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To Enhance Environmental and Supply Chain Performance through Blockchain Technology based on Green Supply Chain Management

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Abstract

In the current research, the use of green supply chain management (GSCM) at a stage level is investigated in order to gain the potential benefits of blockchain to enhance the performance of the supply chain and the environment. While some previous research has identified blockchain as a potential solution for sustainability, there is a lack of empirical evidence regarding the indirect processes of blockchain in the upstream, midstream and downstream. This paper fills this gap by discussing this mediating role of GSCM and environmental performance. Survey survey was conducted with 200 participants in the manufacturing, logistics and other areas to apply the quantitative research design in the cross-sectional research design. The researchers adopted Partial Least Squares Structural Equation Modeling (PLS-SEM) executed in SmartPLS to set up direct, indirect and serial connections of meditations. Cronbach alpha, composite reliability, AVE, HTMT, and SRMR are the standard measures that were used to assess reliability, validity, and model fit. Results indicate an upstream supply chain's practices (green; 0.844), midstream (β=0.811), and downstream (β=0.819) supply chains are significantly influenced by blockchain technology. The direct effect on the environmental performance is small though (β=0.024, $p>0.05$). The environmental performance (β= 0.624) and the midstream (β =0.168) have a significant effect on the environmental performance and hence the latter has a strong influence on the supply chain performance (β= 0.649).

Keywords: Blockchain Technology, PLS-SEM, Sustainability, Digital Transformation

Introduction

Background of Study

Global supply chains have surged in number and the attention given to the problems of environmental sustainability and transparency in the way they operate has grown at the same time, and organizations have consequently looked to new digital technologies as a means of control over the intricate networks of supply. The blockchain technology is a relatively new development which can be considered as a revolutionary digital infrastructure that can contribute and enhance

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the traceability, transparency and trust between the partners of the supply chain. By providing a decentralised and immuable registry across the supply chains, where the various stakeholders can monitor the product flows and share data in real time, the capability of Blockchain can help improve accountability and reduce information asymmetry for various stakeholders. As discussions of blockchain technology grow more scholarly and deepen, it seems clear that the technology has the potential to greatly enhance supply chain transparency and governance.

Problem Statement

There are still some key problems that remain in the supply chain networks despite the increased interest in sustainable supply chains and digital innovation. Lack of transparency, traceability and environmental accountability are still key challenges regarding the effective implementation. The traditional supply chain systems frequently have silos and lack visibility, alongside a lack of trustworthy means of confirming sustainability practices at various points in the chain. These restrictions can be a major obstacle to the effective implementation of green SCM measures.

Objectives of the Study

- To research the issue of blockchain engineering in supporting the activities of green demand chain management in upstream, midstream and downstream supply chain processes.
- To study the impact of stage administration of the supply chain on the environmental performances of the industries in the supply chain.
- The environmental public presentation and the general supply chain performance were tested to assess the association between them.
- To explore how the implementation of green supply chain practices in the blockchain can affect the sustainability of the environment and supply chain execution.

Research Questions

RQ1. How is Green Supply Chain (GSC) practices adopted using blockchain technology in the upstream, midstream and downstream of supply chain activities?

RQ2. In which aspects the green supply chain (GSC) management, stage-wise, influences the environmental performance in the industries of the supply chain?

RQ3. How is the overall supply chain execution in blockchain enabled green supply chains and environmental action?

Literature Review

The blockchain app is a disruptive digital technology that enhances the supply chain systems in terms of transparence, traceability and trustfulness. It is a decentralized and unchangeable registry of data which helps to share information between various stakeholders without the intermediaries. In the supply chain environment, blockchain allows better real-time tracking of transactions, reduction of information asymmetry and better coordination of network partners. As pointed out in the recent literature, the application of blockchain has an impactful influence on visibility and governance of supply chains particularly in complex global supply chains where transparency is perceived as valuable (Zhao, 2024; Jasrotia, 2024; Zhang, 2025).

Theoretical Foundation

Resource-Based View (RBV)

The Resource Based View (RBV) offers a basic foundation for understanding how the resources and capabilities that are internal to a firm can lead to sustained competitive advantage. RBV states that organisations with resources that are valuable, rare, difficult to imitate, and non-substitutable, will be able to perform better. From the perspective of this study, blockchain technology can be viewed as a strategic organizational capability that enhances selected capabilities within supply chain, such as transparency, coordination and data reliability. Some recent literature indicates that the use of advanced digital technologies offers some benefits to companies to make better use of their resources, which in turn optimizes their operations and makes them more efficient in the performance of their supply chains (Khan et al., 2022; Dubey et al., 2023; Queiroz & Wamba, 2021).

Theory of Acceptance and Use of Technology (TAUT)

The Theory of Acceptance and Use of Technology (UTAUT) models the reasons why organizations adopt and use new technologies by identifying the determinants that influence adoption and use: performance expectancy, effort expectancy, social influence and facilitating conditions. All these factors influence the organization's intention to use and implement technological innovations effectively. For the purpose of this study, UTAUT can be used as an appropriate framework to analyze the adoption of blockchain technology by firms for green supply chain practices. Recent studies have shown that many industries are embracing blockchain technology because of its advantages of transparency, operational efficiency, and sustainability outcomes (Queiroz & Wamba, 2021; Dubey et al., 2023; Kshetri, 2018). In addition, external factors, like regulatory needs and stakeholder expectations, and organizational readiness and technological infrastructure have a strong influence on the adoption process (Tornatzky & Fleischer, 1990; Oliveira & Martins, 2011). These factors are especially significant in a sustainable setting where companies are encouraged to operate within environmental objectives. Previous studies have also shown that adoption of technology is an important factor influencing organizational performance and innovation results.

