommendation for future research.

Keywords: blockchain; low carbon supply chain; integration; carbon emission; supply chain management; New Zealand

1. Introduction

The climate change has become one of the major challenges in today's world. Governments attempt to address the climate change using a wide range of strategies and approaches. There are significant number of studies showing that human activities have responsible for increased levels of carbon dioxide which lead to increase in the temperature of the Earth's atmosphere and significant climate changes. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change, a group of 1300 independent scientific experts from countries all over the world under the auspices of the United Nations, concluded there's a more than 95 percent probability that human activities over the past 50 years have warmed our planet [1]. There is little doubt that the natural disasters such as tsunamis, floods, wildfire, droughts, heat waves, are the results of human activity. According to Shaw et al. [2] up to 90% of an organization's environmental impact lies in the supply chain, either upstream (suppliers, manufacturing phase) or downstream (consumers, product use phase); hence, it is imperative to reduce the emission of carbon dioxide (CO_2) in supply chains [3].

www.manaraa.com

Many international companies are shifting the focus of their carbon reduction management strategy from their organization level to the supply chain level in response to the climate change [4].

The supply chain is a connected network of various companies including manufacturers, suppliers, distributors, retailers and customers with the ultimate aim of delivering goods and services and meeting the customer demand [5]. In supply chains, the carbon emission is produced through various activities from processing raw materials all the way to final customers [6,7]. A low-carbon supply chain may be defined as the reduction of carbon emissions in the operations of product development, production process, and logistics [8]. The low carbon supply chain management has broad features such as pollution/waste reduction, general environmental regulation compliance, environmental reputation of firm, and overall environmental performance. Although much research has been conducted on the green supply chain, very few studies attempt to look at the problem from a value chain perspective. With an increasing pressure of regulations and policies, enterprises and its supply chains face a looming problem on how to measure and manage the carbon emission across the entire supply chains. As the carbon emission is a complex issue, it requires system integration to resolve the problem. Focal companies may have a power to influence their upstream and downstream supply chains. Having said that, organizational integration can be an important approach through which all supply chain members make an attempt to comply with standards and environmental regulations.

Technology plays a vital role to manage the complexity and risks in today's supply chains [9]. Data analytics has been used to optimize supply chain operations. Such trend is transforming industries to the next generation which is referred to as Industry 4.0 [10]. Industry 4.0 is high levels of automation of industrial practices, using modern smart technology using internet of things (IoT) technologies with minimum need for human intervention [11]. Blockchain is one of the emerging technologies in the industry 4.0 [12]. It is a digital, and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamper-proof records [13]. It enables companies to store almost every event or transaction on the distributed ledger and provide the potential solutions to address the visibility and traceability within a supply chain [14]. Blockchain technology has a huge potential to be applied in many applications for different purposes. Thus, it is significant to explore the application of blockchain in green supply chain. A fusion of Industry 4.0 technologies, from robotics and automation to data analytics, blockchain technology, 5G, mixed reality and the application of artificial intelligence, is becoming a major force to continue to drive economic growth in next couple of decades [10]. Traditional bar-coded and RFID tracking systems have limited purposes and fixed structures [10]. An inclusive blockchain system, in which a flexible platform is offered to integrate stakeholders and offer useful information from the beginning to the end of a supply chain [10], may help achieve the goals of a sustainable supply chain.

Though there has been an inclination to adopt blockchain technology in logistics and supply chain [15], we are at the early stage of leveraging the potentials of such a technology [16]. On the other hand, managing low carbon emissions has been an important topic in supply chain management [8]. Hence, the purpose of this study is to develop a conceptual framework to understand the way that blockchain facilitates supply chain integration and the role of blockchain in a low carbon supply chain. More specifically, the study analyses the relationships among blockchain technology, supply chain integration and carbon emissions. We adopted the Resource-based View (RBV) and Socio-technical Theory (STT) to support the proposed research framework. RBV posits that the procession of scare resources can lead to the firm competitive advantage as long as the firm is able to protect it and the substitution of such a resource is non-existence [17,18]. Literature review posits that technological advances are considered as organizational resources which can lead to competitive advantages [19,20]. Blockchain technology, as a form of organizational resource, has the ability to streamline the automation of inter- and intra-organizational processes [21] and influence the way that organizations collaborate and interact with one another and ultimately improve the productivity and sustainability of the supply chain [22].

المنارة للاستشارات
www.manaraa.com

Based on STT, there are two subsystems including technical sub-system and the social sub-system in every organization, which should be properly designed to maximize the system performance [23,24]. To address the above issues, a review of the literature on blockchain and carbon emissions in supply chain management were undertaken in the study. Also, a pilot study was conducted in New Zealand to understand the blockchain technology from a managerial perspective. A panel discussion was performed to obtain further insight which ultimately led to a proposed research framework. This paper is a part of sustainable value chain research project to building future sustainable supply chain in New Zealand industries. The project aims to reduce the carbon emissions at a supply chain level. Building on the tenets of STT we argue that blockchains are important objects of social science and not for their 'moneyness' per se [25]. The STT was used in developing the proposed research framework in this study to ensure both social and technical elements of the blockchain in supply chain are considered. In fact, the social element is linked to the impact of blockchain on society specifically on organizations interacting with each other in a sustainable supply chain.

The remainder of this paper is organized as follows. First, we provide a review of the relevant literature. We then show the research method in Section 3. Section 4 discusses the framework and research propositions followed by the discussion and conclusion sections.

2. Literature Review

2.1. Low Carbon Supply Chain

Due to the increased global concerns on greenhouse gas emissions (GHG) in recent decade there have many changes in the ways the supply chain traditionally functions [26]. The low carbon supply chain is a strategic, environmentally-aligned initiative that aims to achieve operational excellence and waste reductions by focusing on energy efficiency and reducing carbon emissions [8]. The objective of low carbon supply chain management is to reduce overall carbon emissions in a supply chain network. Chan [27] defined the concept of carbon management as the measurement and management of emissions of carbon dioxide (CO_2) and of the other five greenhouse gases: Methane (CH_4); Nitrous oxide (N_2O); Sulphur hexafluoride (SF_6); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs) covered by the Kyoto Protocol. As suggested by Chan [22], the greenhouse gases consists of a list of different gases however, in practice, many companies will only focus on measuring and managing carbon dioxide emissions [27]. Carbon footprint is the total greenhouse gas emissions caused directly and indirectly by an individual, organization, event or product [28]. Hence, it is imperative to measure, track and analyze the emissions through entire supply chain to minimize the negative impacts and maximize the overall benefits. Shaw, Shankar [2] showed that operations is responsible for just 19 percent of the total greenhouse gas emission generated in supply chain. In fact, 81 percent of the gas emission is generated by other indirect activities such as transportation, greenhouse gas emission generated by the first-tier suppliers and other members of the supply chains.

The concept of low carbon supply chain is developed based on the boarder concept of sustainable operations [8] and green supply chain management [29]. Although there are past research on green supply chain management [8,30–33], a few studies have focused on carbon emission. Due to the external pressures imposed by government regulations many companies take the carbon emission as an important issue in their strategic decisions. Compliance with ethics standards on protecting environment is another important consideration in the supply chain [34]. Auditing of suppliers for compliance with ethical standards requires huge resources and effects. Blockchain may offer an effective and efficient solution to manage the carbon emission by integrating the supply chain partners and enhancing the supply chain collaboration [10]. Low carbon supply chain can be achieved through various ways such as low carbon product design, low carbon production process, low carbon procurement, low carbon distribution, and low carbon logistics [8].

