Blockchain Integration in Islamic Finance: A New Era for Banking Sector in Pakistan

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ABSTRACT

Purpose
This study explores the integration of Blockchain technology within Islamic banks in Pakistan.
Methodology
Using a cross-sectional survey approach, data were collected from 500 participants, using a five-point Likert scale adopted questionnaire. Participants include banking professionals, Blockchain freelancers, technology experts, and academics. The analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM).
Findings
The results reveal that Blockchain technology adoption significantly improves the sustainable performance of Islamic Banking in Pakistan. The most transformative feature of Blockchain technology, i.e., transparency, governance, and traceability, has a significant positive impact on sustainable performance. Whereas the mediation analyses show that traceability and governance partially mediate the relationship between Blockchain technology and Islamic banking performance. Results further reveal that Blockchain technology demonstrates strong potential to enhance transaction efficiency, reduce operational costs, and improve security, all while ensuring compliance with Shariah Law.
Conclusion
The study concludes that implementing Blockchain technology can substantially enhance the sustainable performance of Islamic banking in Pakistan. The study incisively demonstrates the key reasons and implications for employing Blockchain technology in the Islamic banking sector. The findings thereof can be applied as an insightful manual for policymakers and industry experts to better understand, promote, and support the adoption of Blockchain technology in Islamic Banking institutions

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1. Introduction

The contemporary world is undergoing rapid transformation. Recent literature suggests that we are at a turning point in history, transitioning from an industrialized economy to one shaped by emerging technologies (Mbaidin, Alsmairat, & Al-Adaileh, 2023). The early twenty-first century has witnessed widespread digitalization, forging a strong connection between technology and society. This transformation enables intelligent and efficient support for individuals (For & Sulastiningsih, 2021).

The advent of Blockchain technology (BCT) is recognized as a significant revolution in the digitalization of computing systems (Guo & Yu, 2022). Blockchain is a distributed, decentralized ledger technology that securely records information or transactions across multiple users and locations. Its potential applications span various fields, including banking, finance, and healthcare (Willaby, Burns, Costa, & MacCann, 2015). Designed to address trust issues in transactions by eliminating intermediaries, Blockchain offers transformative potential—particularly in banking and finance—by automating processes and encrypting data without human intervention.

The Islamic banking industry is one sector that must adapt and integrate this technology, especially since many scholars find no legitimate prohibition against its use. Blockchain is vital for enhancing transparency, monitoring, security, and governance in information management. The use of smart contracts in Islamic banking, Takaful, zakat collection, WAQF management, and smart Sukuk can lead to more efficient operations.

This study explores the application of Blockchain technology within the context of Islamic banking in Pakistan. Its use in Pakistani Islamic banks is unprecedented, underscoring its innovative nature. Implementation is expected to bring significant advancements and transformative effects, not only within Islamic banks but also across Pakistan's broader technological landscape. According to Mohd Haridan et al. (2023), integrating Blockchain technology is anticipated to have a substantial impact on the Islamic banking sector.

The study's importance lies in its pioneering approach, examining an uncharted area of research: the adoption of Blockchain technology within Islamic banks in Pakistan. It investigates four key dimensions of impact, both individually and collectively. The findings suggest that Blockchain adoption in Islamic institutions will lead to significant improvements and foundational changes. Therefore, implementing this technology is essential in today's rapidly evolving digital world (Moll, 2023).

Blockchain, as an evolving technology, has transformed several businesses as well as created a lot of opportunities for scholars in the study possibilities across a wide range of industries, sparking a great pact of interest among researchers (Abdurrahman et al., 2024). The meta-analyses regarding the application of Blockchain technology on Islamic Banking and finance worldwide since its emergence is reflected in figure-1.

Figure 1 illustrates the global trend in publications since the emergence of Blockchain technology and its application in Islamic banking. Over the last five years, there has been a significant increase in the number of publications on this topic, particularly in 2023. During this period, the interest in the application of Blockchain technology in Islamic banking has grown substantially.

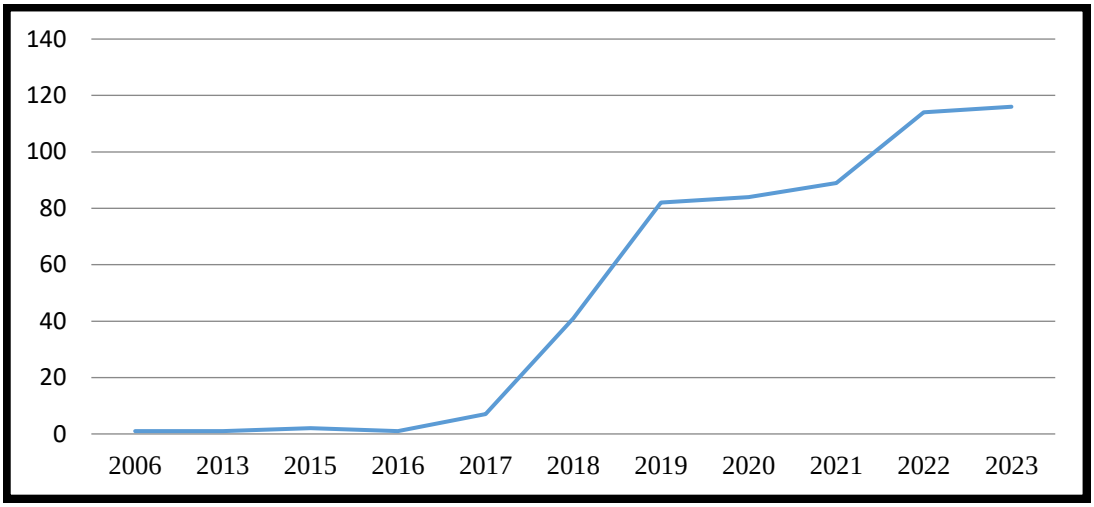

Figure.1.World Wide Publication Trend
Source: Author's own elaboration

Figure 2 shows the graphical trend of publications on the application of Blockchain technology in Islamic banking. The trend demonstrates a significant increase over time. In the last three years, a substantial upward trend has been observed in the number of publications, making this topic highly researchable for scholars in Pakistan. A notable increase in available literature was observed during 2022-2023.