Mediation & Moderation Perspective

The utilization of blockchain technology is also highly known to be an enabler of green supply chain management (GSCM) through which aid in transparency, traceability, and collaboration between stages of the supply chain become possible. It helps firms monitor supplier activities, be aware of their environmental performance, and have a sustainable sourcing policy implemented with decentralized data sharing systems (Jasrotia, 2024; Amin, 2025). Regarding mediation technological impetus will help elevate the GSCM practices and in the end enhance the environmental performance by blockchain. Moreover, this relationship could be mediated by the organizational preparedness and technological support, which could strengthen the impact of blockchain on the introduction of GSCM (Amin, 2025). The previous studies also show digital inte-

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gration support the practices of supply chain coordination and sustainability (Kouhizadeh and Sarkis, 2020; Queiroz, 2020).

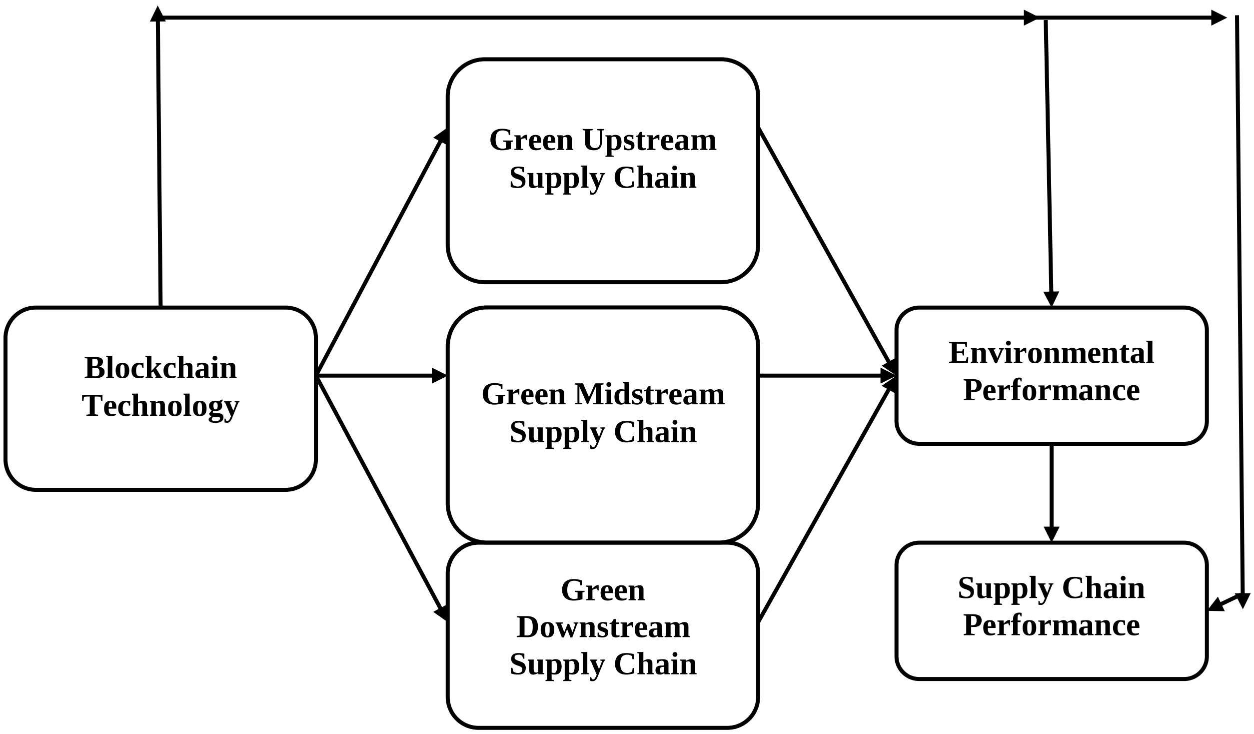

Figure 1 Conceptual Framework

Hypothesis Development

Blockchain Technology and Green Upstream Supply Chain

The implementation of blockchain technology has a significant impact on the progressive development of the practices of the green upstream supply chain, in particular when it comes to facilitating the supply chain's transparency and traceability in the supplier chain activities. It enables companies to check the compliance of the suppliers with the environmental standards, trace the source of raw materials, and sustain the sourcing process (Amin, 2025; Jasrotia, 2024;).

H1: Green Upstream Supply Chain has a substantial positive effect on the Blockchain Technology.

Green Midstream Supply Chain and Blockchain Technology

The blockchain technology plays a crucial role in the implementation of the green midstream supply chain practice, where it offers transparency in operation and production inside the chain. It allows observing the production processes, resource consumption, and waste production in real-time, aiding the manufacture in a green way (; Wang et al., 2024; Khan, 2024). Moreover, blockchain can help to facilitate information exchange between different departments to enhance coordination and decision-making processes that will enable energy-efficient production processes (Bhatt, 2025).

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H 2: Blockchain Technology is positively significant to Green Midstream Supply Chain.

Blockchain Technology and Green Downstream Supply Chain

The blockchain technology is a positive development to the green downstream supply chain by promoting transparency of logistics and distribution and product lifecycle control. It enables businesses to track shipping, optimize shipping, and carry out shipment responsibly in the context of the environment (Amin, 2025; Wang et al., 2024). This enhances the levels of logistics and promotes sustainable waste management and recycling programs. Besides, blockchain assists organizations in keeping the environment regulation up-to-date throughout the distribution networks (Bhatt, 2025).

H3: Blockchain Technology positively affects Green Downstream Supply Chain in a significant way.

