

Literature Review of Enterprise Digital Transformation and Green Supply Chain

Yuehan Gao *

School of business, MACAU UNIVERSITY OF SCIENCE AND TECHNOLOGY, Macao, China

* Corresponding Author Email: 1230005036@student.must.edu.mo

Abstract. Amid the challenges of global climate change and resource scarcity, the Chinese government continues to promote green development in pursuit of carbon neutrality. Enterprises are under increasing pressure to undertake green transformation, with digital transformation emerging as a key enabler of this process. This paper examines the connotations, development stages, measurement methods, theoretical foundations, and manifestations of digital transformation systematically. It also explores the mechanisms by which it influences green supply chains. By analyzing the literature on digital transformation and green supply chains from 2010 to 2025 and integrating resource-based theory with dynamic capabilities theory, this paper constructs an integrated framework for how digital transformation impacts green supply chains. The paper finds that digital transformation can effectively improve the efficiency, operational transparency, and innovation capabilities of green supply chains by optimizing resource allocation, alleviating financing constraints, and enhancing operational transparency and innovation. While measurement methods for digital transformation provide important tools for assessing its maturity, existing research remains limited in terms of indicator system construction and cross-context applicability. This paper provides room for further research.

Keywords: Digital transformation, green supply chain, Technology.

1. Introduction

Some global challenges like climate change, resource shortages, and environmental degradation are becoming increasingly severe. It makes the urgency of sustainable development increasingly prominent. Pursuant to international agreements, all or select nations have committed to emission reductions, wherein enterprises play a pivotal role in achieving national carbon neutrality and sustainable development objectives. The development of green supply chains (GSCs) represents a critical strategy for enterprises to effectuate low-carbon transformations. China has encouraged the supply chain to develop in digital and green direction [1], helping enterprises to integrate digital transformation (DT) technologies into the green supply chain. The development and promotion of green supply chains are urgent, and enterprises gradually focus their research efforts on decarbonization of the supply chain to promote environmental improvement. Digital technology is constantly advancing, and many enterprises are during the digital transformation wave [2], Digital transformation will significantly enhance the sustainability performance of renewable energy enterprises and can reduce carbon emissions by improving supply chain collaboration. Therefore, combining the process of digital transformation with the development of green supply chains will effectively promote the green development of supply chains. Digital technology is continuously evolving globally [3]. For many enterprises, it has become a key driving factor to innovate their business models worldwide.

The early stage of digital technology development was from 2005 to 2012 [4]. The decline in mobile communication (3G), data storage and processing costs promoted the initial development of DT, and ICT hardware was widely popularized during this stage, with enterprises beginning to use basic digital tools. Since 2014[5], research on digital transformation has significantly increased, but it is mainly concentrated in developed countries, while research in developing countries is relatively scarce. The research scope on digital transformation includes disruptive technologies, shared platforms and ecosystems, as well as new potential technologies. Existing research mostly focuses on the overall impact of digital transformation on supply chain efficiency; fewer studies are analyzing

the role of digital transformation from a green supply chain perspective. This review constructs a theoretical framework by integrating some views and theories. By revealing specific mechanisms of digital transformation of green supply chain, this review enriches the theoretical framework at the intersection of supply chain and sustainable development.

The study integrates digital transformation (DT) and green supply chains (GSCs) systematically and explores how DT drives the development of GSCs. It also provides a new perspective for achieving carbon neutrality and environmental sustainability goals. This study is significant both theoretically and practically. Most existing literature uses empirical analysis to examine the relationship between digital transformation and green supply chains [6]. Digital transformation promotes green technology innovation and the expansion of green production by improving information transparency and resource allocation efficiency. Technologically, the Internet of Things (IoT) and artificial intelligence (AI) can effectively support the R&D and application of green technologies within the supply chain, enhancing the environmental performance of the entire supply chain. Economically, digital transformation can reduce coordination costs within the supply chain [7], making green supply chain implementation more efficient. Regarding production collaboration, the use of digital platforms fosters connections between upstream and downstream companies [2], facilitates the sharing of green technologies, and drives green supply chain transformation. Researchers have studied the relationship between DT and GSCs from various perspectives, finding a strong and generally positive correlation. However, no review has yet been published on this topic. Therefore, this study proposes a detailed review of the relationship between DT and GSCs, filling this research gap.

This paper makes three contributions to the existing literature. First, this review has adopted an inductive approach to integrate existing knowledge, explaining the digital transformation process [8], influencing factors, and outcomes. It emphasizes digital transformation as an evolution of IT-enabled transformation, calling for future research to focus on dynamic capabilities and ethics to advance the field of strategic Information System. Some studies also focus on the research of other factors [9]. It explores the specific methods by how these factors enhance the performance of enterprises. Selma Vaska et al. [5] employed a structured review approach, highlighting the fragmentation of the DT field and emerging trends.

