CHAPTER 57

Digitalization for Sustainable Construction Supply Chain Management

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ABSTRACT

The aim of this study is to research the potential impact of digitalization on improving sustainable construction supply chain management, while emphasizing the consolidation of sophisticated technology like Building Information Modeling (BIM), artificial intelligence (AI), and Internet of Things (IoT) technologies. Mixed methods are being used for conducting the study as it integrates surveys with quantitative aspects and qualitative data from key informants like material suppliers, construction companies, and policymakers. Based on the Technology Acceptance Model (TAM), the research analyzes the perceived usefulness and ease of use of digital technologies in enhancing sustainability results. Results indicate that digital technologies greatly support resource efficiency, decrease waste, and enhance supply chain transparency in construction. Nevertheless, impediments in the form of high costs of implementation, shortage of technical know-how, and regulatory issues limit extensive uptake. The research concludes that digitalization, when properly embedded, can catalyze sustainable practice but needs collective efforts from stakeholders, enabling policies, and cost-effective measures. This research adds to the existing body of knowledge on digital transformation in construction, providing applicable findings for practitioners in the industry and policymakers to close the gap between theoretical promise and practical application.

Keywords: Digitalization; Sustainable construction; Supply chain management; Building Information Modeling (BIM); Artificial Intelligence (AI).

1.0 Introduction

The building construction sector is also looking more and more towards digitalization to maximize sustainability in supply chain management, with the motive of efficiency, transparency, and environmental accountability. Building Information Modeling (BIM), blockchain, artificial intelligence (AI), and the Internet of Things (IoT) are being implemented to streamline logistics, minimize waste, and maintain adherence to environmental norms. BIM, especially, has been extensively researched in terms of enhancing project transparency, collaboration, and utilization of resources, with blockchain promoting transparency and traceability of material procurement.

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AI and IoT are also being increasingly adopted for predictive analysis and real-time monitoring, respectively, though additional empirical research remains necessary to determine their long-term payoffs and return on investment.

Although these digital technologies have a theoretical potential, their practical adoption is still in its infancy in the face of obstacles like capital-intensive expenditure, absence of pilot models, and differences in digital infrastructure, particularly in developing economies. The Technology Acceptance Model (TAM) offers an effective model in explaining the use of these technologies, focusing on perceived usefulness and ease of use. Yet, existing literature lacks empirical studies on the incorporation of digitalization into sustainability evaluation techniques such as Life Cycle Assessment (LCA) and the effect of stakeholder coordination, policymaking, and cost-effectiveness. This study tries to bridge such gaps by constructing a TAM-based model containing sustainability-related variables, providing not only theoretical insights but also actionable advice for construction companies.

1.1 Objectives

The research objectives are to identify and measure the role of digitalization and sustainability in construction supply chain management, evaluate the barriers and enablers of digital adoption, and assess the impact of technologies like BIM, AI, and IoT on resource efficiency and environmental compliance. This study aims to bridge the gap between theory and practice, providing insights into how digitalization can enhance sustainability in the construction industry.

2.0 Literature Review

Digitalization plays a pivotal role in enhancing sustainable construction supply chain management by integrating advanced technologies that improve efficiency, transparency, and overall performance. The adoption of digital tools such as Building Information Modeling (BIM), blockchain, and artificial intelligence (AI) facilitates better decision-making processes and fosters collaboration among stakeholders, ultimately leading to more sustainable practices in the construction industry. (Anna Lisa Junge *et al.* 2020) highlight the potential of digital transformation technologies (DTT) to enhance energy efficiency, optimize logistics resources, and reduce transport distances, positively impacting environmental and social sustainability.
Mudigonda *et al.* (2022) emphasize the construction industry's shift toward sustainability through green initiatives and supply chain management (SCM), noting that while suppliers believe they are making sufficient environmental efforts, consumers perceive these efforts as inadequate. The study also identifies high initial investments and a lack of proven models as barriers to sustainable practices. (Koctas-Cotur *et al.* 2024) explore the integration of Industry 4.0 into construction supply chains (CSCs), identifying client collaboration through ICT (BIM) as a critical factor during the design phase. (Frangopol *et al.* 2024) discuss the importance of

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resilience, risk, and sustainability in ensuring the functionality of structures under multiple hazards, emphasizing the need for probabilistic life-cycle frameworks and risk-based decision-making. (Maria Teresa Henriques Alves Ferreira *et al.* 2022) propose integrating sustainability analysis tools like Life Cycle Assessment (LCA) and Carbon Footprint with BIM to optimize building performance and reduce environmental impacts.

Androod *et al.* (2024) reviews the positive impact of digitalization on supply chain sustainability, noting enhanced transparency and real-time data exchange, while also identifying challenges and research gaps. (Lu *et al.* 2024) systematically reviews the application of digital technologies (DTs) like IoT and AI in construction sustainability, identifying key areas such as integration, optimization, and monitoring. (Stroumpoulis *et al.* 2024) highlights the strategic role of digital transformation and information systems in advancing sustainable supply chain management, emphasizing the need for comprehensive sustainability strategies powered by Industry 4.0 technologies. (Sundarakani *et al.* 2024) discuss the challenges and opportunities of digital transformation in supply chain management, particularly in the post-COVID-19 era, and propose a framework to support the logistics industry during disruptive technological changes. Collectively, these studies underscore the transformative potential of digitalization in achieving sustainable construction supply chain management while addressing challenges and identifying future research directions.

