Digitalization and the Greening of Supply Chains

Joseph Sarkis

Foisie Business School, Worcester Polytechnic Institute, Worcester, Massachusetts, USA and Humlog Institute, Hanken School of Economics, Helsinki, Finland

Mahtab Kouhizadeh

Foisie Business School, Worcester Polytechnic Institute, Worcester, Massachusetts, USA,

Qingyun Serena Zhu

College of Business, The University of Alabama in Huntsville, Huntsville, Alabama, USA

Abstract:

There has been a growing need for implementing green and environmentally sustainable initiatives in supply chain management. Modern supply chain activities contribute to crescive deleterious and irreversible environmental outcomes. Digitalization and technological advancements can effectively support green activities in supply chains and mitigate these outcomes. Using relevant *Industrial Management & Data Systems* research published in this journal over the past 50 years, we provide an overview on the role of traditional and emergent digitalization and information technologies for leveraging environmental supply chain sustainability—while reflecting on potential tradeoffs and conflicts of digitalization and greening. We also provide a focused and succinct evaluation for research directions. A pressures, practices, and performance framework sets the stage for pertinent research questions and theoretical needs to investigate the nexus of digitalization and green supply chain management. Our reflection concludes with a summary and steps forward.

Keywords: digitalization, supply chain management, sustainability, green, information systems

1. Introduction

Industry 4.0 has been hyped for almost a decade (Cetrulo & Nuvolari, 2019). Industry 4.0 is dependent on the digitalization and integration of cyber-physical systems within and across organizations. Although a relatively recent phenomenon within the research and practitioner literature, automation and digitalization have defined or were part of earlier industrial revolutions.

Although not as old as the industrial revolution, there has also been increased attention and importance toward environmental sustainability for organizations and their supply chains. These topics have merged paths in a number of ways from both a positive and negative perspective. Positively they can be complementary and support each other, for example technology that aids in renewable energy production and management. Negatively, the advent of technologies that require greater energy and materials consumption due to their automation or digitalization.

The conflicts and paradoxes have existed for generations between digitalization and supply chain environmental sustainability—or green supply chains. The promise for efficiency exists, but there are also rebound effect possibilities; where efficiencies allow for less expensive per unit usage which motivate greater use overall (Berkhout et al., 2000; Sarkis, 2019).

Traditional green information systems and technology can support environmental activities as processes with development of software and organizational information processing capabilities. These systems and technologies also have negative environmental consequences ranging to and including energy usage, resources depletion, hazardous material, solid waste, and plastics waste (Bai & Sarkis, 2013). Such conflicts and paradoxes become more complex as emergent technologies—including the Internet of things (IoT), blockchain technology and quantum computing—see greater diffusion. Emerging technologies can be effective enablers to advance green supply chain management (GSCM) (Jiang et al., 2020). Similar to traditional information systems, these emergent technologies might also have a number of drawbacks, such as high operating and adoption cost, technology immaturity, and high energy consumption; amongst other uncertainties associated with technological transitioning.

Digitalization includes greater use of both traditional and emergent information systems, but a careful broader consideration is whether digitalization efforts can benefit rather than burden the environment. There are both internal—to the organization—and external relationships and issues with respect to environmental supply chain management concerns. There are also theoretical perspectives to investigate the management of digitalization and GSCM.

In this paper, we do not necessarily provide an answer to the tradeoff dilemma, but it should be a concern that is carefully considered from a broader analytical perspective based on the 50-year publications in the journal *Industrial Management & Data Systems* (*IMDS*).

We provide an initial discussion and background on GSCM, digitalization, and practices; linking this work to *IMDS* published investigations. Some of this background looks at current and past works; some considers the future. We then provide a theoretical evaluation of this integrative field. We do this at a broad level to understand the current intellectual structure and propose a future research agenda. Challenges and concerns are also discussed.

2. Background

This section provides a literature and knowledge foundation of the digitalization and GSCM. A number of related literature streams help explore the relationship between digitalization and GSCM. Initially we revisit the value propositions of GSCM; second, we summarize and analyze 134 identified research publications on traditional green information systems and green supply chain management published in IMDS. Third, we provide insights into emergent information technologies including IoT, blockchain technology and quantum computing; and their potential applications within GSCM. The relationships are discussed.

2.1 Green supply chain management

Sustainable and green supply chain management have been used interchangeably by academics and practitioners. Our nuance here is to consider green supply chain management as focus on environmental sustainability actions by organizations and their supply chains. Thus—for the purpose of this review—environmental supply chain management and green supply chains are synonymous.

The green supply chain also has a variety of components including upstream supply management, internal organizational activities, downstream supply management, and closing the loop activities (Bai et al., 2018). These four dimensions include multiple internal organizational functions in addition to separate external organizations. The flows and boundaries of green supply chains have included multiple dimensions as has the complexities involved with managing them through performance measures—see Sarkis (2012) for a detailed review of boundaries and flows within a green supply chain context.

2.2 Traditional Green Information Systems and Digitalization in *IMDS*

Organizations have encountered institutional pressures to alter their strategic perspectives (e.g. see Bai et al. (2015); Batenburg et al. (2008)). These pressures require organizations and individuals to re-evaluate and redesign operational activities and supply chain functions. Green information systems—our traditional digitalization category—refer to hardware, systems and other infrastructure that are designed to improve the flow and management of information from an environmental sustainability perspective (Sarkis et al., 2013). Evidence of this greening prominence and its influence on organizational strategic planning have been evaluated in many research publications and investigations in *IMDS* (Wang et al., 2019).

A comprehensive literature search, using keywords “information systems”, “information technology”, “sustainable-” or “green supply chain” results in 134 *IMDS* publications during the past 50 years.

Traditional organizational information systems may be categorized into four groups based on their organizational management level, transaction processing systems (TPS), management information systems (MIS), decision support systems (DSS), and executive support systems (ESS) (Oz, 2008). TPS focus on operational organizational activities and support real-time and relatively short-term information requirements. MIS and DSS support tactical managerial planning. These systems typically involve analytically driven decision-making tool development or data driven information management instruments. ESS serve the needs and requirements of upper management at a strategic organizational level. ESS Information is aggregated from the lower level systems and aggregated to facilitate longerterm planning (Henderson et al., 1987). Various environmental practices can be mapped across functions and along the supply chain from the applications of each information systems. An exemplary summary of *IMDS* publications that describe how information system support the greening of organizations is summarized in Table 1.

Table 1 describes how each organizational functional area, including supply chain linkages, uses or has digitalization—information—supported green or sustainable practices. In each cell exemplary *IMDS* published investigations are referenced. Note the breadth and variety of investigations has contributed to these topics. In fact, they can rival any other management or business journal in terms of coverage and comprehensiveness. These results show how IMDS is contributing to broader social and environmental impact; well beyond traditional business and management concerns.

--- Insert Table 1 about here ---

Figure 1 summarizes the thematic focus and paper allocation of *IMDS* journal publications during the past 50 years. Amongst the 134 total information systems related publications (Figure 1 left pie chart), 44 publications (or 33%) explicitly relate to green and sustainable supply chain development. The right hand-side pie chart in Figure 1 summarizes the information system type most prevalent in each of the 44 publications that relate to GSCM. We identify 10 publications as ESS—at a strategic level; 15 investigations focus on DSS and 10 studies focus on MIS at a managerial level of application; and 9 papers predominantly focus on TPS. Green information systems and technological innovation undergo dramatic development as a research field; these fields have witnessed significant contributions from IMDS published research.

--- Insert Figure 1 about here ---

Amongst the major types of traditional information systems, DSS are the most widely applied (11% of all 134 identified studies) for sustainable supply chain decision making processes, especially in engineering and design, manufacturing and production, and logistics functions. These papers include various decision support tools that facilitate data storing, processing, analyzing and management for enhanced sustainability performance. ESS are also developed for supply chain sustainability in *IMDS*. The earliest investigation (Miller & McKinney, 1998) include how information systems are used to manage regulatory environmental pressures. Later applications have demonstrated their need for strategic competitiveness reasons.