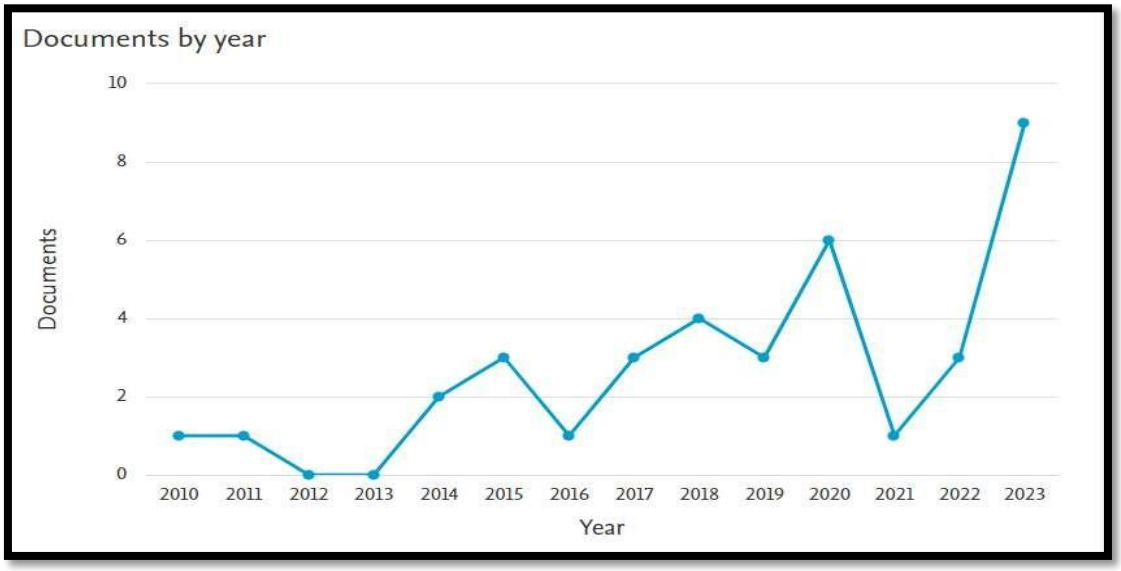

Figure.2.Publication Trend in Pakistan
Source: Author's own elaboration

Table.1.Most Cited Papers

S. No.	Year	Captioned	Author	Journal	Cite Sore
Time	2006	Precious Metal Backed Cryptocurrency in Islamic Finance	Charles, W. E	Journal of Islamic Banking and Finance	141
2	2013	Role and Status of the Shariah Advisory Council in Enhancing the Islamic Financial System in Malaysia	Mohd, D. M. I. A. B.	JournalPengiran	0
3	2015	Trends in crypto-currencies and Blockchain technologies: A monetary theory and regulation perspective	Peters, G. W., Panayi, E., & Chapelle, A. (2015)	A monetary theory and regulation perspective. arXiv preprint arXiv:	386
6	2017	Developing a Digital Currency from an Islamic Perspective: Case of	Alzubaidi, I. B., & Abdullah, A. (2017)	International Business Research	84

		Blockchain Technology			
13	2018	Banking with Blockchain-ed big data	Hassani, H., Huang, X., & Silva, E. (2018).	Journal of Management Analytics	304
54	2019	Fintech and Islamic finance.	Alam, N., Gupta, L., &Zameni, A. (2019).	Springer (BooK)	139
136	2020	FinTech, Blockchain and Islamic finance: an extensive literature review	Rabbani, M. R., Khan, S., &Thalassinos, E. I.	um.edu.mt	272
220	2021	Socioeconomic Impact of COVID-19 in MENA region and the Role of Islamic Finance	Hassan, M. K., Rabbani, M. R., & Abdulla, Y.	International Journal of Islamic Economics and Finance (IJIEF)	117
309	2022	Fintech in Islamic finance literature: A review.	Alshater, M. M., Saba, I., Supriani, I., &Rabbani, M. R. (2022)	Heliyon	118
423	2023	Islamic Fintech Ecosystem Development in Pakistan: A Meta-Analysis	Sadiq, M. N., Ahmad, A., Baig, U., &Raza, M. (2023).	. Journal of Asian Development Studies	79
529	2024	Digital banking regulations: a comparative review between Nigeria and the USA	Ofodile, O. C., Odeyemi, O., Okoye, C. C., Addy, W. A., Oyewole, A. T., Adeoye, O. B., &Ololade, Y. J	Finance & Accounting Research Journal,	28

Source: Author's own elaboration

Table 1 shows the most cited papers from 2006 to 2024. The paper authored by Peters, G. W., Panayi, E., & Chapelle, A. (2015) received the highest citation score, with 386 citations. Figures 1 and 2, along with Table 1, demonstrate that Blockchain technology (BCT) and its application, particularly in Islamic banking, have rapidly evolved in recent years. It is now imperative to study and analyze the existing knowledge about Blockchain technology and its application in Islamic banking (Habil et al., 2024).

As modern life increasingly demands the latest technology, individuals are more willing to adopt these emerging technologies. BCT is a disruptive digital revolution and cutting-edge technology that is revolutionizing business models across global industries. The twenty-first century is epitomized by technological advancement. From this perspective, we concentrated our research on the key success factors and strategic roadmap for implementing Blockchain technology, specifically within the context of Islamic banks operating in Pakistan (H. Mbaidin et al., 2024; Vadivelu, 2022).

The significance of the existing research can be derived from the following points. First, the existing research study is important because it focuses on the implementation of Blockchain technology and its impact on the sustainable performance of Islamic banking institutions. Second, since there has been very limited research in this area, this study is unique and could serve as a basis for future research. Finally, no study has been conducted to test the individual or combined effects of traceability, transparency, and governance on the sustainable performance of Islamic banking institutions operating in Pakistan.

This research aims to first describe in detail what Blockchain technology (BCT) is. Second, examine the impact of Blockchain technology implementation on Islamic banking institutions. Third, to investigate the mediating roles of traceability, transparency, and governance in the effect of Blockchain technology on the sustainable performance of Islamic banks in Pakistan. Finally, to examine the impact of traceability, transparency, and governance separately on Islamic banks sustainable performance.

2. Literature Review

Recently, with digitalization, the Blockchain technology (BCT) has attained substantial research interest owing to its inspiring features (Abdulrahman et al., 2022). The usage of cryptography ensures immutability, transparency, and decentralization, which has significantly affected information sharing among peers (Gomez-Trujillo et al., 2021; Mbaidin et al., 2023; Oriekhoe et al., 2024; Tenorio-Fornés et al., 2021).

Initially, the Blockchain technology was introduced by Satoshi Nakamoto in the year 2008, and with the passage of time it gained momentum. The first, application of this technology was Bitcoin, which emerged as the first decentralized digital currency in the world using a peer-to-peer network, eradicating the role of centralized entities such as intermediaries or financial institutions (Cunha et al., 2021). In order to establish integrity and authenticity within the network, Bitcoin uses consensus models.

Ali et al. (2024) opined that Blockchain technology has expanded its application beyond the early usage in finance, overcoming the limitations of its first generation. Ma et al. (2020) believe that Ethereum, as a second-generation application, holds significant potential for crowdsourcing owing to its reliable smart contract capabilities. A "smart contract" is essentially a self-executing agreement where the terms between a buyer and seller are clearly specified in code, which is automatically transmitted across a decentralized Blockchain network. The 3rd generation BCT is enriched with more significant applications, assimilated confirmation features which increase its efficiency, speed, and affordability, making it more proficient compared to its earlier version. These advanced features make possible quick responses, cost efficiency, as well as improved efficiency. The 4th generation BCT, assimilated with Artificial Intelligence (AI), revolutionized this technology with advanced features of security, automation, predictive capabilities, and data analysis facilities. These features make BCT a driving force in innovation for new avenues built upon the improvements in third-generation BCT (Alawadhi et al., 2022; Bhattacharya et al., 2024; Hassan et al., 2022; Lashkari & Musilek, 2021; Salhab et al., 2023; Shikhteymour et al., 2023).

