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Supply Chain Integration and Sustainable Organizational Performance: Moderating Role of Blockchain Adoption

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Abstract

This research aims to investigate the impact of supply chain integration (SCI) on sustainable organizational performance (SOP). SCI includes supply chain agility (SCA), supply chain agility visibility (SCV), and supply chain agility flexibility (SCF), which examined the effect on SOP and green supply chain management (GSCM). This query also examines the moderating role of blockchain adoption (BA) on the relationship between SCI and GSCM, and the mediating role of GSCM in the relationship between SCI and SOP. A purposive sampling approach is used to collect data from 364 blockchain adopters who are also directly connected to SCI within the Bangladeshi manufacturing sector. The dataset is analyzed by the Structural Equation Model (SEM). The results revealed a substantial impact of SCA, SCV, and SCF on SOP. Additionally, GSCM plays a significant role in SCA, SCF, and SOP, whereas there is no significant effect of GSCM on SCV and SOP. In the moderation analysis, BA significantly and positively moderates the relationships among SCA, SCF, and GSCM. However, no significant effect of BA was found between SCV and GSCM. This research adds value to the existing literature on the Bangladeshi manufacturing sector by integrating SCA, SCV, and SCF, which were examined separately in previous studies.

Keywords:

Supply Chain Integration;
Sustainable Organizational Performance;
Blockchain Adoption;
Green Supply Chain Management;
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1- Introduction

In response to the growing awareness of environmental issues worldwide, Green Supply Chain Management (GSCM) has emerged as a concept that integrates environmental concerns with sustainable practices to support intra- and inter-firm management across upstream and downstream supply chains. Small and medium-sized businesses (SMEs) operating in the logistics sector are actively seeking strategies to meet sustainability targets [1] that align with the sustainable development goals (SDGs) and enhance competitive advantages [2]. Sustainable service attributes “such as faster turnaround times, higher reliability, lower operating costs, and efficient storage and delivery of items [3, 4]” can significantly enhance a firm’s competitive advantage. However, logistics service providers recognize that incorporating sustainable practices into their supply chains (SC) requires addressing challenges such as poor communication,

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transportation delays, and management of their ecological footprint [5]. At the same time, domestic businesses struggle with SC complexities, necessitating adaptable and flexible SC, even though larger enterprises are better equipped with information technology for integration [6, 7]. Given the importance of SC operations in delivering goods to final consumers, businesses must adopt a green perspective in their supply networks, leading to a sustainable supply chain (SSC) [8-11].

In this context, blockchain technology (BT) can be instrumental in leading necessary changes within SCs and businesses. The implementation of BT may assist SC by enabling cost savings, maintaining quality, and preventing fraud and falsification. Potential benefits of blockchain adoption (BA) can yield significant benefits for SSC and sustainable organizational performance (SOP) when effectively implemented. Additionally, it may strengthen SC integration and enhance the visibility and traceability of supply networks, thereby improving sustainable performance [12]. Manufacturing facilities are struggling to handle internal and external SC-related issues while seeking ways to operate profitably, socially, environmentally, and sustainably [13]. This scenario necessitates identifying gaps between Industry 4.0 (I4.0) and sustainability concerns, including information flows, risk management, data transparency and traceability, and an integrated sustainability approach [14-16].

Achieving supply chain integration (SCI) presents challenges, particularly in its ability to improve a firm's sustainability performance (SP). Growing evidence suggests that SCI may raise a firm's SP by facilitating the adoption of environmentally friendly practices in its purchasing and material management operations [17]. Effective SCI facilitates a sustained competitive advantage and improved firm performance by enhancing communication and collaboration on environmental issues [18]. Similarly, supply chain visibility (SCV) enables the surveillance of the entire SC. Sharing information is the foundation of sustainable SCV, which facilitates linking sustainability goals, such as environmental, social, and economic goals, with firm objectives. SSC prioritizes SCV to strengthen SC actors and enhance competitive edge. In addition to offering related benefits, BT may facilitate the efficient implementation of sustainable SCV. Recent studies have highlighted the linkages between SCV capacity and capabilities in firms [19, 20].

The concept of supply chain agility (SCA) is becoming increasingly significant as supply networks are viewed as units of competitiveness. The SCA incorporates both operational benefits and enhances client response and flexibility [21]. SCA enables businesses to react swiftly to unforeseen shifts in client needs, expedite the restructuring of dynamic departmental alliances, and encourage cooperation and production across businesses. As a result, it strengthens their management and boosts productivity. Additionally, agility helps deliver high-quality goods to the right customers on time [22]. Moreover, supply chain flexibility (SCF) enables supply networks to operate with minimum interruptions, even in difficult circumstances. Furthermore, it has been demonstrated that responsiveness and lead times can be improved by integrating flexible supply chain techniques with cutting-edge technologies such as real-time data analytics and the Internet of Things. Within the framework of supply chain performance (SCP), SCF expedites organizational capacity to realign operational procedures toward sustainability goals, such as carbon reductions, resource efficiency, or compliance with regulatory requirements, contributing to greater supply chain maturity [23]. Green prototypes enhance ecological performance by reducing environmental impacts and waste in companies [24-26].

Studies have indicated that sustainable supply chain performance (SSCP) and stakeholder satisfaction are greatly enhanced by sustainable operating techniques [27]. Some studies have incorporated BT into the SSCP nexus SCI and reported promising effects on firm performance [28]. The findings support dynamic capabilities theory by demonstrating that BT enhances SC efficiency and organizational resources. BT emerges as a promising enabler of sustainable supply chain practices through supply chain integration (SCI), supporting earlier research on ICT-enabled SCs. In the context of the China-Pakistan Economic Corridor, Khan et al. [27] found that BT—through features such as visibility, transparency, relationship management, and smart contracts—improves organizational performance by supporting circular economy practices. Green practices enhance environmental performance (EP), which in turn supports economic outcomes. Rahman et al. [29] illustrate how BT can enhance SCP, SCF, and SCA, and how these factors affect businesses' EP.

Bangladeshi manufacturing companies, especially the RMG sector, are now globally recognized and connected to international brands. As a result, global buyers increasingly seek transparency and traceability when procuring products from overseas. However, as Bangladesh still lags in adopting digital technologies, ensuring a proper, more accurate flow of information remains challenging. As the manufacturing sector in Bangladesh undergoes digital transformation, blockchain, when integrated with SCI, can facilitate reliable information sharing and promote green practices. As an immutable ledger, BT can enhance transparency and trust. In this context, examining the effects of SCV and GSCM provides valuable insights.

Although previous studies have shown how BTs enhance sustainability performance [2, 7, 27, 28], our study addresses several remaining gaps. Most studies have discussed that supply chain integration enhances firm performance. However, our study discussed that SCA and SFA can have different effects when blockchain adoption is considered as a moderator [30, 31]. Although the moderating effect has been suggested in prior work [32], there is no empirical evidence for it in a developing-country context, such as the RMG sector in Bangladesh. This study attempts to fill this gap. Moreover, the role of GSCM practices in accelerating SCA and SCF has not been explored in previous literature and is addressed in this study. Additionally, the mediating effect of GSCM was considered, which was not examined in previous studies among these variables. Therefore, the authors integrated SCI, GSCM, and SOP, including the moderating effect of BA in the case of manufacturing industries.