Our summary shows that *IMDS* has significantly contributed to the investigation of these types of strategic, managerial and operational digitalization tools. Green IS and IT practice has been an important research area in *IMDS;* some of it significantly linking to GSCM. Linking these current measures and dimension to inter-organizational (supply chain) and multiple stakeholders using emergent technologies are important future research directions and are now discussed as potential directions and opportunities for *IMDS*—specifically—and GSCM research in general.

2.3 Emergent technologies and green supply chain management

Advanced technologies play critical roles in leveraging supply chain activities. Supply chains inherently include various activities that may damage the natural environment. These activities may encompass upstream supply chain, such as supply and source management; focal organization, such as production management; downstream supply chain, such as demand management; and closing the loop, including recycling activities.

Technological advancements support supply chain management activities offering tremendous potential and advantages. Some advantages include better information traceability and management, enhanced communication and cooperation across the entire supply chain, and improved reliability and trust. Emerging technologies can be effective enablers for green supply chain management. However, from the sustainability perspective, they might have a number of pitfalls.

High adoption and operating cost, technological immaturity, and the need for large amounts of energy for computation and storage are some greening and business shortcomings (Kamble et al., 2019; Kouhizadeh et al., 2020).

In this section, we introduce three platform-based digital technologies that have been—and continue to be—addressed as promising supply chain management advancements. Although these digital technologies may be integrated with each other to provide greater synergistic benefits, standalone adoptions are also common. We focus on the IoT, blockchain technology, and quantum computing in this article. Table 2 demonstrates some exemplary applications of these technologies. We use these applications in supporting green initiatives at various supply chain levels—upstream, international organizational, downstream, and closed-loop activities.

--- Insert Table 2 about here ---

2.3.1 The Internet of Things

IoT is defined as the interconnection of entities that have identities and physical attributes, as well as virtual personalities operating on a smart infrastructure—typically those that are Internet-based (Miorandi et al., 2012; Mishra et al., 2016). Real-time data collection, information sharing and communication can enhance supply chain performance (Dweekat et al., 2017; Gunasekaran et al., 2016). Although IoT research has grown rapidly in recent years, the application of IoT for supply chain management is still underdeveloped and requires further consideration (Ben-Daya et al., 2019; Mishra et al., 2016).

IoT devices can effectively virtualize, track, and authenticate products in the supply chain. Connected physical IoT devices can monitor and assess the source of materials and products to determine whether they came from authenticated renewable resources. The real-time information provided by IoT can enable the ability to evaluate the storage condition and environmental factors associated in procurement and purchasing (Agarwal et al., 2019; Manavalan & Jayakrishna, 2019; Tsang et al., 2018). Leveraged with global positioning systems (GPS), radio frequency identification (RFID), blockchain, and other digital technologies, IoT can effectively support green supply chain performance.

IoT is a key manufacturing sector Industry 4.0 technology (Manavalan & Jayakrishna, 2019). IoT links entities in the factory and across organizations enabling cyber-physical systems to autonomously perform operations and exchange information (Kagermann et al., 2013). A smart factory design can integrate green initiatives as well. Green production smart facility design in provides minimal green-house emissions, or redesign and replace these facilities with more environmentally friendly plans.

IoT devices track the movement of products in the supply chain (Tu, 2018) and provide information regarding supply chain speed and environmental performance. Supply chain companies have applied information to design smart transportation systems that minimize environmental burden while accurately planning shipments, assuring on-time delivery and locating products in real-time (Li, 2011). IoT device sensors can track products through their entire life cycle, supporting operational activities needed for recycling, recovering, or reclaiming.

2.3.2 Blockchain Technology

Blockchain is a digital technology that contains decentralized ledgers of transactional records on a peer-to-peer network. Records on blockchain ledgers are shared among a network of participants transparently and securely. Blockchain technology allows users to maintain and transfer data through ledgers. Removing third parties and intermediaries, blockchain technology links dispersed entities supporting efficient and cost effective transactions (Swan, 2015).

Current supply chain processes are multifaceted with high transaction volumes which limit visibility and hinder effective information management (Hofmann, 2017). Blockchain technology provides a unified secure platform for sharing various supply chain management data and managing trade processes (Chang et al., 2019). The blockchain further offer numerous opportunities for addressing green and sustainable supply chain issues.

Blockchain technology provides a platform for resource sharing. This capability allows suppliers to share their extra resources through a peer-to-peer network without the need for trust amongst peers. The technology is designed to provide trust and remove intermediaries from transactions. A blockchain-based platform can create a market of users who share their resources—resulting in fewer excess resources and lessened waste. For example, suppliers who share excess storage and transportation capacity with a secure blockchain network. This approach supports the sharing economy paradigm—especially pertinent to greening of supply chains from material, resource, and energy use (Kouhizadeh et al., 2019a). Decentralized energy management is another application of blockchain technology that supports renewable energy resources distribution and payment; with established localized peer-to-peer type systems. Reliable distribution and monitoring energy-related process can be conducted on blockchain ledgers (Li et al., 2019).

Blockchain technology has the potential to leverage internal organizational processes. Large organizations with complex and diverse facilities can benefit from adopting blockchain technology (Clohessy & Acton, 2019). Operations processes and shop floor routine monitoring using blockchain ledgers can include materials, energy, and waste monitoring. This process digitalization is a basis for green performance assessment. Evaluated processes that create more wastes or use excessive energy are candidates for improvement or removal (Kouhizadeh & Sarkis, 2018, 2020).

Organizational environmental performance benchmarking with counterparts and competitors is another potential opportunity to further advance green operations initiatives. Blockchain technology also enables collaborative manufacturing activities among organizations (Li et al., 2018). Collaborative warehousing is an example of such activities with sharing warehouse and storage space for materials and products. Blockchain technology links organizations to coordinate and manage shared warehouses. This application aids efficiency combining multiple organizational resources—saving money and waste.

Waste reduction improves environmental performance. Wastes across the supply chain can be targeted (Kumar et al., 2012). However, consumer waste production that generally exists in downstream supply chains is difficult to measure using traditional systems. Blockchain technology can address this issue by providing a platform to connect all entities in the supply chain including consumers (Lamichhane, 2017). Blockchain ledgers enable traceability of waste to goods and products. Consumers may inform manufacturers of wastes—that are to be managed—and be rewarded through blockchain's cryptocurrencies, e.g. Bitcoin (Kouhizadeh et al., 2019b). This information enhances and supports waste management and waste reduction programs. Blockchain's smart contracts have the capability to store terms and conditions of waste programs and digitally trigger the required recovery actions. This application enhances waste exchanges among companies (Ongena et al., 2018).

Closing-the-loop activities—including recycling, refurbishing, reclaiming and recovering—are indispensable for building a green supply chain (Zhu et al., 2008). Blockchain technology, to leverage these activities, provides transparency and traceability of materials across the product life cycle. For closing-the-loop these blockchain capabilities are especially pertinent for end-of-life activities including tracing products and materials through reverse logistics networks.

A recent practice gaining significant practical attention for helping in closed-loop support is open access to repair services with the help of digitalization or the *right to repair* regulatory policies (Hernandez et al., 2020; Svensson et al., 2018). Through this legislation companies are required to share their product blueprints so consumers and other companies can repair the products to extend their life. The instruction and repairing information can be easily shared using blockchain ledgers. Relatedly, blockchain technology opportunities exist for open innovation by offering a platform for knowledge sharing for closing-the-loop activities. The open innovation paradigm allows organizations to extend their boundaries by connecting outside resources to explore new opportunities and integrate these innovations into their operations (De La Rosa et al., 2017).

