

Driving Sustainability in the Digital Transformation of the Letters of Credit Supply Chain: Evidence from Bangladesh's Banking Sector

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Abstract— Letters of Credit (LCs) are pivotal in global trade finance, yet traditional processes are plagued by inefficiencies, fraud, and a lack of transparency, particularly in developing economies such as Bangladesh. This study investigates how three technological innovations Blockchain Database Integration (BDI), Collaborative Platforms (COP), and Compliance Automation (CAU) drive the evolution of a Sustainable Letters of Credit Supply Chain (SLCSC), mediated through the development of a Technology-based LC Supply Chain (LCSC). Drawing on a sample of 400 LC stakeholders in Bangladesh, the research employed a quantitative methodology using a reflective measurement model. Data were analyzed using Exploratory Factor Analysis (EFA) in IBM SPSS and Structural Equation Modeling (SEM) in IBM AMOS to assess reliability, validity, and the hypothesized relationships. The results indicate that Compliance Automation exerts a strong, significant positive effect on the LCSC ($\beta = 0.661$, $p < 0.001$) and Collaborative Platforms a weaker but significant effect ($\beta = 0.087$, $p = 0.04$), whereas Blockchain Database Integration has no significant effect ($\beta = 0.016$, $p = 0.687$). The LCSC, in turn, exerts a strong positive impact on the SLCSC ($\beta = 0.938$, $p < 0.001$). The findings demonstrate that compliance automation is the primary enabler of a technology-based LC supply chain, while the influence of blockchain remains constrained by prevailing infrastructural and regulatory conditions. The study's principal contribution is to disaggregate the technological drivers of trade-finance digitalization into three empirically distinct constructs and to demonstrate that their influence on sustainability is fully mediated by the technology-based LC supply chain, providing structural-model evidence of this mechanism from Bangladesh's banking sector. The study offers critical insights for banks, businesses, and policymakers seeking to modernize LC operations for enhanced efficiency, security, and eco-efficiency.

Keywords— Blockchain Database Integration; Collaborative Platforms; Compliance Automation; Letters of Credit; Supply Chain Sustainability; Structural Equation Modeling; Digital Trade Finance

1. Introduction

In the intricate web of global commerce, the Letter of Credit (LC) remains a fundamental instrument, providing a critical safety net for international trade transactions. By

acting as a bank-guaranteed payment promise upon the fulfillment of specific terms, LCs effectively distribute risk between exporters and importers, thereby fostering trust and mitigating default in cross-border exchanges [1]. Despite this historical robustness, the traditional LC process is increasingly beleaguered by inherent inefficiencies. Its heavy reliance on paper-based documentation, manual verification, and a labyrinth of intermediaries creates significant bottlenecks, leading to delays, high operational costs, and a heightened vulnerability to fraud and forgery [2]. These challenges are particularly acute in developing economies such as Bangladesh, where such inefficiencies can stifle economic growth and integration into global trade networks.

In response to these systemic issues, technological innovations are heralding a new era for trade finance. Building upon the foundational potential of blockchain technology established in previous research [3], three specific technological forces have emerged as potential catalysts for change: Blockchain Database Integration (BDI), Collaborative Platforms (COP), and Compliance Automation (CAU). Blockchain Database Integration provides a tamper-evident, shared, and distributed ledger that can render LC records immutable and auditable across counterparties. Collaborative Platforms digitalize and synchronize the multi-stakeholder environment of an LC transaction, creating a single source of truth that enhances transparency and coordination [4]. Compliance Automation, in turn, leverages Artificial Intelligence (AI), including Machine Learning (ML) and Natural Language Processing (NLP), to automate the arduous process of document scrutiny and regulatory checks, drastically reducing processing time and human error [5]. Together, these innovations are forging what can be termed a Technology-based Letters of Credit Supply Chain (LCSC): a streamlined, digitized, and intelligent LC ecosystem.

The evolution towards this technology-based supply chain is not merely an operational upgrade; it is a pivotal step toward sustainability. A Sustainable Letters of Credit Supply Chain (SLCSC) aligns with the Triple Bottom Line framework, aiming to reduce environmental impact (e.g.,

through paperless operations), enhance social governance (e.g., via transparency and fraud reduction), and improve economic efficiency (e.g., through cost and time savings). While the role of blockchain as an enabler has been explored, there is a distinct gap in empirical research investigating how BDI, COP, and CAU specifically drive the adoption of the LCSC, and how this, in turn, contributes to achieving sustainability objectives in the LC supply chain.

This study aims to fill this gap by examining the direct and mediated impact of Blockchain Database Integration, Collaborative Platforms, and Compliance Automation on sustainable LC practices. Specifically, it investigates the LCSC as the critical mediating mechanism that translates technological innovation into sustainable outcomes. Drawing on a sample of 400 professionals in Bangladesh's trade finance sector and utilizing Structural Equation Modeling (SEM), this research tests four core hypotheses to answer the following questions:

RQ1: Does Blockchain Database Integration (BDI) significantly influence the Technology-based Letters of Credit Supply Chain (LCSC)?