Green Upstream Supply Chain and Environment Performance

Environmental performance is a key part of Green Upstream Supply Chain.Environmental performance is an integral component of Green Upstream Supply Chain. The green upstream supply chain practices are important to the environmental performance as they enable sustainability sourcing and reduce the environmental risks associated with the raw materials sourced. By implementing green procurement in companies, they can minimize waste, decrease emissions, improve resource utilization, and maintain sustainable business operations (Liu et al., 2024; Yimer, 2025; Khan, 2024). Another reason is that suppliers that take care of the environment would mean that sustainability is embedded from the initial stage of the supply chain (Hariyani, 2024).

H 4: Green up supply chain impacts positively on the Environmental Performance in a significant manner.

Green Midstream Supply Chain and Environmental Performance

Green midstream supply chain is one of the most important practices that will improve the performance of the environment by increasing energy efficiency and reducing waste in the production processes. The use of environmentally sustainable production processes offers significant emission reductions, and better utilization of resources (Wang et al., 2024; Liu et al., 2024; Khan, 2024). The practices are sustainably-oriented and contribute to the overall environmental performance ().

H5: Green Midstream Supply Chain contributes to the Environmental Performance in a significant positive manner.

Green Downstream Supply Chain and Environmental Performance

The green downstream supply chain practices have a significant role in improving the environmental performance in the context of sustainable logistics, distribution and waste management. The practices lower the emission of carbon, enhance recycling methods, and elevate the environmental compliance (Amin, 2025; ; Liu et al., 2024). Also, effective logistics systems lead to lower fuel consumption, as well as better sustainability outcomes (Khan, 2024).

H6: Green Downstream Supply Chain positively affects the Environmental Performance significantly.

Supply Chain Performance and Environmental Performance

The environmental performance positively effects on the supply chain performance because it contributes to efficient supply chain performance, reduces cost and improves compliance of regulations. With high environmental performance, organizations can better optimize the use of resources and improve the operation performance (Wang, 2025; Liu et al., 2024). Moreover, competitive advantage is achieved via sustainable practices that increase the brand reputation and trust in the stakeholders (Khan, 2024).

H7: there is a high positive correlation between Environmental Performance and Supply Chain Performance.

Blockchain Technology, Green Upstream Supply Chain and Environmental Performance

Using the blockchain technology, the environmental performance improvement is done indirectly by promoting “green upstream supply chain” practices by enhancing transparency and traceability of the supplier's activities. It allows companies to check on sustainable sourcing, adherence among suppliers and to make sure that the procurement process is environmentally responsible (Amin, 2025; Jasrotia, 2024). These developments in the upstream operations lead to a reduction in environmental risks and better use of resources, thus improving the environmental performance.

H8: Green Upstream Supply Chain is the factor mediator between the relationship between Blockchain Technology and Environmental Performance.

Blockchain Technology, Green Midstream Supply Chain and Environmental Performance

The impact of the blockchain technology on the environmental performance is closely linked to the impact it has had on the manufacturing and in-house operations areas of the green midstream supply chain. It allows monitoring real-time production processes, resource use, and waste production, which increases sustainability in the production (Wang et al., 2024; ; Khan, 2024). As one of the actors of environmental performance mediation, the enhancement of processes' efficiency and reduction of environmental waste are achieved through the use of blockchain facilitated practices, known as midstream practices, (Bhatt et al., 25).

H9: Green Midstream Supply Chain is between Blockchain Technology and Environmental Performance.

Blockchain Technology, Green Downstream Supply Chain and Environmental Performance

Blockchain technology and other green downstream supply chain practices can be implemented to enhance environmental performance by optimizing the logistics process, tracking the products, and reducing waste management processes. With its ability to track product movement, optimize routes, and facilitate eco-friendly product delivery practices, it is an invaluable asset for companies looking to reduce their environmental footprint. (Amin, 2025; Wang et al., 2024). The carbon emissions reduction and sustainability impact of such gains from the downstream operations reduces the carbon emissions and improves the sustainability impact of the green downstream practices, hence the green downstream practices play as a major mediator (Bhatt, 2025).

H10: Green Downstream Supply Chain mediates the association between Blockchain Technology and Environmental Performance.

Blockchain Technology, Environmental Performance and Supply Chain Performance

Environmental performance is a mediator between blockchain technology and supply chain performance. The use of blockchain technology can help to improve the sustainability of the environment in several ways, including providing transparency, tracking emissions, and ensuring compliance with environmental policies (; Bhatt, 2025; Amin, 2025). Improved environmental performance in this way will lead to cost reduction, operational efficiency and reputation enhancement, and hence the performance improvement of the supply chain will be enhanced (Wang, 2025).

H11: Environmental Performance mediates the relationship between Blockchain Technology and Supply Chain Performance.

Blockchain, GSCM (All Stages), Environmental Performance and Supply Chain Performance (Serial Mediation)

An overall mediation process is provided, which involves the performance of the supply chain in the context of stage-based green supply chain and the environmental performance of the supply chain, using blockchain technology. Blockchain, enhancing environmental performance and ultimately supply chain performance (Jasrotia, 2024; Amin, 2025;) can be applied to improve upstream sustainability practices, downstream sustainability practices and midstream sustainability practices. This serial mediation is an indication of a holistic process in which technological innovation makes sustainability and results in enhanced operational performance (Bhatt, 2025).

H12: Green Supply Chain Management (Upstream, Midstream, Downstream) and Environmental Performance mediate the relationship between Blockchain Technology and Supply Chain Performance sequentially.

