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To Be Digital Is to Be Sustainable—Tourist Perceptions and Tourism Development Foster Environmental Sustainability

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Abstract: The Technology Acceptance Model (TAM) is widely used in many areas but is rarely applied to determine the link between tourists' perceptions of tourism development and environmental sustainability. Therefore, this study aimed to (1) explore the relationships among tourism development, tourists' perceptions, and environmental sustainability, (2) examine the mediating role of blockchain technology in these relationships, and (3) analyze the use of the TAM for sustainable practices in tourism. Data were collected from tourists on their perceptions of the impact of tourism on the environment, their use of information technology (IT) during their visits, and their willingness to pay for sustainable tourism practices. The data collected from 473 respondents were analyzed using partial least squares structural equation modeling (PLS-SEM). The findings reveal that tourism development and perceptions have a significant impact on environmental sustainability. Furthermore, blockchain technology directly affects environmental sustainability and partially mediates the relationship between tourism development and tourists' perception constructs on environmental sustainability. This study contributes to the understanding of the relationships among tourism development, tourist perceptions, and environmental sustainability, analyzed through the lens of the TAM. Although the TAM has been used in several technology adoption and behavioral studies, this is its first application in the context of sustainable tourism, specifically used in exploring perceptions of environmental sustainability, limited to the environmentally rich Gilgit-Baltistan region in Pakistan.

Keywords: tourist perceptions; tourism development; blockchain technology; environmental sustainability, sustainable tourism, environmental certification

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1. Introduction

Tourism, environmental sustainability, and information technology (IT) are interconnected in today's world. The more the tourism industry grows, the more challenging it is to mitigate its negative effects on the environment. This issue has led to increased conscious efforts to develop sustainable tourism practices [1]. Environmental sustainability is defined by Thiele [2] as the responsible management and conservation of natural resources to ensure the well-being of the environment, minimize negative environmental impacts, maintain biodiversity, and ensure that human activities such as tourism practices do not deplete resources or cause long-term harm to ecosystems. Tourism, environmental

sustainability, and information technology (IT) have a relationship that is intricate and diverse. Through IT integration, sustainable tourism practices, such as communications, managing resources, promoting responsible tourism behavior, and others, can be enhanced and upgraded [3].

Moreover, social media, blockchain technology, and smart tourism destinations have emerged as potential tools to facilitate sustainable tourism practices [4]. In the field of tourism, blockchain technology was defined by Rashideh [5] as a decentralized, transparent, and secure digital ledger system that facilitates data sharing, transactions, and contract management among stakeholders without the need for intermediaries. This technology ensures the accountability, trust, and efficiency of tourism-related events by recording information in a tamper-proof manner. To address environmental sustainability and meet international standards in Pakistan, it is of utmost importance that IT applications, such as blockchain, be employed to overcome environmental challenges, improve resource management, increase economic growth, and enhance the overall well-being of the population. Such an approach can bring more sustainability and prosperity to a country [1].

Blockchain technology functions as a trusted intermediary between tourist perception, tourism development, and sustainability by ensuring trust, efficiency, and accountability in the value chain [6]. Blockchain technology aligns tourist expectations with sustainable tourism development and incentivizes eco-conscious behavior. Furthermore, it facilitates green investments and ensures the transparent reporting of environmental impacts, thus fostering a positive cycle between tourism growth and sustainability [7]. This intermediary role of blockchain strengthens the relationships among tourist perceptions, tourism development, and environmental sustainability, ensuring long-term benefits for both the environment and the tourism economy. This research focuses on the mediating role of blockchain technology in shaping tourist perceptions, tourism development, and environmental sustainability while also considering the influence of smart tourism technologies and social media in enhancing these interactions. Fatema et al. [8] highlighted the role of technological advancements, particularly artificial intelligence (AI) and the Internet of things (IoT), in transforming the tourism sector by using data-driven solutions, real-time monitoring and management of tourism-related information, and the adoption of green initiatives to facilitate environmentally friendly tourism activities. A study conducted by Jiang and Phoong [9] revealed that the adoption of digital tourism was enhanced due to the COVID-19 pandemic lockdown. This challenged the tourism industry to transform itself through the adoption of these technologies so that industry players could harness the benefits of technological innovations. Moreover, they found that digitalization increased tourism product consumption, product development, and social development. The study underscored the key role of innovative technologies in positively impacting the socioeconomic dimensions of sustainable development. Rodrigues et al. [10] explored how information and communication technologies reshaped the tourism industry by integrating key ICT tools: AI, IoT, and blockchain technology. They found that advanced ICTs tools have created an intelligent value chain and smart production process in the tourism sector.