2.3.3 Quantum Computing

Quantum computing is another emergent technological innovation that utilizes the power of quantum physics to rapidly, electronically and analytically solve complex problems with a high degree of accuracy. Although digitalization of supply chains provides numerous benefits, it can create huge amounts of data that derive from different sources—*big data*. This data originating from multiple sources is difficult to integrate and manage. Quantum computing has the capability to utilize this data for supporting smart operations and manufacturing contributing to organizational greening (Kusiak, 2018).

Quantum computing applications show promise to advance supply chains and address climate change concerns [1]. Despite the great potential, this concept is immature and no research paper has examined this technology for supply chain management. Some professional organizations have started exploring quantum computing. Large high-tech companies such as IBM, Microsoft, and Google are now offering quantum computing solutions for businesses.

Quantum computing has potential to optimize energy usage in the entire supply chain (Ajagekar & You, 2019). This innovation can help organizations and their supply chains to accurately measure their utility and resource usage and adjust their facilities to consume the least amount of energy with self-

[1] https://fortune.com/longform/business-quantum-computing/

adjustment features. Manufacturing companies may leverage this technology to manage energy distribution and optimize their production processes. Quantum computing also have potential to support design of environmental models to effectively predict climate change phenomena and carbon capture storage technology that aims to prevent carbon dioxide from entering the atmosphere. Although allowing for broader meteorological study applications to complex supply chains is a potential application.

One of the most promising applications of quantum computing is in dynamic routing and scheduling (Sanjeev, 2019). Identifying the optimal route for logistics and delivery is a time-intensive task when using traditional computers. Quantum computers can simultaneously evaluate multiple routing models and run traffic simulations to find the best transportation route (Shaw, 2019). Transportation through the optimal route can save time, cost, energy, and support environmental sustainability. The dynamic routing problems can further integrate multifaceted environmental considerations to determine and analyze optimal green solutions.

Quantum computing applications support for closing-the-loop activities are also possible. Extensive quantum computing capabilities are useful for product recovery plans and optimization. Depending on the condition of products, the technology can simulate different scenarios to find the optimal process that maximizes the usability, reusability and life cycle of products. This information can further be utilized to find the optimal green design of products.

Quantum computing has been noted as a potential game changing and disruptive technology for supply chain management (Sanjeev, 2019). Although the potential is manifold, quantum computing is still in the very early stages of development and diffusion. The technology is very expensive and requires complicated and highly controlled environments to utilize at this time. However, the promise is there and we feel that it may offer solutions to intractable green supply chain problems and support a variety of other existing and emergent technologies.

3. Research Agenda and Framework

We now summarize a research agenda to advance understanding of the green supply chain-digitalization nexus. We outline some of the relationships along a pressures, practices, and performance perspective–see Figure 2—which is a common study structure for green supply chain within *IMDS* and other journal publications (e.g. Zhang and Yang (2016); Zhu and Sarkis (2007)). This structure for evaluating research is also related to reviews that use an antecedent, decision (practice), outcome type of analysis (Paul & Criado, 2020).

Research method and theoretical developments may occur at different levels of analysis—as described in Table 1 and Figure 2. For example, the analysis for whether certain antecedents exist, the practices adopted, and the outcome may be specific to whether the level of analysis is the individual, team, organization, supply chain, or nation.

We offer three major and popular organizational theories to help set a research agenda—especially for case study or empirical research. *Institutional, Stakeholder,* and *Resource Based* theoretical perspectives—some of the most popular GSCM research theoretical lenses (Liu et al., 2018; Sarkis et al., 2011) —are briefly overviewed with exemplary research questions.

3.1 Institutions and Institutional Theory Study

At the supply chain and organizational level, the adoption of various technologies for GSCM result from various internal and external pressures. External institutional pressures will cause organizations and their supply chains to adopt technology to aid GSCM. According to *institutional theory,* there are coercive, normative and mimetic isomorphic pressures that will cause organizations to respond in similar ways (Bai et al., 2015; DiMaggio & Powell, 1983).

Institutional theory also includes legitimacy, institutional fields, and institutional logics dimensions that cause heterogeneous responses to these pressures. Also, changes in green supply chains can be catalyzed by *institutional entrepreneurs* (Peters et al., 2011); organizations or individuals that seek to make changes to institutional fields to address environmental and technological concerns.

The research questions are manifold from an institutional theoretical perspective. Ranging from what pressures will cause the most effective or most rapid change to ones that result in the greatest improvements and investments for digitalization and GSCM. There are also institutional field questions related to which institutional field—based on geography, culture, region, or industry—is likely affecting pressures to green using the various digitalization technologies. An institutional entrepreneurial perspective can help establish which organization or individual is likely to change policies or practices for the adoption of GSCM digitalization technologies.

3.2 Stakeholders and Stakeholder Theory Study

Another popular theoretical perspective—often related to institutional theory—is stakeholder theory. Stakeholder theory stipulates that organizations and supply chains will keep or alter strategic policies and practices based on people, organizations, and other actor pressures that have some 'stake' in the policies or practices. Stakeholders may include owners, customers, employees and suppliers—who are deemed to alter internal change to the supply chain or organization. External stakeholders may include government, competitors, consumer advocates, environmentalists, special interest groups and the media (Freeman, 2010).

The salience and influence of stakeholders from outside or inside the organizational supply chain boundary tends to vary. There are also relationships to stakeholders and the type of institutional pressures they may offer. There are also situations where engaging and action with stakeholders may also cause change (Ayuso et al., 2011). Organizations may decide which stakeholders require attention through a stakeholder analysis especially when it comes to the development and application of interorganizational systems (Gupta, 1995).

The relationships between stakeholders and institutional theory have been linked closely given that stakeholders can provide different institutional pressures. For example, governments can provide coercive and mimetic pressures by actions such as mandatory requirements with coercive penalties and fines. Governments may also offer benchmark programs to help organizations learn from or mimic each other. Stakeholders can also offer internal pressures based on value systems—*norms*—and can also coerce new practices. Stakeholders use their values and beliefs to help determine institutional logics and fields (Ioannou & Serafeim, 2015). Stakeholder theory has also been related to other popular theories such as resource dependence and relational view theories.

A multitude of research questions arise from stakeholder theory for digitalization and GSCM. Which stakeholders can most enable or serve as barriers to green supply chain digitalization adoption and integration? Stakeholder salience and outcomes—successful or otherwise—after adoption can be investigated. In fact, using stakeholder pressures as moderators can also occur, with pressure moderating the practices and performance (Wolf, 2014). A stakeholder perspective may also gain greater importance as technologies and social media amplify their stakeholder voice (Barnett et al., 2020) and is worthy of investigation from an emergent technology and GSCM perspective.

3.3 The Resource Based View

The resource based view (RBV), similar to institutional theory, is multifaceted with extensions and depth to the RBV theoretical perspective. The theory stipulates that resources including capabilities of organizations are central to organizations building strategic competitive advantage. These resources should be valuable, rare, imperfectly imitable, and non-substitutable (Barney, 1991). They include taking advantage of dynamic capabilities and even expanded to include the natural resource base view of the firm.

From a GSCM digitization perspective, this theory can explain why organizations would decide internally to invest in these technologies. Primarily that it provides them the resources to build a competitive advantage. Currently, given the emergent nature of the technologies and GSCM principles, it may be likely that each could effectively contribute to various RBV competitive constructs. Interestingly, in the seminal article on RBV information processing systems were viewed as the competitive resource (Barney, 1991). Since that time RBV has been widely used to understand information technology relationships to organizational performance (Liang et al., 2010).

A number of research issues arise with the RBV lens. First, is whether the emergent digitalization technologies that integrate activities across organizations are appropriate for RBV. Must each organizational partner within the supply chain gain competitive value from GSCM and digitalization for adoption? Or does a single firm need to experience a competitive advantage and diffuse performance along the supply chain? Relatedly, if stakeholders and institutions require them, then an organization would need to determine if building these tangible and intangible resources are worth the investment from a competitiveness perspective; especially if they are viewed as strategic investments.