Reviewing the literature three types of emissions can be identified as follows: *Direct emissions:* the emissions from sources that are directly owned or controlled by an organization. *Indirect energy*

المنارة للاستشارات
www.manaraa.com

emissions: the emissions generated through using electricity by organizations for different purposes such as heating, cooling, steaming etc. *Other indirect emissions*: throughout the supply chain there are other indirect upstream or downstream emissions generated by sources that an organization does not own or control them however such activities are necessary in the operations of a supply chain [27,28]. The low carbon procurement focuses on the first two emissions. Correia, Howard [28] define the low carbon procurement as the process in which firms try to mitigate the carbon footprint through procurement of goods and services with reduced carbon footprint and work with those suppliers with good record in terms of environmental performance. Achieving the objective of low carbon procurement would lead to the reduction of the overall organizational carbon footprint.

Low carbon product design and production may also need to consider the overall life cycle carbon emissions in supply chains [3]. Low carbon distribution and logistics consider the carbon emissions reduction with regard to transport, warehousing, packaging materials, etc. [35]. Das and Jharkharia [26] suggest two perspectives on low carbon supply chain management. In the first perspective the focus is on the functional and operational aspects of supply chain management and in the second perspective the main focus is on the carbon footprint in the supply chain. The previous studies found that companies can reduce their carbon emission through supply chain optimization [36,37], and managing carbon footprint [29]. Hence, we argue that the blockchain may be adopted as a strategic tool to improve effectiveness and efficiency of an entire supply chain by enhancing the supply chain integration which will eventually acts as a carbon management tool to store, monitor, and track the carbon emissions. With this aim, in this study carbon emission is viewed as a quantifiable indicator for supply chain environmental performance. The overall supply chain carbon emission is the sum of all supply chain partners' carbon emissions.

The application of technology for carbon emission reduction is not a new idea. New technologies may help reduce emissions in the industry 4.0 era [38]; however, in this research, blockchain is not only considered as an operational tool to actually store and track the emissions and credits in supply chains but also enables various stakeholders to monitor and control the overall carbon and environmental performance. More importantly, the blockchain may be considered as a strategic management tool to integrate and optimize the entire supply chain system and reduce the overall carbon emissions with minimum costs [24].

2.2. Blockchain

Blockchain is known as distributed ledger technology [39]. It is a versatile programmable platform for managing contracts, product ownership and provide a distributable tamper-proof audit for real-time applications [40]. Its characteristics include immutability, irreversibility, decentralization, persistence and anonymity [41,42]. With these advantages, it is applicable in almost all fields requiring information sharing among multiple parties [43]. Implementation of blockchain technology are rapidly emerging in supply chain [38]. It is not only a new type of internet infrastructure based on distributed applications but also a new type of supply chain network [44]. It allows participants to secure the settlement of transactions, achieve the transaction, and transfer the assets at a low cost [39]. Blockchain can improve the supply chain efficiency [14], supply chain resilience [45], supply chain visibility [46]. It is an emerging technology which has attracted many research in recent years. Blockchain technology is ready to disrupt nearly every industry and business model [47]. Blockchain can help firms address important issues in supply chain such as trust, transparency, traceability, data fragmentation, data sharing, and interoperability [46,48,49].

There are three types of blockchain including blockchain, private, and consortium blockchains. Public blockchain is a "permission-less" and decentralized blockchains in which everyone can read, and write transactions, perform auditing in the blockchain any time with no specific validator or controller. Private blockchain is a "permissioned" and centralized blockchain system in which the invited participant can only join the system. It is a private data sharing and exchange system among a group of individuals or organizations with mining controlled by one individual or organization.

المنارة للاستشارات
www.manaraa.com

In fact, consortium blockchain is a partially private and permissioned blockchain, the consortium decides the different levels of permissions for the network participants [41]. Permissioned blockchain systems may better address an enterprise's concerns on issues such as transaction security, privacy, and scalability [50].

Blockchain can reduce the overall costs of a supply chain [14,51]. It can significantly improve the overall administrative processes, information sharing, transparency, trust and traceability between different stakeholders [47]. Tang and Veelenturf [38] argue that the blockchain can improve the efficiency and provenance in the freight operations and reduce emission via smart transportation. Queiroz Maciel, Telles [52] conducted a systematic review on the blockchain applications, disruptions and challenges of blockchain adoption, and future of blockchain in supply chain management. Wang, Han [53] conducted a review to look at how the blockchain will influence future supply chain practices and policies. Kshetri and Loukoianova [14] suggested that the current deployment of blockchain-based solutions is more justifiable and more realistic in high-value products. The real-time tracking and tracing blockchain system reduces the overall cost of moving goods in a supply chain. Furthermore, the main benefit of a blockchain is that all members are integrated into one secure network [16].

Blockchain is an information sharing technology, which allows secure exchange of information and support multilateral relationships among parties in a distributed network. Transparency is an important attribute of blockchain [54]. The distributed nature of blockchain ensures the data integrity, information, which is stored on the ledger after validation through a consensus mechanism, is immutable [55], and improves the visibility in a supply chain [50]. The improved visibility facilitated through the technology may also afford product traceability, authenticity and legitimacy [53]. This reduces the needs for trust among different parties and eliminate intermediaries such as banks, this may provide greater accountability and trust in interorganizational business collaboration in supply chains [50].

2.3. Supply Chain Integration

According to the Council of Supply Chain Management Professionals, Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which are suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across firms.

Supply chain management research has fundamentally changed the nature of a firm as the integration across member organizations in a supply chain determines the strength of a firm rather than the control over the internal business processes [56]. Based on RBV, supply chain integration is be viewed as a type of firm capability, which are complex bundles of skills and accumulated knowledge, exercised through organizational processes, which enable firms to coordinate activities and make use of their assets for different purposes [57]. in recent years, supply chain faces various uncertainties and volatile environments, such as Covid-19 pandemic, US-China trade war, etc. hence it seems imperative to create a mechanism to address these challenges and uncertainties. The concept of supply chain integration capability consisting of supply chain visibility, supply chain agility and supply chain flexibility was derived from the previous studies [58–60].

Supply chain integration capability offers an alternative solution to the firms to adopt the mechanisms to manage supply chain uncertainties and risks [59,61]. The types of dynamic supply chain capabilities constitute a supply chain capability, which is a dynamic firm ability to sense (visibility), collaborate (agility), and reconfigure (flexibility) its elements in a supply chain, including internal cross-functional integration and external integration with suppliers and customers [58,61]. Figure 1 illustrates the supply chain integration capability which consists of supply chain visibility, supply chain agility and supply chain flexibility [62,63].

المنارة للاستشارات
www.manaraa.com

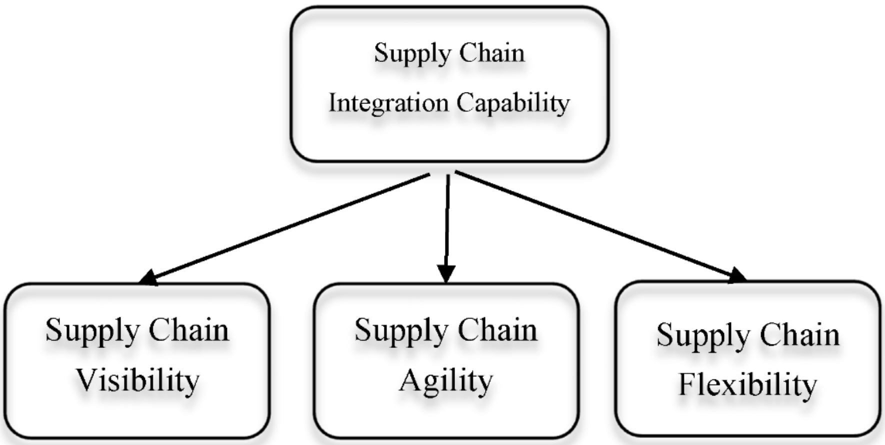

Figure 1. Supply Chain Integration Capability.