Pakistan is poised to become a significant player in the global tourism market with its diverse landscapes, rich cultural heritage, and untapped potential. Gilgit-Baltistan, Pakistan, is home to 14 peaks above 8000 m, including the K2, Broad Peak, Nanga Parbat, and Gashebrum I and II. Its landscape and cultural heritage sites, including the Baltit Fort, Altit Fort, and Shigar Fort, attract tourists from around the world [11]. The world-famous mountain ranges—Hindu-Kush, the Himalayas, and the Karakoram (HKH)—are in northern Pakistan (Gilgit-Baltistan). Recent growth in the tourism industry has contributed to the economic development of the region [12]. However, tourism-related activities can have harmful impacts on the environment if not managed appropriately, threatening

the ecological balance of this environmentally sensitive zone. The incalculable environmental value of Gilgit-Baltistan, with its unique biodiversity and pristine natural attractiveness, makes the study of its environmental sustainability particularly relevant and essential [12]. The integration of IT into the tourism sector offers promising solutions for stimulating sustainable tourism activities by improving resource efficiency and enhancing tourism awareness. The key objectives of this study were to explore the relationships among tourism development, tourist perception, and environmental sustainability, examining the mediating role of blockchain technology in these relationships and analyzing the use of the Technology Acceptance Model (TAM) for sustainable practices in tourism.

2. Literature Review

The Technology Acceptance Model, developed by Davis [13], is crucial in understanding how users such as tourists, businesses, or governments adopt blockchain-based technology in tourism. The extant literature in tourism research has proposed that the adoption of new technologies, such as smart tourism applications, booking platforms, virtual tours, and blockchain, plays a significant role in improving firms' efficiency, capability, and competitiveness as well as enhancing the customer experience.

The use of social media by both firms and customers in the tourism industry enhances engagement by providing real-time communication, personalized recommendations, and an avenue for user-generated content, which could lead to increased revenues. This alludes to the benefits that the tourism sector can gain through the adoption of blockchain and other technologies.

Buhalis and Law [14] assessed the significance of IT in sustainable tourism development. They believe that IT plays an important role in enabling sustainable tourism, through the sharing of information, efficient resource management, and developing environmentally informed attitudes among tourists [14]. Buhalis and Law [14] believe that utilizing technologies such as artificial intelligence (AI), big data, and blockchain can greatly enhance sustainable tourism practices. These researchers further argue that such technologies have the potential to sustain tourism by enabling more efficient resource management, enriching tourism experience, and promoting responsible tourism practices. This IT integration is exemplified with the concept of smart tourism destinations (STDs), which incorporate sustainable or eco-oriented tourism practices. IT integration could mitigate the negative effects of a growing tourism sector on the environment, such as carbon emissions, water and energy consumption, and habitat destruction, as noted by Gössling [15]. In one study, Howard [16] analyzed the effect of implementing sustainable transportation in tourism and inferred that such a system can reduce the negative impacts on the environment. Furthermore, various IT applications such as mobile technologies can support the implementation of sustainable tourism. According to Gretzel [17], the factors that lead to STDs' popularity are the result of IT integration with mobile applications, stakeholder collaboration, and destination management. These mobile applications help in the sharing of information, thus enabling efficient resource management, and encourage environmentally responsible behavior among firms in the tourism sector as well as tourists [17].

Despite the possible payoffs, the integration of sustainable practices and IT applications in the tourism sector faces many challenges. According to El Archi et al. [18], the adoption of digital technology that enables sustainable tourism requires collaboration among stakeholders like operators, policymakers, communities, and technology providers. Therefore, further experimentation and analysis are required to ensure the successful integration of IT applications in tourism, for marketing and management, monitoring environmental impacts, and improving the tourist experience [18]. These initiatives are vital because as Sarfraz et al. [19] observed, successful establishment of STDs stems from the support provided by the application of IT in managing destinations, enhancing tourists'

experiences, and promoting eco practices. The integration of IT, coupled with the launch of sustainable tourism certification policies, plays a significant role in popularizing sustainable tourism and STDs.