3.0 Research Methodology

The research methodology for this study employs a mixed-methods approach, combining quantitative and qualitative techniques to explore the role of digitalization in sustainable construction supply chain management. Primary data was collected through structured surveys targeting key stakeholders, including construction firms, material suppliers, and technology providers, while secondary data was gathered from existing literature and industry reports. A purposive sampling method was used to ensure responses from experts in the field, with a minimum sample size of 100. Quantitative data was analyzed using descriptive statistics and visualization tools like SPSS/Excel, while ethical considerations such as informed consent, anonymity, and data security were strictly adhered to. This approach ensures reliable and valid insights into the adoption and impact of digital technologies on sustainability in construction supply chains.

4.0 Data Analysis

The data analysis section examines the relationship between digitalization and sustainable construction supply chain management using statistical methods. It evaluates key variables such as technology adoption, sustainability performance, and supply chain efficiency to identify trends and insights.

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4.1 Factor analysis

Since values over 0.7 are regarded acceptable for Kaiser-Meyer-Olkin (KMO) sampling adequacy, the sample size is appropriate for factor analysis at 0.797. Bartlett's Test of Sphericity is significant (p =.000), with an estimated chi-square value of 547.288 and 120 degrees of freedom, indicating that the correlation matrix is not an identity matrix and that component analysis is possible. The findings support factor analysis of the data.

Table 1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.797
Bartlett's Test of Sphericity	Approx. Chi-Square	547.288
	df	120
	Sig.	.000

Source: Compiled by authors

According to the "Total Variance Explained" table, the first four components have eigenvalues larger than one and explain 57.886% of the cumulative variance, which is regarded adequate for most social scientific research.

Table 2: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.602	35.010	35.010	5.602	35.010	35.010	3.179	19.866	19.866
2	1.469	9.181	44.191	1.469	9.181	44.191	2.304	14.398	34.264
3	1.149	7.179	51.370	1.149	7.179	51.370	2.213	13.829	48.093
4	1.043	6.517	57.886	1.043	6.517	57.886	1.567	9.793	57.886
5	.996	6.222	64.109						
6	.876	5.477	69.585						
7	.756	4.722	74.308						
8	.704	4.399	78.707						
9	.673	4.207	82.914						
10	.568	3.549	86.463						
11	.498	3.114	89.576						
12	.490	3.060	92.637						
13	.388	2.422	95.059						
14	.360	2.247	97.306						
15	.226	1.414	98.720						
16	.205	1.280	100.000						

Source: Compiled by authors

The first eigenvalues reveal that Component 1 accounts for 35.010% of the variance, followed by Components 2, 3, and 4, which contribute 9.181%, 7.179%, and 6.517%,

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respectively. After extraction and rotation, the variation explained by each component is redistributed as follows: Component 1 accounts for 19.866%, Component 2 for 14.398%, Component 3 for 13.829%, and Component 4 for 9.793%. The rotation contributes to a simpler and more understandable structure by dispersing variation more equally throughout the components. Overall, the four components give a significant representation of the underlying structure of the data. Four factors representing different sustainability methods are shown in the Rotated Component Matrix. Component 1 is highly linked to sustainable product demand, government regulations, lifespan cost analysis, and waste management, suggesting regulatory and consumer-driven sustainability. Component 2 emphasises social and operational sustainability via community participation, worker health and safety, and post-occupancy assessment. Sustainability metrics, carbon footprint, and energy efficiency characterise Component 3, emphasising data-driven sustainability approaches. Finally, Component 4 emphasises environmental innovation in sustainability by linking renewable energy utilisation and sustainable material prioritisation. Varimax's rotation approach simplifies the structure, assuring interpretability and meaningful variable grouping. The report highlights four sustainability pillars: legislative and consumer- driven activities, social and operational standards, quantitative measures, and environmental innovation.

Table 3: Component Matrix[a]

	Component			
	1	2	3	4
@2Consumersareincreasinglydemandingsustainableproducts	.760			
@4Governmentregulationsshouldenforcetheuseofsustainable	.748			
@10Alifecyclecostanalysishasbeenconductedtoensurethe	.666			
@1Usingsustainablematerialscansignificantlyreduceenvironm	.657			.314
@9Acomprehensivewastemanagementplanisinplacethatinclud	.530			
@3Theconstructionindustryismakingsignificantprogresstowa	.523		.522	
@15DigitaltoolssuchasBuildingInformationModelingBIM	.453	.364		.379
@14Engagementwithlocalcommunitieshasoccurredtounderstand		.809		
@13Workerhealthandsafetymeasuresarestrictlyenforcedwit		.737	.334	
@16Apostoccupancyevaluationisplannedtomonitorthebuildi		.668		
@11EnergyefficienttechnologiessuchasLEDlightingandeffi	.321	.323	.300	
@5Ourorganizationusesspecificmetricstomeasuresustainabil			.822	
@6Sustainabilitymetricssuchascarbonfootprintandenergys			.717	
@12Localsuppliersareprioritizedtoreducetransportationemi			.541	.357
@7Renewableenergysourcessuchassolarorwindareutilized				.856
@8Theprojectprioritizessustainableorrecycledmaterialsin	.376			.461
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 6 iterations.				

Source: Compiled by authors

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5.0 Conclusion

This research identifies the revolutionary capability of digitalization in attaining sustainable construction supply chain management. Through the application of technologies like BIM, AI, and IoT, the construction sector can greatly enhance resource efficiency, lower environmental footprint, and increase transparency. Nevertheless, the implementation of these technologies is hindered by high costs, technical challenges, and regulatory loopholes. The results highlight the necessity of cooperation among stakeholders, friendly policy environments, and cost- efficient approaches to bypass these barriers. The study stresses the significance of integrating digital transformation with sustainable objectives, providing practical suggestions for industry professionals and policymakers alike. Through solving these issues, the construction industry can use digital technology to gain long-term sustainability, lower carbon emissions, and increase efficiency in operations, thus making a contribution towards world environmental and economic objectives.

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