RQ2: Does Collaborative Platforms (COP) significantly influence the Technology-based Letters of Credit Supply Chain (LCSC)?

RQ3: Does Compliance Automation (CAU) significantly influence the Technology-based Letters of Credit Supply Chain (LCSC)?

RQ4: Does the LCSC mediate the relationship between (BDI + COP + CAU) and the Sustainable Letters of Credit Supply Chain (SLCSC)?

The findings of this study are poised to offer significant theoretical contributions by validating a novel reflective model and providing practical insights for banks, businesses, and policymakers striving to navigate the digital transformation of trade finance for a sustainable future.

2. Literature Review

2.1. The Evolution of Banking Supply Chain Management (BSCM) and LC Challenges

The concept of Banking Supply Chain Management (BSCM) has evolved significantly from a linear, transaction-focused model to a complex, networked, and customer-centric paradigm. This transformation is largely driven by digital technologies, which have redefined how banks manage financial products and interact with numerous stakeholders within the supply chain [6]. The integration of technologies such as blockchain has been revolutionary, particularly in emerging markets, by enabling real-time data sharing, enhancing transparency, and building trust among participants [7]. Within this networked view, banks are increasingly evaluated through supply-chain performance metrics [8], and are under mounting pressure to embed sustainability into their operations, a demand that is especially pronounced for the banking sector of a climate-vulnerable developing economy such as Bangladesh [9].

Nowhere is the need for this innovation more pressing than in the traditional LC process, especially in a growing

economy such as Bangladesh. The LC supply chain there is severely challenged by an alarming incidence of sophisticated fraud, which threatens individual transactions and the nation's broader financial stability [10]. These fraudulent activities exploit the manual, document-heavy nature of traditional LCs, which are prone to inconsistencies and difficult to verify in real time. Banks often struggle with detection due to outdated scrutiny processes, while the legal and regulatory framework, including the Uniform Customs and Practice (UCP), lacks specific, robust guidelines to combat modern fraud tactics [10]. This context of operational inefficiency and high risk creates a compelling imperative for technological solutions that can enhance security, transparency, and automation.

2.2. Blockchain Database Integration (BDI) in the LC Supply Chain

Blockchain Database Integration (BDI) refers to the incorporation of distributed-ledger technology into the LC process to create a shared, tamper-evident, and synchronized record of trade transactions across all participating institutions. By replacing siloed, paper-based records with a single immutable ledger, BDI is theorized to reduce documentary fraud, accelerate verification, and enhance trust among banks, importers, and exporters [11], [7]. In principle, smart contracts can automate the release of payment upon the fulfilment of stipulated conditions, thereby diminishing reliance on intermediaries. In practice, however, the realization of these benefits is contingent on ecosystem-wide adoption, interoperability among heterogeneous banking systems, and an enabling legal and regulatory framework, conditions that remain underdeveloped in many emerging economies, including Bangladesh. This tension between blockchain's theoretical promise and its practical prerequisites motivates the empirical examination of BDI alongside Collaborative Platforms and Compliance Automation.

2.3. Collaborative Platforms (COP) in Modernizing LC Supply Chains

Collaborative Platforms (COP) refer to digital ecosystems that facilitate seamless cooperation, information sharing, and coordination among all stakeholders in a supply chain, including banks, exporters, importers, shippers, and regulators. In the context of LCs, COPs aim to dismantle information silos, streamline operations, and mitigate risks associated with disjointed communication and paperwork.

A prime example of such a platform is TradeLens, developed by Maersk and IBM. This blockchain-based platform was architecturally designed in three layers, Ecosystem, Platform, and Marketplace, to provide end-to-end visibility across the shipping process [12]. Its use of open APIs allows for integration with existing bank and corporate systems without necessitating a massive infrastructure overhaul. Key capabilities include integrated data visibility for real-time tracking, immutable blockchain records for enhanced security and trust, and a digital environment that substantially reduces paperwork [13]. The impact on the LC supply chain is profound: COPs such as TradeLens drive efficiency and time-saving, reduce risks of fraud and delays, lower operational costs, and contribute to environmental sustainability by moving toward paperless transactions [4]. While challenges such as

standardization and data privacy persist, the opportunities for creating a more transparent and efficient LC process are significant.

2.4. Compliance Automation (CAU) for Accuracy and Efficiency

Compliance Automation (CAU) represents the application of Artificial Intelligence (AI), including Machine Learning (ML), Natural Language Processing (NLP), and Optical Character Recognition (OCR), to automate the interpretation, extraction, and verification of information from LC documents. This technological intervention is transformative for the banking sector, moving compliance from a manual, error-prone back-office function to a streamlined, accurate, and efficient process [5].