Secondly, this review provides guidance for practitioners to integrate digital transformation strategies with business transformation. However, there is currently no review on digital transformation and green supply chains. This study examines the relationship between enterprise digital transformation and green supply chains. It explores the role of digitalization in the supply chain from multiple perspectives, enriching the research perspective on digital transformation and green supply chains.

Thirdly, no existing literature review addresses the intersection of DT and GSCs. This is the first research review focusing on enterprise DT and GSCs. Existing studies focus on the relationship between DT and supply chains, primarily emphasizing the role of digital technologies in supply chain management. Many studies explore how digital transformation improves firm performance and supply chain efficiency. These studies often take a holistic supply chain perspective. The review focuses on the connection and integration of DT and GSCs. This study explores how digital transformation manifests in firm green supply chains, analyzing the mechanisms, and enriches research perspectives in the field.

2. The Connotation, Function and Measurement of Digital Transformation

2.1. Connotation

Many scholars have different definitions of enterprise digital transformation. Yonghong Li et al. [10] described enterprise digital transformation as a systematic process of rebuilding resource capabilities using digital technologies. Based on Teece's dynamic capabilities theory, it integrates

internal and external resources through tools like big data and cloud computing to create organizational capabilities suited for the digital economy.

Based on existing definitions [9], some scholars proposed a conceptual definition, arguing that DT is a process aiming to trigger significant changes in an entity to improve it through the application of information integration, computing, communication, and connection technologies. By summarizing the definitions of digital transformation [11], and by reviewing relevant literature [12], these studies found that the concept of DT presents diversified perspectives of understanding in the academic community. This indicates that DT is still an emerging research field, and there is currently no unified standard for its conceptual framework. For enterprises, the current digital transformation strategy focuses on taking measures to manage the company to achieve the desired future digital state.

2.2. Development

Digital transformation mainly focused on the application and optimization of information technology at the beginning stage [9]. The aim was to help enterprises and organizations enhance the efficiency of their internal operations and the smoothness of communication. During this stage, digital-related technologies were mainly applied through enterprise resource planning (ERP) systems and data management. Take China as an example [13]. With the economic model has transformed to a diversified manner gradually, DT has become an inevitable choice to drive the next round of economic growth. Since 2010, with the development of global digital technologies, enterprises have gradually begun to adopt new technologies. The application of technologies like cloud computing and IoT has further facilitated the digitalization of enterprise operations. During this period, many enterprises began to utilize data for making business decisions, achieving innovation and optimization of their business processes. Traditional industries are gradually transforming towards digitalization and intelligence. Since 2015, the development of digital technology has been rapid, enabling enterprises to achieve strategic changes, which are fundamental. Enterprises have adopted advanced digital technologies, aiming to innovate business models and achieve intelligence at the business level [14]. In a complex business environment, the combination of digital technologies and strategies to achieve a transformation of business models has become even more crucial for enterprises.

Digital transformation is no longer merely a technological change. The enterprise regards it more as a change in terms of culture and management. Enterprises have begun to gradually implement a digital culture, emphasizing innovation and agility during the development process. During the development process of DT, more firms are focusing on optimizing the customer experience and are integrating digital technologies into many aspects of their organizations. In the future, enterprises will prioritize the integration of digital technology innovation and business models [15], driving collaborative development across industries and sectors. Digital transformation will extend into more areas, with environmentally friendly sectors like the green economy and sustainable development being key areas of development. Enterprises should find ways to overcome these challenges to achieve long-term sustainable economic growth.

2.3. Measurement

Table 1 lists several common methods for measuring digital transformation, encompassing various perspectives. These methods utilize diverse indicator systems and analytical approaches to provide researchers and enterprise decision-makers with a deeper understanding of digital transformation. From data collection and text mining to the application of advanced large-scale language models, all measurement methods emphasize precision. These methods also allow for personalized analysis based on an enterprise's actual operating conditions. Through these methods, enterprises can gain a fundamental understanding of their digital transformation status and identify potential shortfalls, enabling them to optimize for future development. These methods accurately reflect the digital maturity and transformation achievements of an enterprise in an ever-changing market environment, establishing a comprehensive assessment framework.

