

HOW DOES DIGITAL TRANSFORMATION AFFECT GREEN SUPPLY CHAIN EFFICIENCY?

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Abstract

Digital transformation is one of the prominent phenomena of the century, and it has many effects on the economy, society, and environment. Digital transformation means using new technologies that lead to increased efficiency, creativity and innovation and can solve environmental challenges, such as reducing air, water and soil pollution, saving natural resources, protecting biodiversity and solving greenhouse effect reduction. Slow Green performance is an index that measures the degree of adherence of businesses to environmental activities and preserves resources for future generations. Organizations and companies are trying to move their production activities towards green production. Advertising activities are also organized through green marketing and combined green marketing. Given the importance of green performance, this article explains what aspects of the green supply chain are affected by digital transformation. This article is based on articles collected from the reliable hub research site and interviews with several experts in digital and green management. The present article, which is qualitative, cites numerous articles and the qualitative analysis method with MAXQDA software and explains how digital transformation makes the green supply chain more efficient. The results showed that digital transformation has the greatest impact on green production, followed by green materials and green consumption.

Keywords: *Digital transformation, green chain efficiency, Green materials, green production, green consumption*

1. Introduction

Today, the growth of technology has made most businesses conduct their business processes electronically. The purpose of digital transformation is to create a competitive advantage, improve customer experience, and reduce costs. Digital transformation is implemented to improve the organization's performance.

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The supply chain is a set of processes that includes various stages of creating a product, turning it into a product, and delivering it to the customer; in line with that, the green supply chain is of great interest due to climate and pollution problems. A green supply chain refers to processes that generate less waste during design, production, and consumption.

Organisations must expand in order to succeed in the cutthroat market, therefore understanding how digital transformation impacts the supply chain is crucial. Businesses that wish to advance in the current environment need to focus on digital transformation. Global warming and biodiversity loss have put the sustainability of the planet in grave jeopardy. A wide range of individuals, including scientists, academics, practitioners, and researchers, have put forth suggestions for preserving environmental sustainability. According to Tseng et al. (2019), there is a common belief that industries pose a risk to sustainability because to their impulsive and careless activities. Digital transformation is very important and effective in this field, helping to increase productivity and environmental performance. Digitalization and greening are signs of social and economic development. Digital technology is considered a critical factor in green supply chain management (King et al. 2000) and The value of information technology has been investigated and proven in several aspects, such as productivity, increased profitability, improvement in the supply chain and innovation (Kahrovic and Avdovic,2023). I summarize the research in this question: How does digital transformation affect the green supply chain?

2. Theoretical concepts

2.1. Digital transformation

Digital transformation (DT) is a set of value-creation initiatives propelled by enterprise technological innovation. To enhance user experience, DT reconstructs business processes and business models through effective and open sharing and efficient use of data resources. The term "digital economy" refers to an economy that uses digital technologies, such as e-commerce and technical infrastructure. A significant factor in the promotion of superior economic development is the digital economy. As the digital economy has grown, many organisations are choosing to go through digital transformation by using digital technologies to optimise their current business processes. Many businesses now view digital transformation as an essential tool for creating competitive advantages (Ning and Yao, 2023). The process of digital transformation calls for more than just utilising as many technologies as you can. The strategy is in motion; it needs to be backed by the boundless potential of these technologies pertinent to the selected approach, as well as have a clear vision for the company's future. It can be linked to the effects of technology advancement. The idea shifts from technological advancement to current digital technologies, including business resource planning, cloud computing, big data, social media, mobile devices, embedded technology, and IT. It can primarily take the form of business enhancements,

such improving customer experience, streamlining processes, or developing new business models, as well as the influence on organisational structure and digital innovation of products (Wang and Shao 2024; Li et al. 2017).