The BCT is known as a distributive technology. When we divide this term BCT into "block," it means a piece of space that records the data, whereas "chain" states how the data in blocks links together by maintaining the sequence (Rehman Khan et al., 2022; Soze, 2017). The study by Andoni et al. (2019) argues that BCT is a digital database that logs transactions in sequence, ensuring traceability, security, and immutability through decentralized verification. Blockchain technology is based on a shared and distributed ledger that logs digital transactions, records, and secures data that is executable. Every block in this chain system is cryptographically and time-stamped, connected with its previous one, providing an immutable sequence of each event.

Likewise, the studies of Aggarwal and Kumar (2021) and Dabbagh et al. (2019) opined that this is a decentralized ledger technology (DLT), which is secure, transparent, and has the ability to verify transaction records due to peer-to-peer networking. BCT provides immutability in documents and traceability of transactions to its users. Similarly, Padmavathi and Rajagopalan (2023) argue that this technology empowers individuals to control and manage their transactions without intermediaries due to its DLT feature. This disruptive technology offers potential applications across many domains like academia, industry, finance, and other service-providing institutions. This versatility in application introduces this technology as a powerful tool for innovation in many sectors.

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Due to a variety of features, this technology has the potential for adoptability across all sectors of the economy. Crucial features include data immutability, transaction traceability, transparency, and transaction privacy. This enables data storage and sharing facilities, recording transactions, as well as simplifying peer-to-peer processes. Moreover, this technology supports the development of smart contracts, which automate intricate business procedures (Fazel et al., 2024; Naz et al., 2019; Righetti, 2021).

BCT delivers a lot of benefits like smoothing supply chain processes, securing individual data, maintaining privacy, and also generating opportunities for new business models. BCT has the potential to completely transform many sectors of the economy, including agriculture, retail business, healthcare services, as well as banking and finance (Dudczyk et al., 2024; Saeed & Jamil, 2022; Tiwari & Anuradha, 2023). This disruptive technology addresses the long-standing issue of centralized data recording and maintenance by offering a decentralization mechanism. This decentralized and distributed ledger feature has a foolproof, fraud-resistant mechanism with highly integrated security through decentralization, hence developing trust in data transparency and its record-keeping (Aybar-Mejía et al., 2021; Lemieux, 2019; Sudhakaran et al., 2020).

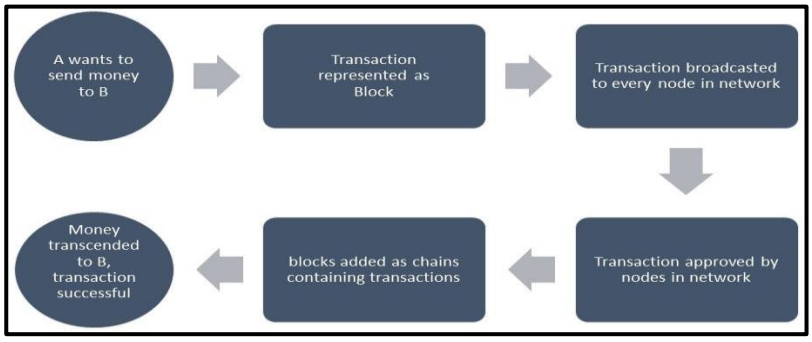

Figure.3.BCT mechanism
Source: Priyadarshini, 2019

In this era of technological advancement wherein individuals wants more and more by consuming lesser time the BCT application and its innovative mechanism also address this issue by offering time and money saving application (Torky and Hassanein 2020). This study emphasized on the significance of BCT in attaining the confidence and trust of individuals as well as fostering in transparency. The key objective of this technology includes more advancement in computing technology that make easy process of registration, dispersal of digital data without imitation, quick financial transactions, maintaining immutable medical records, safeguarding land records with titles, and attracting new investment by offering stamp-proof transaction.

Studies by Ertz and Boily (2019), Jaradat et al. (2024), and Tseng and Shang (2021) have further explored the benefits of this technology. While describing the benefits study noted that this technology has substantial advantage over other computing technology by limiting the role of intermediaries and ensuring secure transaction among two parties over the internet without any central authority or the involvement of other third party. This elimination of intermediaries reduces processing costs and enhances transaction security and efficiency.

Similar study conducted by H. O. Mbaidin et al. (2023) and Yousefi and Tosarkani (2023) this study extended the viewpoint of the previous study by mentioning that this technology provides many benefits such as performance efficiency and sustainability, maintaining trust and collaboration, reducing costs, saving time and money, and increasing security and privacy. Moreover, BCT introduces substantial technological advancements, enhancement in speed of transaction and efficiency, save precious time that is treated as valuable resource of the century.

Blockchain technology application is spreading across all sectors of life and has also become a driving force for corporate expansion. The continuous use of this technology acts as a catalyst for innovation and growth. This distributed ledger technology has emerged as imperious in innovation, attaining interest from the energy sector, tech pioneers, financial institutions, startups, scholars, and government. Due to this assorted history, many scholarly publications recommend that BCT may offer significant benefits, drive innovation, and foster worldwide advancements that have admirably been recognized (Andoni et al., 2019; Z. Wang et al., 2024; Zheng et al., 2017).

BCT, as a distributive technology, has widely affected business, trade, and industry operations in this decade. But those institutions that overlook these emerging innovations risk losing market position. Business and industry rivals who strategically assimilate these emerging technologies into their operations may gain a competitive edge. Hence, it becomes most important for businesses and industry to cogitate and implement these technological advancements. Erol, Ismail, et al. (2021) has recommended that BCT might eventually be regarded as one of the most significant advancements across various industries.

A recent research study concluded by Alaeddin et al. (2021) describes that interest in the application of BCT into business operations is specifically documented among policy decision-makers at Islamic banking and financial institutions. This increasing interest shows recognition of BCT as a promising solution to various challenges within these organizations. With its Sharia-compliant foundation, Islamic FinTech has the potential to emerge as a global leader in the financial sector. Rabbani argues that this approach offers significant advantages in terms of transparency, accessibility, and simplicity. Likewise,

Saifullah et al. (2024) recommend that BCT implementation can strengthen Islamic banking by improving transparency, immutability, and security in its operations.

A similar research study conducted by Aladdin et al. (2021) has also described the disruptive feature of Blockchain technology that can play a key role in transforming the whole service-providing structure of Islamic banking, specifically in the areas of Sukuk, Zakat, and WAQF. Likewise, Urfiyya and Sulastiningsih (2021) opined that integrating BCT into zakat institutions would be groundbreaking in resolving the challenges faced in Islamic practices, particularly in zakat collection and distribution. This method targets increasing transparency and efficiency in managing charitable donations by providing a contemporary way to support outdated practices while staying true to Islamic principles.

Besides, Azganin (2019) has recommended that BCT can considerably increase transparency by authorizing the donors to track their donations to WAQF in land development projects through managing the data of transactions. The foremost benefit of BCT is its consonance with Islamic banking practices. Emerging economies like Pakistan have significant opportunities to leverage Islamic FinTech for cost-effective financial services access. Blockchain also helps maintain stability and protects investors and institutions from fraudulent practices, all while supporting Shariah compliance (Rabbani et al., 2020).

Emerging countries like Pakistan have substantial openings to benefit from Islamic FinTech, as BCT provides a cost-effective way to offer financial services to the users of Islamic banking. Besides, Blockchain technology offers a cost-effective way to provide financial services to users in Islamic banking. Besides ensuring stability, this technology protects banking institutions as well as investors from fraudulent activities by adhering to Shariah principles (Saba et al., 2019). The future of FinTech in Islamic banking appears optimistic, especially in Muslim-majority countries. Nations like Malaysia, Indonesia, Bahrain, the UAE, and Saudi Arabia currently lead the way with the most advanced Islamic finance markets (Abd Wahab et al., 2023; Dahdal et al., 2022).