Table 1. Five measurement methods of digital transformation

Measurement dimension	Primary indicator	Specific process
machine learning and large language models (LLMs) [16]	<ol style="list-style-type: none"> 1. Companies' use of digital technologies: Review company annual reports to identify terms (artificial intelligence, big data, and cloud computing) 2. Digital transformation dummy variable 	<ol style="list-style-type: none"> 1. Data Collection: Annual reports of Chinese listed companies 2. Sentence Segmentation: The text was broken down into individual sentences to build a data pool. 3. Manual Annotation: Researchers manually annotated sentences to determine whether the company used digital technologies. 4. Model Training: ERNIE model 5. Indicator Construction: constructing a digital transformation indicator
Python Text Analysis [15]	<ol style="list-style-type: none"> 1. The degree of Digital Innovation: analyzing the frequency of digital technology keywords of enterprises. 2. Innovation Performance: Measures the innovation capabilities. 	<ol style="list-style-type: none"> 1. Select the characteristic words related to the digitalization scenarios of Chinese A-share listed companies from their annual reports. 2. Use Python text analysis methods to sum up the frequency of occurrence of these words.
Coupling Coordination Degree Model [10]	<p>Digital system:</p> <ol style="list-style-type: none"> 1. Total amount of digital assets 2. Operating Revenue Growth Rate 3. R&D Employee Percentage 4. Labor Productivity <p>Green system: ESG rating and green patents Carbon emissions</p>	<ol style="list-style-type: none"> 1. Data Collection and Indicator Standardization: 2. Comprehensive Development Index Calculation: The comprehensive development index of the enterprise's digital system and green system is calculated separately. 3. Coupling Degree Calculation: Calculate the coupling degree of these two systems.
Digital Maturity Models [17]	<ol style="list-style-type: none"> 1. Customer Experience 2. Product Innovation 3. Strategy 4. Organization 5. Process Digitalization 6. Cooperation 7. Information Technology 8. Expertise and Transformation Management <p>Each dimension is measured by multiple specific maturity requirements.</p>	<ol style="list-style-type: none"> 1. Data Collection and Analysis: Review and expert interviews were conducted to identify specific requirements for each dimension of an enterprise's digital transformation. 2. Dimension Construction and Assessment: The model divides digital transformation into several key dimensions 3. Maturity Grading: An enterprise's overall digital maturity level is assessed by grading its performance across each dimension. 4. Model Application: enterprise's digital transformation status.
Digital Asset Measurement Model [18]	<ol style="list-style-type: none"> 1. Technology Assets: measure the investment in and use of information technology 2. Knowledge and Talent Assets 3. Innovation and R&D Capabilities: innovate ability in new technologies, products, and business models. 4. Data Assets: assesses the ability in data management, analysis, and application 	<ol style="list-style-type: none"> 1. Data Collection and Analysis: Collect data from enterprises. 2. Indicator Standardization: Standardize the collected digital asset data. 3. Asset Valuation: A weighted scoring system is used to score the collected data indicators. 4. Model Application: By establishing a comprehensive digital asset scoring model, enterprises can understand the performance of their digital assets.

3. The Theoretical Basis and Manifestation of Digital Transformation

3.1. Theoretical Basis

3.1.1. Resource-based view (RBV)

The competitive advantage of an enterprise relies on its unique resources. According to Wernerfelt (1984) [19] and Grant (1991) [20], mainstream digital technologies such as AI provide enterprises with new resources. Digital transformation enables enterprises to more accurately assess and optimize their resource allocation. This is related to the resource allocation concept in the RBV theory. Enterprises can use digital tools to analyze the value of their existing resources [21]. Digital transformation can also help enterprises determine how to optimally utilize or enhance these resources. In the supply chain sector, data analytics helps enterprises optimize inventory and maintain good supplier relationships.

3.1.2. Industrial organization theory

The core concept of Industrial Organization Theory [22] is that market structure directly determines an enterprise's pricing strategies, production decisions, and market performance. The theory explores different types of market structures. Digital transformation promotes information flow and transparency, enabling more efficient collaboration across supply chain links. Enterprises can share real-time data through digital platforms, optimizing inventory management and demand forecasting and mitigating the negative impact of information asymmetry on the supply chain. The "related industry support" perspective in this theory suggests that strong upstream and downstream industry networks can help to enhance the flexibility of supply chain [23]. It also drives product and service innovation.

3.1.3. Dynamic capability theory

Dynamic capabilities focus on how enterprises continue, modify or create ordinary capabilities [24]. Specifically, they enable enterprises to innovate and adjust in a rapidly changing market environment to adapt to new market demands. Dynamic capabilities also emphasize that enterprises integrate, build and reconfigure internal and external resources and capabilities. Dynamic capabilities enable enterprises to leverage existing resources for technology integration and innovation. Firms can quickly adjust the structure and processes of their supply chains during digital transformation. By cultivating dynamic capabilities, enterprises can effectively integrate new technologies into their supply chains, thereby improving the responsiveness of their supply chains. Dynamic capabilities also emphasize cross-organizational and cross-industry collaboration [25], which is particularly important for digital supply chains. By leveraging external collaboration and shared resources, companies can better navigate the challenges of digital transformation.