In LC transactions, CAU systems can automatically check documents against the terms of the credit and international regulations (e.g., UCP 600), flag discrepancies, and validate data, thereby significantly reducing processing time and the potential for human error. Furthermore, AI's predictive capabilities are increasingly deployed for proactive fraud detection and risk prevention, enhancing the integrity of the entire process [14]. However, the adoption of CAU is not without barriers. Challenges include the absence of a tailored regulatory framework for AI in banking, serious concerns regarding data privacy and security, a shortage of skilled personnel to manage these systems, and varying levels of trust and acceptance, often influenced by age and technological familiarity [15]. Overcoming these hurdles is essential for banks to fully leverage CAU to achieve compliance excellence.

2.5. Toward a Sustainable LC Supply Chain (SLCSC)

The goal of integrating technologies such as BDI, COP, and CAU is the realization of a Sustainable Letters of Credit Supply Chain (SLCSC). Sustainability in this context transcends environmental concerns (Planet), encompassing social (People) and economic (Profit) dimensions—the core of the Triple Bottom Line framework. The digitization driven by COP directly reduces the environmental footprint by eliminating paper-based documentation and courier services. The transparency and immutability provided by blockchain-based platforms enhance governance and social trust among stakeholders. Economically, the efficiencies gained from both COP and CAU—through reduced processing times, lower error rates, and minimized fraud—translate into substantial cost savings and more reliable transactions for all parties involved. Recent evidence from supply chains in Bangladesh reinforces that technology-enabled operations can advance environmental, social, and economic sustainability simultaneously [16], [9]. The pathway to sustainability is therefore mediated through the technological transformation of the LC process itself.

2.6. Gaps in the Literature and Justification for the Model

While existing literature provides ample theoretical discussion and case-based evidence on the potential of individual technologies such as blockchain, there is a scarcity of empirical research that specifically models and tests the combined impact of Blockchain Database Integration (BDI), Collaborative Platforms (COP), and

Compliance Automation (CAU) on sustainability outcomes. Previous studies have often focused on operational efficiency or fraud prevention in isolation, neglecting the broader, mediated pathway through which these technologies enable sustainable practices. Furthermore, the specific context of Bangladesh's challenging LC environment provides a critical but under-researched setting for such an investigation.

This study addresses these gaps by proposing and testing a novel model in which BDI, COP, and CAU are independent variables driving the formation of a Technology-based LC Supply Chain (LCSC), which in turn acts as the mediator leading to a Sustainable LC Supply Chain (SLCSC). This approach provides a holistic understanding of how technological integration functions as the essential bridge between innovative practice and sustainable achievement in international trade finance.

3. Methodology

3.1. Research Design

This study employed a quantitative research design using a reflective measurement model, appropriate for testing causal relationships and theoretical constructs [17], [18]. Consistent with a positivist and deductive orientation, the design focused on evaluating the extent to which Blockchain Database Integration (BDI), Collaborative Platforms (COP), and Compliance Automation (CAU) influence the Technology-based Letters of Credit Supply Chain (LCSC), which in turn contributes to a Sustainable Letters of Credit Supply Chain (SLCSC). Structural Equation Modeling (SEM) was adopted to analyze both the measurement and structural relationships among the variables.

3.2. Population and Sample

The target population comprised stakeholders engaged in LC operations in Bangladesh, including bank officials offering LC services and their respective corporate customers (importers and exporters). Because no official register enumerates this dispersed population, its exact size could not be reliably determined; sampling formulae that presuppose a known finite population were therefore unsuitable, and Cochran's [19] formula for an unknown or very large population was applied instead:

$$n_0 = (Z^2 \times p \times q) / e^2$$

With a 95% confidence level ($Z = 1.96$), maximum variability ($p = q = 0.5$), and a 5% margin of error ($e = 0.05$), the formula yielded a minimum sample of approximately 384. Accordingly, 400 valid responses were obtained, exceeding the required minimum and satisfying the sample-size requirements of SEM. A non-probability convenience sampling technique was employed, which is appropriate for reaching knowledgeable respondents within a specialised professional population; all principal LC stakeholder groups (bank officials, importers, and exporters) were represented in the sample.

3.3. Instrument Development

A structured, self-administered questionnaire was used for data collection. Because no single validated instrument existed for the specific constructs under study, the

questionnaire was self-developed, with items generated to reflect the five latent constructs (BDI, COP, CAU, LCSC, SLSC) and grounded in the reviewed literature. Content validity was established through expert review by academics and LC practitioners, and the refined instrument was pilot tested prior to full deployment; item performance was subsequently confirmed through exploratory and confirmatory factor analysis. Respondents indicated their level of agreement on a 5-point Likert scale, where 5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = strongly disagree [20], [18].

3.4. Data Analysis Strategy

Data analysis was conducted in multiple phases using IBM SPSS and IBM AMOS.