Presently, this disruptive technology is being adopted by banking institutions globally. The fund transfer system through banking channels in the UAE is very complex, costly, and time-consuming for banking clients, with additional hurdles like fluctuating exchange rates and hidden charges making overseas transactions more difficult. Hasan et al. (2020) explained how BCT can simplify these processes for Islamic banks, helping them manage profit-sharing agreements more effectively by reducing transaction costs (Mbaidin et al., 2024).

Many studies have described the benefits of the implementation of BCT in Islamic banking and finance worldwide. Septiana and Sanjayawati (2021) suggest that institutions like the Islamic Development Bank and the Organization of Islamic Cooperation (OIC) should take a more active role in building the infrastructure required for Blockchain adoption across Islamic countries. In Pakistan, Islamic banks could implement BCT to reduce intermediary costs, offering a more secure, peer-to-peer payment system that reduces transaction time, costs, and fees (Biriuk et al., 2024; Cocco et al., 2017; Ducas & Wilner, 2017; Farayola, 2024). By adopting this technology, Pakistani Islamic banks could modernize, align more closely with Shariah principles, attract more users and investors, and boost long-term sustainable profits.

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The payments industry is a crucial sector for financial institutions, providing significant revenue and serving as the anchor for other services. Payment records are a vital source of customer data, offering banks valuable insights into customer behavior and opportunities to integrate business processes. Consequently, losing ground in payment transactions would have disastrous consequences for banks (Holotiuk et al., 2017).

In addition to payments, financial intermediaries, such as banks, facilitate the flow of funds from savers to borrowers. To measure the financial performance of this sector, analysts typically start by evaluating banks through the financial data and ratios available in their annual reports. Analyzing these reports helps determine profitability and enables predictions about the bank's future. Annual reports provide a complete financial picture of banks, revealing the basics of earnings and potential problems, which can be assessed and calculated. For measuring bank financial performance, authorities use ratios such as Return on Assets (ROA), Return on Equity (ROE), and Earnings per Share (EPS) (Mursid & Ritanti, 2024). These ratios have been established for many years (Cole, 1972).

The question arises: how can a bank improve its performance, and what steps need to be taken? The answer lies in the implementation of the latest technology. To support this viewpoint, Anjalika and Priyanath (2018) argue that state-of-the-art quality services in the banking sector enhance customer satisfaction and retention, which can be achieved through the use of the latest technology. Technology helps the banking sector maintain

competitiveness, making the implementation of FinTech a crucial factor in improving banking sector performance. Similarly, Das et al. (2017) support this by recommending that FinTech technology has completely transformed banking institutions in the UAE. With the inception of modern banking applications like mobile banking, e-banking, and branchless banking, it becomes imaginable through the adoption of FinTech. This advancement allows the banking sector to deliver high-quality services with more confidence and trust (Mugambi, 2022; Stawicka, 2021).

The institution's environmental aspects show its commitment toward protecting the planet by adopting environmental standards beyond just legal compliance. It involves effectively managing natural resources like energy, land, and water, while reducing waste, emissions, and harmful residues. Proactively addressing these issues enhances both its environmental and social performance (Beck & Ferasso, 2023; Saenz, 2023).

By evaluating the available literature, it has been noted that rare research studies have tried to examine the short-term impact of environmental performance, such as pollutant emissions, resource depletion, waste generation, and energy consumption, rather than the long-term environmental impacts of enterprise activities (Kestane et al., 2019).

Organizational social performance can be defined as how an organization assimilates its social responsibility (CSR) into its vision and mission, guiding actions of social awareness, guiding policies, initiatives, and calculable outcomes as they relate to the firm's societal interactions (Messmann et al., 2023). This includes aspects such as employee relations, health and safety, wages and pay, non-discrimination, employee turnover rate, and opportunities for education and career development, as outlined in the company's Corporate Social Responsibility (CSR) (Stamm, 2023). In banking institutions, CSR plays a key role in determining stakeholder satisfaction, building a solid reputation, and aligning social initiatives with business goals. Studies show that CSR not only enhances a company's image but also improves financial performance.

Blockchain technology (BCT) application in banking services introduces a strong combination of transparency and security (Patelli & Mandrioli, 2020). In today's tech-driven world, bank users desire a facility to track and monitor their transactions. However, without a strong system for traceability, the risk increases, as users often don't realize there's an issue until their data is compromised (Fan et al., 2022). While full transparency is not always ideal, a certain balance of transparency and confidentiality is essential for both financial providers and their clients (Saranya & Maheswari, 2023).

Application of Blockchain in banks can use its distributed ledger feature to give transaction owners control over their traceability (Deshpande et al., 2017). This ledger verifies ownership and claims on financial data, which helps to build trust with clients. BCT is not only cost-effective and time-saving, but it also automates processes and reduces complexity. With smart contracts, BCT can automatically record transactions when they happen, handle any issues that come up, and consistently reduce human errors (Chang et al., 2019; Jameaba, 2023; Surekha et al., 2022).

According to Sunny et al. (2020), BCT can develop trust among banking clients by offering a secure, decentralized, and distributed ledger for recording as well as verifying the transactions (Akintuyi, 2024; Udeh et al., 2024; Uzougbo et al., 2023). BCT provides immutability and transparency facilities on all transactional data, hence, building trust in banking transactions. The decentralized feature of nodes prevents any single entity from

controlling or manipulating records, which strengthens the security and reliability of the entire system (Akpuokwe et al., 2024; Tariq et al., 2019).

Smart contracts of BCT provide automation features in trade finance, mitigating the risk of fraud due to automating payment systems. This feature also improves know your customer (KYC) processes through securely storing clients' information, which helps in identity verification as well as regulatory compliance. Moreover, BCT simplifies auditing and compliance through transparent, immutable transaction records. This transparency feature of BCT improves accountability, mitigates fraud risk, and encompasses customer service, product offerings, and overall banking operations (Centobelli et al., 2022; Sunny et al., 2020). The research clearly shows that Blockchain significantly increases transparency and trust in the banking sector.

Despite the fact that BCT has many benefits, FinTech governance in Islamic banking is still facing significant challenges. The key challenges include a lack of standardized regulations, data security concerns, and a shortage of expertise. Issues like fully integrating technology, addressing technical and security concerns, and information gaps in online peer-to-peer (P2P) lending can increase investment risks and affect lender decisions (Chen & Han, 2012). To manage these risks, Herzenstein et al. (2011) suggest full financial transparency and building trust to improve P2P lending efficiency.

Nowadays, financial services have been transferred online; the risk of fraud increases due to increased access to information. The fast-paced nature of transactions in FinTech can also raise concerns (Miller, 2015). These risks may lead to uncertainty (gharar) in financial contracts, as system failures or hacks may disrupt transactions and enable fraud. Studies by T. Wang and Hsu (2013) and Saifullah et al. (2024) express that strong internal controls on data security and strong governance are vital to minimizing these risks.