Methodology

Research Design

In this study, we use a quantitative research method to analyze the relationship among the blockchain technology, green supply chain management (GSCM), environmental performance, and supply chain performance. Nevertheless, quantitative research is justified in the context of supply chain and sustainability researches, as it allows for testing of hypotheses and the development of relationships between the variables through statistical methods (Queiroz et al., 2022; Kock and Hadaya, 2023; Sarstedt et al., 2022). This will assist the researchers to collect numerical data and analyze them systematically for making objective conclusions. A quantitative approach is suitable in the context of the given research because it will be possible to empirically test the suggested conceptual model and hypotheses through the use of structured data (Ringle et al., 2023; Henseler et al., 2015). The reliability, generalizability and accuracy in measuring the complex relationships in the supply chain research are also noted by the previous researchers (Sekaran and Bougie, 2016; Creswell, 2014). Therefore, it will ensure methodological rigour and will help the thorough statistical analysis.

Data Collection

Insight into the perceptions of the respondents with regard to blockchain technology, green supply chain management (GSCM), environmental performance, and supply chain performance. The survey technique allows gathering standard data on many participants efficiently and aligning the data on the reactions of each participant in terms of consistency and comparability (Queiroz et al., 2022; Sarstedt et al., 2022; Ringle et al., 2023). The data was collected from the online and offline distribution channels and the focus was on professionals working in the field of supply chain management, logistics management and operations management. The strategy makes the response more diverse and enhances the quality of data. Secondly, the use of preconceived scales in the structured questionnaires will help to measure the latent constructs, which is also done in Kock and Hadaya (2023) and Amin et al. (2025).

Sampling Technique

The research uses a non-probability purposive approach to the sampling method to sample out the respondents with the relevant knowledge and experience in supply chain management and blockchain technology. In the case of requiring a specific type of expertise and the researcher's obligation to gather specific data, purposive sampling should be employed (Queiroz et al., 2022; Sarstedt et al., 2022; Ringle et al., 2023). This will ensure that only qualified ones are filling the study, increasing the reliability of the information that they provide. In addition, purposive sampling is an effective sampling method that is widely used in management and technology research due to its ease and convenience (Kock and Hadaya, 2023; Amin, 2025). Previous investigations also substantiate the fact that non-probability sampling methodology can be applied when using exploratory research design and theory-testing research design (Creswell, 2014; Sekaran and Bougie, 2016). In this way, the sampling method is in line with the research objectives and methodology.

Table 1 Instruments Adaptation

Construct	Code	No. of Items	Description	Adopted From
Blockchain Technology	BT	3 (BT1–BT3)	Measures the extent to which blockchain technology enhances transparency, traceability, security, and information sharing within the supply chain.	Kshetri (2018); Queiroz & Wamba (2021); Dubey et al. (2023)
Green Upstream Supply Chain	GUSC	3 (GUSC1–GUSC3)	Measures environmentally sustainable supplier selection, green procurement, and sustainable sourcing practices.	Zhu & Sarkis (2004); Green et al. (2012); Liu et al. (2024)
Green Midstream Supply Chain	GMSC	3 (GMSC1–GMSC3)	Measures green manufacturing, resource efficiency, waste reduction,	Zhu & Sarkis (2004); Wang et

Construct	Code	No. of Items	Description	Adopted From
			and environmentally friendly production processes.	al. (2024); Khan (2024)
Green Downstream Supply Chain	GDSC	3 (GDSC1–GDSC3)	Measures green logistics, eco-friendly distribution, reverse logistics, recycling, and sustainable delivery practices.	Zhu & Sarkis (2004); Wang et al. (2024); Amin (2025)
Environmental Performance	EP	3 (EP1–EP3)	Measures reduction in emissions, waste minimization, energy efficiency, and overall environmental sustainability.	Zhu & Sarkis (2004); Daily et al. (2009); Yimer (2025)
Supply Chain Performance	SCP	3 (SCP1–SCP3)	Measures operational efficiency, responsiveness, cost reduction, and overall supply chain effectiveness.	Li et al. (2006); Flynn et al. (2010); Khan (2024)

Software Used

The analysis of the research is carried out using the program of a popular program in terms of partial least square structural equation modeling (PLS-SEM) software SmartPLS version 4. SmartPLS enables researchers to examine complicated models that have numerous constructs and mediations (Wong, 2013; Henseler, Hubona & Ray, 2016; Dijkstra & Henseler, 2015). It provides a better service in the measurement and structural modelling – including reliability, validity and testing of hypotheses. Furthermore, Small Sample-size and non-normal data distribution would be used to work with using SmartPLS (Hair, Risher, Sarstedt & Ringle, 2019; Reinartz, Haenlein & Henseler, 2009). Previous researchers also affirm that SmartPLS finds a wide application in the research of supply chains and sustainability because of its ability to predict and flexibilities (Chin, 1998; Ringle, Wende & Becker, 2015). In this manner, the selected software can ensure appropriate and accurate data analysis.

Results and Discussion

The results of the study provide good empirical evidence of the validity of the conceptual model that will investigate the issue under study, i.e. the potential of Blockchain technology for the improvement of the environmental and supply chain performance through the implementation of stage-based Green Supply Chain Management. The PLS-SEM structural model analysis reveals that the blockchain technology has a high impact on the green upstream, midstream and downstream supply chain practices, indicating that blockchain is pivotal as a technological enabler of sustainability throughout the supply chain. The findings align with the recent studies that suggested that blockchain can enhance transparency, traceability and coordination between supply chain participants, resulting in more efficient sustainable supply chain operations (Saberi et al., 2019; Queiroz, 2020). Furthermore, the argument of the importance of digital technologies to transform traditional supply chains into data-driven and sustainable supply chains is supported by the previous literature (Ivanov, 2021; Liu et al., 2022).