In Figure 1, the supply chain visibility is considered as the collaboration, sharing of information and trust among the partners and the removal of the barriers between supply chain partners in a global supply chain network [63]. Supply chain agility is a relatively new construct in the operations and supply chain management [63,64]. It is the firm's ability to quickly respond and adjust its supply chain tactics and operations [64]. Hence, the supply chain agility is defined as the capability of the firm to adopt and respond in a speedy manner to the internal and external changes and disruptions. In fact, the agility supports the firms to make timely decisions. Managers need such a capability to deal with problems in a strategic decision-making process and improve the firm responsiveness against environmental changes [62]. Finally, supply chain flexibility refers to a firm capability which enables flexible operations management to meet customer requirements and the economic targets of the involved companies, to reconfigure resources, assets and organizational structures in order create competitive advantage [62,65–67]. Flexibility is an important ability to reconfigure the resources, strategies and operations in a system which allows firms not only to reduce the cost and time but also to mitigate supply chain risks [62,63,68]. The three dimensions of supply chain integration capability are inter-related and presents a mechanism to address the supply chain uncertainties and risks [69].

Supply chain integration has become an important trend in supply chain management [70]. Maloni and Benton [71] argue that effective integration of the supply chain enables firms to achieve competitive advantage through cost reduction and higher levels of responsiveness. Such integration would lead to an improved organizational performance. Childerhouse and Towill [72] suggest that the supply chain can be optimized via effective and efficient operating practices which are integrated throughout the supply chain. There are different forms of supply chain integration including internal, external, supplier and customer integration [73–76]. A truly integrated supply chain is able to reduce costs and create value for the company, its partners and customers [62,73,77].

3. Research Method

The research methodology consists of two main stages which are the examination of the literature and conducting a pilot study. Hence, an extensive literature review was conducted on the low carbon supply chain management, blockchain and supply chain integration. The literature results were reported in the Section 2. Although there are many studies on blockchain and carbon emission, most of current studies focus on the implications of blockchain from engineering and sciences perspectives. However, few studies made an attempt to address the blockchain and carbon emission from a supply chain's perspective. In the industry 4.0 era, emerging technologies have become an increasingly important part in businesses and received a lot of research interests worldwide however, blockchain research remains at a nascent stage in New Zealand businesses [11]. This might be to some extent due to the fact that significant number of businesses in New Zealand are small or

المنارة للاستشارات
www.manaraa.com

medium businesses [78] with limited access to resources for Research and Development activities [79]. This project was funded by New Zealand government to explore the new technologies to support the future sustainability in New Zealand. The pilot study provides further insights on Blockchain applications in New Zealand.

Pilot Study

A pilot study is designed to better understand and verify the future use of blockchain in New Zealand firms. This was the first blockchain research funded by New Zealand government to contribute to the Climate Change Response (Zero Carbon) Amendment Act in New Zealand. According to the Amendment Act, the targets for New Zealand is to reduce net emissions of all greenhouse gases (except biogenic methane) to zero by 2050. Therefore, it is important to manage the carbon emission from a holistic supply chain approach in industries. This requires an interdisciplinary research to develop a conceptual framework to guide technology development in New Zealand industries. Blockchain is a technology, which may be adopted to integrate the supply chain partners and help reduce the greenhouse gases from a supply chain's perspective.

As this is an exploratory study, we use SurveyMonkey platform to conduct a short survey to obtain more insights about blockchain in New Zealand and its future implications and direction from an industry point of view. The short survey leads to less fatigue and consequently better data quality with higher response rates and less response bias [80]. A research instrument was designed and a purposive sampling technique was applied in selecting potential respondents. Hence, the potential respondents were selected from LinkedIn website and Blockchain conferences held in New Zealand. The Purposive sampling allows researchers to achieve a homogeneous sample [81]. Through survey, we invited those New Zealand firms which have adopted the Blockchain technology in their businesses. As a result, fifty firms were identified and invited to the pilot study. The survey was anonymous and was performed to collect the empirical data from the managers in these firms. A total 24 valid responses were received and used for further analysis.

To understand the future use of blockchain we asked the managers to answer a multiple-choice questionnaire on key elements of the blockchain which might influence their firms' decisions about blockchain in the future. Majority of respondents believed in transparency and visibility as most important elements followed by decentralization, trust, security and authenticity. Seven firms indicated other elements such as permissionless characteristic of blockchain, digitization of value, programmability of value, open data and open platforms, privacy of data, economic participation of users. Table 1 summarized the anticipation of blockchain in this survey. The empirical results support our research direction, Blockchain may be used as an important tool to facilitate information management in a real-world environment.

Table 1. Anticipation of blockchain for future.

Blockchain Technology	*Responses (%)*
Transparency and visibility	21 (87.50%)
Decentralized, Trust	17 (70.83%)
Security and authenticity	16 (66.67%)
Global Network	15 (62.50%)
Immutable	12 (50.00%)
Others	7 (29.17%)

4. Research Constructs and Proposition Development

Reviewing literature reveals that most blockchain and carbon emission studies come from engineering and science disciplines. Hence, such studies mainly focus on the technical part of blockchain applications. Blockchain addresses a predominant question about supply chain governance and ever-increasing environmental concerns. As the data and organizational integrity are serious

المنارة للاستشارات
www.manaraa.com

issues in supply chains [82] then supply chain requires international collaboration and the integration. Therefore, the proposed framework in this study presents an underlying mechanism together with the theories to tackle these issues. This study conceptualizes the research framework of blockchain into a low carbon supply chain management based on two key theories of STT and RBV. During the second stage of this study, practitioners and scholars from New Zealand Crown Research Institutes were invited to discuss and review the proposed framework.

STT theory is an intervention approach to manage complex work design for organizational development [83]. In this study, STT theory is extended in the supply chain management context. Modern supply chain objectives have now become more diverse from cost reduction, network optimization, profit maximization to carbon emissions reduction, service level improvements, risk mitigation and value creation [29]. This would lead to profound economic, social and environmental changes. Emerging technologies provide opportunities to change both social and technical systems [24]. In addition, technology is an important resource to form a firm's capability [17]. Blockchain is a decentralized system with unique attributes such as immutable, also knowns as irreversibility. The data can hardly be modified or deleted after being approved by all nodes in the blockchain. Moreover, blockchain offers a secure environment which not only guarantees confidentiality but also authenticity and the feature of nonrepudiation to all activities. Furthermore, blockchain can be expanded globally to change the way to integrate and collaborate in an international supply chain [11].

The conceptual framework indicates that blockchain may be used as a strategic management approach, which provides insight into supply chain management and carbon management, we adopt blockchain to facilitate supply chain integration and reduce carbon emissions in a supply chain. According to STT, the blockchain may be viewed as an operational tool, which may improve the work design in the technical system. For example, track carbon footprint, streamline emissions administrative function, ensure that the appropriate ethical standards are being upheld, and improve efficiency of supply chain management. Overall, this may contribute to building a low carbon supply chain. Supply chain integration has been identified as a key practice to achieve superior performance [84]. It may provide a company with the opportunity to concentrate its core business and compete in a market. As discussed before, in this study, the supply chain integration capability was derived from the previous studies [58,59].