For Islamic banks, connecting with FinTech is needed to address Shariah non-compliance issues as they adopt new technologies. Shariah laws encourage innovation, as long as it aligns with Islamic principles, maintains ethical standards, and safeguards the social and political environment (Almutairi & Quttainah, 2017; Archer et al., 1998). To ensure these standards, it's essential for FinTech companies to collaborate with Shariah boards, which oversee all aspects of Shariah-compliant transactions, models, and operations (Ghayad, 2008).

Prior research shows that advanced Blockchain systems, like Blockchain Management Systems (BMS), can help Islamic banks to streamline their processes and better align with Shariah principles. With this understanding, we are now in a strong position to develop hypotheses for our study.

H_1: Blockchain technology adoption in Islamic Banking has a positive impact on the sustainable performance.

H_2: Traceability plays an imperative role in connecting Blockchain technology adoption with the sustainable performance of Islamic banks.

H_3: Transparency serves as a positive link between Blockchain technology adoption and the sustainable performance of Islamic banks.

H_4: Governance plays a key role in mediating between the adoption of Blockchain technology and a sustainable performance of Islamic banks.

H_5: Transparency, linkage by good governance has a positive impact on the association-ship Blockchain technology implementation and sustainable performance of Islamic banks.

H_6: Traceability, mediated through governance, influences the relationship between Blockchain Technology adoption and the sustainable performance of Islamic banks.

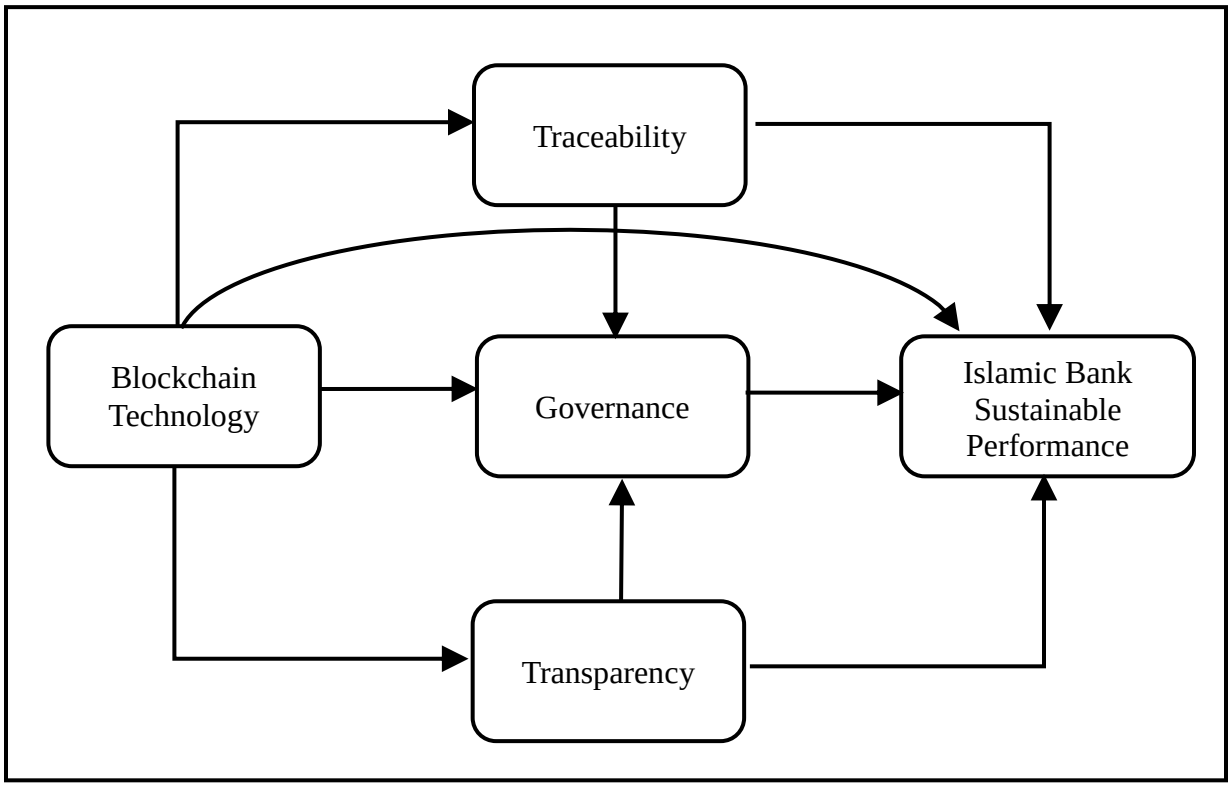

Figure.4.Conceptual Framework
Source: Author's own elaboration

3. Methodology

This study investigates the effect of four main feature of Blockchain technology on the sustainable performance of Islamic banks in the context of Pakistan applying through quantitative research design. Data was collected using a cross-sectional approach to capture a snapshot of the phenomenon at a specific point in time. The primary objective is to investigate how Blockchain technology, transparency, traceability, and governance impact the banks' sustainable performance.

The data was collected through a structured self-administered questionnaire, which included two parts; (1) demographic information (gender, organization, age) and (2) constructs that were measured in terms of five-point likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The population segment was the Blockchain Technology (BCT) professionals, freelancer, academicians and other major stakeholders in the Islamic banking industry in Pakistan, such as the bank staff, regulators, IT experts and customers. The questionnaires were distributed physically and online in September-November of the

year 2024. The purpose of the study was explained to respondents and they were instructed to give written consent. The proponents of ethical standards were adhered to using anonymity and confidentiality measures. Out of 500 distributed surveys 465 were mailed back; 15 with incomplete answers were ruled out and 450 only were valid. The sample was made up of male participants only and their average age was 41.8yrs. The level of experience in the field was between 0-2 years (8 percent) and 2-5 years (25.7 percent). The sample size met the criteria, which would allow strong statistical analysis to be conducted through Structural Equation Modeling (SEM).
This questionnaire was spread through emails and professional social media. There were no incentives, and participation was voluntary, and confidentiality was assured. Its design was meant to produce unbiased contributions of a wide pool of professionals, which would make the findings on the topic of BCT implementation in Islamic banking rather valid.

Scales used were validated scales of previous studies:

- **Blockchain Technology**: 10-item measure (Kalyar et al., 2020)
- **Traceability:** 8-item scale (Gunasekaran et al., 2017).
- **Sustainable Performance:** (TBL Framework) the variables of environmental, social, and economic dimensions were assessed by using 4-item scales (Khan et al., 2017).
- **Transparency and Governance:** 16-item and 12-item, respectively (Seyedsayamdost & Vanderwal, 2020).