This study aims to explore the relationship between supply chain integration "namely, supply chain agility, visibility, and flexibility" and sustainable organizational performance. GSCM is considered a mediator, while blockchain adoption (BA) is considered a moderator, contributing to the existing body of literature. Drawing on the RVB theory, this study explains how BT can serve as an effective resource for integrating SC capabilities and enhancing sustainable performance. In addition, this study advances the SDGs related to climate action and responsible production and consumption by addressing environmental and energy-saving issues. The proposed framework offers a strategic model that helps manufacturing companies develop and deliver sustainable services to achieve long-term performance. Given that achieving environmental goals requires long-term, resource-intensive efforts, working with SC partners is a practical and necessary approach to achieving green, sustainable business outcomes.

The findings suggest that sustainable supply chain operations require more visible, transparent, traceable, trustworthy, and reliable data, characteristics that closely align with blockchain technology. Trust, enabled by BT features, facilitates stronger collaboration and integration with SSC. Given that BT's characteristics address key challenges in green and sustainable operations, their relevance in this context is substantial. Since green and sustainable objectives are inherently long-term, supply chain participants can benefit from establishing shared norms and guidelines that all participants should abide by to the greatest extent feasible.

2- Theoretical Background and Hypotheses Development

This study is based on the Resource-based View (RBV) Theory, which explains that firms achieve competitive advantage through resources that are irreplaceable, precious, and scarce. Wernerfelt [33] emphasized that a company's capabilities and existing resources are at the core of shaping strategic decisions, regulatory responses, and financial stability. The RBV highlights the effective distribution and use of resources, self-reliance, inimitability, and diversity of capabilities to foster competitive advantage, particularly in SC and operations management. Meanwhile, SCI, comprising features of supply chain-related ability, visibility, and flexibility, is incorporated as a set of firm-level capabilities that enhance operational efficiency. This approach is consistent with earlier research that employs the RBV to align SCM, specific technology adoption, and firm performance [34-39]. Moreover, under the RBV, BT is conceptualized as a strategic resource that links the SCA, SCV, and SCF.

To better capture the environmental and social dimensions of sustainability, this study further integrates the natural resource-based view (NRBV), which holds that organizational competitiveness is sustainable only when firms can address environmental and social constraints [40, 41]. Within our proposed framework, the different dimensions of SCI (SCA, SCV, and SCF) are considered strategic assets that optimize the logistics process, reduce waste, and lower carbon emissions, which is consistent with the NRBV's 'Pollution Prevention' principle. Additionally, BT or Blockchain adoption (BA) acts as a digital asset that ensures transparency at every step of the supply chain, thereby enhancing social sustainability and ethical business practices [31]. As noted by Elkington [42], modern corporate sustainability requires organizations to simultaneously improve economic performance, mitigate environmental harm, and contribute to societal well-being. SCM stands as a critical component in this mechanism, as most sustainability impacts from organizations take place within the whole SC, meaning from upstream throughout downstream operations [43].

The growing relevance of GSCM underscores the need to incorporate environmental factors into SC decision-making processes. Effective implementation of GSCM practices depends on SC capabilities, such as agility, visibility, and flexibility. Recent advancements in BT have the potential to increase SC capacity, enabling companies to reinforce supply chain resilience and achieve environmentally sustainable operations. The following subsection elaborates on the theoretical relationships among the proposed constructs and reviews empirical evidence supporting the theoretical framework.

2-1- Supply Chain Agility (SCA) and Sustainable Organizational Performance (SOP)

The RBV offers a sound theoretical foundation for examining how SCA contributes to SOP. From an RBV perspective [33], agility, or SCA, refers to a valuable organizational capability that enables operational excellence, reduces waste, and enhances financial growth. Similarly, SCA refers to an organization's ability to respond effectively to unplanned, uncertain disruptions through lean management at low operational costs [44]. A high degree of SCA enables companies to adapt rapidly to market changes, disruptions, and uncertainty, thereby supporting sustainability outcomes across social, environmental, and economic dimensions. Agility plays a crucial role in SCM by accelerating and facilitating operational functions through its speed, alertness, and flexibility [45, 46]. Earlier studies highlight the significance of agility, flexibility, and responsiveness in SC operations, which are essential for achieving swift, effective supply chain performance [47].

In the context of Industry 4.0, agile SCs are increasingly important for swift market responses and sustainable product needs, while ensuring efficient crisis management and resource efficiency. These capabilities collectively advance SOP, including environmental protection, social responsibility, and financial performance [14]. Recent studies have supported the positive relationship between SC responsiveness and achieving sustainability targets. In highly industrialized and dynamic setups, SCA and responsiveness are no longer optional but mandatory for improving operational efficiency and firm competitiveness [48]. For instance, Faisal [49] demonstrated a positive nexus between SCA and sustainable performance. At the same time, other studies point out that organizational performance is strengthened when sustainability practices are supported by responsiveness and SCA [50].

Building on this body of literature, this study examines the direct relationship between SC responsiveness and sustainability in the Bangladeshi manufacturing sector, which faces unique structural and operational challenges within its SCM [51]. Therefore, this study proposes the following hypothesis:

H1: *SCA significantly and positively influences the SOP.*

2-2- Supply Chain Visibility (SCV) and Sustainable Organizational Performance (SOP)

SCV refers to the capability to evaluate, monitor, and obtain real-time SC information [52]. From a strategic and organizational perspective, SCV strengthens the abilities of forms to improve decision-making, manage risk effectively, and align operational activities with sustainable targets. Accordingly, SCV is positively associated with SOP. Earlier evidence supports that SCV influences the performance of commercial and state-owned corporations by improving coordination across the SC, accountability, and operational control [53]. Enhanced visibility facilitates compliance with sustainable standards and regulations by enabling access to better information, empowering firms to identify risks, improve decision-making, and mitigate potential environmental challenges [54].

Transparency across the SC further strengthens trust and relationships with external stakeholders, including suppliers, distributors, and buyers, increasing collaboration and shared responsibility for sustainable targets. Consistent with this, Day et al. [55] argue that SCV plays a significant role in improving social and EP outcomes. Moreover, Khan et al. [56] underscore that effective information exchange, facilitated by high levels of SCV, strengthens the connection between SCV, effectiveness, and operational excellence, thereby supporting the achievement of sustainability practices. SCV enables firms to identify inefficiencies in the business process, reduce waste, and ensure responsible sourcing, thereby contributing to SOP. Consequently, the following hypothesis is proposed:

H2: *SCV significantly and positively influences SOP.*

2-3- Supply Chain Flexibility (SCF) And Sustainable Organizational Performance (SOP)

This study proposes SCF, defined as the ability to respond to variations in product mix, volume, and delivery [57], leading to improved SOP. A flexible SC enhances SOP by enabling adjustments towards sustainable production, minimizing waste through lean management, and sustaining access to sustainable materials [58]. Recent findings demonstrate that SCF is a significant determinant of sustainable performance in an interconnected and dynamic operational environment [23, 59]. This study evaluates how organizational flexibility in manufacturing affects environmental and economic performance within the socio-technical operational paradigm. Prior work, notably Khan et al. [60], provides a core understanding of operational flexibility and excellence, along with their organizational advantages in dynamic contexts. Thus, this study developed the following hypothesis:

H3: *SCF significantly and positively influences SOP.*

2-4- The Mediating Role of Green Supply Chain Management (GSCM)

Emerging awareness of societal and environmental issues, along with increasingly stringent environmental regulations and stakeholder pressure to adopt sustainable practices, can drive organizations to accelerate and strengthen GSCM practices [61]. This study further proposes that GSCM mediates the relationship between SCA, SCV, and SCF (as dimensions of SCI) and SOP performance. The positive effects of SCA, SCV, and SCF are expected to be realized through the implementation of GSCM practices, as prior theoretical research suggests [62]. An agile SC enhances green sourcing through improved operational functions, whereas SCV enables more effective monitoring of green practices, and flexibility allows easier adaptation to green product designs. By providing the necessary technological infrastructure, high levels of blockchain integration facilitate effective GSCM. Prior research highlights that operational attributes, such as flexibility, visibility, and agility, are critical for effective GSCM implementation, while adequate technological infrastructure plays an enabling role in executing these practices

This study specifically examines GSCM mediation in Bangladeshi manufacturing and the effects of BA on this mediation, thus providing new perspectives on these elements within developing economies. SCI is most effective in GSCM when transparent and reliable technologies, such as blockchain, exist [63]. Blockchain can potentially act as a 'Boundary Condition, amplifying the positive relationship between SCI and GSCM. Because BT adoption does not initiate GSCM but rather accelerates existing capabilities, it makes more theoretical sense to model it as a moderator rather than a mediator [64, 65].