One of the growing areas of interest as new technologies and newer issues in GSCM emerge, is the dynamic capabilities theoretical perspective of RBV (Gupta et al., 2020). How the capabilities diverge and evolve will be critical to investigate the future diffusion of these technologies. Thus, dynamic capabilities brings in a longitudinal nature to investigate these relationships; based on the pressures, practices, and performance framework.

3.4 Emergent Theoretical Perspectives

We shall not delve as deeply into potential and promising theories—there are very many. We provide some at multiple levels of analysis. For the individual level, there are leadership and motivation theories and individual level technology adoption models; some of these latter theories have integrated motivation theory. The theory of planned behavior and technology acceptance have been utilized for individual level management intention to adopt green information systems (Dalvi-Esfahani et al., 2017); which also integrated personal values. Digitalization requires acceptance by managers and employees for effective implementation requiring organizations to build individual knowledge resource capacity.

Role theory is one particular individual level socio-psychological theory that stipulates that everyday activity and management is based on socially defined categories—e.g. technology, purchasing, supply chain, or sustainability manager (Biddle, 1986; Sluss et al., 2011). These roles are likely to contribute to the discussion and evaluation—as well as results. Role theory has also been applied to the group level of analysis—with the Belbin team-role theoretic perspective (Batenburg & van Walbeek, 2013); where individuals will play different roles within a team and their characteristics to accomplish tasks. Such constructs can be used to investigate what team and individual characteristics work or are barriers to advancing digitization and GSCM practices; along with performance. When looking into management and worker roles, can technology and greening advocacy become an element of employee roles? What will it require to build these organizational role capacities?

At an organizational level, organizational change plays a large role in innovative practices, policies, and processes justification, adoption, and implementation. Digitalization of GSCM are two innovations that will require organizational and inter-organizational change. Multiple organizational change theories exist and include organizational learning and continuous improvement theoretical perspectives. An older—but especially pertinent—theoretical lens within and between organizations is force *field theory* (Lewin, 1951; Swanson & Creed, 2014).

Field theory—also called *force field theory*—is typically an organizational level theoretical perspective that has expanded to supply chain and inter-organizational concerns. Yet, the application to GSCM or inter-organizational technological perspectives has yet to gather substantial attention in the literature (Swanson et al., 2017). Based in organizational sociology this theory fundamentally states that organizations face pressures to change and barriers to change. Change will occur only when pressures are greater than the barriers. The theory is gaining traction since it helps attach theoretical meaning to studies focusing on barriers and enablers to green supply and digitalization technology (e.g. Kouhizadeh et al. (2020); Kang et al. (2018)).

A third theory that may show some promise in understanding GSCM and digitalization adoption is one whose home resides in the environmental sociology field and appears at the macro-economic and environmental policy level of analysis. *Ecological modernization theory* (EMT) (Spaargaren & Mol, 1992) stipulates that technological advancement can help decouple economic growth from environmental degradation. Although it has received some criticism (e.g. York and Rosa (2003))—the theory has been applied to GSCM and traditional organizational technologies (Bai et al. (2015); Tseng et al. (2018); Bergendahl et al. (2018)).

EMT can help set the stage to answer a research question on whether the performance outcomes of digitalization of GSCM can result effectively in either or both improved environmental and economic performance. Or at least improve economic performance without hurting environmental performance; or alternatively improving environmental performance without degrading economic performance of organizations and their supply chains.

These example theoretical perspectives and research questions apply to various stages of the pressures, practices, and performance research framework. They also are varying in applicability with a dependence on the level of analysis. Many such examples exist beyond what we feel are promising perspectives.

3.5 A Compendium of theoretical lenses and methodology

The number of theories applicable to digitalization and GSCM is quite broad due to the complexities involved in these concepts. Both digitalization and GSCM fields have started to adopt and integrate theories from multiple disciplines with dozens identified—see for example Sarkis et al. (2011); Swanson et al. (2017); Treiblmaier (2018)). We identified a few of them in this section with research questions identified. The research questions may consider multiple levels of analysis and various relationships in the pressures, practices, and performance model. There are situations where the constructs and theoretical lenses may help explain and evaluate direct relationships at a single level, or multiple relationships across levels. The complexity of organizational and supply chains provide ample opportunity for investigating research questions that are important for managers, organizations, investors, and policy makers.

We did not delve into research methodological approaches here—but the list and variety can be just as expansive. Given the relative emergent nature of these evaluations, case and field studies with grounded theory or action research approaches are needed to build initial comprehension and sensemaking. Some broad-based empirical studies have started to occur; but the difficulties arise since few organizations have fully implemented these emergent concepts.

Formal analytical modeling research has occurred to help prescribe solutions and further understand the process. Multi-attribute decision modeling are promising, as are soft-computing methods (Tseng et al., 2018); but care must be taken in presenting normative prescriptive research solutions; when the constructs, factors, and nuances in this type of research are still evolving.

--- Insert Figure 2 about here ---

4. Conclusion

In this article we reflected on various digitalization technologies and their relationships to green supply chain management. These concepts and practices are both emergent; but are also broadly evident in the *IMDS* literature from the past 50 years. Extensive relationships and issues exist from the most basic information systems and greening of organizations and supply chains to more advanced—untested—digitalization technologies that span organizations and countries.

Completing research studies in a field that has two emergent and dynamic concepts—digitalization and GSCM—is difficult. Completing standard research and empirical analysis, that looks back at previous practices, to predict future relationships may not be adequate (Pagell & Shevchenko, 2014). Many areas of managerial and supply chain research may have practice leading research. New practices are studied with academic research lagging and seeking to make sense of practice. In the case of green supply chains and their digitalization the opposite is true. Academic research is leading industry practice; which may explain the popularity of the field since researchers can guide practice and actually influence social and industrial development.

Forward seeking research is needed. New theoretical perspectives—if they can help understand and advance the fields—are necessary; but, we should not forget effective existing theory. The world is changing from technological, social, and environmental understanding perspectives. We hope our reflections set the stage for the *IMDS* and broader scholarly community to further understand and develop insights to help improve our world, our lives, and our work.

Figure 1: Green information systems and green supply chain management in *IMDS* – thematic focus and paper quantity allocation

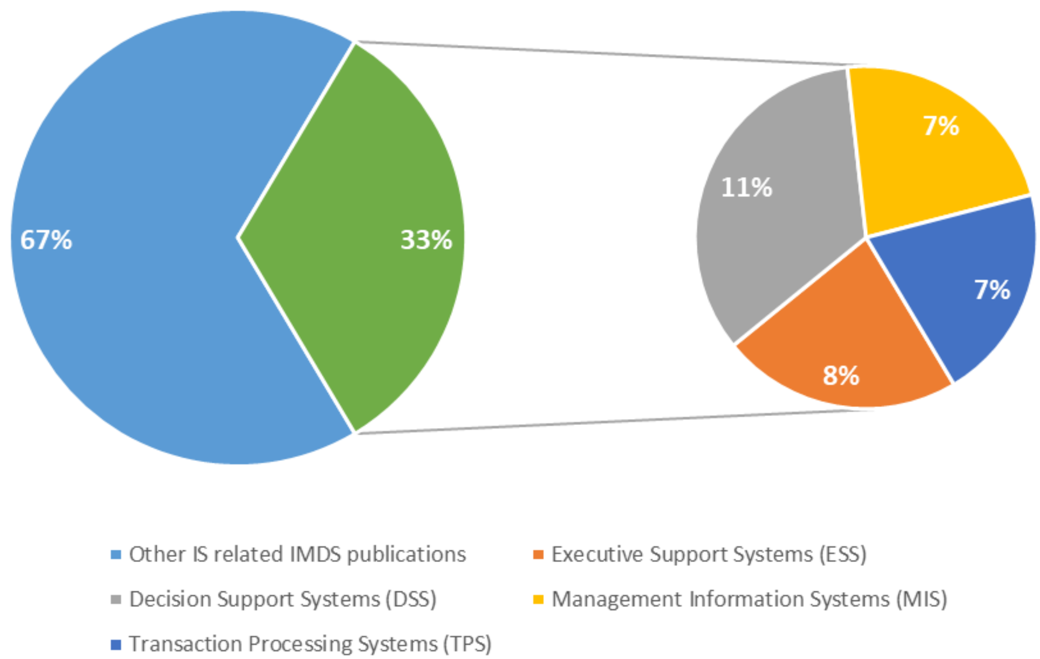

Figure 2: Proposed conceptual framework for the digitalization in green supply chains