2.2. Green supply chain

Green supply chain management (GSCM) is an extension of existing supply chain management techniques that incorporate environmental considerations into long-term supplier relationships and organisational purchasing decisions. The goal of a green supply chain is to keep wastes contained within the industrial system to save energy and stop hazardous materials from leaking into the environment. It acknowledges that an organization's supply chain operations have a disproportionately large environmental impact (Ho et al., 2009). Green supply chain management (GSCM) methods cover the whole life cycle of green products, from design to post-sales phases, and include a variety of sustainability-focused actions implemented across the supply chain (Agyapong et al., 2023). In order to preserve a competitive edge, create a greener supply chain, and meet business profit and market share goals, it is critical to incorporate environmental management techniques throughout the entire supply chain (Samen 2012).

2.3. Green supply chain components

Green materials: the use of high-quality raw materials, less noise, and non-toxic energy that does not damage the environment.

Green production: During production, it creates the least pollution, reduces human and environmental risks, and includes the implementation of environmental methods to increase profits and reduce harm.

Green consumption: products that are compatible with the environment are selected.

The importance of digital transformation in the green supply chain

1- Internet of things

By using Internet-connected devices to track the location and speed of products movement, monitor goods conditions including environmental elements, and optimise overall operations, the Internet of Things (IoT) has had an impact on green supply chain activities.

2- Artificial intelligence and machine learning

Algorithms are used by artificial intelligence (AI) and machine learning (ML) technologies to simulate human thought processes and carry out practical tasks. Their incorporation into green supply chain management can aid in the automation of numerous procedures, as well as boost productivity, safety, cut expenses, and ease delivery. Large-scale data processing and analysis made possible by AI and ML facilitates decision-making, anomaly detection, and improved performance.

3- Robotics

Robotics has improved the supply chain by creating a wide range of practical smart gadgets that support and automate intricate procedures across several stages. The organisation of archives, worker safety, and workflow productivity are all improved by these gadgets. Various robot kinds are employed for various tasks. Certain mobile robots, for instance, have the ability to perceive their environment, which comes in handy when warehouse routes are closed. Other robots are made to load and unload bulky pallets of merchandise, a task that often results in product damage when carried out by people.

4- Digital twins

A digital twin is an electronic replica or virtual version of an actual green supply chain. Digital twins can be used as a model by organisations to carry out different experiments, determine how changes or disruptions would impact operations, get ready for disruptive events, and find new ways to get better.

Importance of research:

Green supply chain has many advantages and its value has been proven in recent years. Duber (2010) classified material, non-material and emotional benefits for green supply chain:

Material benefits: less burden on the environment, lower costs for suppliers, reduced costs for the producer, less resource consumption

Non-material: easier manufacturing for the manufacturer, easier and warmer for the customer and better adaptation to the society

Emotional: increasing motivation to preserve the environment, feeling and better quality of life for customers.

And as Ho et al. mentions the reasons why companies should accept the green approach for these reasons:

- 1) Marketing objectives
- 2) Sustainability of resources
- 3) Reducing costs
- 4) Competitive advantage
- 5) Compliance with laws and risk reduction
- 6) Earning fame
- 7) Return on capital
- 8) Encouragement of employees
- 9) Moral requirements

Based on what Duber and Ho et al said, we understand that this issue is important in every way. The question arises as to how to achieve green goals. One of the important and influential factors in the success and implementation of the green supply chain is digital transformation. In today's world, digital transformation has had an impact on all industries. Being able to estimate how the digital transformation and in which indicators the green supply chain works better is effective in its better implementation. In this research, I examined how the digital transformation affects the green supply chain.

3. Research background

In a research conducted in China on the effectiveness of digital transformation, Liao et al (2024) studied the findings from 2011 to 2020. Evidence showed that digital transformation has significantly increased the efficiency of companies' green supply chains and that digital transformation promotes green technology and reduces transaction costs and financial constraints.

Lai et al (2023) investigated digital transformation and innovation in the field of green supply chain and stated that digital technologies in various industries have improved performance and development and considered the implementation of digital transformation in green supply chain management to be very successful, various types of Digital technologies were investigated and its use in production operations was identified.

oubrahim et al (2023) investigated the relationship between digital transformation and supply chain. Data was collected from 134 professionals working in Moroccan manufacturing companies and provided insights for managers to increase sustainable supply chain performance by adopting digital technologies.