Based on STT, technology can improve the workflow and contribute to a social system in organizations [83]. In this study, the supply chain is considered as a complex technical and social system in STT, each supply chain member should be equally treated and well looked after. In a conventional supply chain system, the focal company normally has too much power and may control and influence other companies in supply chains. It is difficult to manage and audit the unethical business practice if the focal companies lacked organizational integrity. Ethics and sustainability audits are a common practice to evaluate the social and environmental performance of vendors, but firms struggle with proper follow-up to the auditing results [34]. For example: the company may report a fake carbon emission, modify data or use falsified documents. The blockchain is an information sharing technology, which can ensure data integrity, improve the supply chain visibility, connectivity and traceability among stakeholders to integrate the supply chain and manage organizational integrity. Further, blockchain is a trustworthy and secure platform that promotes the supply chain agility, which in turn is a strategic competitive capability.

Based on RBV, technology is considered as one of the most valuable organizational resources, which can create organizational capabilities. Supply chain visibility is a firm capability to obtain and sense up-to-date information of the critical activities and processes [85]. Blockchain enables firms to respond to the risks and adjust the management strategies and/or directions [45], deliver customized, equitably priced and superior quality products in an efficient and time bound manner [38,86]. Furthermore, blockchain improves the flexibility for coping with supply chain disruptions [45]. Kamble, Gunasekaran [87] suggest that blockchain, through an enhanced transparency and superior ability in tracking products in supply chain is instrumental in achieving higher levels of supply chain

المنارة للاستشارات
www.manaraa.com

integration. Therefore, blockchain may be implemented to support the supply chain capability enabling effective interaction, modification and resilience. Thus, the incorporation of blockchain technology into the supply chain management improves visibility, agility, and flexibility of each stage in a supply chain network. Based on the above discussion, the following proposition is proposed:

Proposition 1. ***Blockchain technology is positively related to the supply chain integration.***

As discussed before supply chain integration can be further investigated through three dimensions of visibility, agility, and flexibility. Hence the following three propositions are extracted:

Proposition 1a. *Blockchain technology is positively related to the supply chain visibility in a supply chain.*

Proposition 1b. *Blockchain technology is positively related to the supply chain agility in a supply chain.*

Proposition 1c. *Blockchain technology is positively related to the supply chain flexibility in a supply chain.*

From the socio-technical perspective, technology variable is closely associated with work task structure [23,24]. In addition, various factors such as competitions, globalizations, constant change in customer preferences, and organizational strategies push firms toward investing in new technologies. Investment in technological innovations is a strategic decision to reduce carbon emissions [35]. Blockchain technology can be used to track the carbon footprint, transactions and carbon emissions data from different stakeholders in a complex supply chain network [38]. Also blockchain has the ability to be used in corporate carbon trading through a reliable flow of information, point to point transactions records between all firms in a supply chain which leads to decentralization and finally easier access to the carbon trading market by reducing the entry threshold [88]. In fact carbon emission trading is among most cost effective mechanisms to reduce carbon footprint [89]. Carbon emission trading works based on setting a price tag on carbon emission and create new investment opportunities to attract fund for green technology development [90,91]. Khaqqi et al. [92] proposed a novel Emission Trading Scheme (ETS) in which the blockchain plays an important role in improving the compliance levels with ETS requirements.

Meanwhile, with immutability, transparency and traceability provided by blockchain, the accuracy of data can be guaranteed. For example, the traceability allows participants to monitor and manage the entire supply chain system and carbon credit system processes. Ashley and Johnson [93] suggest that blockchain can be used to easily track carbon credits from generation through ownership trades to ultimate redemption. As a result, the efficiency, credibility and consistency of carbon emission practices can be improved at a supply chain level. More importantly, blockchain may enhance the information sharing and trust among the supply chain partners to achieve a low carbon supply chain. Furthermore, smart contract as an important contributor in blockchain technology can provide an automated execution function in the system. This results in a simple audit process which is able to significantly reduce the associated time and cost, and enables producers to monetize their credits immediately after generation. Consequently, the overall carbon emissions can be minimized, and total cost can be optimized in the supply chain network [94]. Therefore, the blockchain may be used directly as an operational tool to store, monitor, track and manage carbon emissions from participants throughout life cycle carbon emissions in a supply chain network. Based on the above discussion we develop below propositions:

Proposition 2. ***The blockchain technology may directly reduce overall carbon emissions in a blockchain enabled low carbon supply chain.***

Proposition 2a. *Information sharing among the supply chain partners may be negatively related to the carbon emission in a supply chain.*

المنارة للاستشارات
www.manaraa.com

Proposition 2b. *Trust among the supply chain partners may be negatively related to the carbon emission in a supply chain.*

Proposition 2c. *Traceability among the supply chain partners may be negatively related to the carbon emission in a supply chain.*

Given the importance of supply chain integration within the broader domain of a supply chain management it is imperative to understand the supply chain integration within the context of carbon emissions and its vital role for the success of any low carbon supply chain management strategy. Suppliers who measure and publicly reveal the greenhouse gas emissions of their operations are strategically more preferable than others because of their transparency and give more freedom to their buyers to manage their carbon emissions [2]. Supply chain integration capabilities build a collaborative relationship among the supply chain partners. The supply chain visibility, supply chain agility, and supply chain flexibility enable firms to enhance their collaborations, responsivity and connectivity across the supply chain. For example, collaborative decision making regarding the selection of transport mode between supply chain partners can reduce overall carbon emissions in supply chains [36]. Theißen and Spinler [4] emphasized that collaborative CO_2 reduction management requires working closely with supply chain partners. Das and Jharkharia [26] argue that firms would be able to reduce their overall greenhouse gas emissions through close collaboration in product design, transportation and inventory allocation with their suppliers. The incorporation of supply chain integration capabilities into low carbon supply chain management strategy can lead to an improvement in the emissions reduction strategies. Thus, we propose that below propositions:

Proposition 3. ***Supply chain integration is negatively related to the overall carbon emissions in a blockchain enabled low carbon supply chain.***

Proposition 3a. *Supply chain visibility is negatively related to the carbon emission in a supply chain.*

Proposition 3b. *Supply chain agility is negatively related to the carbon emission in a supply chain.*

Proposition 3c. *Supply chain flexibility is negatively related to the carbon emission in a supply chain.*

5. Blockchain-Enabled Low Carbon Supply Chain Framework

Supported by theories of the resource-based View and Socio-technical theory blockchain technology can optimize the supply chain processes and structure and create a competitive advantage in a low carbon supply chain. Blockchain has been discussed in the context of supply chain management and carbon emissions [93], however, there is limited research on how the blockchain can be applied in a low carbon supply chain [95]. This requires a strategic framework for organizations to work across the supply chain in a more pragmatic way. Figure 2 shows three main research constructs discussed in previous section which are blockchain, supply chain integration, and environmental performance.

Based on STT, blockchain technology is considered as an exogenous construct capturing three important variables of blockchain consisting of trust, information sharing and traceability. On the other hand, the supply chain integration, as a firm capability, consists of three latent variables of visibility, agility and flexibility. The supply chain integration capability acts as a mediating construct in the framework. The proposed framework aims to capture the mechanisms through which blockchain influences the supply chain integrations and environmental performance. With the blockchain as the strategic tool of carbon emission reduction, these efforts are mediated by supply chain integration. Meanwhile, in the technical system, blockchain may be used directly as an operational tool of carbon emission reduction to manage overall emissions and, ultimately, lead to positive or negative carbon emission performance outcomes. As discussed earlier, one of the advantages is that blockchain is

المنارة للاستشارات
www.manaraa.com

able to improve the organizational integrity due to the data immutable, transparency and traceability. The environmental performance is operationalized by the actual carbon emissions.