In an examination of the role of IT in promoting tourism destinations by Pshenichnykh and Novi [20], the use digital media was recommended to market tourism destinations. They note that user-generated content has become a very important reference resource for tourists for pre-trip planning and during their travels to the intended destination [20]. In addition, user-generated content, especially in the eco-oriented tourism subsector, can promote sustainable tourism by introducing strategies for sustainable tourism practices, promoting responsible tourist behavior, and enhancing the overall tourism experience [20].

User-generated content is one of the latest innovations in the use of IT in the tourism and hospitality industries. According to Law et al. [21], IT is widely adopted in tourism to enhance communication, facilitate resource management, and improve the tourism service quality. Brazytė et al. [22] found that hotel guests perceive sustainability efforts positively, with reviews that mention sustainability initiatives receiving higher ratings. Thus, hoteliers should educate guests on sustainability measures to enhance satisfaction, as guests value these visible and impactful practices [22]. Furthermore, Erol et al. [23] studied the prospects of blockchain technology application in sustainable tourism, highlighting the potential in using blockchain technology to solve the challenges of sustainable tourism development globally.

Social media platforms have also become important for promoting sustainable tourism practices. Fathy et al. [24] found that the destination image significantly mediates the relationship between social media marketing and sustainable tourism development, which further informs practitioners and academicians about the role of social media marketing in relation to developing the destinations' image, towards sustainable tourism development. In addition, Louati et al. [25] highlighted AI-driven efficiencies as an important tool for resource management and waste reduction in the tourism sector. They further proposed that AI is a valuable tool in assisting stakeholders to make decisions that enable the practice of sustainable tourism. A study by Kim et al. [26] examined the impact of AI in tourism management, focusing on the use of AI for data analysis techniques and forecasting. The study concluded that AI enables easier and more accurate predictions of tourist demand and resource utilization [26]. Another study by Al-Romeedy et al. [27] found that AI plays a positive role in sustainable tourism entrepreneurship, as it enables a more holistic approach to address challenges in the tourism sector by integrating environmental, social, and economic considerations into business practices. Thus, the study proposes that AI can help tourism businesses to practice sustainable tourism through responsible and ethical business practices. This observation is supported by Gajić et al. [28]'s research, which explored the impact of AI on tourists' perceptions and attitudes in the tourism and hospitality sector. They found that quality AI has a positive and significant impact on visitors' engagement indicators in terms of trust and loyalty, thus demonstrating the positive manner in which tourist behavior can be impacted by advanced technology [28].

3. Methods

Data were collected from tourist respondents on their perceptions of tourism development, tourist perceptions, blockchain technology, and environmental sustainability. This study was approved by the Multimedia University Research Ethics Committee (reference no: EA0182024). Prior to participation, all respondents were provided with detailed information about this study's aims and were required to provide written informed consent. The data collection procedure was conducted through a structured questionnaire. It was administered both online, via email and social media platforms, and face-to-face with

tourists visiting the Gilgit, Hunza, and Nagar Districts of Gilgit-Baltistan. This mixed approach was used to enhance response rates and capture diverse perceptions. The data collection period spanned from 6 June to 31 July 2024, thus ensuring a sufficiently broad timeframe to capture possible variations in tourist experiences. Non-probability convenience sampling was used to collect responses from domestic and international tourists. Whilst this approach simplified the data collection process, it may limit the generalizability of the findings, particularly as most respondents were domestic rather than foreign tourists. Future work could address this limitation by employing probability-based sampling techniques to include a more diverse and representative sample. The required sample was calculated by using the formula provided below, with confidence level = 95% and margin of error (e) = 5%. The calculated required sample size was 388 tourists. In order improve research reliability, this study's collected sample size was greater than that value, at 473 domestic and international tourists.

$$SS = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

To capture participant feedback, a five-point Likert scale ranging from "1—Strongly Disagree" to "5—Strongly Agree" was used. The Likert scale is widely used for capturing attitudes and opinions. On the other hand, it is important to acknowledge that the scale may introduce response bias, as individuals may interpret scale points differently. Future work could consider alternative scaling methods or mixed-methods approaches in data collection to enhance the robustness of this study's findings. PLS-SEM was employed, as it is well-suited for assessing complex relationships among latent variables. This analysis method can handle small to moderate sample sizes and is effective in examining predictive associations in exploratory research [29,30].