3.1.4. Contingency theory

Supply chain management has been influenced greatly by contingency theory [26]. With the shift in supply chain dynamics, there comes a differing approach to management and decision-making. Digital innovations have led to further complexity and fluidity in supply chain management functions. Digital transformation has rendered information more accessible and has thus pushed leaders to quickly assess the extant situation context and adopt the best possible leadership style to overcome supply chain challenges. Digital transformation has further extended the options for cooperation and communication in supply chain networks [27]. To ensure smooth cooperation and optimize supply chain efficiency, leaders are required to vary their style of management accordingly to the unique structure of the supply chain and inter-member relationships.

In summary, this section explores the dramatic impact of digital transformation to the supply chain based on multiple theoretical perspectives. Widespread application and incorporation of digital technologies help organizations allocate resources in a more efficient manner, thus increasing the transparency and efficiency of supply chains. Digital transformation not just aids organizations in maximizing resource allocation but also optimizes the agility and flexibility of the supply chain. It

achieves this by speeding information flow and reducing transaction costs. In addition, digital transformation places new challenges to organizational leadership and design. Leaders are thus compelled to shift their leadership strategy flexibly to meet certain demands of operations. This set of theories provides a consistent template to understanding how digital transformation impacts supply chain administration, which demonstrates the crucial role of digital technology in enhancing competitive superiority along the supply chain.

3.2. Manifestation

3.2.1. Technological level

Digital transformation relies on the implementation of multiple innovative technologies [28]. The Internet of Things (IoT) can track logistics dynamics and operational carbon emissions, enabling data collection and transmission across the supply chain, while also helping to reduce energy waste and optimize transportation routes. Artificial Intelligence (AI) can analyze massive amounts of data to optimize the use of raw materials, reduce redundant procurement and overproduction, thereby promoting the development of a green supply chain. Furthermore, blockchain technology provides companies with a transparent, tamper-proof system that helps them track the source of raw materials and obtain green certification. It ensures compliance with green procurement and supplier selection regulations, fostering trust between upstream and downstream companies. This reduces uncertainty associated with environmental compliance risks.

3.2.2. Strategic level

At a strategic level, digital transformation brings transparency and visibility to the supply chain [29]. Digitalization provides end-to-end transparency within the green supply chain, enabling companies to more intuitively understand their environmental performance. This transparency enhances internal green management and meets current market requirements for green compliance. The agility and flexibility of the supply chain also reflect the level of a firm's digital transformation. Within the green supply chain, this agility manifests itself in the ability to quickly adjust production processes and supply plans to adapt to new environmental standards and green consumer demand. Digital transformation enables companies' green supply chains to embody circular economy principles. For example, companies with advanced digital transformation can use data analysis to improve waste recovery efficiency and resource reuse within their supply chains. Through digital transformation and the application of digital technologies, companies can not only reduce the environmental impact of their production processes but also create new economic value through green innovation.

3.2.3. Mechanism Level

At the mechanism level, digital transformation can facilitate knowledge sharing between corporate R&D departments and external technical resources, thereby accelerating the development of green technologies in the supply chain. Furthermore, firms' transportation and supervision costs are significantly reduced, thanks to the application of smart logistics and blockchain technologies during digital transformation. Another manifestation is the development of digital ecosystems within enterprises [30]. In the process of building digital ecosystems, enterprises are shifting their strategic focus to interaction and symbiosis with external partners. Enterprises are increasingly connecting with other industries through digital platforms. This indicates a growing level of digital transformation. Furthermore, digital platforms provide enterprises with a way to share resources and information, enabling them to participate in the global digital economy. For example, e-commerce platforms are more than just channels for selling products. Within enterprises, digital transformation can drive the redistribution of power. This is reflected in the gradual shift from traditional centralized management to decentralized management. Many enterprises are using data-driven approaches to empower employees to make decisions more autonomously, eliminating the need for multiple approval processes. This significantly enhances a firm's flexibility and ability.

To sum up, digital transformation manifests itself not only in technological advancements but also in innovations in the green supply chain of enterprises.

4. Specific Mechanisms by which Digital Transformation Technologies Impact Green Supply Chains

4.1. Green Information

Many studies find that environmental information promotes green innovation by enabling enterprises to obtain institutional resources [31]. It helps enterprises enhance their reputation by leveraging five-star information with analyzing the disclosed content. In addition, enterprises can efficiently conduct data analysis using digital tools and gain access to information resources that facilitate green innovation. By optimizing enterprises' selection of suppliers and logistics management [32], supply chain competitive advantage has a significant effect between institutional pressure (IP) and enterprise environmental performance (EP).