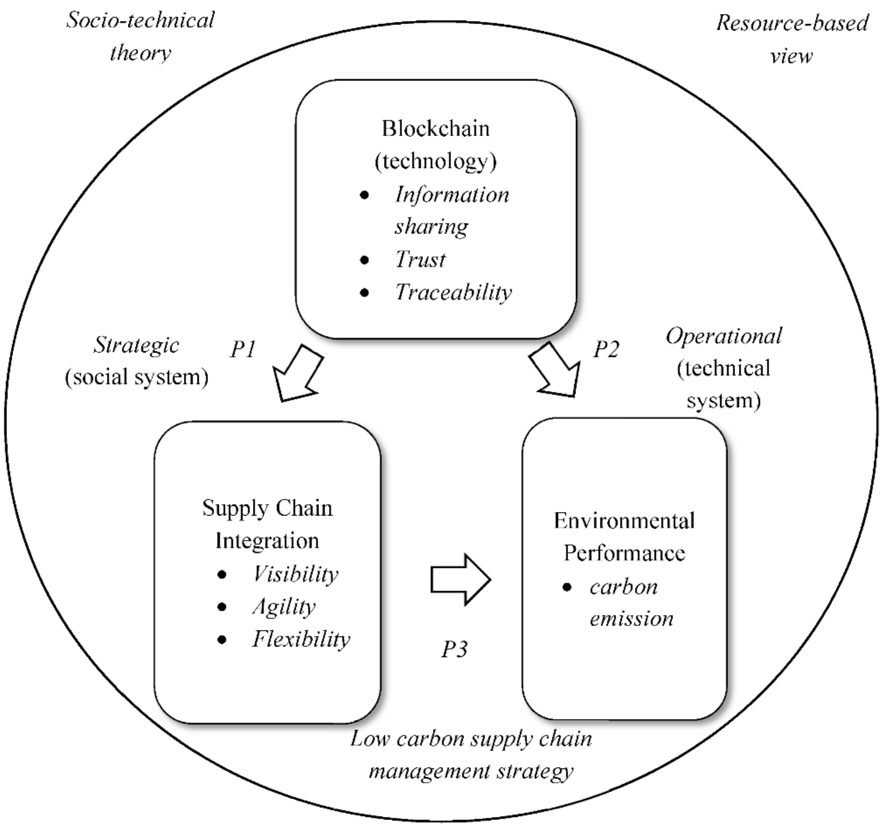

Figure 2. The Proposed Conceptual Framework.

6. Discussion and Research Agenda

Blockchain is an important technology in the industry 4.0 era [9]. It is gaining interest in supply chain management research recently. Due to the increased concerns arising from climate change and global warming and increasing pressure from government regulations and policies, firms seek the opportunities to improve both economic and environmental performance. However, in most cases it is difficult task to evaluate and manage the social and environmental impact of the operations such as pollutions, carbon emissions, etc. and many firms struggle with proper follow-up of the auditing results of their operations [34]. Moreover, managing organizational integrity requires huge resources and efforts [96]. In recent years, new technologies have provided opportunities for organizations to consider the green practices in their processes. Such technological innovations also provide opportunities for firms to rethink the supply chain integration and low carbon emission by applying new technologies. In this conceptual paper, based on theories of resource-based view and socio-technical theory, we proposed a blockchain-enabled framework for low carbon supply chain. We focus on two perspectives in the blockchain and supply chain literature: the first perspective focuses on the 'technical system' and the second perspective focuses on the 'social system' in supply chains. Blockchain has unique attributes, such as data immutable, transparency and traceability. A pilot study is conducted to further investigate the future application of blockchain in supply chain. The results support our conceptual ideas in the framework. Blockchain can help improve the data transparency and supply chain visibility. This, in turn, improves organizational integrity. Therefore, we proposed blockchain as a strategic management tools to enhance the supply chain integration capabilities across entire supply chain in the social system, meanwhile, it can be used as a carbon operational tool to store

www.manaraa.com

and track carbon footprint to enable carbon emissions reduction in the technical system. In addition, the research propositions were derived from the proposed framework.

Development of blockchain is still emerging now [11]. However, blockchain shows many potential applications for carbon management and carbon footprint. It can be an effective resolution to manage emissions data and carbon credits from participants in complex supply chains [93,94]. Very few business supply chain studies have been conducted on the blockchain and low carbon management. This paper presents a pilot study in New Zealand and offers propositions and a conceptual framework. The capabilities of supply chain integration encompass supply chain visibility, supply chain agility and supply chain flexibility [58]. The relationships between blockchain and supply chain integration offer future opportunities to examine the applications of Blockchain in the supply chain management. The relationships between supply chain integration and carbon emission may shed light on the low carbon supply chain management strategy. The technology optimizes the tasks and structure, and maximize the performance [23]. The improved supply chain visibility allows stakeholders to share and monitor the real-time emission information across the supply chain. The agility embedded in blockchain technology then helps firms quickly respond to the emission changes from other parties. The flexibility of blockchain technology can better prepare the firms to reconfigure the resources, strategies and operations in collaboration with other members of supply chain. This supports collaborative CO_2 reduction management [4].

Development and application of blockchain in different supply chains are still at early stage [11]. However, blockchain technology shows many potential applications for carbon management and carbon footprint. It can be an effective tool to store and track emissions information and carbon credits from different participants in complex supply chains [93,94]. Information sharing, trust among the supply chain partners, and traceability can reduce the carbon emission in a supply chain. Other technologies including robotic technology, Artificial Intelligence (AI), Internet of Things (IoT), and big data analytics can be used in conjunction with blockchain technology for different purposes in the industry 4.0 era [54,97–99]. For example, IoT systems can assist blockchain improving traceability by connecting sensors, providing the consumers and retailers are willing to trace of their entire operations in the supply chain. Automatic sensors can further help improve the data accuracy and integrity. In the relevant literature, the blockchain technology often promotes the supply chain collaboration and integration by facilitating information sharing, traceability and automation in digital transformation [42,100]. This results in overall carbon emission reduction [26].

Managerial Implications

Based on the discussion above, some managerial implications can be formulated. First, it should be noted that the blockchain has many potential applications for business use. We focused on the application of blockchain in low carbon supply chain management in this article. For example, the information sharing, trust and traceability may help reduce the overall carbon emissions in a supply chain. Of course, blockchain has other attributes, which may be explored and applied in the supply chain optimization in the future researches. In this study, the information sharing, trust and traceability were used to develop the research propositions in the framework. This may provide directions for managers to build a low carbon supply chain by deploying and enhancing the relevant attributes of blockchain. In addition, this may imply that blockchain can offer good communication and supply chain relationships among the business partners. Further studies may be conducted to empirically validate the framework with larger data and explore more alternative areas, such as digitalization, risk management, and organizational integrity. Second, instead of viewing blockchain as a technology, blockchain may be considered as a strategic management approach to facilitate supply chain integration across industries. The supply chain integration capability is viewed as a dynamic capability to address the ever-increasing concerns on carbon emission. Managers can set the focus on how blockchain can be used to enhance the supply chain integration in real-world operational environments. Also,

المنارة للاستشارات
www.manaraa.com

future empirical research may be conducted to validate the relevant measurements, indicators and further explore best business practices for different industries.