3.1. Hypotheses Development

Baloch et al. [31] carried out a study highlighting the relationship of tourism development with environmental sustainability. They argued that tourism development has positive and negative effects on environmental sustainability. Moreover, their study suggested that, to balance the tourism business and ecological issues, the role of governments ought to be integrated with policy interventions so that environmental sustainability can be ensured. Saltik and Akova [32] explored the crucial role of tourists' perceptions in influencing their attitudes towards environmental sustainability. This study's analysis indicated that the awareness of tourists towards environmental sustainability can shape their travel behavior and thus enable them to apply sustainable practices during their trip and at the destination. González-Mendes et al. [33] argued about the importance of adopting advanced technology, particularly blockchain, to maintain safe and secure business transactions and enable efficient service management by tourism companies seeking to expand their business. Bolívar et al. [34] investigated tourists' demand for secure, trustworthy services by adopting blockchain technology for a better travel experience. This study examined the service providers' perceptions about adopting blockchain technology and its promise to provide enhanced tourism services imbued with transaction security. Studies by Sarfraz et al. [19], Baydeniz [35], Erol et al. [23], and Tyan et al. [36] highlighted the significance of adopting blockchain technology to enhance sustainable tourism practices. They found that blockchain integration empowers businesses to establish supply and value chains that are environmentally sustainable, reduce transactional fraud, and thus facilitate sustainable tourism. Based on the above studies, the following hypotheses were proposed:

H1. *Tourism development influences environmental sustainability.*

H2. *Tourists' perceptions influence environmental sustainability.*

H3. *Tourism development influences blockchain technology adoption.*

H4. *Tourists' perceptions influence blockchain technology adoption.*

H5. *Blockchain technology adoption influences environmental sustainability.*

H6. *Blockchain technology mediates the link between tourism development and environmental sustainability.*

H7. *Blockchain technology mediates the link between tourists' perceptions and environmental sustainability.*

The given hypotheses explore the relationships between tourism development, tourists' perceptions, blockchain technology adoption, and environmental sustainability. Hypotheses 1 and 2 were developed to investigate the relationship between tourists' perceptions and tourism development with environmental sustainability. These hypotheses consider the consequences of tourism-related activities and visitors' attitudes towards environmental consequences. Hypotheses 3 and 4 were formulated to analyze the relationship between tourism development and tourists' perceptions with the adoption of blockchain technology, uncovering how the extent to which stakeholders positively perceive blockchain's capability ensures transparent and reliable tourism service operations. Meanwhile, Hypothesis 5 investigates the impact of blockchain technology on environmental sustainability and Hypotheses 6 and 7 highlight the intervening link of blockchain technology between tourism development or tourists' perceptions and environmental sustainability, confirming that environmental sustainability can be achieved through the adoption of technology, particularly blockchain.

3.2. Measures

All the constructs of this study were measured using previously tested questionnaires. 'Tourism development' was measured with a five-item scale: "Tourism increases employment opportunities for local residents", "Tourism increases income for local residents", "Tourism increases the standard of living for local residents", "Tourism increases infrastructure development for local residents", and "Tourism increases opportunities for local businesses", adopted from questions developed by Nunkoo [37] and Gu and Wong [38]. The scale's alpha value for this survey was 0.794, which was considered acceptable.

Next, 'tourists' perceptions' were measured with a four-item scale: "Tourism has increased the quality of life in this area", "Increasing the number of tourists visiting this area would improve the local economy", "Non-residents should be allowed to develop tourism attractions in this area", and "The community should control and restrict tourism development in this area", from Perdue's [39] study. The scale's alpha value for this survey, was 0.663, which was within the acceptable range.

Moving on, 'blockchain technology adoption' was measured with a five-item scale, namely, "Blockchain technology is getting popular in the hospitality and tourism industry", "The disintermediation feature of blockchain technology is the most important attraction for hospitality and tourism related organizations", "I believe that various applications of blockchain technology can be used in hospitality and tourism industry", "To my understanding, the operating cost of blockchain technology applications is not much", and "I believe that blockchain technology can help to secure data in hospitality and

tourism industry", which was adopted from the questions developed by Chaudhuri [40]. This scale's alpha value was 0.773, within the acceptable range.