As a part of sustainable supply chain management practices [33], the Green Information System (GIS) influences environmental performance by providing crucial environmental information. According to the NRBV theory, GIS helps enterprises convert environmental information into strategic capabilities. Green Information System identifies pollution sources and efficiency improvement points through data analysis. Experts used the Naïve Bayesian Algorithm to study environmental information of Chinese listed companies [31]. It shows this information promotes green innovation. The tool detects greenwashing by analyzing disclosure data. It also reveals impacts on green supply chains through resources like loans and subsidies. Machine learning improves transparency and resource allocation.

Jiaying Feng et al [34]. used the structural equation model and artificial neural network method to show that environmental information disclosure boosts green technological innovation through green finance. This enhances enterprises' green financial value. It also affects the use of green innovation technology in the supply chain. Jiao Yuanyuan et al [35]. found three paths for environmental information disclosure. These are the emulation model, the leading and guiding model, and the stable demonstration model. They also used propensity score matching to assess their impact on enterprise performance. The conclusion showed that fsQCA can handle the complex causal relationships of enterprises and reveal how environmental factors affect supply chain performance. The leading and guiding model path enhances performance through digital analysis and supports the construction of leadership in green supply chains. Other paths may also have the potential to reduce enterprise performance, and attention should be paid to the issue of information asymmetry when using them.

4.2. Risks

Digital transformation technologies can enhance the dynamic capabilities of the supply chain and risk management strategies [36]. In high-risk settings, digital transformation has a stronger impact. The evolutionary game model shows that a larger supply chain disruption risk (θ) speeds up system convergence. Digitalization lowers θ , helping firms shift from non-cooperative (0,0) to cooperative green production (1,1), reducing resource waste and pollution risks.

By establishing the digital transformation supply chain risk [37], digital transformation technologies can enhance supply chain resilience and indirectly influence the sustainability of green supply chains. Natural and social environmental risks are directly related to the green supply chain. Digital transformation can alleviate environmental uncertainties through risk prediction, diagnosis and control, promoting low-carbon and sustainable practices. Digital transformation technologies can also optimize ESG performance through the IB-SCEE model [38], and identify the minimum/maximum risks based on economic and distribution results. This enhances the sustainability and resilience of the GSC. Digital transformation technologies can be positioned as enabling tools for enterprise risk assessment [39]. In the green supply chain, they can reduce credit

uncertainty through intermediary, regulatory and governance mechanisms, thereby enhancing resilience.

In summary, the macro-environmental risks can significantly enhance the impact of DT on the GSC and reduce the probability of supply chain disruptions. However, digital transformation also presents potential challenges, including data privacy, computational complexity, and transformation costs. Enterprises should combine policy support to promote the optimization of digital technologies and achieve a comprehensive low-carbon transformation of the supply chain.

4.3. Financing Restriction

Muhammad Zafar Yaqub et al. [40] pointed out that for small and medium-sized enterprises, digital transformation is regarded as a key driving force for achieving environmental and social sustainability in the supply chain. This includes better tracking of products purchased in an ethical manner, reducing waste and emissions, and promoting a circular economy. However, if financial constraints limit a company's ability to invest in these technologies, it will not be able to fully realize these benefits. Lack of financial resources is the main obstacle to the success of digital transformation. Furthermore, even with digital finance, small and medium-sized enterprises will still face financing constraints [12], which will prevent them from having the resources to invest in the green supply chain. Therefore, in the context of financing constraints, the government should formulate relevant policies to enable small and medium-sized enterprises to access affordable digital technologies and encourage them to utilize digital technologies for real-time information sharing and efficient supply chain data management.

Digital technology can enhance the supply chain's ability to cope with financial shocks [41]. Through real-time data monitoring and risk prediction, enterprises can promptly identify and respond to potential risks, thereby strengthening the stability of the supply chain during periods of resource scarcity and financing difficulties. The success of an enterprise's GSCs management often relies on the close cooperation and information sharing of all aspects [42]. Therefore, enterprises can utilize digital platforms to share real-time green standards, compliance requirements, and environmental data within the supply chain, thereby promoting the efficiency of product circulation in the green supply chain.