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Demographic Profile

Table 1: Demographic Profile

Variable	Category	Fre (N)	tage (%)
Gender	Man	128	64
	woman	72	36
Age Group	21–30 Years	58	29
	31–40 Years	74	37
	41–50 Years	44	22
	Above 51 Years	24	12
Educational Qualification	Bachelor's Degree	70	35.0
	Master's Degree	104	52.0
	MS / MPhil	18	9.0
	Doctorate (PhD)	8	4.0
Professional Experience	Less than 6 Years	46	23.0
	6–11 Years	82	41.0
	12–16 Years	42	21.0
	More than 16 Years	30	15.0
Organizational Role	Technical / Operational Staff	68	34.0
	Team Leaders / Supervisors	56	28.0
	Middle-Level Management	48	24.0
	Top / Senior Management	28	14.0
Industry Type	Manufacturing Firms	92	46.0
	Logistics & Transportation	56	28.0
	Information Technology	30	15.0
	Other Sectors	22	11.0

Reliability and Validity Analysis

Table 2: Reliability and Validity Analysis

validity and reliability Overview				
	Cronbach's alpha	**Composite reliability (rho_a)**	**Composite reliability (rho_c)**	**Average variance extracted (AVE)**
BLOCK-CHAIN_TECHNOLOGY	0.887	0.887	0.930	0.815
ENVIRONMENTAL_PERFORMANCE	0.856	0.858	0.912	0.776
GREEN DOWNSTREAM_SUPPLY CHAIN	0.862	0.864	0.916	0.784
GREEN MIDSTREAM_SUPPLY CHAIN	0.908	0.909	0.942	0.844

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GREEN UPSTREAM_SUPPLY CHAIN	0.832	0.841	0.899	0.747
SUPPLY CHAIN_PERFORMANCE	0.853	0.855	0.911	0.773

Based on the results from the construct reliability and validity, it can be seen that the measurement model has the characteristics of good convergent validity and good internal consistency for all constructs. Cronbach's alpha coefficients are between 0.832 and 0.908, which are in the acceptable range of 0.70 and above, thus indicating acceptable to strong reliability. Likewise, composite reliability values (rho_a and rho_c) exceed 0.85, and the rho_c values range from 0.899 to 0.942 demonstrating high consistency and reliability among the measurement items. Further, the Average Variance Extracted (AVE) values for all constructs are more than 0.50, suggesting good convergent validity.

Bootstrapping PLS SEM

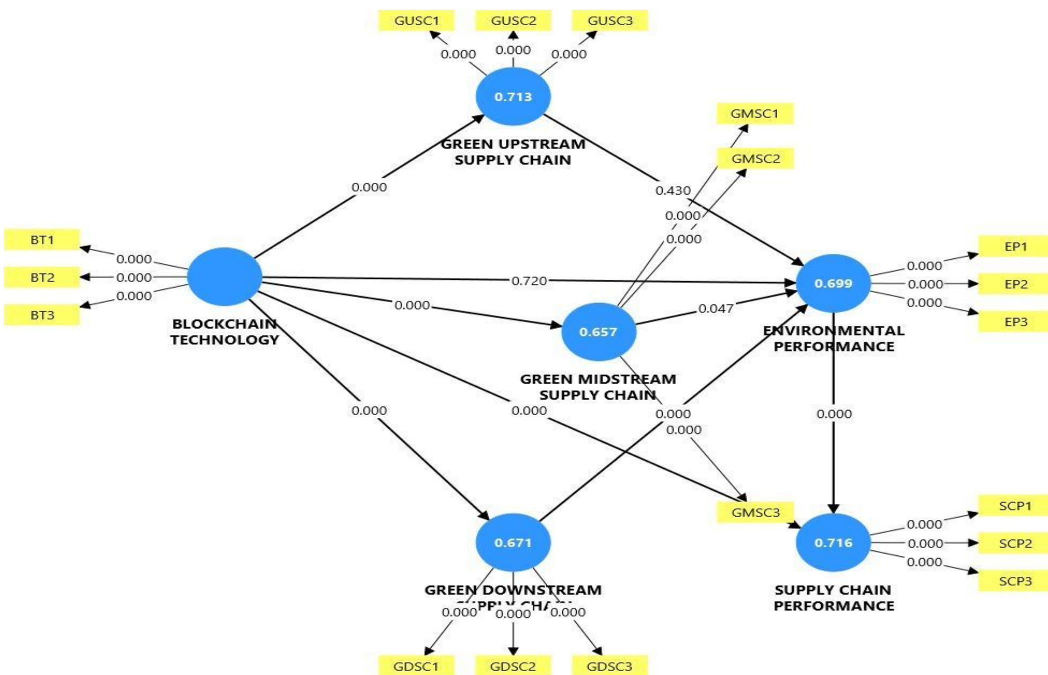

Figure 2: Bootstrapping PLS SEM

The findings of the structural model show that the relationships between the main constructs of the study are strong and statistically significant. Blockchain technology is found to have a strong positive impact on the practices of the green upstream, midstream and downstream supply chain, with p-values of 0.000 for all paths. This underlines the significance of blockchain as a technology enabler for the various steps of the supply chain process in the context of supporting sustainability. Moreover, the R^2 values of green upstream (0.713), green midstream (0.657), and green downstream (0.671) suggest that blockchain technology accounts for a significant amount of variance in these constructs and, therefore, has strong explanatory power.