Finally, 'environmental sustainability' was measured using a five-question scale adopted from Alcock [41]'s study: "Scientists will find a solution to global warming without people having to make big changes to their lifestyle", "I am environmentally friendly in most things that I do", "Most people in the Gilgit-Baltistan today need to change their way of life so that future generations can continue to enjoy a good quality of life and environment", "I personally need to change my way of life so that future generations can continue to enjoy a good quality of life and environment", and "How frequently does the need to reduce carbon emissions affect what you do, for example by choosing to drive less or to turn lights off when you can?".This scale's alpha value was 0.781, which was acceptable. Further analysis of the constructs' reliability and validity can be found in the following section.

4. Results

4.1. Sociodemographic Details

The sociodemographic analysis of the 473 study participants indicated that 66.81 percent were male, and 33.19 percent were female (Table 1). The survey respondents were between 19 and 30 years old (32.77 percent), 31 and 42 years old (46.93 percent), and 43 and 54 years old (20.30 percent). The demographic details further indicated that 91.34 percent of the respondents were local tourists, while 8.67 percent were international tourists.

Table 1. Details of the respondents.

Variables	Frequency	Percentage (%)
Gender		
Male	316	66.81
Female	157	33.19
Age		
19–30	155	32.77
31–42	222	46.93
43–54	96	20.30
Tourist Type		
Local	432	91.34
Foreign	41	8.66

N = 473 respondents.

The PLS-SEM procedure usually comprises two sub-models—the measurement and structural models [42,43]. The measurement model must be presented prior to assessing the structural path relationships found in the structural model. These models are discussed in the following sub-sections.

4.2. Measurement Model

The standard factor loadings of this study's questionnaire items ranged from 0.420 to 0.886, which were considered acceptable, as they were equal to or greater than 0.4, as recommended by Howard [16]. As mentioned in the previous section, the constructs' alpha values ranged from 0.663 to 0.794, indicating that all the constructs for this study were reliable [44]. The composite reliability (CR) values of all the constructs ranged from 0.724 to 0.897, which were greater than 0.7, as per the recommended criteria [29]. The attained values of composite reliability confirm that all items used in this study acquired internal consistency and reliability, enabling analyses of these constructs to be used in drawing

conclusions for this study. The average variance extracted (AVE) values of all the constructs ranged from 0.507 to 0.538, which were greater than 0.5. This confirmed that the questionnaire items of this research were effectively constructed and reliably represented the factors being studied. With the AVE and CR scores being above the requisite thresholds and showing the robustness of this study, the findings of this study can thus be used or applied by researchers, readers, and policymakers with confidence. The measurement model's values indicated a high level of internal consistency. A multicollinearity test was employed by examining the variance inflation factor (VIF). According to Hair et al. [30], the VIF values should not exceed 10. The VIF values of all the items in this study ranged from 1.095 to 2.589, which were acceptable. The results of the measurement model, including the items TD1, BCT1, TP1, etc., are shown in Figure 1 and Table 2.

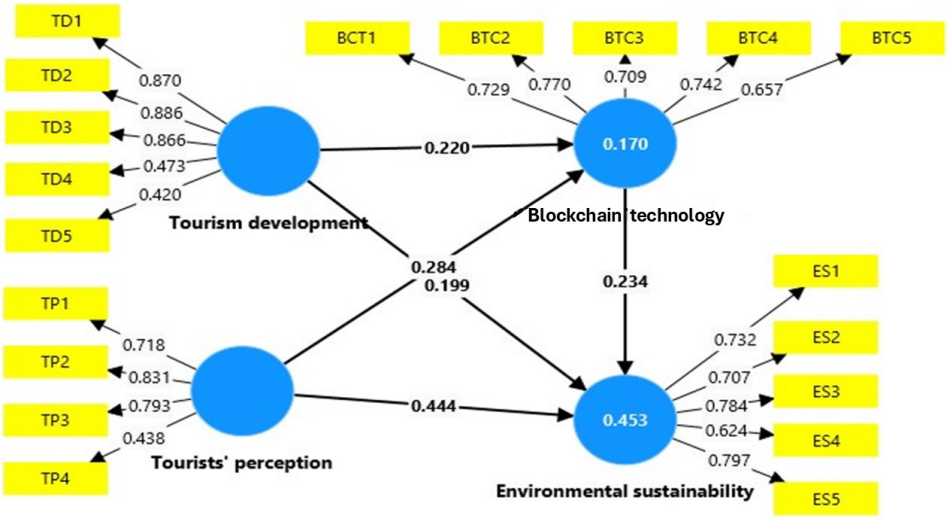

Figure 1. Measurement model.