7. Conclusions

In this research, we conceptualized the emerging blockchain technology and supply chain integration capability in low carbon supply chain management based on of the resource-based view and socio-technical theory. We showed how the incorporation of blockchain technology into the low carbon supply chain management can help firms reduce their overall carbon missions across their supply chains. The research propositions were shown in the conceptual framework. The blockchain is adopted to enhance supply chain integration capabilities and technological advance to reduce carbon emission in supply chains. This enables low carbon supply chains. Carbon emission is a major contributor to climate change. The firms need to work closely together in supply chains to achieve collaborative carbon emissions reduction. Blockchain is one of important emerging technologies in the industry 4.0 era which offers many potential applications for supply chain collaboration and integration. However, very few relevant studies have been done in these areas. Many recent blockchain and carbon emission studies are from engineering and sciences. Although the energy requirements of blockchain transactions are significant, due to the nature of exploratory research, the specific energy consumption of blockchain excluded from the paper. This can be further investigated in future research. In the proposed framework, the use of blockchain for carbon emissions reduction and supply chain integration was discussed. We adopted blockchain to enhance supply chain integration capabilities and technological advance to enable overall carbon emission reduction. In this study, we didn't separate the different types of blockchain in the conceptual model. They may be investigated in the future studies. Also, future work can apply this framework using empirical studies in specific industries or business cases. The business research provides valuable insights into implementation of blockchain in the low carbon supply chain management, and also contributes to blockchain and supply chain management literature.

Author Contributions: Conceptualization, M.W., B.W.; Methodology, M.W.; Writing—original draft, M.W.; Writing, review & and editing, A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: This work is performed under the support of Scion (New Zealand Forest Research Institute), which is a Crown Research Institute focused on improving the international competitiveness of the New Zealand forestry industry and building a stronger bio-based economy.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. NASA. The Intergovernmental Panel on Climate Change. Available online: https://climate.nasa.gov/causes/ (accessed on 22 November 2020).
2. Shaw, K.; Shankar, R.; Yadav, S.S.; Thakur, L.S. Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Syst. Appl.* **2012**, *39*, 8182–8192. [CrossRef]
3. Böttcher, C.F.; Müller, M. Drivers, practices and outcomes of low-carbon operations: Approaches of German automotive suppliers to cutting carbon emissions. *Bus. Strategy Environ.* **2015**, *24*, 477–498. [CrossRef]
4. Theißen, S.; Spinler, S. Strategic analysis of manufacturer-supplier partnerships: An ANP model for collaborative CO_2 reduction management. *Eur. J. Oper. Res.* **2014**, *233*, 383–397. [CrossRef]
5. Mentzer, J.T.; DeWitt, W.; Keebler, J.S.; Min, S.; Nix, N.W.; Smith, C.D.; Zacharia, Z.G. Defining supply chain management. *J. Bus. Logist.* **2001**, *22*, 1–25. [CrossRef]
6. Alonso, A.A.; Álvarez-Salgado, X.A.; Antelo, L. Assessing the impact of bivalve aquaculture on the carbon circular economy. *J. Clean. Prod.* **2021**, *279*, 123873. [CrossRef]

المنارة للاستشارات
www.manaraa.com

7. Fuchs, S.J.; Espinoza, D.N.; Lopano, C.L.; Akono, A.-T.; Werth, C.J. Geochemical and geomechanical alteration of siliciclastic reservoir rock by supercritical CO_2-saturated brine formed during geological carbon sequestration. *Int. J. Greenh. Gas Control* **2019**, *88*, 251–260. [CrossRef]
8. Shaharudin, M.S.; Fernando, Y.; Jabbour, C.J.C.; Sroufe, R.; Jasmi, M.F.A. Past, present, and future low carbon supply chain management: A content review using social network analysis. *J. Clean. Prod.* **2019**, *218*, 629–643. [CrossRef]
9. Wang, M.; Asian, S.; Wood, L.C.; Wang, B. Logistics innovation capability and its impacts on the supply chain risks in the Industry 4.0 era. *Mod. Supply Chain Res. Appl.* **2020**, *2*, 1–16. [CrossRef]
10. Lee, J.; Bagheri, B.; Kao, H.A. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. *Manuf. Lett.* **2015**, *3*, 18–23. [CrossRef]
11. Wang, M.; Wu, Y.; Chen, B.; Evans, M. Blockchain and Supply Chain Management: A New Paradigm for Supply Chain Integration and Collaboration. *Oper. Supply Chain Manag. Int. J.* **2020**, *14*, 111–122. [CrossRef]
12. Lasi, H.; Fettke, P.; Kemper, H.G.; Feld, T.; Hoffmann, M. Industry 4.0. *Bus. Inf. Syst. Eng.* **2014**, *6*, 239–242. [CrossRef]
13. Treiblmaier, H. The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. *Supply Chain Manag. Int. J.* **2018**, *23*, 545–559. [CrossRef]
14. Kshetri, N.; Loukoianova, E. Blockchain Adoption in Supply Chain Networks in Asia. *IT Prof.* **2019**, *21*, 11–15. [CrossRef]
15. Pournader, M.; Shi, Y.; Seuring, S.; Koh, S.L. Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *Int. J. Prod. Res.* **2019**, *58*, 1–19. [CrossRef]
16. Gurtu, A.; Johny, J. Potential of blockchain technology in supply chain management: A literature review. *Int. J. Phys. Distrib. Logist. Manag.* **2019**, *49*, 881–900. [CrossRef]
17. Wernerfelt, B. A resource based view of the firm. *Strateg. Manag. J.* **1984**, *5*, 171–180. [CrossRef]
18. Halldorsson, A.; Kotzab, H.; Mikkola, J.H.; Skjøtt-Larsen, T. Complementary theories to supply chain management. *Supply Chain Manag. Int. J.* **2007**, *12*, 284–296. [CrossRef]
19. Wu, F.; Yeniyurt, S.; Kim, D.; Cavusgil, S.T. The impact of information technology on supply chain capabilities and firm performance: A resource-based view. *Ind. Mark. Manag.* **2006**, *35*, 493–504. [CrossRef]
20. Nandi, M.L.; Nandi, S.; Moya, H.; Kaynak, H. Blockchain technology-enabled supply chain systems and supply chain performance: A resource-based view. *Supply Chain Manag. Int. J.* **2020**, *25*, 841–862. [CrossRef]
21. Falazi, G.; Hahn, M.; Breitenbücher, U.; Leymann, F. Modeling and execution of blockchain-aware business processes. *SICS Softw. Intensive Cyber-Phys. Syst.* **2019**, *34*, 105–116. [CrossRef]
22. Deloitte. Blockchain: Enigma. Paradox. Opportunity, Deloitte LLP, United Kingdom. 2016. Available online: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Innovation/deloitte-uk-blockchain-full-report.pdf (accessed on 20 November 2020).
23. Cartelli, A. Socio-Technical Theory and Knowledge Construction: Towards New Pedagogical Paradigms? *Issues Inf. Sci. Inf. Technol.* **2007**, *4*, 1–14.
24. Bostrom, R.P.; Heinen, J.S. MIS Problems and Failures: A Socio-Technical Perspective. Part I: The Causes. *MIS Q.* **1977**, *1*, 17–32. [CrossRef]
25. Hayes, A. The socio-technological lives of bitcoin. *Theory Cult. Soc.* **2019**, *36*, 49–72. [CrossRef]
26. Das, C.; Jharkharia, S. Low carbon supply chain: A state-of-the-art literature review. *J. Manuf. Technol. Manag.* **2018**, *29*. [CrossRef]
27. Chan, M.-K. *Carbon Management. A Practical Guide for Suppliers*; University of Cambridge: Cambridge, UK, 2009.
28. Correia, F.; Howard, M.; Hawkins, B.; Pye, A.; Lamming, R. Low carbon procurement: An emerging agenda. *J. Purch. Supply Manag.* **2013**, *19*, 58–64. [CrossRef]
29. Sundarakani, B.; De Souza, R.; Goh, M.; Wagner, S.M.; Manikandan, S. Modeling carbon footprints across the supply chain. *Int. J. Prod. Econ.* **2010**, *128*, 43–50. [CrossRef]
30. Seuring, S.; Brix-Asala, C.; Khalid, R.U. Analyzing base-of-the-pyramid projects through sustainable supply chain management. *J. Clean. Prod.* **2019**, *212*, 1086–1097. [CrossRef]
31. Saberi, S.; Kouhizadeh, M.; Sarkis, J.; Shen, L. Blockchain technology and its relationships to sustainable supply chain management. *Int. J. Prod. Res.* **2019**, *57*, 2117–2135. [CrossRef]
32. Lin, Y.-H.; Tseng, M.-L. Assessing the competitive priorities within sustainable supply chain management under uncertainty. *J. Clean. Prod.* **2016**, *112*, 2133–2144. [CrossRef]