Outer Loadings

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Table 6: Outer Loadings

Outer loadings
Mean, STDEV, T values, p values

	OS (O)	SM (M)	SD (STDEV)	T statistics (|O/STDEV|)	P values
BT1 <- BLOCK-CHAIN_TECHNOLOGY	0.899	0.899	0.015	58.472	0.000
BT2 <- BLOCK-CHAIN_TECHNOLOGY	0.909	0.909	0.014	63.439	0.000
BT3 <- BLOCK-CHAIN_TECHNOLOGY	0.900	0.900	0.016	55.468	0.000
EP1 <- ENVIRONMEN-TAL_PERFORMANCE	0.886	0.886	0.017	50.946	0.000
EP2 <- ENVIRONMEN-TAL_PERFORMANCE	0.886	0.885	0.023	39.163	0.000
EP3 <- ENVIRONMEN-TAL_PERFORMANCE	0.871	0.871	0.020	42.525	0.000
GDSC1 <- GREEN DOWN-STREAM_SUPPLY CHAIN	0.903	0.903	0.013	69.219	0.000
GDSC2 <- GREEN DOWN-STREAM_SUPPLY CHAIN	0.891	0.891	0.015	58.056	0.000
GDSC3 <- GREEN DOWN-STREAM_SUPPLY CHAIN	0.861	0.860	0.025	35.005	0.000
GMSC1 <- GREEN MID-STREAM_SUPPLY CHAIN	0.912	0.911	0.016	55.284	0.000
GMSC2 <- GREEN MID-STREAM_SUPPLY CHAIN	0.934	0.934	0.009	99.309	0.000
GMSC3 <- GREEN MID-STREAM_SUPPLY CHAIN	0.911	0.911	0.013	71.576	0.000
GUSC1 <- GREEN UP-STREAM_SUPPLY CHAIN	0.873	0.874	0.014	61.606	0.000
GUSC2 <- GREEN UP-STREAM_SUPPLY CHAIN	0.881	0.881	0.019	47.470	0.000
GUSC3 <- GREEN UP-STREAM_SUPPLY CHAIN	0.838	0.836	0.030	27.778	0.000
SCP1 <- SUPPLY CHAIN_PERFORMANCE	0.879	0.878	0.016	55.060	0.000
SCP2 <- SUPPLY CHAIN_PERFORMANCE	0.899	0.899	0.014	64.329	0.000
SCP3 <- SUPPLY CHAIN_PERFORMANCE	0.860	0.859	0.022	39.610	0.000

In the results of outer loadings, high reliability of the indicators can be seen and the validity of the measurement model is clear. All the factor loadings are between 0.838 and 0.934 (above the recommended 0.70) implying that all indicators are significant in the respective constructs.

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Moreover, the T-statistic values are very high (27.778 to 99.309) and all the p-values are 0.000, which proves that all loadings are significant at high confidence level. The low standard deviation values also show that there is stability and consistency in the estimate of bootstrap samples.

Hypothesis Testing

Table 7: Hypothesis Testing

Path coefficients
Mean, STDEV, T values, p values

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
BLOCKCHAIN_TECHNOLOGY -> ENVIRONMENTAL_PERFORMANCE	0.024	0.022	0.067	0.359	0.720
BLOCKCHAIN_TECHNOLOGY -> GREEN DOWNSTREAM_SUPPLY CHAIN	0.819	0.819	0.025	32.256	0.000
BLOCKCHAIN_TECHNOLOGY -> GREEN MIDSTREAM_SUPPLY CHAIN	0.811	0.811	0.032	25.139	0.000
BLOCKCHAIN_TECHNOLOGY -> GREEN UPSTREAM_SUPPLY CHAIN	0.844	0.845	0.022	37.661	0.000
BLOCKCHAIN_TECHNOLOGY -> SUPPLY CHAIN_PERFORMANCE	0.248	0.246	0.064	3.905	0.000
ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.649	0.651	0.061	10.628	0.000
GREEN DOWNSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE	0.624	0.617	0.086	7.229	0.000
GREEN MIDSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE	0.168	0.175	0.084	1.986	0.047
GREEN UPSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE	0.064	0.065	0.081	0.789	0.430

The specific indirect effects obtained from the given results prove to be a good indication of mediation in the model as the practices of the green downstream supply chain are very vibrant.The specific indirect effects obtained from the given result are a good indication of the mediation in the model as the practices of green downstream supply chain are very vibrant. The mediating role of environmental performance in the relationship between blockchain technology and supply chain performance is negligible ($\beta = 0.016$, $p = 0.724$), which supports the fact that environmental performance does not mediate the relationship between the two.

Mediation Analysis

From the figure, it can be observed that the findings of the structural model shows that the blockchain technology is strongly and significantly correlated with all three dimensions of green supply chain management. That is, the usefulness of blockchain technology in green upstream (0.844), green midstream (0.811), and green downstream (0.819) supply chain activities is high, explaining the role of the new technology as a key enabler to sustainability in all the levels of the

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supply chain. The R2 of the green upstream (0.713), green midstream (0.657), and green downstream (0.671) also shows that blockchain accounts a high ratio of variance of these constructs implying that it has a high predictive power.

Table 8: Mediation Analysis

SIDE **Mean, STD-EV, T-test , p values**	**Original sample (O)**	**Sample mean (M)**	**Standard dDEV (STDEV)**	**T test (|O/STDEV|)**	**P values**
BLOCKCHAIN_TECHNOLOGY -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.016	0.015	0.044	0.353	0.724
GREEN DOWNSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.405	0.402	0.070	5.765	0.000
BLOCKCHAIN_TECHNOLOGY -> GREEN MIDSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.088	0.092	0.046	1.927	0.054
GREEN MIDSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.109	0.113	0.054	2.016	0.044
BLOCKCHAIN_TECHNOLOGY -> GREEN UPSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.035	0.036	0.045	0.776	0.438
GREEN UPSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.041	0.043	0.053	0.776	0.438
BLOCKCHAIN_TECHNOLOGY -> GREEN DOWNSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE -> SUPPLY CHAIN_PERFORMANCE	0.332	0.329	0.057	5.801	0.000
BLOCKCHAIN_TECHNOLOGY -> GREEN UPSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE	0.054	0.055	0.068	0.787	0.431
BLOCKCHAIN_TECHNOLOGY -> GREEN MIDSTREAM_SUPPLY	0.136	0.143	0.072	1.901	0.057