Table 2. Factor loadings of the constructs.

Construct	Item	Loading	Alpha Value	CR	AVE	VIF
Tourism Development			0.794	0.897	0.538	
	TD1	0.870				2.280
	TD2	0.886				2.589
	TD3	0.866				2.126
	TD4	0.473				1.744
	TD5	0.420				1.738
Tourist Perceptions			0.663	0.724	0.507	
	TP1	0.718				1.346
	TP2	0.831				1.562
	TP3	0.793				1.499
	TP4	0.438				1.095
Blockchain Technology			0.773	0.784	0.522	
	BCT1	0.729				1.434
	BCT2	0.770				1.473
	BCT3	0.709				1.544
	BCT4	0.742				1.444
	BCT5	0.657				1.448
Environmental Sustainability			0.781	0.791	0.535	
	ES1	0.732				1.565
	ES2	0.707				1.441

ES3	0.784	1.821
ES4	0.624	1.312
ES5	0.797	1.759

4.3. Discriminant Validity and R^2 Coefficient of Determination

In this study, two criteria, Fornell–Larcker and HTMT, were used to assess the discriminant validity of the constructs. The square root of AVE for each construct was greater than that construct's correlation to other latent constructs, implying adequate discriminant validity based on the Fornell–Larker criterion [45]. As per the HTMT criterion, all values were less than 0.85, thus further proving the absence of discriminant validity issues (see Table 3).

Table 3. Discriminant validity of constructs (Fornell–Larcker and HTMT Criteria).

Constructs	1	2	3	4
	Fornell–Larcker			
1. Blockchain technology	0.723			
2. Environmental sustainability	0.455	0.732		
3. Tourism development	0.314	0.419	0.734	
4. Tourist perceptions	0.356	0.593	0.330	0.712
	HTMT			
1. Blockchain technology				
2. Environmental sustainability	0.578			
3. Tourism development	0.373	0.448		
4. Tourists' perceptions	0.493	0.782	0.443	

The R^2 in this study's measurement model indicated that a moderate proportion of the total variance (17.0 percent) in blockchain technology is explained by tourism development and tourists' perceptions, suggesting that while these factors play a role in influencing blockchain adoption, other factors may also be significant. This indicates the need for further exploration of additional enablers such as regulatory frameworks, technology infrastructure, and stakeholder readiness to enhance blockchain integration in the tourism sector, towards creating STDs. On the other hand, a substantial proportion (45.3 percent) of the total variance in environmental sustainability is explained by tourism development, tourists' perceptions, and blockchain technology (Table 4 and Figure 1). This suggests that blockchain technology, in combination with tourism-related factors, plays a considerable role in shaping environmental sustainability effects.

Table 4. Coefficient of determination R^2 values.

Construct	R^2	Result
Blockchain technology	0.170	Moderate
Environmental sustainability	0.453	Substantial

4.4. Structural Model

The results of the measurement model are listed in Table 5. The path values show a significant impact of tourism development on environmental sustainability ($\beta = 0.251$, $t = 5.802$, $p < 0.05$), supporting H1. The path values also show a significant impact of tourists' perceptions on environmental sustainability ($\beta = 0.510$, $t = 12.601$, $p < 0.05$), which supports H2. In addition, the path values show a significant impact of tourism development on blockchain technology ($\beta = 0.220$, $t = 4.436$, $p < 0.05$), as well as tourists' perceptions on blockchain technology ($\beta = 0.284$ $t = 5.867$, $p < 0.05$), thus supporting H3 and H4. The path

coefficient values show that blockchain technology significantly impacts environmental sustainability ($\beta = 0.234$, $t = 5.616$, $p < 0.05$), which supports H5. The indirect path coefficient values indicate that blockchain technology partially mediates the association between tourism development and environmental sustainability ($\beta = 0.052$, $t = 3.465$ $p < 0.05$) as well as tourists' perceptions and environmental sustainability ($\beta = 0.666$, $t = 3.673$, $p < 0.05$), which support H6 and H7.

Table 5. Structural path coefficient.