3.1. Demographic Profile of Respondents

The breakdown of the demographics of the survey respondents is given here:-

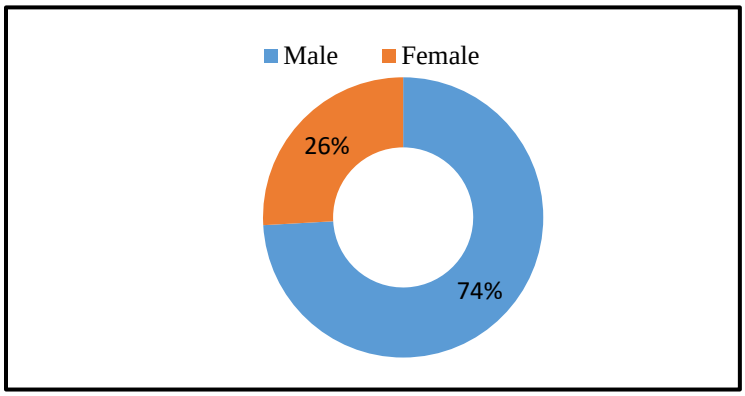

Figure.5.Gender Distribution
Source: Author's own elaboration

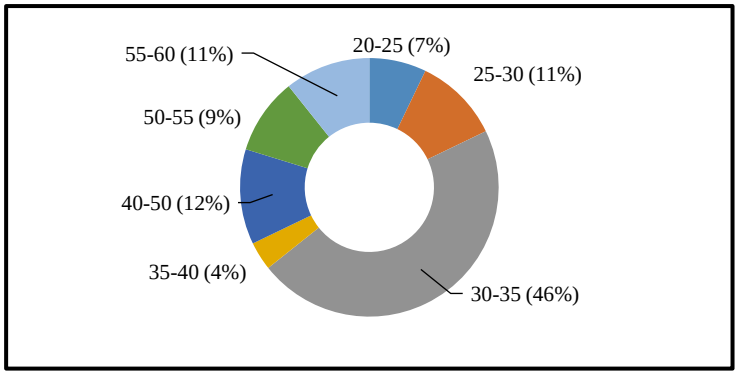

Figure.6.Respondent Age Bracket
Source: Author's own elaboration

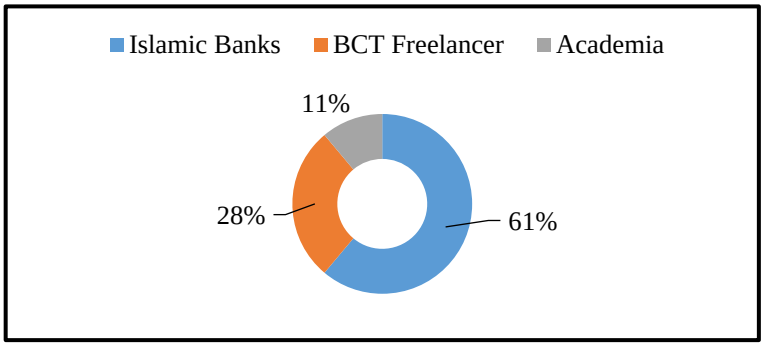

Figure.7.Participants Affiliation
Source: Author's own elaboration

4. Data Analysis

Partial Least Squares Structural Equation Modeling (PLS-SEM) software was applied for data analysis. The analysis consists of two stages. In the first attempt, the measurement model was tested in order to ensure that the indicators truly reflected the theoretical concepts and were reliable and valid. In the second, the structural model was tested to understand how BCT, transparency, traceability, and governance each relate to sustainable performance. This step-by-step approach allowed us to deeply explore how Blockchain technology impacts the long-term success of Islamic banks.

Table.2. Convergent validity, internal consistency, and Reliability.

Constructs	Items	Loading Value	Cornbrash's Alpha	rho-A	Composite Reliability	AVE
Blockchain Technology	BCT-1	0.722	0.852	0.856	0.886	0.495
	BCT-10	0.543				
	BCT-11	0.640				
	BCT-12	0.737				
	BCT-3	0.713				
	BCT-5	0.738				
	BCT-6	0.728				
	BCT-9	0.781				
Traceability	T-1	0.570	0.745	0.745	0.816	0.360
	T-10	0.669				
	T-11	0.555				

	T-12	0.633				
	T-14	0.557				
	T-16	0.514				
	T-8	0.553				
	T-9	0.718				
Governance	Gov-12	0.615	0.788	0.808	0.850	0.490
	Gov-13	0.560				
	Gov-14	0.722				
	Gov-15	0.757				
	Gov-16	0.835				
	Gov-17	0.676				
Transparency	Tr-11	0.596	0.895	0.909	0.914	0.500
	Tr-12	0.569				
	Tr-15	0.513				
	Tr-2	652				
	Tr-3	0.751				
	Tr-4	0.716				
	Tr-5	0.831				
	Tr-6	0.784				
	Tr-7	0.905				
	Tr-8	0.541				
	Tr-9	0.801				
Financial Performance	FP-1	0.761	0.916	0.921	0.930	0.529
	FP-10	0.671				
	FP-11	0.703				
	FP-12	0.612				
	FP-2	0.659				
	FP-3	0.559				
	FP-4	0.638				
	FP-5	0.635				
	FP-6	0.770				
	FP-7	0.784				
	FP-8	0.778				
	FP-9	0.733				

Constructs	**Items**	**Loading Value**	**Cornbrash's Alpha**	**rho-A**	**Composite Reliability**	**AVE**
Environmental Performance	EP-1	0.648	0.882	0.892	0.911	0.630
	EP-2	0.637				
	EP-3	0.636				
	EP-4	0.844				
	EP-5	0.806				
	EP-6	0.758				
Social Performance	SP-1	0.754	0.850	0.854	0.894	0.628
	SP-2	0.745				
	SP-3	0.826				
	SP-4	0.889				
Sustainable Performance	FP-3	0.600	0.955	0.957	0.959	0.505
	FP-12	0.609				
	FP-5	0.630				
	EP-3	0.635				
	FP2	0.636				
	FP-4	0.639				
	FP-2	0.662				

	EP-1	0.663
	SP-5	0.665
	FP-10	0.673
	SP-2	0.693
	FP-11	0.704
	SP-1	0.716
	FP-9	0.735
	EP-6	0.759
	FP-1	0.762
	SP-3	0.763
	SP-4	0.763
	FP-6	0.766
	FP-7	0.783
	FP-8	0.806
	EP-5	0.804
	EP-4	0.865

Source: Author's own elaboration

4.1. Constructs and Observed Variables

Table-2 shows that Blockchain Technology (BCT), Traceability (Tra), Governance (Gov), Transparency (Trns), Financial Performance (FP), Environmental Performance (EP), and Sustainable Performance (SP) all these are pre-perceived conceptual constructs. These pre-perceived constructs which are not directly observable but are measured using the data collected.

Factor loadings show how well each survey question reflects the underlying concept when it measures. When these values are above 0.7, it indicates a strong connection between the question and the concept, suggesting the survey items are significant representations of the construct.

The VIF helps in identify any multicollinearity issues in the model, which occur when variables are closely related. Generally, VIF values above 5 or 10 indicate serious multicollinearity problems (Hair Jr et al., 2021). In this analysis, all VIF values are below these limits, meaning there are no significant multicollinearity concerns. As a result, the model's estimates are stable and not skewed by overlapping variables.

4.2. Reliability and Validity

Cronbach's Alpha (Cα), besides rho-a, and rho-c is normally applied to test internal reliability and consistency. If the values are over 0.7, it means that items hold significant internal consistency and can measure the underlying concept. The Average Variance Extracted (AVE) reflects how much variation is observed in the data of each construct. If the AVE is above 0.5, it suggests that the construct explains a significant portion of the variation in the data set (Alomari, 2023; Arifin et al., 2024). In this study, the results in Table 3 show that all constructs meet or exceed these threshold values, meaning they have strong internal consistency and convergent validity.