The present hypothesis posits that SCA strengthens SOP by using GSCM as a mediating mechanism. This GSCM pathway becomes more effective at higher levels of BA. Agile SCs portray better adoption of environmentally and socially responsible practices in GSCM due to their high responsiveness. Implementing GSCM practices enables organizations to enhance their SOPs. Blockchain efficiency and transparency in tracking green SCM initiatives strengthen the implementation of GSCM and, consequently, enhance agility through lean SC technologies and business intelligence reporting [66]. Recent research has shown that agility enables green practices, which, in turn, promote sustainability [67]. This study seeks to establish how GSCM provides a broader understanding of mediation mechanisms. Prior findings demonstrate that BT implementation strengthens the relationship between agility and GSCM and that both external and internal GSCM measures contribute to cost reduction across sectors [68]. Thus, this study posits the following hypothesis:

H4: *GSCM mediates the association between SCA and SOP in organizations with higher BA levels.*

SCV creates a significant and positive effect on SOP through GSCM, with a stronger effect when BA is higher and increasing [69]. To achieve better SCV, organizations are supported by BT, which promotes their ability to monitor, detect, and control the environmental and social impacts of their operations through GSCM practices, thereby enhancing SOP [54]. By deploying and establishing higher levels of BT adoption, a clear, seamless, and unalterable SC transaction database is created, thereby enhancing the visibility of GSCM initiatives [70]. Transparency systems enable organizations to implement socially and environmentally friendly practices that enhance sustainability, an area of growing research interest [71]. This study provides evidence that expands understanding of how information flow mechanisms contribute to performance improvements in green initiatives. This study posits that BT strengthens the effect of visibility on GSCM practices, with BA acting as a conditional factor in the mediation pathway linking transparency to sustainable green practices. Accordingly, the following hypothesis is proposed.

H5: *GSCM positively and significantly mediates the association between SCV and SOP in organizations with higher levels of BA.*

This study demonstrates that SOP is positively and significantly correlated with SCF when GSCM serves as a mediator, and that BA strengthens the mediating effect of GSCM. Sutduean et al. [72] found that flexible SC exhibit greater capacity to adopt green practices, which, in turn, support improvements in SOP. GSCM practices facilitated by SCF eventually lead to better SOP [73]. The flexible and adaptive nature of BT enables advanced contracting, analysis of intelligence reports, tracking, and management of green initiatives, thereby enhancing GSCM implementation through capabilities based on flexibility [27]. Recent studies also indicate that adaptable organizations are more effective in executing green practices to improve sustainability outcomes [74]. This research adds to the literature by clarifying how GSCM performs its mediating functions across broader contexts. Existing evidence further links BA to greater flexibility in GSCM implementation [75]. Accordingly, this study examines this mediation pathway in Bangladeshi manufacturing industries and assesses how BA conditions the transformation of flexibility into environmental sustainability. Consequently, this study posits the following hypothesis:

H6: *GSCM positively mediates the association between SCF and SOP for organizations with higher levels of BA.*

2-5- The Moderating Role of Blockchain Adoption (BA)

BA can be driven by institutional pressures, such as authoritative requirements for transparency and traceability, as well as industry trends aimed at adopting best practices to achieve legitimacy and sustainability among stakeholders (customers, suppliers, investors, etc.) [76]. Blockchain deployment influences the relationship between SCA, SCV, SCF, and GSCM implementation, and it also affects SOP through the adoption of cutting-edge technologies, information immutability, transparency, and smart contracts [77]. The proposed model predicts that higher levels of BA support the adoption of sustainable practices, thereby strengthening the positive linkages among SCA, SCV, SCF, and GSCM implementation and effectiveness, particularly as natural resource scarcity intensifies across industries [2]. To execute and monitor green initiatives more effectively, the transparency and agility of blockchain enable SCs to operate with immutable, transparent, and seamless processes [78]. Recent studies indicate that such relationships are moderated by technology in similar settings. BT's capacity is further demonstrated by its ability to promote and enhance environmentally and socially responsible SC operations. This study offers insights into how technology amplifies the impact of SC capabilities.

This study specifically contributes by explaining how BA acts as a moderator between SCI dimensions and GSCM in the Bangladeshi manufacturing context, and by highlighting the enabling capabilities of emerging technology in green SCM. Organizations adopting blockchain at higher levels are expected to exhibit a stronger positive connection between SCA and GSCM [78]. The nature of an agile SC supports such outcomes, as it provides advantages in executing new procedures, including green initiatives [2]. Traceability, real-time data visibility, and enhanced coordination are facilitated by BT's operational capabilities, which strengthen GSCM implementation and improve transparency and monitoring [36]. Thus, agile SCs reinforce the management and implementation of GSCM policies and practices to achieve sustainability. BT further enables tracking of environmental changes in production and rapid verification of checks through its verification systems [29]. Recent studies present evidence of the role of technology in increasing the effectiveness of agile SC practices in GSCM. This study examines the association between blockchain implementation and its influence on agility measures, as well as its direct contribution to GSCM by mitigating weaknesses in SC functions [79]. A wider research agenda is needed to establish a stronger theoretical foundation for explaining how technology enhances the linkages between SC characteristics and management practices.

This study contributes to the understanding of how BT strengthens agile SCs in implementing green practices in developing economies [80]. This is because BT serves as a technological infrastructure that enhances SC productivity. According to Contingency Theory, the effect of one variable depends on situational conditions. SCI is most effective in GSCM when transparent and reliable technologies, such as blockchain, are present [81]. Therefore, this study proposes the following hypothesis:

H7: *BA positively moderates the relationship between SCA and GSCM.*

A higher level of BA across organizations will strengthen the positive relationship between SCV and GSCM outcomes. SCV information influences the monitoring and management of environmental and social performance requirements in both public and private organizations [82]. The implementation of BT creates an unalterable, seamless SC documentation system that enhances organizational visibility across operations, thereby improving GSCM tracking and implementation [83]. BT also enables the verification of sustainability information related to materials and their origins, from the point where visibility initiatives commence to final destination points [54]. Recent research highlights the need to empirically validate how technology applications increase visibility measurements for SSC [84]. Some studies indicate that BT is directly associated with increased visibility and improvements in GSCM practices [85]. This study investigates BA as a moderating factor that strengthens and enhances transparency-driven visible SCs' adoption of green supply management practices in emerging countries, such as Bangladesh's manufacturing sector [86]. A wider examination of this topic would establish stronger theoretical foundations explaining how technology affects the relationship between visibility and green outcomes [87]. Consequently, this study proposes the following hypothesis:

H8: *BA positively moderates the relationship between SCV and GSCM.*

The association between SCF and GSCM is stronger among firms that use BT to a greater degree across organizations [88]. Firms with agile, flexible, and immutable SCs can more easily adapt to changing products and processes required by sustainability initiatives, thereby supporting zero-carbon emissions goals [89]. Organizations that adopt BT gain a secure, adaptable information management system across dynamic SCs, thereby strengthening their ability to perform GSCM activities [90]. This technological platform enables sustainable material tracking across varying customer demands using BT. Recent scholarly studies by Long et al. [78] provide quantitative results illustrating how technology strengthens the influence of flexibility on SSC methods. The analysed evidence shows that BA produces direct positive outcomes between improved flexibility and more effective GSCM operations. Such a comprehensive inquiry helps establish theoretical insights into how technology enhances flexibility to achieve environmentally sustainable outcomes in this cutting-edge era. This study examines BA as a moderating factor in the SCF-GSCM relationship in the Bangladeshi manufacturing sector, demonstrating how this technology enhances the implementation and sustainability of green practices for adaptable SCs. Thus, this study proposes the following hypothesis:

H9: *BA positively and significantly moderates the relationship between SCF and GSCM.*

3- Methodology

3-1- Research Measures

The study used variable measurement items from existing research that had undergone validity and reliability assessments. A 5-point Likert scale was proposed for questionnaire development. BA is one of the variables sourced from Wang et al. [91] and serves as a moderating variable in this study. SCI comprises three dimensions: SCV, SCA, and SCF, which are also SOP and GSCM predictors [91, 92]. GSCM plays a significant role as a mediator [93, 94]. SOP was the final dependent variable in this study [91, 95]. Each factor item has a unique and different value. All variables are shown in the framework (see Figure 1).

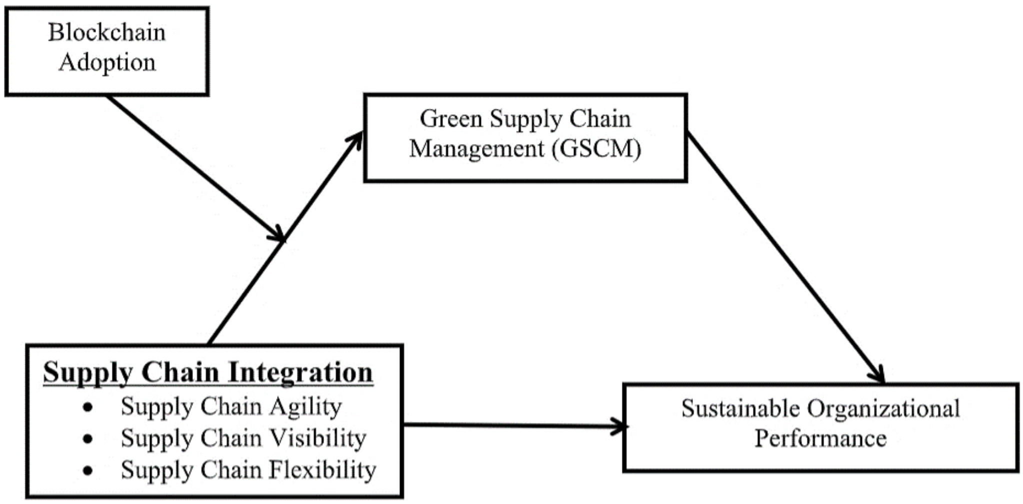

Figure 1. Research model

3-2- Sampling Method and Data Collection

A considerable number of manufacturing businesses operate in Bangladesh, and some have implemented BT in their SC systems. A purposive sampling technique, a nonprobability sampling method, was used to select participants for this study. This approach was appropriate because BT adoption among manufacturing companies in Bangladesh remains limited due to several SC-related constraints. Accordingly, the researchers consulted executives from leading manufacturing companies to identify which departments are involved in SC activities and actively leverage BT, ensuring the collection of accurate and relevant data. Based on this process, six departments were selected: R&D, production, marketing, HRM, information technology, and procurement. In addition, an "other" category was included to capture blockchain adopters involved in SCM beyond these departments, ensuring comprehensive coverage.

Data were collected using online and offline methods. For the online phase, research assistants contacted managers, executives, and directors in January 2025 via social media such as LinkedIn and email to ask whether their companies had adopted BT. After obtaining affirmative responses, the authors sent a questionnaire to the respondents for completion and provided support when queries arose during the process. As a result, approximately 120 respondents completed the form. Siddiqui [96] suggested that a minimum sample size of 300 is required to conduct SEM analysis. Therefore, a second data collection phase was conducted offline through in-person surveys. Two research assistants, based in Dhaka and Chittagong, were hired to collect accurate, relevant data. Before data collection, the assistants participated in a briefing session to clarify procedures and address potential questions. They commenced field visits during February and March and collected responses from 260 respondents by the end of March. However, 16 incomplete responses were excluded. Consequently, a total of 364 valid responses were used for data analysis.

3-3- Common Method Bias

A single-factor test by Harman was administered to assess Common Method Bias, following Malhotra et al. [97]. This analysis confirmed that a single factor accounted for 39.355% of the total variance, which is below the 50% threshold, indicating that common method bias is unlikely to be a significant concern [98].

4- Results

4-1- Data Analysis and Hypothesis Testing

The complete collinearity test developed by Kock [99] was used to evaluate common method bias. The variation inflation factor (VIF) cutoff value for each connection should be below 3.30 [99]. As shown in Table 1, all VIF values for both vertical and lateral relationships in the structural model are below 3.30, indicating that common method bias is not a concern. The data were also assessed for multicollinearity. A correlation coefficient exceeding 0.80 between independent variables indicates a serious multicollinearity issue [100]. However, all correlation values are below the suggested level, indicating that multicollinearity is not present.

Table 1. Variation Inflation

Construct	BA	GSCM	SCA	SCF	SCV	SOP
Blockchain Adoption (BA)		2.42				
Green Supply Chain Management (GSCM)						1.00
Supply Chain Agility (SCA)		2.69				
Supply Chain Flexibility (SCF)		2.90				
Supply Chain Visibility (SCV)		2.66				
Sustainable Organizational Performance (SOP)						

4-2- Profile of Respondents

Table 2 presents the respondents' demographic information. Most respondents were male (76.10%). 36.54% of the participants were aged 35–44 years. Almost 46.15% of respondents had less than 5 years of work experience, and 24.45% worked in procurement. The highest percentage of employees work in lower-level management, and they can test the BT. Most of the respondents were from the middle and junior-level management for two reasons: easy access to collect information and greater adherence to delivering quality performance.

Table 2. Demographic Profile of Respondents

	Frequency	Percent
Gender		
Male	277	76.10
Female	87	23.90
Age		
25-34 years old	89	24.45
35-44 years old	133	36.54
45-54 years old	103	28.30
55 and above	39	10.71
Work Experience		
Less than 5 years	168	46.15
6 to 10 years	142	39.01
Above 10 years	54	14.84
Job Position		
Junior Management	137	37.64
Middle Management	113	31.04
Senior Management	69	18.96
Other	45	12.36
Job Scope		
R & D	61	16.76
Production	13	3.57
Marketing	18	4.95
Human Resource	64	17.58
Information Technology	88	24.18
Procurement	89	24.45
Other	31	8.52
Present Level of Blockchain Technology Understanding		
Learning the Technology	106	29.12
Testing the Technology	188	51.65
Implementing the Technology	70	19.23

4-3- Descriptive Statistics of Variables

The study's descriptive analysis, shown in Table 3, involved analyzing several statistical measures related to the latent variables, including the mean and standard deviation. SOP had the highest mean value, 3.91, and the lowest standard deviation, 0.91. With a standard value of 1.11, SCV had the lowest mean score (3.53) of all the constructions, with a standard deviation of 1.11. Additionally, all the mean values ranged from 3.55 to 3.90.