Relationship	β Value	*t* Value	*p* Value	Decision
H1: Tourism development → environmental sustainability	0.251	5.802	0.000	Supported
H2: Tourists' perceptions → environmental sustainability	0.510	12.601	0.000	Supported
H3: Tourism development → blockchain technology	0.220	4.436	0.000	Supported
H4: Tourists' perceptions → blockchain technology	0.284	5.867	0.000	Supported
H5: Blockchain technology → environmental sustainability	0.234	5.616	0.000	Supported
H6: Tourism development → blockchain technology → environmental sustainability	0.052	3.465	0.001	Supported
H7: Tourists' perceptions → blockchain technology → environmental sustainability	0.666	3.673	0.000	Supported

5. Discussion

This study provides a comprehensive analysis of the relationships amongst tourism development, tourists' perceptions, blockchain technology, and environmental sustainability constructs in Gilgit-Baltistan, a tourist destination located in the northern area of Pakistan. Tourism development has been shown to have a significant relationship with environmental sustainability. The results are consistent with the studies of Roxas et al. [46] and Wondirad and Ewnetu [47] and show that sustainable tourism practices are among the factors that could heighten environmental conservation. Eco or sustainable tourism development practices are essential for stimulating environmental consciousness, thus contributing to the protection of nature. This study recommends sustainable practices in tourism development that are in harmony with the environment. Moreover, this study's results indicate that tourists' perceptions of the tourism sector in this study's area significantly impact their perception of their own lifestyles' environmental sustainability. These results are consistent with earlier research, such as Gautam [48] and Tkaczynski [49]. These authors claim that tourists who value sustainability are more likely to engage in environmentally friendly behaviors during their visits to various destinations. Tourists perceived that environmentally conscious visitors were helpful for environmental protection.

The findings further indicate that sustainable tourism development practices and tourist perceptions foster blockchain technology adoption in the different regions of Gilgit-Baltistan. This study recommends the use of blockchain technology, which can mitigate environmental damage. The results are consistent with those of earlier studies by Özgit et al. [50] and Tyan et al. [36], which claimed that IT can enhance transparency and trust in sustainable tourism practices. Moreover, the results indicate that blockchain technology is a prominent factor contributing towards ensuring environmental sustainability. This result corroborates previous research by Friedman et al. [51] and Alhasan and Hamdan [52]. They highlighted that blockchain technology is a potential tool for improving resource management and reducing environmental impacts through its application in enhanced data tracking and accountability systems. Finally, the results also allow us to conclude that the links between tourism development, tourists' perceptions, and environmental sustainability are partially mediated by blockchain technology. This aligns with prior studies, which found that blockchains are transformative tools for achieving more sustainable and transparent tourism practices [19,53]. The use of blockchain technology not only directly impacts environmental sustainability but also enhances the positive effects of tourism development and tourists' perceptions on environmental sustainability.

The use of this technology ensures efficiency, transparency, and accountability in resource management and enables stakeholders to monitor and mitigate environmental impacts effectively. Additionally, blockchain technology enhances trust among tourists by promoting eco-friendly practices and supporting sustainable tourism initiatives, thereby aligning tourism growth with the principles of environmental stewardship. In line with the studies carried out by Baloch et al. [31], Saltik and Akova [32], and González-Mendes et al. [33], this study revealed that blockchain technology plays crucial role in ensuring security and transparency of records. Therefore, tour operators and other tourism service providers' environmental sustainability initiatives in Gilgit-Baltistan can be linked through the use of blockchain technology, thus empowering them and making them accountable while dealing with visitors in Gilgit-Baltistan, Pakistan, particularly in pricing, equal distribution of the due shares of tourism income among the stakeholders or local community, and conservation efforts. The further implication of this study's findings is that blockchain technology will enable transparent reviews and ratings on decentralized platforms. Therefore, using blockchain technology will not only reduce the risk of misinformation but will also help visitors in making informed travel decisions.

The findings further highlight the practical implications of blockchain technology in improving transparency, efficiency, and trust in sustainability initiatives within the tourism sector. Industry stakeholders and policymakers can leverage these insights to develop strategies that promote responsible tourism practices while integrating blockchain-based solutions for enhanced environmental sustainability performance. Moreover, policymakers can frame a clear policy direction for the industry stakeholders, particularly travel agents, tour operators, hospitality service providers, and the support sector, to ensure the use of technology ensures transparency in all business dealings.