Table 3.Reliability and Validity

Construct	Cornbrash's Alpha	rho-A	rho-c	R^2	Adjusted R^2
Blockchain Technology	0.852	0.856	0.886	-	-
Traceability	0.745	0.745	0.816	0.519	0.513
Governance	0.788	0.808	0.850	0.425	0.411
Transparency	0.895	0.909	0.914	0.525	0.513
Financial Performance	0.916	0.921	0.930	0.925	0.924
Environmental Performance	0.882	0.892	0.911	0.838	0.836
Social Performance	0.850	0.854	0.894	0.835	0.828
Bank Sustainable Performance	0.955	0.957	0.959	0.576	0.555

Source: Author's own elaboration

4.3. Model Fit

The R^2 and adjusted R^2 values help measure how much variation is explained in the dataset by the constructs in the model. Adjusted R^2 estimates more accurate values of included variables, especially when there are multiple predictors. If values are closer to 1 means the model is explaining the data significantly. Table 3 shows a summary of the model fits for the data. All the variables show strong reliability.

4.4. Discriminant Validity

The Heterotrait-Monotrait Ratio (HTMT) is used to assess discriminant validity among constructs. Values below 0.85 or 0.90 generally indicate that the constructs are distinct and not overly correlated. Table 4 displays HTMT values well below these thresholds, demonstrating strong discriminant validity. For example, the HTMT values for Blockchain Technology (BCT), Traceability (Tra), Governance (Gov), Transparency (Trns), Financial Performance (FP), Environmental Performance (EP), Social Performance (SP), and Sustainable Performance (SP) are all 0.072, significantly below the 0.85 threshold. This confirms that these constructs are distinct from one another.

Table.4.FornellLarcker Criterion

	BSP	BCT	EP	FP	Gov	SP	Traceability	Transparency
BSP	**0.711**							
BCT	0.616	**0.704**						
EP	0.916	0.586	**0.795**					
FP	0.962	0.620	0.804	**0.727**				
Gov	0.509	0.794	0.470	0.472	**0.700**			
SP	0.911	0.916	0.796	0.815	0.496	**0.793**		
Traceability	0.683	0.505	0.568	0.678	0.631	0.645	**0.600**	
Transparency	0.644	0.613	0.601	0.604	0.690	0.601	0.646	**0.707**

Source: Author's own elaboration

4.5. Hypothesis Testing

Table 5 shows the findings extracted from Structural Equation Modeling, demonstrating hypotheses (H_1 to H_8) testing causal links as well as mediation between dimensions like Blockchain Technology and Success bank sustainable performance. The study's theoretical predictions align with observed effect sizes, as indicated by original sample estimates.

Table.5. Hypothesis Testing

Hypothesis	Total Effect (IV to ID)			Direct Effect (IV to DV)			Indirect Effect (IV to DV)				Results	Decision
	Coefficient	t. value	p. value	Coefficient	t. value	p. value	Coefficient	SD	t. value	p. value		
H1 BCT → BSP	0.616	9.296	0.000	0.309	2.406	0.016	0.283	0.117	2.413	0.016	Partially	Supported
H2 BCT → Gov → BSP	0.341	3.496	0.000	-0.236	1.586	0.113	0.168	0.066	2.565	0.001	Fully	Supported
H3 BCT → Traceability → BSP	0.72	13.88	0.000	0.720	13.875	0.000	0.012	0.050	2.435	0.015	Partially	Supported
H4 BCT →Transparency→ BSP	0.417	4.994	0.000	0.202	2.288	0.022	0.017	0.039	1.812	0.070	Fully	Supported
H5 BCT→Traceability→Gov→BSP	0.801	5.932	0.000	0.801	5.932	0.000	0.185	0.072	2.567	0.010	Partially	Supported
H6 BCT→Transparency→Gov→BSP	0.63	7.815	0.000	0.63	7.815	0.000	0.505	0.107	4.728	0.000	Partially	Supported

Source: Author's own elaboration

In order to determine the mediational effects in the proposed framework, a mediation analysis was done and attention was paid to the role of governance, transparency, and traceability as a medium between Blockchain Technology and sustainable performance of Islamic banks. This method made it possible to discover how blockchain mediates its effect on sustainability results and why the mediators are important because they determine the overall effect. The results, as shown in Table 4.3, reveal that H_1 demonstrated that Blockchain Technology implementation has a positive impact on the sustainable performance of Islamic banking with a substantial indirect effect ($\beta = 0.283$, $p = 0.016$), indicating only partially mediates. The results reveal that H_2 shows full mediation passing through governance, as the direct effect became insignificant ($p = 0.113$), and the indirect path was significant ($\beta = 0.168$, $p = 0.001$). In H_3, Traceability partially mediated the BCT–BSP relationship. Although the direct effect remained significant, the indirect effect ($\beta = 0.012$) was also statistically significant ($p = 0.015$). H_4 revealed full mediation via Transparency, even though the indirect effect was modest ($\beta = 0.017$, $p = 0.070$), still supporting the mediating role. H_5 involved a serial mediation through Traceability and Governance. The indirect path ($\beta = 0.185$, $p = 0.010$) supported partial mediation, implying that both intermediaries play a critical role in strengthening the impact. Lastly, H_6 confirmed a strong partial mediation effect via Transparency and Governance with a high indirect coefficient ($\beta = 0.505$, $p < 0.001$), showing a robust mediating chain.

In addition to the mediation analyses, Figure-08 presents sample means from bootstrapping, offering a robust measure of the consistency of effect sizes across multiple samples. Standard deviations reflect variability within bootstrap samples, providing insight into the spread of estimations. The t-statistics, calculated as the ratio of original sample values to their standard deviations, robustly indicate the reliability and magnitude of the associations. High t-values across the hypotheses underscore the strength of the observed effects, supporting the anticipated model links. P-values close to zero in the study signify clear statistical significance, allowing us to reject the null hypothesis of no correlations between the constructs.