Table 3. Descriptive Statistics

	N	Mean	Standard deviation
Blockchain Adoption (BA)	364	3.58	1.07
Supply Chain Visibility (SCV)	364	3.53	1.11
Supply Chain Agility (SCA)	364	3.74	1.00
Supply Chain Flexibility (SCF)	364	3.74	1.01
Green Supply Chain Management (GSCM)	364	3.85	0.87
Sustainable Organizational Performance (SOP)	364	3.91	0.91
Valid N (listwise)	364		

4-4- Testing of Hypothesis using Partial Least Squares (PLS-SEM)

PLS-SEM analysis was performed in two phases. According to Hair et al. [101], PLS-SEM uses independent ordinary least squares regression to examine the connection between the measurement and structural models. SmartPLS 4 (version 4.0.9.2) was used in this study.

4-4-1- Assessing Measurement Model

The measurement model was assessed by conducting reliability and validity tests. Hair et al. [102] suggested four aspects of each model construct for assessing the reflective measurement model. They are the size and significance of indicator loadings, construct reliability, convergent validity, and discriminant validity.

I. Internal Consistency and Convergent Validity

Cronbach's alpha (CA) measures internal consistency, rho_a and rho_c measure composite reliability, and average variance extracted (AVE) and outer loadings assess convergent validity. The dependability of a group of indicators is measured by CA and composite reliability (CR) in Table 4. According to Hair et al. [101], a CA and CR value of 0.70 is acceptable, but a higher threshold of 0.8 or 0.9 is preferable. Items SCF4 and SCF5 were excluded from the research due to their low outer loadings. All item codes were renamed accordingly. The CA and CR values for each construct in Table 5 exceed the suggested values, indicating strong internal consistency.

Table 4. Test of Internal Consistency and Convergent Validity

Constructs	Items	Outer Loadings	Cronbach Alpha (CA)	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Blockchain Adoption (BA)	BA1	0.91	0.95	0.95	0.95	0.82
	BA2	0.91				
	BA3	0.90				
	BA4	0.93				
	BA5	0.89				
Supply Chain Agility (SCA)	SCA1	0.86	0.92	0.93	0.94	0.77
	SCA2	0.91				
	SCA3	0.90				
	SCA4	0.82				
	SCA5	0.89				
Supply Chain Flexibility (SCF)	SCF1	0.88	0.88	0.89	0.93	0.81
	SCF2	0.92				
	SCF3	0.91				
Supply Chain Visibility (SCV)	SCV1	0.91	0.94	0.94	0.95	0.81
	SCV2	0.93				
	SCV3	0.90				
	SCV4	0.85				
	SCV5	0.90				
Green Supply Chain Management (GSCM)	GSCM1	0.82	0.89	0.89	0.92	0.69
	GSCM2	0.85				
	GSCM3	0.82				
	GSCM4	0.85				
	GSCM5	0.82				
Sustainable Organizational Performance (SOP)	SOP1	0.85	0.88	0.90	0.91	0.67
	SOP2	0.76				
	SOP3	0.84				
	SOP4	0.82				
	SOP5	0.82				

Table 5. Results of HTMT

	BA	GSCM	SCA	SCF	SCV	SOP
Blockchain Adoption (BA)						
Green Supply Chain Management (GSCM)	0.44					
Supply Chain Agility (SCA)	0.82	0.60				
Supply Chain Flexibility (SCF)	0.78	0.63	0.77			
Supply Chain Visibility (SCV)	0.81	0.46	0.75	0.73		
Sustainable Organizational Performance (SOP)	0.16	0.29	0.20	0.23	0.12	

Convergent validity was assessed using the AVE and outer loadings. According to Hair et al. [101], loading values should be greater than 0.70, indicating that the variables account for over 50% of the indicator's variation and resulting in adequate item dependability. Every item in the outside loadings is more than 0.70, as shown in Table 4. To verify convergent validity, Ringle et al. [103] recommended that all AVE values be higher than the permissible cutoff of 0.50. The AVE values in Table 4 are greater than 0.50 and range from 0.67 to 0.82. Thus, there is no problem with the convergent validity. According to Figure 2, all outer loading values support the study's validity.

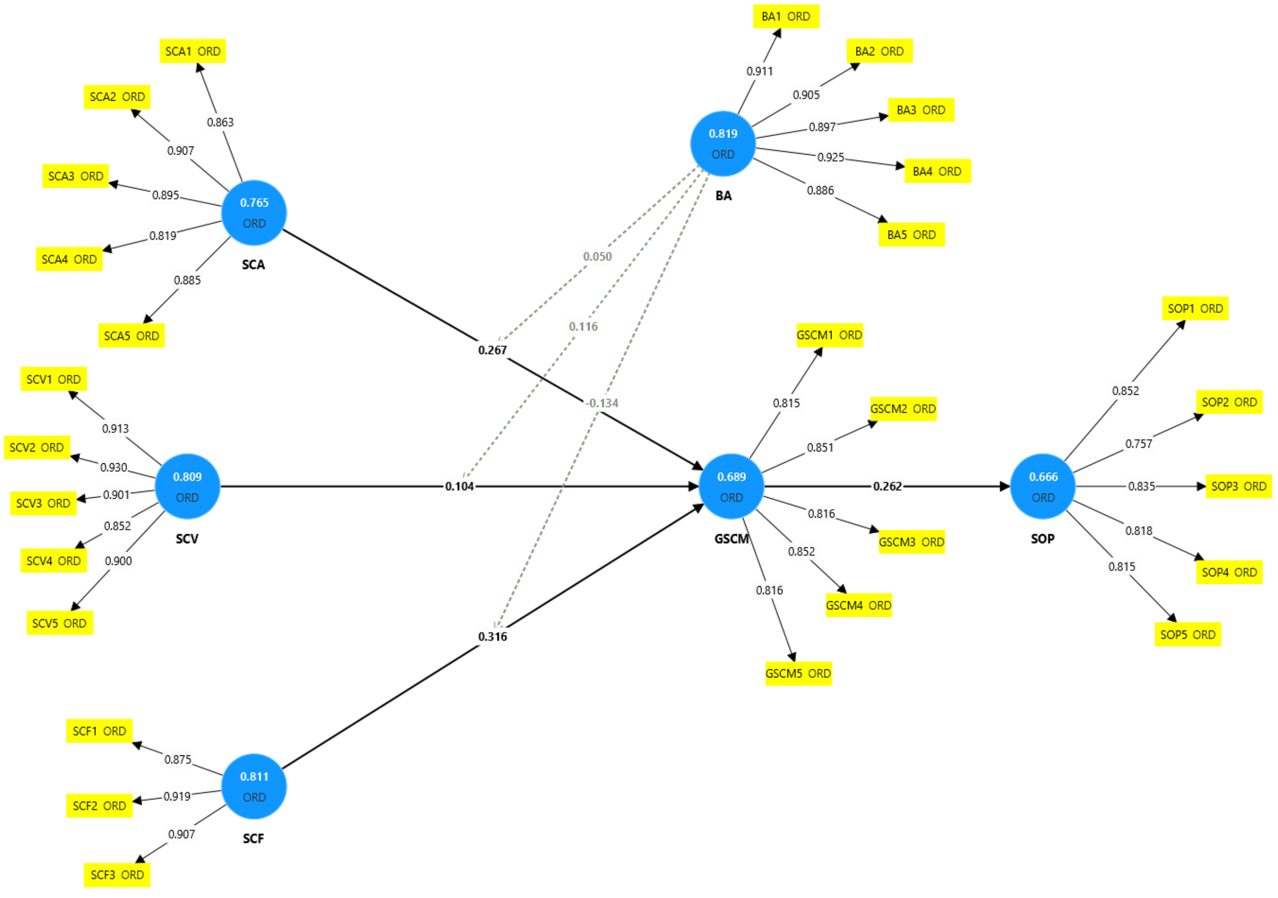

Figure 2. Measurement Model of The Framework

II. Discriminant Validity

Assessing discriminant validity is the final phase of the reflective measurement approach. Discriminant validity refers to the degree to which a construct is empirically different from other components in the structural model [101]. The "Heterotrait-Monotrait ratio (HTMT)" was used to evaluate discriminant validity (Table 5). According to Hair et al. [101], the HTMT value should be below 0.90. All the numbers from the HTMT findings were below 0.90, suggesting that discriminant validity is not a problem.