The study has identified three moderating factors related to the issue of financing constraints, which are information disclosure quality, financial development depth, and economic policy uncertainty [43]. For small-sized enterprises, high-quality information disclosure can effectively increase their chances of obtaining financing. Especially in the field of GSC, excellent environmental and sustainable development reports can attract more investors and lenders who meet the green standards. For firms located in regions with less developed financial sectors, the emergence of digital transformation and supply chain finance has provided new financing channels. Especially through the credit and financing solutions offered by supply chain partners, it can effectively alleviate the financing pressure caused by the underdeveloped local financial market. The uncertainty of policies increases the financing risks for enterprises, especially during the green transformation process, where the uncertainty of policies may lead enterprises to hesitate or postpone their green investments. The implementation of digital supply chain finance can reduce the negative impacts brought about by this policy uncertainty. Financial institutions and enterprises can obtain more policy information through digital platforms, thereby making more flexible financing decisions. On the other hand, enterprises can use Internet of Things technology, along with sensors and radio frequency identification technologies, to monitor the production, transportation, and inventory of green products in real time. "Inventory pledge financing" is one of the three major models of supply chain finance. Digital technologies have greatly enhanced the feasibility of this model. In the context of financial restrictions, digital technologies can improve the efficiency of financing and promote the adoption of green technologies by reducing the financial barriers to technological innovation. Enterprises can collaborate with financial institutions and suppliers through digital platforms to obtain financial

support and promote the development of green innovation projects, thereby enhancing the green competitiveness of the entire supply chain.

4.4. Public and Media Attention

In the era of digitalization, social media and online platforms provide a channel for stakeholders to express their opinions and feedback. Enterprises share information with their supply chain partners through digital means, respond to consumers and society's expectations for the supply chain to be environmentally friendly, thereby enhancing trust and cooperation between the enterprise and its stakeholders [44]. Moreover, the media can often influence an enterprise's reputation management and supply chain decisions by setting the agenda and drawing public attention to environmental issues in the supply chain. For example, as mentioned in the literature [45], when there is a problem that harms the environment in a certain link of the supply chain, media coverage can lead consumers or stakeholders to resist the products of that enterprise, thereby urging the enterprise to take more environmentally friendly and sustainable supply chain management measures when providing services, which also promotes the practice of the enterprise's green supply chain. The environmental protection demands of the media are increasing, and enterprises' requirements for green supply chain management are also constantly rising. Digital transformation technologies can provide enterprises with more efficient ways to monitor and optimize the environmental impact in their supply chains. Through these technologies, enterprises can track the source of raw materials, transportation methods, and their environmental impact in real time, reduce negative environmental impacts, and respond to public demands.

Digital technology helps enterprises respond to pressure from the government and consumers [46], and promotes the green transformation of the supply chain. It enhances environmental performance and reduces related risks through data-driven management.

4.5. Efficiency

In term of a research and development perspective, digital transformation technologies help drive green innovation and optimize product design. Digital technologies can reduce resource consumption and pollution in the process design and life cycle management of smart products, enhancing product sustainability [32]. With the help of GIS and the Internet of Things, companies can monitor production and logistics processes in real time, identify environmental risks, and optimize resource allocation. Data analysis technology aids in accurately predicting demand and reducing waste, thereby lowering energy consumption and carbon emissions.

Digital tools help incorporate environmental considerations during the product design phase, promoting green product development [33]. Big data analysis can also help research and development personnel identify eco-friendly materials and technologies, reducing resource consumption and pollution throughout the product life cycle from the source. In addition, digital technologies improve the operational efficiency of green supply chains, particularly in production and logistics collaboration, enabling real-time monitoring and strategic adjustments of energy use and emissions. Combined with big data and artificial intelligence, processes are further optimized, the carbon footprint is reduced, and green operation goals are supported. Enterprises can optimize their supply chain processes by leveraging big data and artificial intelligence, which can reduce the carbon footprint in production and operation, thereby supporting the goal of green operations.

4.6. Conclusion

This study reviews digital transformation (DT) and its role in green supply chains (GSCs). According to existing research, DT builds on dynamic capabilities theory to combine internal and external resources for the digital economy. DT evolved from basic tools (2005-2012) to innovation in developed countries (post-2014) and cultural shifts after 2019, focusing more on green economy and cross-industry collaboration gradually. This study also shows that Measurement methods have include machine learning to check annual reports for tech use, Python text analysis for keyword

frequency, coupling models for digital-green synergy, maturity models for areas like customer experience, and asset models for tech and innovation investments. These methods offer clear, tailored ways to assess DT. Theories supporting DT in GSCs include Resource-Based View for resource optimization, Industrial Organization Theory for market collaboration, Dynamic Capability Theory for supply chain flexibility, and Contingency Theory for adaptive leadership. This review elucidates the multifaceted role of digital transformation within green supply chains. DT manifests technologically through tools such as IoT for emissions tracking, AI for predictive forecasting, and blockchain for enhanced transparency; strategically via improved visibility and circular economy integration; and mechanistically by facilitating knowledge sharing and decentralized decision-making. Ultimately, DT profoundly influences GSCs by bridging information asymmetries, responding to stakeholder pressures through digital platforms, and elevating operational efficiency via real-time monitoring and data-driven waste minimization.