- **Preliminary Data Examination:** Prior to inferential testing, the data were screened for missing values, common method bias, and multicollinearity. As the online questionnaire required a response to every item, no missing data were present. Common method bias was assessed using Harman's single-factor test [21], and multicollinearity among the predictors was evaluated using tolerance and the variance inflation factor (VIF).
- **Exploratory Factor Analysis (EFA):** EFA was employed in IBM SPSS to determine the inherent relationships among the items and to condense the observed variables into underlying factors [18], evaluating item loadings and the optimal factor structure.
- **Reliability and Validity:** Internal-consistency reliability was assessed using Cronbach's alpha and composite reliability (CR); convergent validity was evaluated through the average variance extracted (AVE); and discriminant validity was assessed using both the Fornell-Larcker criterion [22] and the Heterotrait-Monotrait (HTMT) ratio [23].
- **Confirmatory Factor Analysis (CFA):** CFA was conducted in IBM AMOS to test the extent to which the measured variables represented the constructs of the study, confirming the hypothesized measurement structure.
- **Structural Equation Modeling (SEM):** SEM was used to test the direct and mediated relationships among the latent variables [18], assessing regression weights, critical ratios (C.R.), and p-values.

3.5. Ethical Considerations

All respondents participated voluntarily. Informed consent was obtained via an introductory section of the questionnaire. Data confidentiality and anonymity were strictly maintained. No personal identifiers were collected, and participation could be withdrawn at any time. The study aligns with the ethical standards of research involving human participants.

4. Results and Findings

4.1. Descriptive Statistics

The 400 respondents comprised various stakeholders in the LC domain, including bankers, exporters, and importers, and were diverse in age, gender, industry affiliation, and

years of experience with trade finance. Most held mid- to senior-level positions in banks and trading firms, providing a knowledgeable base for the study.

4.2. Preliminary Analysis: Missing Data, Common Method Bias, and Multicollinearity

Because the online questionnaire required a response to every item before submission, the dataset contained no missing values. Common method bias was examined using Harman's single-factor test: the first unrotated factor accounted for 47.4% of the total variance, below the conventional 50% threshold, indicating that common method bias is unlikely to be a serious concern [21]. All five constructs achieved acceptable internal-consistency reliability (Cronbach's α ranging from 0.720 to 0.869), and the collinearity diagnostics for the three exogenous predictors (BDI, COP, and CAU) were well within accepted limits (VIF between 1.96 and 2.26; tolerance above 0.44), confirming that multicollinearity did not threaten the structural estimation [24].

4.3. Reliability and Validity: Exploratory Factor Analysis (EFA)

An Exploratory Factor Analysis (EFA) was employed to determine the inherent relationships among the items and to assess the constructs' reliability and validity. As reported in Table 1, factor loadings ranged from 0.55 to 0.83, comfortably above the recommended 0.40 threshold [18]; accordingly, no item was dropped. The Kaiser-Meyer-Olkin measure of sampling adequacy ranged from 0.767 to 0.894 across constructs, exceeding the 0.50 criterion, and Bartlett's test of sphericity was significant for every construct ($p < 0.001$), confirming the data's suitability for factor analysis. Cronbach's alpha ranged from 0.786 to 0.869, exceeding the 0.70 cut-off and indicating adequate reliability.

Table 1. Exploratory Factor Analysis of the Constructs

Variable / Dimension	Factor Loading	KMO & Bartlett's Test	Cronbach's α
COP		KMO = 0.767 Bartlett's χ^2 = 566.289 Sig. = 0.000	0.786
COP_1	0.75		
COP_2	0.74		
COP_3	0.69		
COP_4	0.55		
CAU		KMO = 0.847 Bartlett's χ^2 = 868.709 Sig. = 0.000	0.862
CAU_1	0.79		
CAU_2	0.83		
CAU_3	0.71		
CAU_4	0.73		
CAU_5	0.71		
LCSC		KMO = 0.894 Bartlett's χ^2 = 1003.006 Sig. = 0.000	0.869

Variable / Dimension	Factor Loading	KMO & Bartlett's Test	Cronbach's α
LCSC_1	0.66		
LCSC_2	0.74		
LCSC_3	0.79		
LCSC_4	0.65		
LCSC_5	0.76		
LCSC_6	0.75		
SLCSC		KMO = 0.793 Bartlett's χ^2 = 655.181 Sig. = 0.000	0.843
SLCSC_1	0.75		
SLCSC_2	0.73		
SLCSC_3	0.75		
SLCSC_4	0.76		

Note. N = 400. KMO = Kaiser–Meyer–Olkin measure of sampling adequacy. Bartlett's test of sphericity was significant ($p < 0.001$) for all constructs.

4.4. Convergent and Discriminant Validity

Convergent validity was supported: composite reliability (CR) values ranged from 0.827 to 0.901 and average variance extracted (AVE) values from 0.542 to 0.681, exceeding the 0.70 and 0.50 thresholds, respectively, for all five constructs. Discriminant validity was assessed using both the Fornell–Larcker criterion [22] and the more stringent Heterotrait–Monotrait (HTMT) ratio [23]. The criteria were satisfied for Blockchain Database Integration and Collaborative Platforms; however, Compliance Automation, the LCSC, and the SLCSC exhibited high inter-construct proximity (HTMT between 0.94 and 1.00), indicating limited empirical discrimination among these conceptually adjacent constructs. This is an expected consequence of measuring the same supply chain for both performance and sustainability and is acknowledged as a limitation of the reflective measurement model.