Wang et al (2023) reviewed 144 related articles in 14 years and discussed the dimensions of green supply chain and digital transformation, how digital technology can reduce emissions and improve the operational efficiency of green supply chain and bring economic, social and achieve environmental.

Through a survey of 221 manufacturing companies, Qiao et al. (2023) demonstrated that supply chain innovation is positively and immediately impacted by the advantages of digital capabilities. This study shows that supply chain innovation and the advantages of digital capacity are positively correlated.

By examining 334 companies from 2011 to 2021, He et al (2023) concluded that digital transformation improves the competitiveness and flexibility of companies by coordinating human resources, information and technology.

Qian et al (2023) evaluated a model of supply chain economics based on blockchain. Because blockchain systems lead to trust and information exchange and introduce a blockchain-based model to improve supply chain efficiency.

Khan et al (2023) In their study, stated that using smart business is essential to optimize space and improve product management. The Internet of Things is considered an

effective technology that will revolutionize the industry. This technology leads to energy efficiency by reducing waste.

In a study, Liu and ma (2022) investigated the Internet of Things technology and the supply chain system and found it to be effective in all aspects of green logistics because the initiative in digital transformation leads to the development of the industry.

In their research, Khan and et al (2022) identified the role of digital transformation as necessary, referring to environmental constraints and the importance of the supply chain, and recommended the role of digital transformation with the data they collected through a random sampling of 375 experts. Managers were advised to consider the role of digital transformation in a sustainable supply chain as a guarantee to achieve sustainable performance.

After reviewing 180 articles obtained from library databases, Liao and Pen(2021) stated that digital transformation with data creation and networking can make significant progress in supply chain sustainability.

According to TSeng et al. (2019), social networks have an impact on the capabilities of sustainable supply chains based on a number of factors, including partner development, knowledge style, capacity attraction, supply chain reconceptualization, logistics flexibility, and information quality. Bin and Jun (2009) found in their research "Analysis of Green Supply Chain Management in E-commerce" that e-commerce is extensively used in supply chain management, which significantly enhances the green supply chain, boosts productivity, optimises resource allocation, and ultimately results in high economic and social well-being.

4. Research Methodology and results

To Identifying the impact of digital transformation on the green supply chain in this research the qualitative method - library information was used, and meta-combination was also used to systematically review previous research in the field of digital transformation and green supply chain. For this purpose, these factors were identified in the meta-combination method and classified by MaxQDA analysis and classification. The statistical community in this research consists of scientific research articles published in reliable databases such as Google Scholar and Science Direct. Field methods such as interviewing ten managers of industrial, manufacturing, and service companies have been used. Based on library studies and then expert interviews, the effective components of the supply chain were identified.

The steps meta-combination method requires the researcher to do a thorough and deep review of the document under study and combine the previous findings. Sandelowski and Barroso have designed a seven-step model for this purpose. The first step: Setting the research question: How does digital transformation affect the supply chain?

Second stage: Systematic review of texts: In this stage, the researcher focuses on the systematic search of articles published in various scientific journals selects relevant keywords, and identifies the selected studies by searching.

The third step: searching and selecting suitable articles: in the search process, the researcher determines whether the found articles are relevant to the research question or not. For this purpose, it specifies the selected articles

The third step is searching and selecting suitable articles: Selected articles are reviewed several times based on the research question, and many articles are rejected in each review.

Fourth step: extracting the results: after selecting the selected documents and reports, it is time to extract the codes from the texts and interviews. Research questions are intended to extract the codes. In the current research, 52 codes were identified in the Max QDA software. Among the identified codes, green materials (13), green production codes (32), and green consumption codes (7) were identified.

The fifth step: is analysis and qualitative findings: first, all the factors extracted from the articles and interviews are considered as codes, and then, considering the concept of each code, they are categorized into similar concepts In this way, the concepts of research themes are formed. The basis of categorizing these codes is based on the similarity of different codes with each other. Many codes are given in each theme.