4-5- Coefficient of Determination (R^2)

R^2 is used to measure the predictive accuracy. R^2 also illustrates the relationship between exogenous and endogenous variables. According to Hair et al. [101], R^2 has a value between 0 and 1, where 0 denotes no association, and 1 denotes a perfect one. When the R^2 A value of 0.26 indicates significant predictive accuracy; 0.13 indicates moderate, and 0.02 indicates weak [104]. The endogenous variable R^2 value in Table 6 is more than 0.26, indicating a significant level of predictive accuracy for the model

Table 6. **Results of Coefficient of Determination (R^2)**

	R-square	R-square adjusted
Sustainable Organizational Performance (SOP)	0.34	0.33

4-6- Importance-Performance Map Analysis (IPMA)

According to Ringle et al. [105], conventional PLS-SEM analyses provide information on the relative relevance of components in explaining other constructs within structural models. The authors further propose that importance-performance map analysis (IPMA), which considers each construct's performance, broadens the scope of PLS-SEM results. Accordingly, decisions can be made at two levels, namely performance and importance. Table 7 indicates that GSCM is important for explaining the target construct, SOP. To be more precise, SOP performance increases with the overall effect of GSCM, with a value of 71.37 per unit increase in GSCM performance. The element at the core of this construct is particularly relevant for management activities because of the relatively high value of GSCM, followed by SC flexibility (see SCF) and agility (see SCA). In contrast, SC visibility (see SCV) shows comparatively lower performance, indicating substantial room for improvement. The importance-performance analysis of the constructs and indicators is shown in Figures 3 and 4.

Table 7. **IPMA Results from the Full Data Set**

Sustainable Organizational Performance (SOP)		
Latent Variable	**Total Effect (Importance)**	**Index Value (Performance)**
Blockchain Adoption (BA)	-0.02	64.70
Supply Chain Agility (SCA)	0.07	68.45
Supply Chain Flexibility (SCF)	0.08	68.59
Green Supply Chain Management (GSCM)	0.26	71.37
Supply Chain Visibility (SCV)	0.03	63.34