4.5. Confirmatory Factor Analysis (CFA) and Model Fit

Following the EFA, Confirmatory Factor Analysis (CFA) was used to assess the validity of the five-factor measurement model. The advocated benchmark values for good fit are CMIN/DF < 5.0 , CFI and TLI > 0.90 , and RMSEA < 0.10 [24]. As summarized in Table 2, the CFA yielded CMIN/DF = 4.077, TLI = 0.964, CFI = 0.922, and RMSEA = 0.089, indicating that the measurement model corresponds well to the data and confirms acceptable construct validity.

Table 2. Measurement Model Fit Indices

Goodness-of-Fit Index	Measurement Model (1st-Order)
CMIN/DF (< 5.0)	4.077
TLI (> 0.90)	0.964
CFI (> 0.90)	0.922
RMSEA (< 0.10)	0.089
Interpretation	Good fit

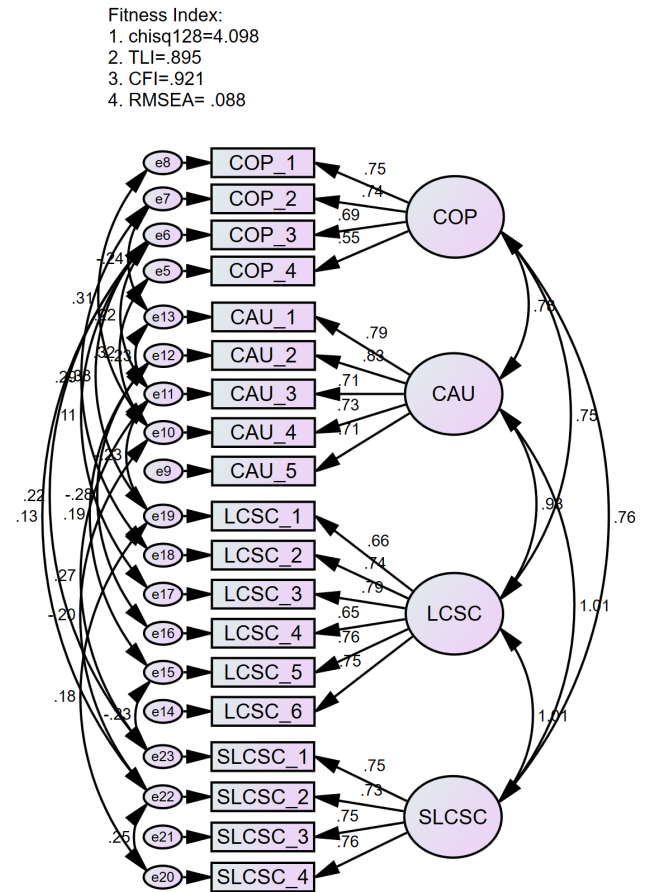


Figure 1. Measurement Model (Confirmatory Factor Analysis)

4.6. Structural Equation Modeling (SEM) and Hypothesis Testing

The hypothesized structural model was evaluated using SEM to test the direct and mediated paths. As reported in Table 3, the structural model achieved an acceptable fit across all indices (CMIN/DF = 4.679, TLI = 0.923, CFI = 0.902, RMSEA = 0.082), justifying interpretation of the path coefficients.

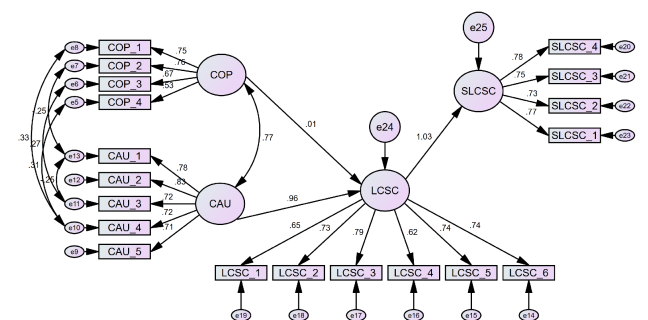


Figure 2. Structural Equation Model (SEM)

Table 3. Structural Model Fit Indices

Goodness-of-Fit Index	Structural Model
CMIN/DF (< 5.0)	4.679
TLI (> 0.90)	0.923
CFI (> 0.90)	0.902
RMSEA (< 0.10)	0.082

Goodness-of-Fit Index	Structural Model
Interpretation	Good fit

The path coefficients, reported in Table 4, indicate that Compliance Automation exerts a strong, significant positive effect on the LCSC ($\beta = 0.661$, $p < 0.001$), supporting H3. Collaborative Platforms exert a weaker but statistically significant effect ($\beta = 0.087$, $p = 0.04$), supporting H2, whereas Blockchain Database Integration has no significant effect ($\beta = 0.016$, $p = 0.687$), so H1 is not supported. The LCSC, in turn, exerts a strong positive effect on the SLCSC ($\beta = 0.938$, $p < 0.001$), supporting H4.