المنارة للاستشارات
www.manaraa.com

33. Kouhizadeh, M.; Sarkis, J. Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability (Switzerland)* **2018**, *10*, 3652. [CrossRef]
34. Gonzalez-Padron, T.L. Ethics in the Supply Chain: Follow-Up Processes to Audit Results. *J. Mark. Channels* **2016**, *23*, 22–33. [CrossRef]
35. Chen, X.; Wang, X.; Kumar, V.; Kumar, N. Low carbon warehouse management under cap-and-trade policy. *J. Clean. Prod.* **2016**, *139*, 894–904. [CrossRef]
36. Hoen, K.M.R.; Tan, T.; Fransoo, J.C.; Van Houtum, G.-J. Switching transport modes to meet voluntary carbon emission targets. *Transp. Sci.* **2014**, *48*, 592–608. [CrossRef]
37. Rudi, A.; Fröhling, M.; Zimmer, K.; Schultmann, F. Freight transportation planning considering carbon emissions and in-transit holding costs: A capacitated multi-commodity network flow model. *EURO J. Transp. Logist.* **2016**, *5*, 123–160. [CrossRef]
38. Tang, C.S.; Veelenturf, L.P. The strategic role of logistics in the industry 4.0 era. *Transp. Res. Part E Logist. Transp. Rev.* **2019**, *129*, 1–11. [CrossRef]
39. Tschorsch, F.; Scheuermann, B. Bitcoin and Beyond: A Technical Survey on Decentralized Digital Currencies. *IEEE Commun. Surv. Tutor.* **2016**, *18*, 2084–2123. [CrossRef]
40. Biswas, B.; Gupta, R. Analysis of barriers to implement blockchain in industry and service sectors. *Comput. Ind. Eng.* **2019**, *136*, 225–241. [CrossRef]
41. Puthal, D.; Malik, N.; Mohanty, S.P.; Kougianos, E.; Das, G. Everything You Wanted to Know About the Blockchain: Its Promise, Components, Processes, and Problems. *IEEE Consum. Electron. Mag.* **2018**, *7*, 6–14. [CrossRef]
42. Yli-Huumo, J.; Ko, D.; Choi, S.; Park, S.; Smolander, K. Where Is Current Research on Blockchain Technology?—A Systematic Review. *PLoS ONE* **2016**, *11*, e0163477. [CrossRef]
43. Makridakis, S.; Christodoulou, K. Blockchain: Current challenges and future prospects/applications. *Future Internet* **2019**, *11*, 258. [CrossRef]
44. Chen, G.; Xu, B.; Lu, M.; Chen, N.-S. Exploring blockchain technology and its potential applications for education. *Smart Learn. Environ.* **2018**, *5*, 1–10. [CrossRef]
45. Min, H. Blockchain technology for enhancing supply chain resilience. *Bus. Horiz.* **2019**, *62*, 35–45. [CrossRef]
46. Wu, H.; Li, Z.; King, B.; Ben Miled, Z.; Wassick, J.; Tazelaar, J. A distributed ledger for supply chain physical distribution visibility. *Information (Switzerland)* **2017**, *8*, 137. [CrossRef]
47. Khatoon, A.; Verma, P.; Southernwood, J.; Massey, B.; Corcoran, P. Blockchain in energy efficiency: Potential applications and benefits. *Energies* **2019**, *12*, 3317. [CrossRef]
48. Wang, Z.; Wang, T.; Hu, H.; Gong, J.; Ren, X.; Xiao, Q. Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Autom. Constr.* **2020**, *111*, 103063. [CrossRef]
49. van Hoek, R. Developing a framework for considering blockchain pilots in the supply chain-lessons from early industry adopters. *Supply Chain Manag.* **2020**, *25*, 115–121. [CrossRef]
50. Kumar, A.; Liu, R.; Shan, Z. Is Blockchain a Silver Bullet for Supply Chain Management? Technical Challenges and Research Opportunities. *Decis. Sci.* **2020**, *51*, 8–37. [CrossRef]
51. Astarita, V.; Giofrè, V.P.; Mirabelli, G.; Solina, V. A Review of Blockchain-Based Systems in Transportation. *Information (Switzerland)* **2020**, *11*, 21. [CrossRef]
52. Queiroz Maciel, M.; Telles, R.; Silvia, H.B. Blockchain and supply chain management integration: A systematic review of the literature. *Supply Chain Manag. Int. J.* **2019**, *25*, 241–254. [CrossRef]
53. Wang, Y.; Han, J.H.; Beynon-Davies, P. Understanding blockchain technology for future supply chains: A systematic literature review and research agenda. *Supply Chain Manag.* **2019**, *24*, 62–84. [CrossRef]
54. Frank, A.G.; Dalenogare, L.S.; Ayala, N.F. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *Int. J. Prod. Econ.* **2019**, *210*, 15–26. [CrossRef]
55. Ølnes, S.; Ubacht, J.; Janssen, M. Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Gov. Inf. Q.* **2017**, *34*, 355–364. [CrossRef]
56. Christopher, M. *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*, 2nd ed.; Finacial Times Management: London, UK, 1998.
57. Lai, K.-h. Service capability and performance of logistics service providers. *Transp. Res. Part E Logist. Transp. Rev.* **2004**, *40*, 385–399. [CrossRef]
58. Wang, M.; Jie, F. Managing supply chain uncertainty and risk in the pharmaceutical industry. *Health Serv. Manag. Res.* **2020**, *33*, 156–164. [CrossRef] [PubMed]