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CHAIN -> ENVIRONMENTAL_PERFORMANCE					
BLOCKCHAIN_TECHNOLOGY -> GREEN DOWNSTREAM_SUPPLY CHAIN -> ENVIRONMENTAL_PERFORMANCE	0.512	0.505	0.072	7.096	0.000

PLS SEM

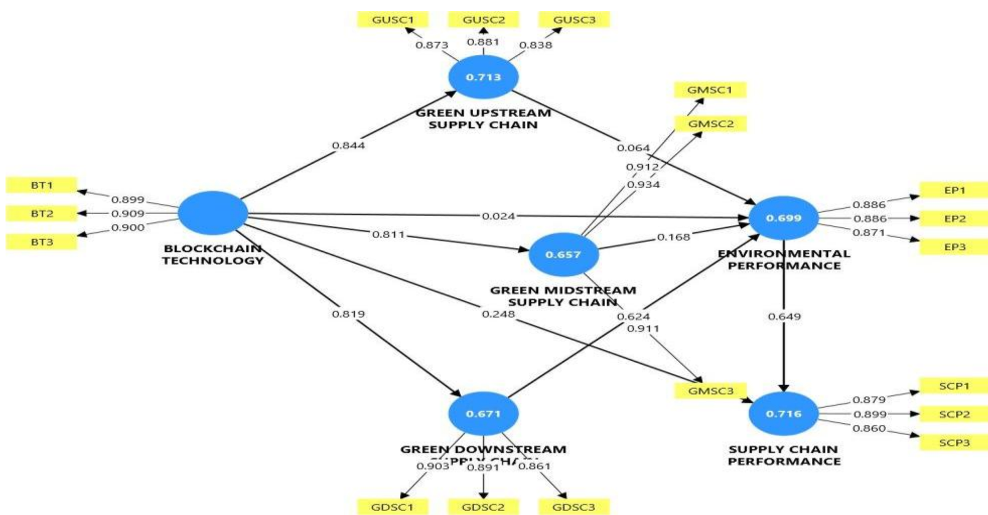

Figure 3: PLS SEM

The results of the structural model as presented in the figure demonstrate the strong and statistically significant relationships between blockchain technology and all three dimensions of green supply chain management. Specifically, the use of blockchain technology has a significant positive effect on the green upstream (β = 0.844), green midstream (β = 0.811), and green downstream (β = 0.819) supply chain practices, thus further supporting its contribution to the sustainability of supply chain stages. The R^2 values for the constructs green upstream (0.713), green midstream (0.657), and green downstream (0.671) also support this: blockchain accounts for a large share of the variance in these constructs, which means that it has a strong predictive power.

Table 9: Model Fitness

Model fit		
Fit summary		
	Saturated model	**Estimated model**
SRMR	0.052	0.073
d_ULS	0.460	0.919
d_G	0.418	0.504
Chi-square	925.435	1014.910
NFI	0.852	0.838

The fitting results of the structural model indicate the overall fitting is acceptable. The value of the SRMR is 0.073 which is less than the recommended level of 0.08 indicating a good fit of the model. In the same way, the value of NFI of 0.838 is nearly equal to the acceptable value of 0.90 which indicates a reasonably good fit of the model, particularly in the context of PLS-SEM where a pretty low value can be tolerated. It is seen that the values of d ULS (0.919) and d G (0.504) are not very large and hence the difference between the two correlation matrices, namely, the empirical and the model-implied, is not significant.

Discussion

The findings of this work have certain theoretical implications that extend the Natural Resource Based View (NRBV), Resource Based View (RBV), and UTAUT when considering blockchain-enabled sustainable supply chains. The results validate the RBV by emphasizing that technological capabilities can be strategic resources which help to increase the competitiveness of companies. Blockchain technology has a great impact on GSCM practices in the upstream, midstream, and downstream stages in this respect. The conclusions from the results imply, from an NRBV point of view, that technology is not sufficient to influence the environmental performance, but rather when combined with a structured operational practice that addresses sustainability issues. This means that the green capabilities are built using digital tools and processes for sustainability rather than on implementing single technologies. The concurrent findings of weak and non-significant direct relationship between blockchain technology and environmental performance also cast a shadow on the supposed “straightforward” connections between digital technologies and sustainability gains. Rather, the results indicated that environmental outcomes are realized through a set of systems of resources and organizational practices, not from a single technological solution.

Conclusion

This paper demonstrates blockchain's significant and transformative contribution to sustainable supply chains, especially its impact on green supply chain management (GSCM) at each stage. The results have shown that blockchain has a significant impact on the activities of the upstream, midstream, and downstream supply chains, particularly in terms of increasing transparency and traceability and enabling real-time data sharing. The results are consistent with the Resource Based View (RBV) and Natural Resource Based View (NRBV) theories that assert that technological capabilities are essential for gaining competitive advantage and environmental sustainability. But it is also revealed from the study that blockchain does not have a direct influence on the environmental performance. This implies that sustainability results are not created by technology per se, but by its combination with operational practice and organizational processes. That is, environmental improvements benefit from the integration of the digital technologies within articulated sustainability strategies, and not from their mere use.