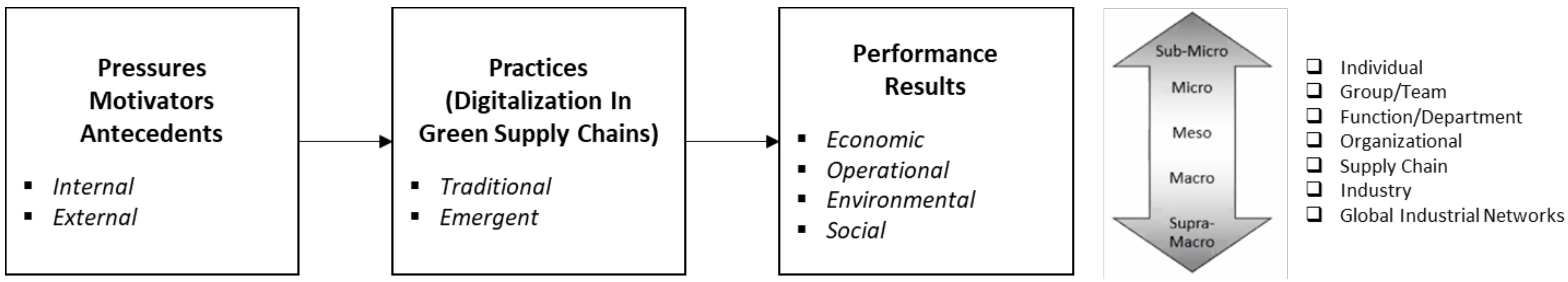

Table 1: Green information systems and green and sustainable supply chain management in IMDS

MANAGERIAL DECISION LEVEL	STRATEGIC LEVEL	MANAGERIAL LEVEL		OPERATIONAL LEVEL
Functional area	***Executive Support Systems (ESS)***	***Decision Support Systems (DSS)***	***Management Information Systems (MIS)***	***Transaction Processing Systems (TPS)***
Engineering and design	• New Product Requirements (Quazi, 2001); • Environmental Liability Issues (Cannon & Woszczynski, 2002).	• Justification Models for designs (Sánchez ‐ Rodríguez & Martínez ‐ Lorente, 2011); • Design for Environment (DFE) decision tools (Bai et al., 2015); • Decision models for product portfolio management (Bai et al., 2018);	• Life Cycle Analysis (LCA) (Lee et al., 2012); • Product data management systems (Smith, 2004).	• Environmental product and process performance information (Lee, 2012) • Product lifecycle information acquisition and management (Yang et al., 2007);
Procurement	• Liability information sharing and management (Verma & Singh, 2017)	• Supplier selection decision models with environmental factors (Ghadge et al., 2017; Jabbour & Jabbour, 2009);	• Reports concerning environmental performance of suppliers (Leszczynska, 2012);	• Updating inventory of environmentally sensitive material (Green et al., 2012);
Manufacturing and production	• Regulatory compliance in manufacturing (Miller & McKinney, 1998); • Environmental technology information (Jiang et al., 2020).	• product lifecycle data to assist end-of-life disassembly planning tools (Yang et al., 2007); • Quantitative evaluation models for sustainable supply chain assessment (Muñoz et al., 2008; Tseng et al., 2015);	• Sharing of knowledge and services in manufacturing ecosystems (Li et al., 2018);	• Environmental collaboration and monitoring practices (Green et al., 2012);

MANAGERIAL DECISION LEVEL	STRATEGIC LEVEL	MANAGERIAL LEVEL		OPERATIONAL LEVEL
Sales and marketing	• Green consumer market development systems (Castka & Balzarova, 2008); • Green value assessment in environmental management systems adoption (Dalvi-Esfahani et al., 2017).	• Forecasting tools for green product requirements (Zhong et al., 2017); • Design for e-commerce channels for additive manufacturing (Shukla et al., 2018).	• Information on different market-oriented sustainability programs (Clark et al., 2014).	• Environmental awareness purchasing intention model to promote green purchasing (Xu et al., 2019).
Logistics	• Information and communications technology in long term data management and plans (Zhong et al., 2017).	• Decision support systems for sustainable logistics such as inter-modal transport, port operations (Qaiser et al., 2017); • Logistics provider selection decision models with environmental factors (Govindan et al., 2016); • Simulation tools for transportation and energy planning and network design (Shin et al., 2012).	• Reports on daily and weekly usage of fuel-driven vehicles (Ghadge et al., 2017).	• Amount of packaging returns for day and scheduling of reclaimed materials (Singh et al., 2010).
Finance	• Enterprise resource planning to enhance shareholder returns (Hwang & Min, 2015).	• Capital budgeting DSS tools integrating environmental factors in sustainable partner network (Polyantchikov et al., 2017).	• Financial environmental budget reports (Moneva & Ortas, 2010); • GRI Sustainability reporting (Moneva et al., 2007).	• Daily transactions of greenhouse gas emissions permits (Kazancoglu et al., 2018).

MANAGERIAL DECISION LEVEL	STRATEGIC LEVEL	MANAGERIAL LEVEL		OPERATIONAL LEVEL
Human resources	• Environmental and safety requirements in union negotiations (Mishra et al., 2016).	• Personnel selection for environmental programs (Massoud et al., 2011).	• Environmental training records (Govindarajulu & Daily, 2004; Lee & Cheong, 2011).	• Workforce environmental awareness training (Madsen & Ulhøi, 2001); • Virtual communications and collaborations (Pérez - López & Alegre, 2012).

Table 2: Platform-based technologies and green supply chain management

	Upstream Supply Chain Management	Internal Organizational Activities	Downstream Supply Chain Management	Closing the Loop Activities
Internet of Things (IoT)	• Green source of materials and products (Agarwal et al., 2019; Tsang et al., 2018).	• Smart and green factory design and manufacturing (Kagermann et al., 2013).	• Smart and green transportation system (Li, 2011).	• closed loop product lifecycle management (Paksoy et al., 2016).
Blockchain Technology	• Resource sharing (Kouhizadeh & Sarkis, 2018); • Decentralized energy management (Li et al., 2019).	• Green operations performance evaluation (Kouhizadeh & Sarkis, 2018, 2020); • Collaborative warehouse management (Tian, 2016).	• Waste management (Lamichhane, 2017; Ongena et al., 2018); • Green incentivization (Kouhizadeh et al., 2019b).	• Enabled “right to repair” practices (Hernandez et al., 2020; Svensson et al., 2018); • Open innovation (De La Rosa et al., 2017).
Quantum Computing	• Green energy and resource planning (Ajagekar & You, 2019).	• Green manufacturing optimization (Sanjeev, 2019).	• Green logistics optimization (Shaw, 2019).	• Product recovery optimization (Sanjeev, 2019).

REFERENCES

Agarwal, S., Sharma, V., & Pughat, A. (2019), "Supplier selection problem in IoT solutions", *International Journal of Pervasive Computing and Communications*, Vol. 15 No. 1, pp. 16-19.

Ajagekar, A., & You, F. (2019), "Quantum computing for energy systems optimization: Challenges and opportunities", *Energy*, Vol. 179, pp. 76-89.