This study focuses mainly on the relationship between DT and GSCs in China in existing research, overlooking emerging markets and diverse regions. Existing research suggests that measurements of DT and GSC can have biases and ignore dynamic variables. Challenges include technological integration issues, data privacy risks, financing constraints for SMEs, policy uncertainty, and talent shortages. Future research should expand reviewed studies to unlisted firms, other transportation modes, and global contexts. It can develop integrated models, unified standards for cross-border work, and address long-term impacts to better optimize DT-driven GSCs. In the future, digital transformation will also bring enterprises more opportunities for innovation and competitive advantages in various fields.

References

- [1] Lam P, Häbler J, Bachinger M, Franz M, Voss M, Weischer L. Strategic engagement on Chinese initiatives for green supply chains: An overview of Chinese approaches with recommendations for stakeholders in policy making, diplomacy and advocacy, 2024.
- [2] Fan W, Wu X, He Q. Digitalization drives green transformation of supply chains: A two-stage evolutionary game analysis, *Annals of Operations Research Preprint*, 2024.
- [3] Fitzgerald M, Kruschwitz N, Bonnet D, Welch M. Embracing digital technology: a new strategic imperative. *MIT Sloan Management Review*, 2014, 55 (2): 1 - 12.
- [4] Bröring, L. P. J. Mapping the digital journey: A tool for measuring digital transformation progress. 2025.
- [5] Vaska S, Massaro M, Bagarotto E M, Dal Mas F. The digital transformation of business model innovation: a structured literature review. *Front. Psychol.* 2021, 11.
- [6] Song F. The effects of digital transformation on corporate energy efficiency: A supply chain spillover perspective. *Frontiers in Sustainability*, 2025, 6.
- [7] Li B, Xu C, Wang Y, Zhao Y, Zhou Q, Xing X. Digital transformation, supply chain collaboration, and enterprise growth: Theoretical logic and Chinese practice. *European Research on Management and Business Economics*, 2024, 30 (1).
- [8] Vial G. Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 2019, 28 (2), 118 – 144.
- [9] Aw E.C.-X. et al. Adapt or die! embrace digital transformation for better firm performance: A Causal recipe, *Internet Research*, 2025, 1 – 21.
- [10] Li Y, Xie H, Liu C. Research on synergy measurement and digital finance driving mechanism of enterprise digital transformation and greening upgrade: an empirical analysis based on the complex system coordination degree model. *Sustainability*, 2025, 17 (11), 4886.
- [11] Chnias S, Hess T. Understanding digital transformation strategy formation: Insights from Europe's automotive industry. 2016.
- [12] Tilson D, Lyytinen K, Sørensen C. Research commentary: digital infrastructures: the missing IS research agenda. *Information Systems Research*, 2010, 21 (4): 748 – 759.