Future Research Directions

This research also opens up various possibilities in future research through the identification of key limitations in terms of research design, theoretical and contextual scope of research. First, the study is a cross sectional quantitative study, which does not allow the observation of the changes in the use of blockchain and sustainability practices over time. The future research can use longitudinal or mixed methods to gain better insight into the way blockchain-enabled green supply chain management develops in various phases of its implementation (Queiroz et al., 2022; Sarstedt et al., 2022; Ringle et al., 2023). Also, although the current study incorporates NRBV, RBV, and UTAUT, future studies can broaden the theoretical backdrop with the help of other perspectives like the institutional theory or dynamic capabilities that clarify the pressure of external forces and adaptiveness in the adoption of sustainability (Amin, 2025). Previous studies also indicate that multi-theoretical models offer a better explanation of the changes brought about due to technology (Hart and Dowell, 2011; Barney, 1991). Thus, future studies should strive to be theoretically integrated and diversified methods to get the best findings.

References

1. Belhaj, M., & Lehman, D. R. (2024). Store image and emotional engagement in experiential retail environments. *Journal of Retailing and Consumer Services, 76*, 103512.
2. Biswas, D., Szocs, C., Chacko, R., & Wansink, B. (2025). Shining light on atmospherics: How ambient factors influence consumer behavior in retail settings. Journal of Marketing Research, 62(1), 45–61.
3. Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand experience: What is it? How is it measured? Does it affect loyalty? Journal of Marketing, 73(3), 52–68. https://doi.org/10.1509/jmkg.73.3.52
4. Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). Sage Publications.
5. Dick, A. S., & Basu, K. (1994). Customer loyalty: Toward an integrated conceptual framework. Journal of the Academy of Marketing Science, 22(2), 99–113. https://doi.org/10.1177/0092070394222001
6. Fong, L. H. N., Wong, I. A., & Hong, J. F. L. (2023). Experiential branding and emotional attachment in luxury retail environments. Journal of Business Research, 165, 114071.
7. Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1), 39–50. https://doi.org/10.1177/002224378101800104
8. Grewal, D., Baker, J., Levy, M., & Voss, G. B. (1998). The effects of store atmosphere on consumers' purchase intentions. Journal of Retailing, 74(3), 331–352.
9. Gulati, R., Sharma, P., & Mehta, S. (2023). Emotional attachment and customer loyalty in experiential retailing. Journal of Consumer Marketing, 40(5), 621–636.
10. Gupta, S., Malhotra, N., Czinkota, M., & Foroudi, P. (2022). The role of sensory marketing and experiential value in consumer engagement. Journal of Business Research, 145, 597–609.
11. Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). A primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.). Sage Publications.
12. Huang, Z., Liang, X., & Tian, Y. (2022). Emotional attachment and experiential consumption behavior in retail marketing. Journal of Retailing and Consumer Services, 68, 103070.
13. Hultén, B. (2011). Sensory marketing: The multi-sensory brand-experience concept. European Business Review, 23(3), 256–273. https://doi.org/10.1108/09555341111130245
14. Kotler, P. (1973). Atmospherics as a marketing tool. Journal of Retailing, 49(4), 48–64.

15. Krishna, A. (2012). An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. Journal of Consumer Psychology, 22(3), 332–351. https://doi.org/10.1016/j.jcps.2011.08.003
16. Krishna, A., Cian, L., & Sokolova, T. (2024). Sensory marketing and consumer experience in modern retail environments. Journal of Consumer Research, 51(2), 210–229.
17. Loureiro, S. M. C., Bilro, R. G., & Angelino, F. J. A. (2020). The role of sensory brand experience in emotional attachment and consumer loyalty. Journal of Product & Brand Management, 29(2), 186–201.
18. Mehrabian, A., & Russell, J. A. (1974). An approach to environmental psychology. MIT Press.
19. Nunkoo, R., Teeroovengadum, V., Thomas, P., & Leonard, L. (2025). Experiential marketing and emotional attachment in retail consumer behavior. Journal of Retailing and Consumer Services, 78, 103889.
20. Oliver, R. L. (1999). Whence consumer loyalty? Journal of Marketing, 63(Special Issue), 33–44. https://doi.org/10.1177/00222429990634s105
21. Park, C. W., MacInnis, D. J., Priester, J., Eisingerich, A. B., & Iacobucci, D. (2010). Brand attachment and brand attitude strength: Conceptual and empirical differentiation of two critical brand equity drivers. Journal of Marketing, 74(6), 1–17.
22. Pine, B. J., & Gilmore, J. H. (1998). Welcome to the experience economy. Harvard Business Review, 76(4), 97–105.
23. Qatawneh, M. I., Al-Hawary, S. I. S., & Alolayyan, M. N. (2024). Customer experience and loyalty behavior in experiential retailing. International Journal of Retail & Distribution Management, 52(1), 55–72.
24. Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education.
25. Schmitt, B. (1999). Experiential marketing. Journal of Marketing Management, 15(1–3), 53–67. https://doi.org/10.1362/026725799784870496
26. Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill-building approach (7th ed.). Wiley.
27. Shahid, S., Paul, J., Gilal, F. G., & Ansari, S. (2022). The role of sensory branding and customer experience in developing emotional attachment. Journal of Brand Management, 29(6), 715–730.
28. Spence, C., & Gao, X. (2025). Multisensory experiential marketing and consumer engagement in retailing. Psychology & Marketing, 42(3), 412–428.
29. Yoo, C. Y., & MacInnis, D. J. (2005). The brand attitude formation process of emotional and informational ads. Journal of Business Research, 58(10), 1397–1406.
30. Zha, D., Melewar, T. C., Foroudi, P., & Jin, Z. (2022). Visual merchandising and consumer experiential value in retail settings. Journal of Retailing and Consumer Services, 66, 102913.