Ayuso, S., Rodríguez, M. Á., García‐Castro, R., & Ariño, M. Á. (2011), "Does stakeholder engagement promote sustainable innovation orientation?", *Industrial Management & Data Systems*, Vol. 111 No. 9, pp. 1399-1417.

Bai, C., & Sarkis, J. (2013), "Green information technology strategic justification and evaluation", *Information Systems Frontiers*, Vol. 15 No. 5, pp. 831-847.

Bai, C., Sarkis, J., & Dou, Y. (2015), "Corporate sustainability development in China: review and analysis", *Industrial Management & Data Systems*, Vol. 115 No. 1, pp. 5-40.

Bai, C., Shah, P., Zhu, Q., & Sarkis, J. (2018), "Green product deletion decisions: An integrated sustainable production and consumption approach", *Industrial Management & Data Systems*, Vol. 118 No. 2, pp. 349-389.

Barnett, M. L., Henriques, I., & Husted, B. W. (2020), "The rise and stall of stakeholder influence: How the digital age limits social control", *Academy of Management Perspectives*, Vol. 34 No. 1, pp. 48-64.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of management*, Vol. 17 No. 1, pp. 99-120.

Batenburg, R., Benders, J., & Van der Blonk, H. (2008), "Technical isomorphism at work: ERP‐embedded similarity‐enhancing mechanisms", *Industrial Management & Data Systems*, Vol. 108 No. 1, pp. 60-69.

Batenburg, R., & van Walbeek, W. (2013), "Belbin role diversity and team performance: is there a relationship?", *Journal of Management Development*, Vol. 32 No. 8, pp. 901-913.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019), "Internet of things and supply chain management: a literature review", *International Journal of Production Research*, Vol. 57 No. 15-16, pp. 4719-4742.

Bergendahl, J. A., Sarkis, J., & Timko, M. T. (2018), "Transdisciplinarity and the food energy and water nexus: Ecological modernization and supply chain sustainability perspectives", *Resources, Conservation and Recycling*, Vol. 133, pp. 309-319.

Berkhout, P. H., Muskens, J. C., & Velthuijsen, J. W. (2000), "Defining the rebound effect", *Energy policy*, Vol. 28 No. 6-7, pp. 425-432.

Biddle, B. J. (1986), "Recent developments in role theory", *Annual review of sociology*, Vol. 12 No. 1, pp. 67-92.

Cannon, A. R., & Woszczynski, A. B. (2002), "Crises and revolutions in information technology: lessons learned from Y2K", *Industrial Management & Data Systems*, Vol. 102 No. 6, pp. 318-324.

Castka, P., & Balzarova, M. A. (2008), "Adoption of social responsibility through the expansion of existing management systems", *Industrial Management & Data Systems*, Vol. 108 No. 3, pp. 297-309.

Cetrulo, A., & Nuvolari, A. (2019), "Industry 4.0: revolution or hype? Reassessing recent technological trends and their impact on labour", *Journal of Industrial and Business Economics*, Vol. 46 No. 3, pp. 391-402.

Chang, S. E., Chen, Y.-C., & Wu, T.-C. (2019), "Exploring blockchain technology in international trade", *Industrial Management & Data Systems*, Vol. 119 No. 8, pp. 1712-1733.

Clark, J. W., Toms, L. C., & Green, K. W. (2014), "Market-oriented sustainability: moderating impact of stakeholder involvement: Business process re-engineering for letter of credit", *Industrial Management & Data Systems*, Vol. 114 No. 1, pp. 21-36.

Clohessy, T., & Acton, T. (2019), "Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective", *Industrial Management & Data Systems*, Vol. 119 No. 7, pp. 1457-1491.
Dalvi-Esfahani, M., Ramayah, T., & Rahman, A. A. (2017), "Moderating role of personal values on managers' intention to adopt Green IS: Examining norm activation theory", *Industrial Management & Data Systems*, Vol. 117 No. 3, pp. 582-604.
De La Rosa, J. L., Torres-Padrosa, V., El-Fakdi, A., Gibovic, D., Hornyák, O., Maicher, L., & Miralles, F. (2017), "A survey of blockchain technologies for open innovation", Proceedings of the 4th Annual World Open Innovation Conference.
DiMaggio, P. J., & Powell, W. W. (1983), "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields", *American Sociological Review*, Vol. 48 No. 2, pp. 147-160. doi:10.2307/2095101
Dweekat, A. J., Hwang, G., & Park, J. (2017), "A supply chain performance measurement approach using the internet of things: Toward more practical SCPMS", *Industrial Management & Data Systems*, Vol. 117 No. 2, pp. 267-286.
Freeman, R. E. (2010), "Strategic management: A stakeholder approach", Pitman, Boston.
Ghadge, A., Kaklamanou, M., Choudhary, S., & Bourlakis, M. (2017), "Implementing environmental practices within the Greek dairy supply chain: Drivers and barriers for SMEs", *Industrial Management & Data Systems*, Vol. 117 No. 9, pp. 1995-2014.
Govindan, K., Khodaverdi, R., & Vafadarnikjoo, A. (2016), "A grey DEMATEL approach to develop third-party logistics provider selection criteria", *Industrial Management & Data Systems*, Vol. 116 No. 4, pp. 690-722.
Govindarajulu, N., & Daily, B. F. (2004), "Motivating employees for environmental improvement", *Industrial Management & Data Systems*, Vol. 104 No. 4, pp. 364-372.
Green, K. W., Zelbst, P. J., Bhadauria, V. S., & Meacham, J. (2012), "Do environmental collaboration and monitoring enhance organizational performance?", *Industrial Management & Data Systems*, Vol. 112 No. 2, pp. 186-205.
Gunasekaran, A., Subramanian, N., Tiwari, M. K., Yan, B., Yan, C., Ke, C., & Tan, X. (2016), "Information sharing in supply chain of agricultural products based on the Internet of Things", *Industrial Management & Data Systems*, Vol. 116 No. 7, pp. 1397-1416.
Gupta, A. (1995), "A stakeholder analysis approach for interorganizational systems", *Industrial Management & Data Systems*, Vol. 95 No. 6, pp. 3-7.
Gupta, S., Meissonier, R., Drave, V. A., & Roubaud, D. (2020), "Examining the impact of Cloud ERP on sustainable performance: A dynamic capability view", *International Journal of Information Management*, Vol. 51, pp. 102028.
Henderson, J. C., Rockart, J. F., & Sifonis, J. G. (1987), "Integrating management support systems into strategic information systems planning", *Journal of management information systems*, Vol. 4 No. 1, pp. 5-24.
Hernandez, R. J., Miranda, C., & Goñi, J. (2020), "Empowering Sustainable Consumption by Giving Back to Consumers the 'Right to Repair'", *Sustainability*, Vol. 12 No. 3, pp. 850.
Hofmann, E. (2017), "Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect", *International Journal of Production Research*, Vol. 55 No. 17, pp. 5108-5126.
Hwang, D., & Min, H. (2015), "Identifying the drivers of enterprise resource planning and assessing its impacts on supply chain performances", *Industrial Management & Data Systems*, Vol. 115 No. 3, pp. 541-569.