- [13] Di Wang, Xuefeng Shao, Research on the impact of digital transformation on the production efficiency of manufacturing enterprises: Institution-based analysis of the threshold effect, *International Review of Economics & Finance*, 2024, 91: 883 - 897.
- [14] Xu M, Zhang Y, Sun H, Tang Y, Li J. How digital transformation enhances corporate innovation performance: The mediating roles of big data capabilities and organizational agility, *Heliyon*, 2024, 10 (14): 2405 - 8440.
- [15] Shan H. Y. Digital innovation, dynamic capabilities and enterprise innovation performance. *American Journal of Industrial and Business Management*, 2023, 13: 1005 - 1023.
- [16] Xingye J, Congjiang Z, Mingyue F, Tao L, Huihua N. Measurement problem of enterprise digital transformation: New methods and findings based on large language models. *China Economist*, 2025, 20 (02): 70 – 95.
- [17] Ahmad A, Alshurideh M, Al Kurdi B, Aburayya A, Hamadneh S. Digital transformation metrics: a conceptual view. *Journal of Management Information and Decision Sciences*, 2021, 24 (7), 1 - 18.
- [18] Sascha Kraus, Susanne Durst, João J. Ferreira, Pedro Veiga, Norbert Kailer, Alexandra Weinmann. Digital transformation in business and management research: An overview of the current status quo, *International Journal of Information Management*, 2022, 63.
- [19] Wernerfelt B. A resource-based view of the firm. *Strategic Management Journal*, 1984, 5 (2), 171 – 180.
- [20] Grant R.M. The resource-based theory of competitive advantage. *California Management Review*, 1991, 33: 114 - 135.
- [21] Ning L, Yao D. The impact of digital transformation on supply chain capabilities and supply chain competitive performance. *Sustainability*, 2023, 15 (13), 10107.
- [22] Porter M. E. *The competitive advantage of nations*. New York: Free Press, 1990.
- [23] Jean Tirol. "The theory of industrial organization.", MIT Press Books, The MIT Press, 1988.
- [24] Teece D. J, Pisano G, Shuen A. Dynamic capabilities and strategic management. *Strategic Management Journal*, 1997, 18 (7), 509 – 533.
- [25] Winter S. G. Understanding Dynamic Capabilities. *Strategic Management Journal*, 2003, 24 (10), 991 – 995.
- [26] Lawrence P. R, Lorsch J.W. *Organization and environment: managing differentiation and integration*. Division of Research, Graduate School of Business Administration, Harvard University, Boston, 1967.
- [27] Fiedler F. E. A contingency model of leadership effectiveness, *Advances in Experimental Social Psychology*, 1964, 149 – 190.
- [28] Liao F. et al. Digital transformation and corporate green supply chain efficiency: Evidence from China' *Economic Analysis and Policy*, 2024, 81: 195 – 207.
- [29] Seyedghorban Z, Tahernejad H, Meriton R, Graham G. Supply chain digitalization: past, present and future, *Production Planning & Control*, 2019, 31 (2 – 3): 96 – 114.
- [30] Plekhanov D, Franke H, Netland T. H. Digital transformation: a review and research agenda. *European Management Journal*, 2023, 41 (6): 821 – 844.
- [31] Xing C, Zhang X, Zhang Y, Zhang L. From green-washing to innovation-washing: environmental information intangibility and corporate green innovation in China, *International Review of Economics & Finance*, 2024, 93: 204 - 226.
- [32] Wiredu J, Yang Q, Kwasi Smpene A, Akwasi Gyamfi B, Asongu Simplicie A. The effect of green supply chain management practices on corporate environmental performance: does supply chain competitive advantage matter, *Business Strategy and the Environment*, 2023, 33 (3), 2578 – 2599.
- [33] Mugoni, E., Kanyepe, J. and Tukuta, M. Sustainable Supply Chain Management Practices (SSCMPS) and environmental performance: A systematic review, *Sustainable Technology and Entrepreneurship*, 2024, 3 (1), 100050.
- [34] Feng J, Yu C, Xufeng W. Untying the nexus between environmental information disclosure, green finance, and green technological innovation: A multi-analytical (SEM-ann) approach, *Frontiers in Environmental Science*, 2024, 12.
- [35] Jiao Y, Cui X, Wang J. Research on the antecedent configuration and performance of corporate environmental information disclosure. *Chinese Journal Management*, 2025, 1 - 10.

- [36] Shi F, Wang C, Qin Z. An evolutionary game model for green production decisions of supply chain enterprises considering supply chain break risk. *International Journal of Intelligent Systems*, 2025.
- [37] Gao Y, Leng Y, Shan B. Control supply chain risks in digital transformation: A new way to improve supply chain resilience. *Journal of Organizational and End User Computing (JOEUC)*, 2022, 34 (7), 1 - 18.
- [38] Qian C, Gao Y, Chen L. Green supply chain circular economy evaluation system based on industrial Internet of Things and blockchain technology under ESG concept. *Processes*, 2023, 11 (7).
- [39] Liu Y, Li S, Yu C, Lv M. Research on green supply chain finance risk identification based on two-stage deep learning. *Operations Research Perspectives*, 2024, 13.
- [40] Yaqub M.Z, Alsabban A. Industry-4.0-Enabled digital transformation: prospects, instruments, challenges, and implications for business strategies. *Sustainability* 2023, 15.
- [41] Li Y, Zhang Y, Geng L. Digital finance, financing constraints and supply chain resilience, international review of economics & Finance, 2024, 96.
- [42] Emtchani F, Nahavandi N. Rafiei F.M. Trade credit financing for supply chain coordination under financial challenges: a multi-leader–follower game approach. *Financ Innov*, 2023, 9 (6).
- [43] Liu J, Wang H, Zhang J. The impact of supply chain finance on financial constraints of small and medium-sized enterprises and the moderating factors. *Applied Economics*, 2024, 1 – 12.
- [44] von Berlepsch D, Lemke F. Gorton M. The importance of corporate reputation for sustainable supply chains: a systematic literature review, bibliometric mapping, and research agenda. *J Bus Ethics*, 2024, 189 (1), 9 – 34.
- [45] Mateska I, Wagner S.M, Stienen L. Media reporting of environmental supply chain sustainability risks: contextual and moderating Ffctors. *J Bus Ethics*, 2025, 199 (1), 285 – 308.
- [46] Marculetiu A, Ataseven C, Mackelprang, A.W. A review of how pressures and their sources drive Sustainable Supply Chain Management Practices, *Journal of Business Logistics*, 2023, 44 (2): 257 – 288.