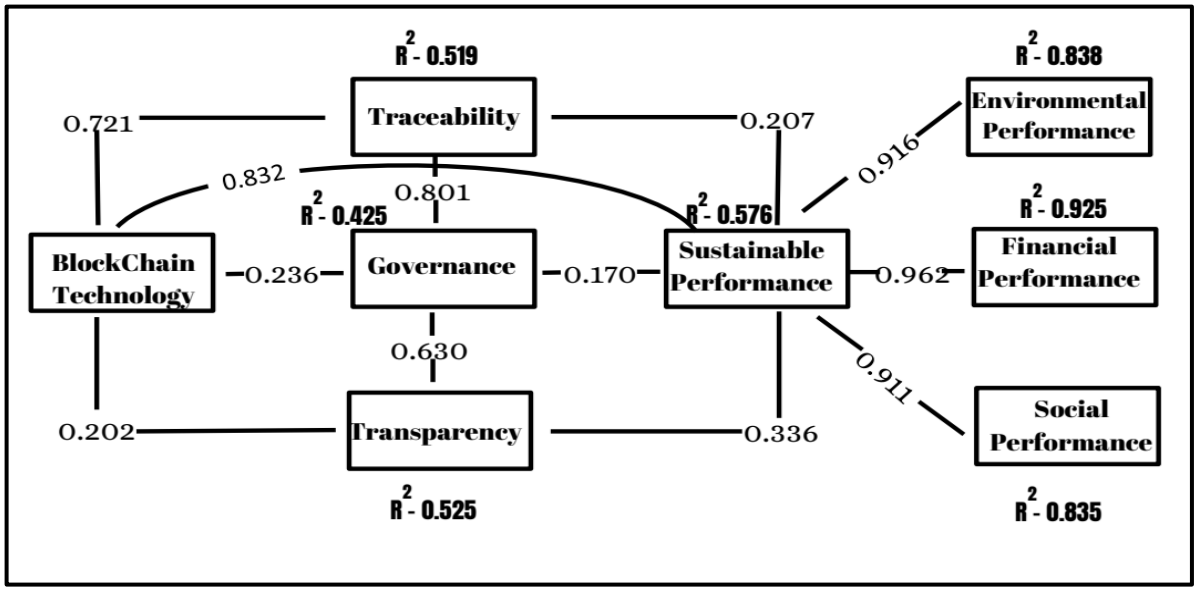

Figure.8.bootstrappingModel
Source: Author's own elaboration

5. Results and Discussion

This study investigates the effective implementation of Blockchain technology in Islamic banks in Pakistan, specifically examining its impact on sustainable performance. Data from a large sample of banking industry experts, freelancers, and academic professionals was rigorously analyzed using Smart PLS and Partial Least Squares Structural Equation Modeling (PLS-SEM).

The Blockchain features studied, namely Traceability (T), Transparency (Tr), and Governance (G)—were represented by observable variables with strong loadings, indicating a positive relationship with the underlying constructs. Reliability metrics, including Cronbach's Alpha and composite reliability (rho_a, rho_c), demonstrated the internal consistency and precision of the constructs.

All constructs have an Average Variance Extracted (AVE) more than 0.5, meaning the constructs have strong convergent validity and capture the variability in the observed data. The R^2 and adjusted R^2 values in the model also show that the independent variable explain a significant portion of the variation in sustainable performance. In other words, the model has significantly explained the proportion of its variability.

Discriminant validity of the measurement model has been confirmed through the Fornell-Larcker criterion, wherein all ratios are below the acceptable threshold, meaning the constructs are different from one another. The hypothesis testing showed that all the relationships, including Transparency, Traceability, and Governance, were statistically significant in explaining how Blockchain technology impacts the sustainable performance of Islamic banking in Pakistan. These findings highlight the key role these factors play in driving sustainable performance within the Islamic banking sector. Similarly in this era of technological advancement the carbon emission and energy efficiency is still growing challenges. Therefore, achieving sustainable performance through the Triple Bottom Line (TBL) lens has become indispensable for Islamic banking. Existing study examine how blockchain technology and its feature mediated the relationship on

sustainable performance outcomes. The finding suggested several key insights. Study first direct hypothesis asserted a significant positive relationship between Blockchain technology and sustainable performance, which has been supported by the results. Islamic Banking Institutions demonstrated their ability to fulfill green service assurances, respond swiftly to customer needs through environmentally responsible practices, and maintain an eco-friendly banking services. Islamic Banking Institutions are actively embedding sustainability into operational processes, emphasizing collaboration, trust, renewable resource utilization, and integrated coordination across their operation. As a result, they not only reduce waste and operational risks but also meet customer demands more efficiently. These study outcomes are align with available research like Abdurrahman, A., Gustomo, A., & Prasetio, E. A. (2024), emphasizing on the necessity of integrating sustainable practices to achieve superior banking performance. Notably, BCT also enhance service quality in banking service offering, fostering customer satisfaction and strengthening inter-banking institutional trust.

The direct impact of Traceability, Transparency, and governance has also been evaluated through study hypotheses three and four, which reveals that all these study variables significantly enhance the sustainable performance, which was also confirmed. Islamic Banking Institutions are improving transaction visibility, managing costs effectively, minimizing waste, and ensuring the timely completion of foreign transfer transactions. Environmentally responsible banking using lean practices contributes significantly to environmental, social, and economic performance. These include pollution control, cleaner production, employee well-being, and improved stakeholder perception. The findings support existing literature, such as (Alaeddin, O., Al Dakash, M., & Azrak, T., 2021). Three indirect hypotheses were tested regarding transparency, traceability, and governance as mediating variables:

- **Traceability and Sustainable Performance:** Traceability fully mediates this relationship. Islamic Banking Institutions that adopt traceability and align their operations with green objectives—through BCT systems, trained workforce, and dynamic networks—are better positioned to deliver sustainable performance. This includes cost reductions, green product/service design, and long-term capability development. The findings align with existing literature, like (Centobelli, Piera, et al., 2022).

- **Transparency and sustainable performance:** The study confirmed that transparency fully mediates the association ship BT and enhances sustainable performance, which in turn supports improved TBL outcomes. Transparency increases customer satisfaction, enabling transaction traceability, supporting auditing, and building trust. BCT becomes instrumental in achieving not just operational, but social and environmental sustainability as well. This mediation results also supported with the study of Centobelli, Piera, et al. (2022).
- **Governance and Sustainable performance:** Governance through Blockchsin technology was tested as mediating variable. The results depict that sustainable performance through BCT is fully moderated. Governance practice in Islamic Banking can improve trust, enhance confidence of Islamic banking services users. This mediation result also supported with the study of Oriekhoe, Osato Itohan, et al. (2024)

6. Conclusion

This era of relentless technological advancement in digital transformation, characterized by revolutionary innovations that have reshaped the future landscape. Blockchain Technology is considered a notable innovation among these technologies, renowned due to having the potential to completely transform all the sectors of the economy, having built in features of transparency, convenience as well as efficiency.

Prominent research studies like those by Alaeddin et al. (2021), have in-depth attempt to explorer the transformative impact of BCT. Likewise, Tijan et al. (2019) also strengthened these findings, emphasizing that Blockchain is at the forefront of the digital revolution by offering a strong foundation for secure, transparent, and efficient transactions across all sectors of the economy.

This research study examines the effect of BCT on Islamic banking institutions operating in Pakistan, investigating its inherent potential to transform this sector through progress and innovation. Empirical evidence highlights the imperative roles of transparency, traceability, and governance in the effective adoption and implementation of Blockchain technology. Rigorous statistical analysis, supported by reliable and valid data, confirms that these four factors are important to effectively integrating Blockchain into Islamic financial institutions within the region.

The findings of this study postulate that BCT has inherent potential to significantly transform the Islamic banking sector operating in Pakistan by offering innovative features that align seamlessly with Shariah compliance standards. It highlights how Blockchain can be a practical and valuable tool for the financial industry, providing a foundation for further scholarly investigation into its multifaceted applications, particularly within Islamic banking.

As the digital era evolves, BCT is expected to play an imperative role in driving innovation and growth, specifically within the Islamic banking institutions operating in Pakistan. By offering more secure, transparent, and efficient solutions, BCT can develop trust and streamline operations effectively, pushing these institutions forward. This study emphasizes the need to embrace Blockchain to unlock its full potential and support future growth in Islamic banking.

Author Contributions

Introduction to the conclusion was carried out by Saifullah under the supervision of Muhammad Wasie Fasih Butt as the main supervisor and Syed Babar Ali as a co-supervisor.

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Conflicts of Interest

All contributed authors declare no conflicts of interest.

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