المنارة للاستشارات
www.manaraa.com

59. Wang, M.; Jie, F.; Abareshi, A. Improving logistics performance for one belt one road: A conceptual framework for supply chain risk management in Chinese third-party logistics providers. *Int. J. Agile Syst. Manag.* **2018**, *11*, 364–380. [CrossRef]
60. Williams, B.D.; Roh, J.; Tokar, T.; Swink, M. Leveraging supply chain visibility for responsiveness: The moderating role of internal integration. *J. Oper. Manag.* **2013**, *31*, 543–554. [CrossRef]
61. Wang, M.; Abareshi, A. Investigating the relationships between Guanxi and supply chain integration in the BRI firms: A conceptual framework for China's belt and road initiative. In Proceedings of the 4th Belt and Road Initiative Conference (BRI 2019) in Collaboration with the Asian Logistics Round Table (ALRT), Bangkok, Thailand, 1–3 August 2019.
62. Lee, S.; Rha, J.S. Ambidextrous supply chain as a dynamic capability: Building a resilient supply chain. *Manag. Decis.* **2016**, *54*, 2–23. [CrossRef]
63. Braunscheidel, M.J.; Suresh, N.C. The organizational antecedents of a firm's supply chain agility for risk mitigation and response. *J. Oper. Manag.* **2009**, *27*, 119–140. [CrossRef]
64. Gligor, D.; Esmark, C.; Holcomb, M. Performance outcomes of supply chain agility: When should you be agile? *J. Oper. Manag.* **2015**, *33–34*, 71. [CrossRef]
65. Zhang, Q.; Vonderembse, M.A.; Lim, J.-S. Logistics flexibility and its impact on customer satisfaction. *Int. J. Logist. Manag.* **2005**, *16*, 71–95. [CrossRef]
66. Seebacher, G.; Winkler, H. A capability approach to evaluate supply chain flexibility. *Int. J. Prod. Econ.* **2015**, *167*, 177. [CrossRef]
67. Yu, K.; Cadeaux, J.; Luo, B.N. Operational flexibility: Review and meta-analysis. *Int. J. Prod. Econ.* **2015**, *169*, 190. [CrossRef]
68. Wang, M.; Jie, F.; Abareshi, A. Evaluating logistics capability for mitigation of supply chain uncertainty and risk in the Australian courier firms. *Asia Pac. J. Mark. Logist.* **2015**, *27*, 486–498. [CrossRef]
69. Wang, M. Impacts of supply chain uncertainty and risk on the logistics performance. *Asia Pac. J. Mark. Logist.* **2018**, *30*, 689–704. [CrossRef]
70. Pati, V.P.K.; Chandran, V.; Bhatti, M.A. Supply chain practices and performance: The indirect effects of supply chain integration. *Benchmarking Int. J.* **2016**, *25*, 1445–1471.
71. Maloni, M.; Benton, W. Power influences in the supply chain. *J. Bus. Logist.* **2000**, *21*, 49–74.
72. Childerhouse, P.; Towill, D.R. Simplified material flow holds the key to supply chain integration. *Omega* **2003**, *31*, 17–27. [CrossRef]
73. Maiga, A. Assessing the Impact of Supply Chain Integration on Firm Competitive Capability. *Int. J. Oper. Res. Inf. Syst.* **2016**, *7*, 1–21. [CrossRef]
74. Kim, S.W. Effects of supply chain management practices, integration and competition capability on performance. *Supply Chain Manag. Int. J.* **2006**, *11*, 241–248.
75. Alfalla-Luque, R.; Marin-Garcia, J.; Medina-Lopez, C. An analysis of the direct and mediated effects of employee commitment and supply chain integration on organisational performance. *Int. J. Prod. Econ.* **2015**, *162*, 242. [CrossRef]
76. Flynn, B.; Huo, B.; Zhao, X. The impact of supply chain integration on performance: A contingency and configuration approach. *J. Oper. Manag.* **2010**, *28*, 58. [CrossRef]
77. Lee, H.L. Creating value through Supply Chain integration. *Supply Chain Manag. Rev.* **2000**, *4*, 30.
78. MBIE. New Zealand's Support for Small Business. In *Ministry of Business*; I. a. E. M., Ed.; New Zealand Government Wellington: Wellington, New Zealand, 2018.
79. Ortega-Argilés, R.; Vivarelli, M.; Voigt, P. R&D in SMEs: A paradox? *Small Bus. Econ.* **2009**, *33*, 3–11.
80. Zikmund, W.G. *Business Research Methods*, 9th ed.; Zikmund, W.G., Ed.; South-Western: Mason, OH, USA, 2013.
81. Bryman, A.; Bell, E. *Business Research Methods*, 3rd ed.; Bell, E., Ed.; Oxford University Press: Oxford, UK, 2011.
82. Tsolakis, N.; Niedenzu, D.; Simonetto, M.; Dora, M.; Kumar, M. Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry. *J. Bus. Res.* **2020**. [CrossRef]
83. Appelbaum, S.H. Socio-technical systems theory: An intervention strategy for organizational development. *Manag. Decis.* **1997**, *35*, 452–463. [CrossRef]
84. Wiengarten, F.; Humphreys, P.; Gimenez, C.; McIvor, R. Risk, risk management practices, and the success of supply chain integration. *Int. J. Prod. Econ.* **2016**, *171*, 361–370. [CrossRef]

المنارة للاستشارات

www.manaraa.com

85. Wang, E.; Wei, H.-L. Interorganizational Governance Value Creation: Coordinating for Information Visibility and Flexibility in Supply Chains. *Decis. Sci.* **2007**, *38*, 647–674. [CrossRef]
86. Potdar, P.K.; Routroy, S.; Behera, A. Agile manufacturing: A systematic review of literature and implications for future research. *Benchmarking Int. J.* **2017**, *24*, 2022–2048. [CrossRef]
87. Kamble, S.S.; Gunasekaran, A.; Gawankar, S.A. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *Int. J. Prod. Econ.* **2020**, *219*, 179–194. [CrossRef]
88. Pan, Y.; Zhang, X.; Wang, Y.; Yan, J.; Zhou, S.; Li, G.; Bao, J. Application of blockchain in carbon trading. *Energy Procedia* **2019**, *158*, 4286–4291. [CrossRef]
89. Labatt, S.; White, R.R. *Carbon Finance: The Financial Implications of Climate Change*; John Wiley & Sons: New York, NY, USA, 2011; Volume 362.
90. Chaabane, A.; Ramudhin, A.; Paquet, M. Design of sustainable supply chains under the emission trading scheme. *Int. J. Prod. Econ.* **2012**, *135*, 37–49. [CrossRef]
91. Bayon, R.; Hawn, A.; Hamilton, K. *Voluntary Carbon Markets: An International Business Guide to What They Are and How They Work*; Routledge: London, UK, 2012.
92. Khaqqi, K.N.; Sikorski, J.J.; Hadinoto, K.; Kraft, M. Incorporating seller/buyer reputation-based system in blockchain-enabled emission trading application. *Appl. Energy* **2018**, *209*, 8–19. [CrossRef]
93. Ashley, M.J.; Johnson, M.S. Establishing a secure, transparent, and autonomous blockchain of custody for renewable energy credits and carbon credits. *IEEE Eng. Manag. Rev.* **2018**, *46*, 100–102. [CrossRef]
94. Manupati, V.K.; Schoenherr, T.; Ramkumar, M.; Wagner, S.M.; Pabba, S.K.; Singh, R.I.R. A blockchain-based approach for a multi-echelon sustainable supply chain. *Int. J. Prod. Res.* **2019**, *58*, 2222–2241. [CrossRef]
95. Wong, L.-W.; Leong, L.-Y.; Hew, J.-J.; Tan, G.W.-H.; Ooi, K.-B. Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *Int. J. Inf. Manag.* **2019**, *52*, 101997. [CrossRef]
96. Paine, L.S. Managing for Organizational Integrity. *Harv. Bus. Rev.* **1994**, *72*, 106–117.
97. Kosba, A.; Miller, A.; Shi, E.; Wen, Z.; Papamanthou, C. Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts. In Proceedings of the IEEE Symposium on Security and Privacy (SP), San Jose, CA, USA, 22–26 May 2016.
98. Christidis, K.; Devetsikiotis, M. Blockchains and Smart Contracts for the Internet of Things. *IEEE Access* **2016**, *4*, 2292–2303. [CrossRef]
99. Gilchrist, A. *Industry 4.0: The Industrial Internet of Things*; Apress: Berkeley, CA, USA, 2016.
100. Viriyasitavat, W.; Anuphaptrirong, T.; Hoonsopon, D. When blockchain meets Internet of Things: Characteristics, challenges, and business opportunities. *J. Ind. Inf. Integr.* **2019**, *15*, 21–28. [CrossRef]

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

المنارة للاستشارات

www.manaraa.com

Reproduced with permission of copyright owner. Further reproduction prohibited without permission.

المنارة للاستشارات

www.manaraa.com