Ioannou, I., & Serafeim, G. (2015), "The impact of corporate social responsibility on investment recommendations: Analysts' perceptions and shifting institutional logics", *Strategic management journal*, Vol. 36 No. 7, pp. 1053-1081.
Jabbour, A. B. L., & Jabbour, C. J. (2009), "Are supplier selection criteria going green? Case studies of companies in Brazil", *Industrial Management & Data Systems*, Vol. 109 No. 4, pp. 477-495.
Jiang, S., Han, Z., & Huo, B. (2020), "Patterns of IT use: the impact on green supply chain management and firm performance", *Industrial Management & Data Systems*, Vol. 120 No. 5, pp. 825-843.
Kagermann, H., Wahlster, W., & Helbig, J. (2013), "Recommendations for implementing the strategic initiative Industrie 4.0: Final report of the Industrie 4.0 Working Group", Forschungsunion, Berlin, Germany.
Kamble, S. S., Gunasekaran, A., Parekh, H., & Joshi, S. (2019), "Modeling the internet of things adoption barriers in food retail supply chains", *Journal of Retailing and Consumer Services*, Vol. 48, pp. 154-168.
Kang, M., Yang, M. G. M., Park, Y., & Huo, B. (2018), "Supply chain integration and its impact on sustainability", *Industrial Management & Data Systems*, Vol. 118 No. 9, pp. 1749-1765.
Kazancoglu, Y., Kazancoglu, I., & Sagnak, M. (2018), "Fuzzy DEMATEL-based green supply chain management performance: Application in cement industry", *Industrial Management & Data Systems*, Vol. 118 No. 2, pp. 412-431.
Kouhizadeh, M., Saberi, S., & Sarkis, J. (2020), "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers", *International Journal of Production Economics*, Vol. 231, pp. 107831.
Kouhizadeh, M., & Sarkis, J. (2018), "Blockchain Practices, Potentials, and Perspectives in Greening Supply Chains", *Sustainability*, Vol. 10 No. 10, pp. 3652.
Kouhizadeh, M., & Sarkis, J. (2020), "Blockchain Characteristics and Green Supply Chain Advancement", In *Global Perspectives on Green Business Administration and Sustainable Supply Chain Management*, pp. 93-109, IGI Global, Hershey, PA.
Kouhizadeh, M., Sarkis, J., & Zhu, Q. (2019a), "At the Nexus of Blockchain Technology, the Circular Economy, and Product Deletion", *Applied Sciences*, Vol. 9 No. 8, pp. 1712.
Kouhizadeh, M., Zhu, Q., & Sarkis, J. (2019b), "Blockchain and the circular economy: potential tensions and critical reflections from practice", *Production Planning & Control*, pp. 1-17. doi:10.1080/09537287.2019.1695925
Kumar, S., Teichman, S., & Timpernagel, T. (2012), "A green supply chain is a requirement for profitability", *International Journal of Production Research*, Vol. 50 No. 5, pp. 1278-1296.
Kusiak, A. (2018), "Smart manufacturing", *International Journal of Production Research*, Vol. 56 No. 1-2, pp. 508-517.
Lamichhane, M. (2017), "A smart waste management system using IoT and blockchain technology", LUT University, Lappeenranta, Finland.
Lee, K. H., & Cheong, I. M. (2011), "Measuring a carbon footprint and environmental practice: the case of Hyundai Motors Co. (HMC)", *Industrial Management & Data Systems*, Vol. 111 No. 6, pp. 961-978.
Lee, L. T. S. (2012), "The pivotal roles of corporate environment responsibility", *Industrial Management & Data Systems*, Vol. 112 No. 3, pp. 466-483.
Lee, S. M., Kim, S. T., & Choi, D. (2012), "Green supply chain management and organizational performance", *Industrial Management & Data Systems*, Vol. 112 No. 8, pp. 1148-1180.
Leszczynska, A. (2012), "Towards shareholders' value: an analysis of sustainability reports", *Industrial Management & Data Systems*, Vol. 112 No. 6, pp. 911-928.
Lewin, K. (1951), "Field theory in social science: selected theoretical papers (Edited by Dorwin Cartwright)", Harper & Brothers Publishers, New York.

Li, L. (2011), "Application of the internet of thing in green agricultural products supply chain management", 2011 Fourth International Conference on Intelligent Computation Technology and Automation.
Li, Z., Bahramirad, S., Paaso, A., Yan, M., & Shahidehpour, M. (2019), "Blockchain for decentralized transactive energy management system in networked microgrids", *The Electricity Journal*, Vol. 32 No. 4, pp. 58-72.
Li, Z., Wang, W. M., Liu, G., Liu, L., He, J., & Huang, G. Q. (2018), "Toward open manufacturing: A cross-enterprises knowledge and services exchange framework based on blockchain and edge computing", *Industrial Management & Data Systems*, Vol. 118 No. 1, pp. 303-320.
Liang, T. P., You, J. J., & Liu, C. C. (2010), "A resource ‐ based perspective on information technology and firm performance: a meta analysis", *Industrial Management & Data Systems*, Vol. 110 No. 8, pp. 1138-1158.
Liu, J., Feng, Y., Zhu, Q., & Sarkis, J. (2018), "Green supply chain management and the circular economy: Reviewing theory for advancement of both fields", *International Journal of Physical Distribution & Logistics Management*, Vol. 48 No. 8, pp. 794-817.
Madsen, H., & Ulhøi, J. P. (2001), "Greening of human resources: environmental awareness and training interests within the workforce", *Industrial Management & Data Systems*, Vol. 101 No. 2, pp. 57-65.
Manavalan, E., & Jayakrishna, K. (2019), "A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements", *Computers & Industrial Engineering*, Vol. 127, pp. 925-953.
Massoud, J. A., Daily, B. F., & Bishop, J. W. (2011), "Perceptions of environmental management systems: An examination of the Mexican manufacturing sector", *Industrial Management & Data Systems*, Vol. 111 No. 1, pp. 5-19.
Miller, P. E., & McKinney, M. M. (1998), "Analyzing effects of regulatory compliance in manufacturing", *Industrial Management & Data Systems*, Vol. 98 No. 3, pp. 108-112.
Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012), "Internet of things: Vision, applications and research challenges", *Ad hoc networks*, Vol. 10 No. 7, pp. 1497-1516.
Mishra, D., Gunasekaran, A., Childe, S. J., Papadopoulos, T., Dubey, R., & Wamba, S. (2016), "Vision, applications and future challenges of Internet of Things", *Industrial Management & Data Systems*, Vol. 116 No. 7, pp. 1331-1355.
Moneva, J. M., & Ortas, E. (2010), "Corporate environmental and financial performance: a multivariate approach", *Industrial Management & Data Systems*, Vol. 110 No. 2, pp. 193-210.
Moneva, J. M., Rivera ‐ Lirio, J. M., & Muñoz ‐ Torres, M. J. (2007), "The corporate stakeholder commitment and social and financial performance", *Industrial Management & Data Systems*, Vol. 107 No. 1, pp. 84-102.
Muñoz, M. J., Rivera, J. M., & Moneva, J. M. (2008), "Evaluating sustainability in organisations with a fuzzy logic approach", *Industrial Management & Data Systems*, Vol. 108 No. 6, pp. 829-841.
Ongena, G., Smit, K., Boksebeld, J., Adams, G., Roelofs, Y., & Ravesteijn, P. (2018), "Blockchain-based Smart Contracts in Waste Management: A Silver Bullet?", 31st Bled eConference: Digital Transformation; Meeting the Challenges, Slovenia.
Oz, E. (2008), "Management information systems", Cengage Learning.
Pagell, M., & Shevchenko, A. (2014), "Why research in sustainable supply chain management should have no future", *Journal of Supply Chain Management*, Vol. 50 No. 1, pp. 44-55.
Paksoy, T., KARAOĞLAN, İ., Gökçen, H., Pardalos, P. M., & TORĞUL, B. (2016), "An experimental research on closed loop supply chain management with internet of things", *Journal of Economics Bibliography*, Vol. 3 No. 1S, pp. 1-20.

Paul, J., & Criado, A. R. (2020), "The art of writing literature review: What do we know and what do we need to know?", *International Business Review*, pp. 101717.

Pérez‐López, S., & Alegre, J. (2012), "Information technology competency, knowledge processes and firm performance", *Industrial Management & Data Systems*, Vol. 112 No. 4, pp. 644-662.

Peters, N. J., Hofstetter, J. S., & Hoffmann, V. H. (2011), "Institutional entrepreneurship capabilities for interorganizational sustainable supply chain strategies", *The International Journal of Logistics Management*, Vol. 22 No. 1, pp. 52-86.