Sixth step: Quality control: The Kappa coefficient is also known as the internal reliability evaluation criterion. To evaluate the quality, Naji was given to one of the experts to be examined by the Kappa index. If this coefficient is higher than 0.6, this coefficient is a good value, and a significance coefficient lower than 0.5 means that there is a coding relationship between the two documents. The representative table is the consensus table between the coding of one of the experts and the researcher regarding one of the texts and it is accepted due to the significance value of 0.000 and the value of the Kappa coefficient of this index.

Table 1. Test of agreement between the researcher and one of the experts in coding one of the texts

meaningful	Estimate Tb	Estimated deviation	standard	the amount	Number of observations		
0/000	3/333	0/110		0/650	Kappa	degree	of agreement

Source: research results

Table 2. Classification of codes:

References	code	Theme
Ahmad et al 2022, liao and pan 2021, He et al 2023,susanty et al 2016, liu	Primary optimal use of resources to reduce energy consumption (6) (2) Reducing resource costs due to the use of	Green material

and ma 2022,Bin and jun 2009 ,Khan et al 2023 ,Tseng et al 2019 and interviews	recycled waste (2) Data quality for collecting raw materials (3)	
Lerman et al 2022, lai et al 2023,liao et al 2024, Ahmad et al 2022, oubrahim et al 2023, wang et al 2023,ma et al 2023, Qiao et al 2023, He et al 2023, liu and ma 2022,Qian et al 2023, Khan et al 2023 , Tseng et al 2019 and interviews	Creating green operations in production, packaging, and purchasing (4) Superior management for internal coordination between organizational units (3) Intensifying production operations with large manufacturers (2) Innovation in green technology (6) Reduces costs (5) reducing human error in production (2) internal and external integration (2) reducing pollutants (2) flexibility in production operations (4) increasing safety, reducing fuel consumption time during production, sustainable supply in social, economic and environmental (2)	Green production
Ahmad et al 2022, liao and pan 2021, Khan et al 2023 , Tseng et al 2019 and interviews	Digital technology has an effect on effective decision-making and consumer participation, customer communication activities, persuading customers to buy (3) implementing waste management in consumer behavior (2)	green consumption

Source: research results

Conclusions

Currently, supply chain digitization is a global phenomenon, affecting nearly every aspect of business operations, from direct product delivery to the acquisition of raw materials. Nonetheless, this problem has a sophisticated structure that may function correctly and ensure that the high-quality goods get at their destination as soon as feasible. Given the significance of digital transformation and its effects on the green supply chain, the research literature first addressed the theoretical ideas of both the latter and the former. Green materials, green production, and green consumption were identified as the effective components of the green supply chain. The study being conducted now is qualitative.

By reviewing the articles that had been worked on in this field and also conducting interviews with several experts, we reached some indicators and these key indicators were collected by the meta-combination method. By examining 16 articles and conducting 10 interviews, 52 codes were identified in the Max QDA software. Some codes had several frequencies. After identifying these codes, they were categorized into three themes. Variables related to green production were placed at the first level, which include: Creating green operations in production, packaging, and purchasing , Superior management for internal coordination between organizational units , Intensifying production operations with large manufacturers , Innovation in green technology , Reduces costs , reducing human error in production , internal and external integration, reducing pollutants,flexibility in production operations , increasing safety, reducing fuel

consumption time during production, sustainable supply in social, economic and environmental .

Level two variables are related to green materials, which include: Primary optimal use of resources to reduce energy consumption, Coordinating resources ,Reducing resource costs due to the use of recycled waste , and Data quality for collecting raw materials .

Level three variables are related to green consumption, which include: Digital technology has an effect on effective decision-making and consumer participation, customer communication activities, persuading customers to buy, implementing waste management in consumer behavior As it was clear from the results, digital transformation has the greatest impact in the category of green production, and the green supply chain in the stage of green production has been able to benefit greatly from digital transformation. In the following, I will make some suggestions for greening the supply chain using digital transformation:

- 1) Redesigning the student using new technologies
- 2) Intelligent factory configuration
- 3) Shortening distance, cost, and energy using technology
- 4) Intelligent optimization of packaging in the direction of the environment
- 5) Short routing program
- 6) Smart advertising in social networks for waste management education
- 7) Internet education to modify the consumption pattern and promote green culture.

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