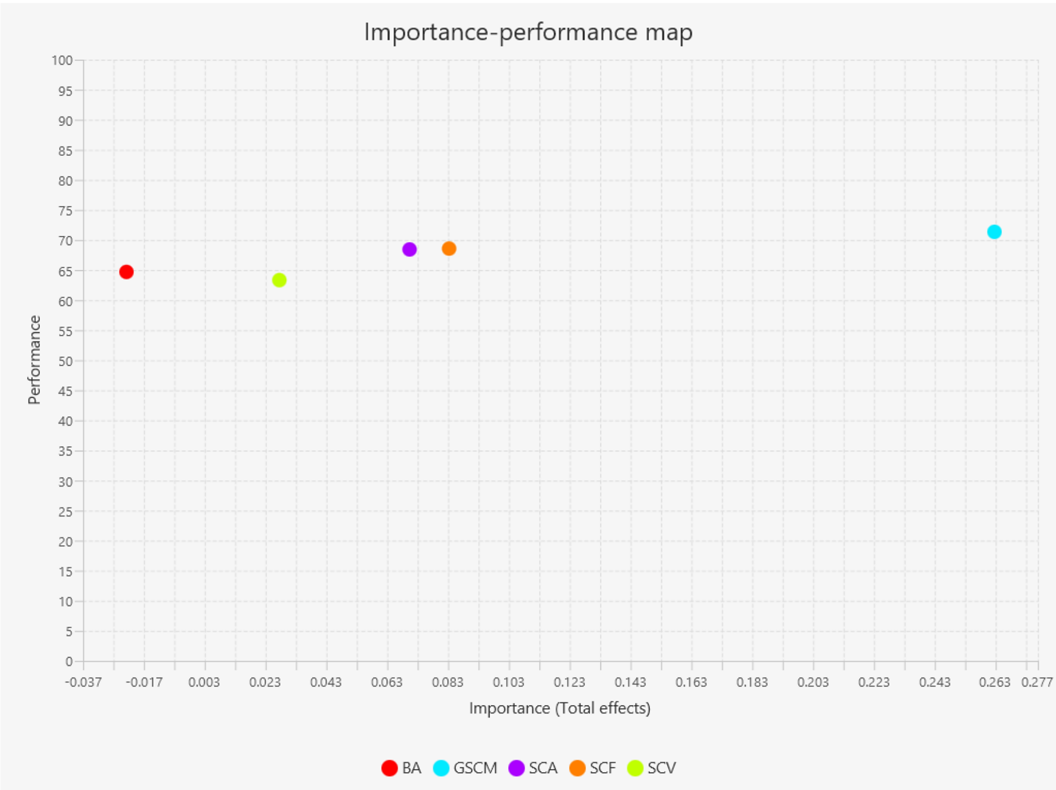

Figure 3. **Importance-Performance Map (Construct)**

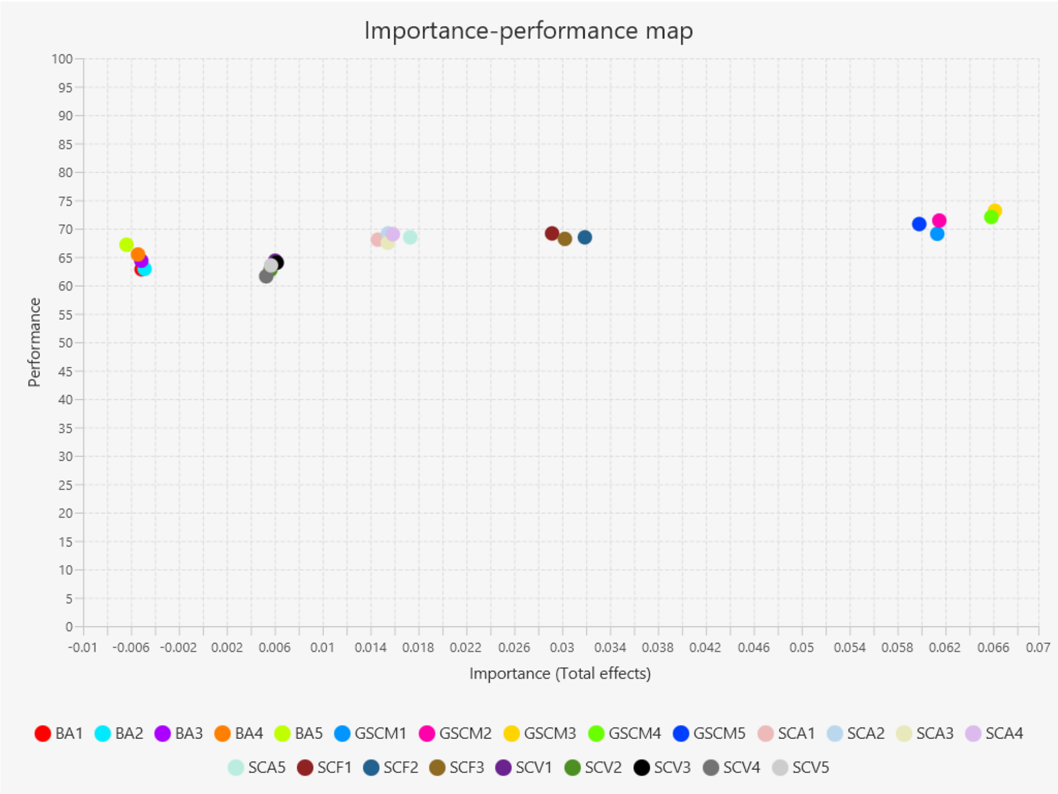

Figure 4. Importance-Performance Map (Indicator)

4-7- Path Coefficient (Hypothesis Testing)

Bootstrapping approaches were used to estimate the construct's path coefficient. The path coefficient values ranged from -1 to +1. Higher absolute numbers indicate a stronger predictive link between the components. According to Hair et al. [106], the p-value is less than 0.05, and the significance value for the T-statistic is 1.96 for two-tailed tests. Tables 8 to 10 show that the t-values of the hypotheses (H5 and H8) are less than the threshold value (p-value > 0.05). Therefore, these hypotheses were rejected. In contrast, the p-values for the other hypotheses were less than 0.05. Therefore, all other hypotheses were accepted.

Table 8. Results of Path Coefficient (Direct Effect)

Hypothesis	Path	Original sample (O)	Sample mean (M)	Standard deviation	T statistics	P values	Decision
H_1	SCA → SOP	0.15	0.15	0.06	2.74	0.01	Supported
H_2	SCV → SOP	0.16	0.16	0.05	2.76	0.01	Supported
H_3	SCF → SOP	0.21	0.21	0.10	2.08	0.04	Supported

Table 9. Result of The Mediation Analysis

Hypothesis	Path	Original sample (O)	Sample mean (M)	Standard deviation	T Statistics	P values	Decision
H_4	SCA → GSCM → SOP	0.09	0.10	0.05	2.15	0.04	Supported
H_5	SCV → GSCM → SOP	0.03	0.03	0.02	1.31	0.19	Not Supported
H_6	SCF → GSCM → SOP	0.08	0.09	0.04	2.27	0.02	Supported

Table 10. Results of Moderation Analysis

Hypothesis	Path	Original sample (O)	Sample mean (M)	Standard deviation	T Statistics	P values	Decision
H_7	BA × SCA → GSCM	0.27	0.28	0.13	2.10	0.04	Supported
H_8	BA × SCV → GSCM	0.10	0.10	0.08	1.38	0.17	Not Supported
H_9	BA × SCF → GSCM	0.32	0.32	0.11	2.83	0.01	Supported

5- Discussion

This study examines how SCI is associated with SOP via GSCM as a mediator, with BA as a moderator. This study investigated the pathways through which SCA, SCV, and SCF affect SOP, thereby enriching the existing scholarly work [67]. Similarly, incorporating GSCM as a mediator and BA as a moderator adds substantial value to current scholarly research [77]. Drawing on the RVB theory, this study demonstrates how blockchain functions as an effective resource for integrating SC capabilities. Furthermore, the research advances the SDGs related to climate action, responsible production, and responsible consumption by implementing environmental and energy-saving interventions.

This study demonstrates that SCA is positively associated with SOP. Higher levels of SCA in a manufacturing organization are associated with higher reported performance [50]. Similarly, SCV is strongly associated with higher SOP, suggesting that greater SC visibility is linked to higher SOP [54]. Nazempour et al. [47] highlighted the importance of agility, flexibility, and reactivity in SC operations for achieving quick operational activities. In the context of Industry 4.0, SC are associated with quicker market responses, supported by flexibility and responsiveness to sustainable product requirements, as well as effective crisis management and resource efficiency, which together are linked to various dimensions of SOP. Faisal [49] demonstrated a positive correlation between SCA and sustainability performance. Evidence from prior studies also suggests that sustainability-related practices, supported by responsiveness, are associated with improved organizational performance [50].

SCF is also positively associated with SOP, as organizations operate in environments of uncertainty and frequent changes in industry conditions [85]. Recent studies indicate that SCF plays a major role in shaping sustainable performance within a complex, dynamic, and interrelated operational environment [23]. Earlier work by Khan et al. [2] offers a fundamental grasp of operational excellence and flexibility, highlighting their organizational benefits in contexts characterized by dynamic objectives. Sustainability-related practices, supported by organizational responsiveness, are associated with improved organizational performance, aligning with earlier studies [50].

These results also support a positive association between SCV and SOP, consistent with previous studies. Day et al. (55) highlight the importance of SCV for improving social and EP outcomes. Earlier work by Khan et al. [27] further suggests that effective information exchange among SCV, operational effectiveness, and operational excellence provides a foundation for the adoption of sustainable practices.

Linking individual SCI dimensions to SOP through GSCM plays a significant role in the industrial context. Higher levels of GSCM implementation are associated with a stronger mediating effect of SCA on SOP, indicating that companies that adopt GSCM capabilities tend to exhibit a stronger association in the SCA-SOP nexus [68, 71]. In addition, GSCM indicates a stronger association between SCF and SOP [72, 107], suggesting that companies are more likely to attain higher levels of SCF and SOP when GSCM practices are well established.

In this study, GSCM does not mediate the nexus between SCV and SOP, which may be attributed to certain contextual limitations. While traceability, real-time tracking, and other GSCM technologies enhance SCV, they may also entail higher costs, greater operational complexity, and longer time requirements. In contexts such as Bangladesh, achieving these capabilities may require longer adjustment periods. Nevertheless, previous studies by Mustafi et al. [69] and Karmaker et al. [70] demonstrate strong mediation effects of SCV and SOP in the industry.

Blockchain implementation strengthens the association between SCA and SCF as relation to GSCM but does not support a moderating effect between SCV and GSCM. High adoption levels of BT play a moderating role in the nexus between SCA and GSCM. Prior studies suggest that quick responses and green management of SC practices can be attained through the adoption of BT [29] Similarly, adaptability to BT adoption plays a moderating role in the relationship between SCF and GSCM. Organizations that adopt BT tend to be better positioned to respond to disruptions, uncertainties, and system changes, which are associated with stronger GSCM practices, reduced waste, and improved economic performance [84, 86, 87].

In contrast, the moderating role of BA does not appear significant in the relationship between SCV and GSCM in this study, consistent with the absence of a mediating effect in this pathway. Nevertheless, previous studies by Mothafar et al. [89], Hu et al. [90], and Long et al. [78] show a significant role of BT adoption in the relationship between SCV and SOP. Overall, the empirical findings confirm several of the proposed relationships among the investigated variables.

5-1- Theoretical Implications

This study adds to academic understanding by drawing on the RBV, which posits BT as a valuable organizational resource that supports SCI and is associated with SOP. With this perspective, organizations develop capabilities by combining existing resources to enhance governance mechanisms and secure financial stability. SC and operation management benefit from the RBV framework, which emphasizes resource distribution, firm-specific capabilities, effective resource utilization, and the development of unique and diverse competencies that help achieve competitive advantages. Accordingly, this study treats BT as a strategic resource consistent with RBV principles.