Table 4. Hypothesis Testing

Hypothesis	Path	β	S.E.	C.R.	p	Result
H1: Blockchain Database Integration positively influences the technology-based LC supply chain.	BDI $\rightarrow$ LCSC	0.016	0.039	0.403	0.687	Not supported
H2: Collaborative Platforms enhance the technology-based LC supply chain.	COP $\rightarrow$ LCSC	0.087	0.044	1.956	0.04	Supported
H3: Compliance Automation strengthens the technology-based LC supply chain.	CAU $\rightarrow$ LCSC	0.661	0.038	17.361	***	Supported
H4: A technology-based LC supply chain contributes positively to the sustainable LC supply chain.	LCSC $\rightarrow$ SLCSC	0.938	0.028	33.126	***	Supported

Note. *** $p < 0.001$; * $p < 0.05$. β = standardized regression weight; S.E. = standard error; C.R. = critical ratio.

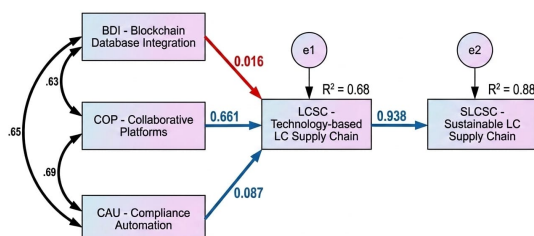


Figure 3. Results of the Direct and Mediation Hypotheses

5. Discussion

5.1. Interpretation of Key Findings

The findings support the proposed model, confirming the significant roles of Compliance Automation (CAU) and Collaborative Platforms (COP) in shaping a Technology-based LC Supply Chain (LCSC), while revealing a non-significant effect for Blockchain Database Integration (BDI). The LCSC, in turn, is confirmed as a strong driver of sustainability (SLCSC).

Contrary to expectation, Hypothesis 1 (BDI $\rightarrow$ LCSC) was not supported ($\beta = 0.016$, $p = 0.687$). Although blockchain is widely theorized to enhance the security and transparency of trade finance, its integration did not translate into a measurable improvement in the LC supply chain within the Bangladeshi banking context. This null result is plausibly attributable to the infrastructural immaturity of blockchain deployment, the absence of an enabling regulatory and legal framework for distributed-ledger records, limited interoperability among banking systems, and the network-dependent nature of blockchain adoption, which yields benefits only when a critical mass of institutions participates. The discontinuation of the flagship TradeLens platform in 2022 exemplifies the fragility of blockchain-based initiatives that depend on broad, coordinated industry adoption.

The strong support for Hypothesis 3 (CAU $\rightarrow$ LCSC) establishes compliance automation as the dominant driver of a technology-based LC process. This suggests that AI-enabled document scrutiny, discrepancy detection, and regulatory checking address the most acute pain points of the traditional LC, manual error, processing delay, and fraud exposure and, crucially, can be adopted at the level of the individual bank without requiring ecosystem-wide coordination [5], [14].

By contrast, the support for Hypothesis 2 (COP $\rightarrow$ LCSC), though statistically significant, reveals a notably weaker relationship. This indicates that although collaborative platforms are valued, their contribution is constrained by the network-dependent nature of adoption: a platform delivers benefit only when a critical mass of counterparties participates, and it confronts standardization, interoperability, and data-privacy barriers. As with blockchain, the platform-based model requires broad industry buy-in to realize its full value, offering a plausible explanation for the comparatively limited effect of COP in this setting.

The powerful support for Hypothesis 4 (LCSC $\rightarrow$ SLCSC) is a central finding. It affirms that the digitization and technological re-engineering of the LC process is the primary mechanism through which sustainability is achieved, consistent with research identifying technology as a mediator [3] and with the assertion by Chang, Chen, and Lu [11] that transparency and traceability directly reduce operational waste and information asymmetry, key components of sustainability.

5.2. Theoretical Contributions

This study makes several theoretical contributions. First, it extends prior research on blockchain in LCs [3] by decomposing the technological drivers into three distinct,

measurable constructs—Blockchain Database Integration (BDI), Collaborative Platforms (COP), and Compliance Automation (CAU)—providing a more nuanced understanding of how different technologies contribute to digital transformation. Second, it validates a refined reflective measurement model that introduces BDI, COP, and CAU as antecedents of the LCSC, offering greater specificity than earlier broad-stroke approaches. Third, the findings contribute to the Technology–Organization–Environment (TOE) framework [25] by empirically demonstrating that whereas some technological factors (CAU and, to a lesser extent, COP) are direct enablers of organizational change (LCSC), others (BDI) are not—underscoring that technological potential is realized only under supportive organizational and environmental conditions.