Polyantchikov, I., Shevtshenko, E., Karaulova, T., Kangilaski, T., & Camarinha-Matos, L. M. (2017), "Virtual enterprise formation in the context of a sustainable partner network", *Industrial Management & Data Systems*, Vol. 117 No. 7, pp. 1446-1468.

Qaiser, F. H., Ahmed, K., Sykora, M., Choudhary, A., & Simpson, M. (2017), "Decision support systems for sustainable logistics: a review and bibliometric analysis", *Industrial Management & Data Systems*, Vol. 117 No. 7, pp. 1376-1388.

Quazi, H. (2001), "Sustainable development: integrating environmental issues into strategic planning", *Industrial Management & Data Systems*, Vol. 101 No. 2, pp. 64-70.

Sánchez‐Rodríguez, C., & Martínez‐Lorente, A. R. (2011), "Effect of IT and quality management on performance", *Industrial Management & Data Systems*, Vol. 111 No. 6, pp. 830-848.

Sanjeev, H. R. (2019), "Quantum Computing: The Next Big Thing in Digital Supply Chain Disruption", TATA Consultancy Services, Retrieved from https://www.tcs.com/blogs/quantum-computing-digital-supply-chain-disruption

Sarkis, J. (2012), "A boundaries and flows perspective of green supply chain management", *Supply Chain Management: An International Journal*, Vol. 17 No. 2, pp. 202-216.

Sarkis, J. (2019), "Sustainable transitions: technology, resources, and society", *One Earth*, Vol. 1 No. 1, pp. 48-50.

Sarkis, J., Koo, C., & Watson, R. T. (2013), "Green information systems & technologies–this generation and beyond: Introduction to the special issue", *Information Systems Frontiers*, Vol. 15 No. 5, pp. 695-704.

Sarkis, J., Zhu, Q., & Lai, K.-h. (2011), "An organizational theoretic review of green supply chain management literature", *International Journal of Production Economics*, Vol. 130 No. 1, pp. 1-15.

Shaw, S. (2019), "Quantum Computing Applications for Supply Chain", Clarkston Consulting, Retrieved from https://clarkstonconsulting.com/insights/quantum-computing-applications-sc/

Shin, K., Shin, Y., Kwon, J. H., & Kang, S. H. (2012), "Risk propagation based dynamic transportation route finding mechanism", *Industrial Management & Data Systems*, Vol. 112 No. 1, pp. 102-124.

Shukla, S., Mohanty, B., & Kumar, A. (2018), "Strategizing sustainability in e-commerce channels for additive manufacturing using value-focused thinking and fuzzy cognitive maps", *Industrial Management & Data Systems*, Vol. 118 No. 2, pp. 390-411.

Singh, R. K., Garg, S. K., & Deshmukh, S. (2010), "Strategy development by small scale industries in India", *Industrial Management & Data Systems*, Vol. 110 No. 7, pp. 1073-1093.

Sluss, D. M., Van Dick, R., & Thompson, B. S. (2011), "Role theory in organizations: A relational perspective", In *Handbook of industrial and organizational psychology, Vol 1: Building and developing the organization.*, pp. 505-534, American Psychological Association.

Smith, A. D. (2004), "Empirical exploration for a product data management (PDA) system at a major telecommunications firm", *Industrial Management & Data Systems*, Vol. 104 No. 6, pp. 513-525.

Spaargaren, G., & Mol, A. P. (1992), "Sociology, environment, and modernity: Ecological modernization as a theory of social change", *Society & natural resources*, Vol. 5 No. 4, pp. 323-344.

Svensson, S., Richter, J. L., Maitre-Ekern, E., Pihlajarinne, T., Maigret, A., & Dalhammar, C. (2018), "The emerging 'Right to repair'legislation in the EU and the US", Proceedings from Going Green–Care Innovation, Vienna.

Swan, M. (2015), "Blockchain: Blueprint for a new economy", O'Reilly Media, Inc., Sebastopol, CA, USA.
Swanson, D., Goel, L., Francisco, K., & Stock, J. (2017), "Applying theories from other disciplines to logistics and supply chain management: a systematic literature review", *Transportation Journal*, Vol. 56 No. 3, pp. 299-356.
Swanson, D. J., & Creed, A. S. (2014), "Sharpening the focus of force field analysis", *Journal of Change Management*, Vol. 14 No. 1, pp. 28-47.
Tian, F. (2016), "An agri-food supply chain traceability system for China based on RFID & blockchain technology", 2016 13th international conference on service systems and service management (ICSSSM).
Treiblmaier, H. (2018), "The impact of the blockchain on the supply chain: a theory-based research framework and a call for action", *Supply Chain Management: An International Journal*, Vol. 23 No. 6, pp. 545-559.
Tsang, Y. P., Choy, K. L., Wu, C. H., Ho, G. T., Lam, C. H., & Koo, P. (2018), "An Internet of Things (IoT)-based risk monitoring system for managing cold supply chain risks", *Industrial Management & Data Systems*, Vol. 118 No. 7, pp. 1432-1462.
Tseng, M.-L., Zhu, Q., Sarkis, J., & Chiu, A. S. (2018), "Responsible consumption and production (RCP) in corporate decision-making models using soft computation", *Industrial Management & Data Systems*, Vol. 118 No. 2, pp. 322-329.
Tseng, M., Lim, M., & Wong, W. P. (2015), "Sustainable supply chain management: A closed-loop network hierarchical approach", *Industrial Management & Data Systems*, Vol. 115 No. 3, pp. 436-461.
Tu, M. (2018), "An exploratory study of Internet of Things (IoT) adoption intention in logistics and supply chain management", *The International Journal of Logistics Management*, Vol. 29 No. 1, pp. 131-151.
Verma, N., & Singh, J. (2017), "An intelligent approach to big data analytics for sustainable retail environment using Apriori-MapReduce framework", *Industrial Management & Data Systems*, Vol. 117 No. 7, pp. 1503-1520.
Wang, C., Zhao, L., Vilela, A. L., & Lim, M. K. (2019), "The evolution of industrial management & data systems over the past 25 years: A bibliometric overview", *Industrial Management & Data Systems*, Vol. 119 No. 1, pp. 2-34.
Wolf, J. (2014), "The relationship between sustainable supply chain management, stakeholder pressure and corporate sustainability performance", *Journal of Business Ethics*, Vol. 119 No. 3, pp. 317-328.
Xu, L., Prybutok, V., & Blankson, C. (2019), "An environmental awareness purchasing intention model", *Industrial Management & Data Systems*, Vol. 119 No. 2, pp. 367-381.
Yang, X., Moore, P. R., Wong, C. B., Pu, J. S., & Chong, S. K. (2007), "Product lifecycle information acquisition and management for consumer products", *Industrial Management & Data Systems*, Vol. 107 No. 7, pp. 936-953.
York, R., & Rosa, E. A. (2003), "Key challenges to ecological modernization theory: Institutional efficacy, case study evidence, units of analysis, and the pace of eco-efficiency", *Organization & Environment*, Vol. 16 No. 3, pp. 273-288.
Zhang, H., & Yang, F. (2016), "On the drivers and performance outcomes of green practices adoption", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 2011-2034.
Zhong, R., Xu, X., & Wang, L. (2017), "Food supply chain management: systems, implementations, and future research", *Industrial Management & Data Systems*, Vol. 117 No. 9, pp. 2085-2114.
Zhu, Q., & Sarkis, J. (2007), "The moderating effects of institutional pressures on emergent green supply chain practices and performance", *International Journal of Production Research*, Vol. 45 No. 18-19, pp. 4333-4355.

Zhu, Q., Sarkis, J., & Lai, K. h. (2008), "Green supply chain management implications for “closing the loop”", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 44 No. 1, pp. 1-18.