Operational efficiency is associated with the incorporation of SCI functions, which include SCV and SCF [34–39]. SOP is linked to the alignment of strategic resources and capabilities. As articulated by Barney [108], RBV posits that competitive advantage arises from resources that are valuable, rare, inimitable, and non-substitutable. This study extends the knowledge of sustainable SCM by exploring GSCM as a mediating element linking SCI to SOP [66]. The findings further suggest that the progress towards the SDGs is closely associated with the implementation of GSCM practices.

This study shows how GSCM serves as a mediator between SCA, SCV, and SCF, thereby enhancing the development of SOP, with positive associations observed between SCA and SCF and between SCV and SCF through GSCM practices. Previous research similarly identifies GSCM as a critical factor in obtaining sustainable outcomes [109, 110]. Although the mediating role of GSCM between SCV and SOP is not statistically significant, GSCM practices appear to contribute to sustainable performance outcomes independently of visibility.

This study also contributes to the BT literature by examining how blockchain influences the relationship between SCI and GSCM. The results indicate that BA is linked to stronger GSCM practice capabilities. In particular, the results highlight the association between blockchain applications and the agility-GSCM relationship and illustrate how internal and external GSCM practices are related to cost reductions across sectors. These findings align with prior studies reporting that BT is associated with improved SC efficiency, as reported by Kshetri [111] and Saberi et al. [31].

Finally, this research addresses a gap in the literature by focusing on BT implementation in the manufacturing SC industry within a developing-country context. Empirical studies on the use of BT in manufacturing SCs in developing countries remain limited. Thus, this study incorporates BT adoption as an additional explanatory factor in the relationship among SCA, SCV, SCF, and GSCM, an aspect largely absent from prior research [56]. Moreover, this study explores the mediating role of GSCM, which has not been examined in previous studies.

5-2- Managerial Implications

For Managers, Firms and Industry

Based on the study findings, SCI functions as a strong tool for organizations to improve SOPs. Managers are encouraged to strengthen SCA, SCV, and SCF to address sustainability targets and competitive challenges better. GSCM plays a central enabling role in linking SCI and SOP; therefore, managers should actively implement GSCM practices to boost economic, social, and environmental performance. Across organizational units, business leaders may consider forming agile response groups to address sustainability challenges and operational disruptions better. Executives should also revisit procurement policies to prioritize suppliers that demonstrate strong sustainability commitments. In this context, onboarding and supplier development initiatives are important to ensure suppliers align with GSCM practices and broader SCI goals.

To enhance transparency, streamline operations, and mitigate environmental issues, managers may focus on improving digital supply chain documentation and information systems. The development of an effective governance framework is crucial to support both sustainability initiatives and technological adoption. Organizations can further strengthen these efforts by initiating dedicated transformation groups to integrate BT with SSC efforts. Managers are encouraged to develop continuous feedback mechanisms with key stakeholders to support effective implementation. Aligning BT and GSCM with key performance indicators (KPIs) with departmental or unit-level objectives can ensure accountability, coordination, and consistent execution across the organization.

For Civil Society

Organizations increasingly require sustainability-focused operations, as stakeholders expect companies to follow sustainable business standards in the current era. SC sustainability operations are better managed when organizations understand that effective decision-making depends on complete visibility, transparency, and traceability, supported by reliable, trustworthy data. BT embodies these attributes and facilitates better integration within the SSC by fostering trust among stakeholders.

The research outcomes show that businesses deploying BT are better positioned to strengthen the implementation of GSCM practices. Managers should be encouraged to consider BT as an enabling mechanism that enhances SCV, builds trust-based relationships among SC actors, and supports more effective and streamlined GSCM implementation. BT's problem-solving capabilities further enable organizations to address multiple issues related to green and sustainable development operations, underscoring its relevance in this domain. From a societal perspective, these developments create opportunities to simultaneously support financial growth, expand sustainability practices, and minimize environmental degradation.

For Government

The government and policymakers in Bangladesh should consider developing a national framework for blockchain technology. Manufacturing companies that adopt GSCM practices could be supported through policy instruments such as tax incentives or soft loans. In addition, increased investment in digital infrastructure is essential to enable SMEs to integrate more effectively into SC and participate in sustainability-driven initiatives.

6- Conclusion

This study aimed to investigate the relationship between SCI and SOP. SCI was operationalized through aspects related to SC agility (SCA), visibility (SCV), and flexibility (SCF), which are associated with both SOP and GSCM. This study also examines the moderating role of BA in the relationship between SCI and GSCM, while considering GSCM as a mediating mechanism between SCI and SOP. The theoretical framework was grounded in the RBV and the natural resource-based view.

The results indicate that SCA, SCV, and SCF are positively associated with SOP. Mediation analysis shows that GSCM plays a significant mediating role in the relationships between SCA and SOP and between SCF and SOP. In contrast, no significant mediating effect is observed between SCV and SOP. Furthermore, moderation analysis suggests that BA positively moderates the relationships between SCA and GSCM, as well as between SCF and GSCM.

This study has some limitations that should be addressed in future investigations. First, the data were collected from manufacturing firms in Bangladesh, which may limit the generalizability of the findings. Future studies could broaden the research boundaries by including firms from different countries to investigate how results vary across institutional and cultural settings. Second, this study focuses on the manufacturing sector. Subsequent examinations may explore additional industries, particularly the service sector, to validate the associations identified in this investigation across diverse business environments. Third, although Harman's single-factor test was employed to assess common method bias, future studies are encouraged to apply complementary techniques (e.g., marker variables) to strengthen methodological robustness further.

Fourth, this study adopted a quantitative approach. Future investigations could incorporate qualitative methods, such as case studies and in-depth interviews, to gain deeper insights into the underlying mechanisms and contextual factors shaping the relationships among the studied variables. Finally, while this study investigated blockchain adoption as a moderating factor, future studies may explore alternative moderators and mediators, such as organizational culture, regulatory frameworks, and government regulations, to further expand the understanding of the SCI-SOP relationships.

7- Declarations

7-1- Author Contributions

Conceptualization, T.T. and K.O.S.; methodology, T.T.; software, S.C.; validation, K.O.S., M.A.E., and N.I.; formal analysis, T.T. and N.I.; investigation, K.N.; resources, S.D. and S.F.; data curation, T.T., K.N., S.D., and S.F.; writing—original draft preparation, T.T. and S.D.; writing—review and editing, K.O.S., K.N., M.A.E., N.I., and S.F.; visualization, N.I. and S.C.; supervision, K.O.S. and M.A.E.; funding acquisition, M.A.E. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available upon request from the corresponding author.

7-3- Funding

This research was supported by the Indonesian Endowment Fund for Education (LPDP) on behalf of the Indonesian Ministry of Higher Education, Science, and Technology, and managed under the EQUITY Program (Contract No. 4300/B3/DT.03.08/2025 and 297/UN3/HK.07.00/2025).

7-4- Institutional Review Board Statement

This study was conducted in accordance with the general ethical standards for research involving human participants. Participation was entirely voluntary, and all respondents were informed of the study's purpose, confidentiality, and their right to withdraw at any time. Informed consent was obtained before data collection, and no sensitive or personally identifiable information was collected. All responses were anonymized and used solely for academic purposes. Ethical review and approval were waived for this study because it involved minimal risk and only anonymous survey data, which did not require formal Institutional Review Board approval according to institutional guidelines.

7-5- Informed Consent Statement

Informed consent was obtained from all the participants involved in the study.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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