5.3. Practical Implications

For banks and financial institutions, the results present a clear strategic roadmap. Investment should be prioritized in compliance-automation capabilities, as these show the strongest direct path to technological modernization and can be deployed within the institution's own operations. Collaborative platforms remain valuable but warrant a more phased, consortium-based approach, focusing on achieving critical mass among counterparties, ensuring interoperability, and addressing data-security concerns.

For exporters, importers, and logistics providers, the study demonstrates that engaging with technology-driven LC platforms is not merely an operational choice but a strategic move towards more secure, efficient, and sustainable trade practices. For regulators and policymakers, the findings highlight an urgent need to develop clear legal frameworks that recognize digital documents and smart contracts, and to establish standards for AI applications in trade finance, fostering an environment conducive to adoption.

5.4. The Mediated Path to Sustainability

The results paint a clear picture: the journey to a Sustainable LC Supply Chain (SLCSC) is mediated through technology. Compliance Automation and, to a lesser extent, Collaborative Platforms do not directly create sustainability; they enable the creation of a Technology-based LC Supply Chain (LCSC). It is this digitized, efficient, and transparent system that inherently produces the sustainable outcomes, reduced paper use (environmental), enhanced trust and fraud prevention (social), and lower costs and faster processing (economic). This confirms that technological integration is the indispensable gateway to achieving sustainability in traditional financial instruments such as the Letter of Credit.

6. Conclusion and Future Research

6.1. Conclusion

This study set out to empirically investigate the impact of Blockchain Database Integration (BDI), Collaborative Platforms (COP), and Compliance Automation (CAU) on achieving a Sustainable Letters of Credit Supply Chain (SLCSC), with the Technology-based LC Supply Chain (LCSC) acting as the mediating mechanism. The analysis

of data from 400 professionals in Bangladesh's trade finance sector provides robust support for the proposed model.

The findings lead to four central conclusions. First, Compliance Automation emerges as the primary driver of technological modernization in the LC process, significantly enhancing accuracy, efficiency, and fraud control. Second, Collaborative Platforms exert a statistically significant but comparatively weaker influence, reflecting the network, standardization, and interoperability barriers that impede platform-based adoption. Third, Blockchain Database Integration shows no significant direct effect on the LCSC, indicating that its theoretical promise remains unrealized under the prevailing infrastructural and regulatory conditions of the Bangladeshi banking sector. Finally, and most importantly, the study establishes that the transformation toward sustainability is mediated through the creation of a technology-based LC ecosystem that yields a reduced environmental footprint, enhanced social governance, and greater economic efficiency.

The contribution of this study is threefold. Theoretically, it advances the banking supply-chain literature by decomposing trade-finance digitalization into three measurable constructs, Blockchain Database Integration, Collaborative Platforms, and Compliance Automation and by empirically establishing the technology-based LC supply chain as the mediating mechanism through which these technologies deliver sustainability. Methodologically, it validates a reflective measurement model for the sustainable LC supply chain in a developing-economy context. Practically, it offers banks, firms, and regulators prioritized, evidence-based guidance, identifying compliance automation as the most tractable lever for near-term modernization. Collectively, these contributions consolidate the proposition that technological integration is the critical gateway to sustainability in traditional financial instruments such as the Letter of Credit.

6.2. Limitations

Despite its contributions, this study is subject to several limitations. The geographical focus on Bangladesh may limit the generalizability of the findings. The use of a non-probability convenience sampling technique, though practical for reaching a niche population, carries a potential risk of selection bias. In addition, the measurement model exhibited limited discriminant validity among Compliance Automation, the LCSC, and the SLCSC ($HTMT \geq 0.94$); accordingly, construct overlap cannot be fully excluded, and the strong estimates linking these constructs should be interpreted with corresponding caution. Finally, the cross-sectional design captures perceptions at a single point in time rather than outcomes over a longer period, and self-reported perceptual data may not fully correspond to objective operational performance.

6.3. Future Research Directions

Future studies can build on this work in several ways. Longitudinal research would help track how the adoption of COP and CAU influences LC performance and sustainability over time. Comparative studies across

countries or industries could uncover contextual factors affecting technology adoption. Qualitative inquiries involving in-depth interviews with bankers, technology developers, and regulators would provide richer insight into implementation challenges. Finally, integrative models incorporating organizational culture, leadership support, and customer readiness could further explain the journey toward a sustainable digital trade-finance ecosystem.

References

- [1] R. Toorajipour, P. Oghazi, V. Sohrabpour, P. C. Patel, and R. Mostaghel, "Block by block: A blockchain-based peer-to-peer business transaction for international trade," *Technological Forecasting and Social Change*, Vol. 180, Art. 121714, 2022, <https://doi.org/10.1016/j.techfore.2022.121714>.
- [2] S. E. Chang, Y.-C. Chen, and T.-C. Wu, "Exploring blockchain technology in international trade," *Industrial Management & Data Systems*, 2019, <https://doi.org/10.1108/imds-12-2018-0568>.
- [3] M. I. Majumder and M. M. Habib, "Blockchain integration in sustainable letters of credit supply chain," *International Journal of Supply Chain Management*, Vol. 14, No. 2, 2025, <https://doi.org/10.59160/ijscm.v14i2.6306>.
- [4] W. A. H. Ahmed and A. Rios, "Digitalization of the international shipping and maritime logistics industry," in *The Digital Supply Chain*, pp. 309–323, 2022, <https://doi.org/10.1016/b978-0-323-91614-1.00018-6>.
- [5] M. A. Khalil and L. Kerbache, "Artificial intelligence role in automation of trade document examination under letter of credit process," in *Proc. 5th European Int. Conf. Industrial Engineering and Operations Management*, IEOM Society International, pp. 1303–1304, 2022.
- [6] H. M. Adel and R. A. Younis, "Interplay among blockchain technology adoption strategy, e-supply chain management diffusion, entrepreneurial orientation and human resources information system in banking," *International Journal of Emerging Markets*, Vol. 18, No. 10, pp. 3588–3615, 2021, <https://doi.org/10.1108/ijoem-02-2021-0165>.
- [7] Y. Wang, C. H. Chen, and A. Zghari-Sales, "Designing a blockchain enabled supply chain," *International Journal of Production Research*, Vol. 59, No. 5, pp. 1450–1475, 2020, <https://doi.org/10.1080/00207543.2020.1824086>.
- [8] F. Saleheen and M. M. Habib, "Evaluating supply chain performance through financial metrics: A study in a manufacturing industry," *International Journal of Supply Chain Management*, Vol. 13, No. 2, pp. 35–44, 2024.
- [9] A. Nandy and M. M. Habib, "Green supply chain management practice in the banking sector: A literature review," *International Journal of Supply Chain Management*, Vol. 12, No. 3, pp. 18–26, 2023, <https://doi.org/10.59160/ijscm.v12i3.6188>.
- [10] R. B. Rafique and T. J. Duraisingham, "The risk of fraudulent letter of credit transactions in Bangladesh: A growing threat to Bangladesh's economy," *Journal of Financial Crime*, 2023, <https://doi.org/10.1108/jfc-07-2023-0179>.
- [11] S. E. Chang, Y.-C. Chen, and M. F. Lu, "Blockchain-enabled trade finance innovation: A potential paradigm shift on using letter of credit," *Sustainability*, Vol. 12, No. 1, Art. 188, 2020, <https://doi.org/10.3390/su12010188>.
- [12] TradeLens, "Solution architecture — TradeLens documentation," 2019. [Online]. Available: https://docs.tradelens.com/learn/solution_architecture/
- [13] TradeLens, "CMA CGM and MSC complete TradeLens integration and join as foundation carriers," 2020. [Online]. Available: <https://www.tradelens.com>
- [14] D. C. Vijai, "Artificial intelligence in Indian banking sector: Challenges and opportunities," *International Journal of Advanced Research*, Vol. 7, No. 4, pp. 1581–1587, 2019, <https://doi.org/10.21474/ijar01/8987>.
- [15] M. Rahman, T. H. Ming, T. A. Baigh, and M. Sarker, "Adoption of artificial intelligence in banking services: An empirical analysis," *International Journal of Emerging Markets*, Vol. 18, No. 10, pp. 4270–4300, 2021, <https://doi.org/10.1108/ijoem-06-2020-0724>.
- [16] S. Islam and M. M. Habib, "Integrating forecasting & planning management for sustainable hospital supply chains and societal advancement," *International Journal of Supply Chain Management*, Vol. 13, No. 4, 2024, <https://doi.org/10.59160/ijscm.v13i4.6263>.
- [17] K. J. Sileyew, "Research design and methodology," IntechOpen, 2019, <https://doi.org/10.5772/intechopen.85731>.
- [18] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 3rd ed. Thousand Oaks, CA: SAGE Publications, 2022.
- [19] W. G. Cochran, *Sampling Techniques*, 3rd ed. New York: Wiley, 1977.
- [20] C. R. Kothari, *Research Methodology: Methods and Techniques*, 4th ed. New Delhi: New Age International, 2019.
- [21] P. M. Podsakoff, S. B. MacKenzie, J. Y. Lee, and N. P. Podsakoff, "Common method biases in behavioral research: A critical review of the literature and recommended remedies," *Journal of Applied Psychology*, Vol. 88, No. 5, pp. 879–903, 2003.
- [22] C. Fornell and D. F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *Journal of Marketing Research*, Vol. 18, No. 1, pp. 39–50, 1981.
- [23] J. Henseler, C. M. Ringle, and M. Sarstedt, "A new criterion for assessing discriminant validity in variance-based structural equation modeling," *Journal of the Academy of Marketing Science*, Vol. 43, No. 1, pp. 115–135, 2015.

- [24] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 8th ed. Andover, UK: Cengage Learning, 2019.
- [25] L. G. Tornatzky and M. Fleischer, *The Processes of Technological Innovation*. Lexington, MA: Lexington Books, 1990.