5.1. Practical Implications

Firstly, this empirical study highlights the importance of tourism development with a focus on sustainability, especially at nature-centric tourism destinations. The policymakers developing tourism in Gilgit-Baltistan and similar regions should prioritize sustainable practices to foster environmental conservation, such as promoting sustainable transportation options and eco-friendly accommodation. Secondly, this study emphasizes the important impact of tourists' perceptions on environmental sustainability. Tourism stakeholders should implement educational programs and awareness campaigns to encourage environmentally responsible practices among local and foreign tourists. Once awareness is widespread in tourists, they will naturally engage in activities that will support environmental sustainability practices at various tourist destinations. Thirdly, this study reveals that blockchain technology can enhance transparency of and trust in sustainable tourism practices. It is essential that tourism operators consider adopting blockchain to track and verify sustainable practices, ensure accountability, and attract more environmentally conscious tourists. These findings relating to the role of blockchain technology suggest that the integration of this technology can improve resource management in the tourism sector. Tourism companies can utilize blockchain technology to monitor resource use, thus reducing waste and minimizing the impact and occurrence of activities harmful to the environment. Finally, government bodies should consider creating incentives or regulatory frameworks that promote the adoption of blockchain in this sector to enhance the sustainability of tourism activities.

5.2. Theoretical Implications

An important contribution of this study is that it enhances the academic understanding of how sustainable tourism practices can lead to environmental conservation, supporting the idea that environmentally responsible tourism development can have positive

environmental outcomes. Another contribution is that this study strengthens the theory that tourists' perceptions are closely tied to environmental sustainability [47]. Moreover, this study recommends that the way tourists perceive sustainability can drive their behavior, which in turn affects environmental sustainability. Moreover, the proper utilization of blockchain can enhance the sustainability of tourism practices and further improve accountability, transparency, and resource management. The outcomes of this study offer a new dimension to theoretical discourses on the role of technology in sustainable tourism. In addition, this study offers new insights into the links between tourism development, tourists' perceptions, and environmental sustainability through the mediating role of blockchain technology. This study suggested that the use of blockchain not only directly affects sustainability but also amplifies the positive effects of other STD initiatives. These findings add to the theoretical understanding of how technology can interact with other variables to promote sustainable tourism outcomes. Lastly, this study bridges the gap between tourism studies, environmental sustainability, and technology, with an emphasis on blockchain technology. All in all, the findings of this study provide a comprehensive theoretical framework that integrates these diverse fields, thus providing a basis for future research to explore the interconnectedness of these domains.

5.3. Conclusions

In conclusion, the results of this study provide robust support for the proposed hypotheses, thus highlighting the critical role that tourism development, tourists' perceptions, and blockchain technology play in developing environmental sustainability. This conclusion underscores the importance of integrating technological advancements, such as blockchain, in tourism strategies to achieve more environmentally sustainable outcomes. The finding that blockchain technology acts as a mediator between the two independent constructs on environmental sustainability also provides avenues for further research into how emerging technologies can be leveraged to enhance the sustainability of the tourism industry.

Based on these findings, it is recommended that policymakers and the government facilitate the tourism service providers' efforts to integrate blockchain technology by providing high-speed internet, building secure data hubs, and arranging training programs for the stakeholders. This initiative will not only enhance the flow and trust of visitors but will also create a great opportunity for the government of Gilgit-Baltistan to increase its tourism tax revenue, as the Gilgit-Baltistan government ought to diversify its revenue stream from being dependent on federal grants. Moreover, policymakers should ensure the mandatory use of blockchain technology through legislation. This will bind service providers, visitors, and the government to comply with the requirements of eco-friendly certification, and national as well as international sustainability goals such as the Sustainable Development Goals (SDGs) provided by United Nations.

5.4. Limitations and Future Directions

This study is limited by being based in the Gilgit-Baltistan region of Pakistan. While this regional focus provides in-depth insights into this region's potential for incorporating blockchain technology to ensure more environmentally sustainable outcomes, the findings may not be directly generalized to other regions with different environmental, social, and economic conditions. Therefore, future research should consider conducting similar studies in various geographical settings to validate the results. The adoption of blockchain is still in its nascent stages, particularly in developing regions, such as Pakistan. Future studies should fully address potential barriers to blockchain adoption, such as technological infrastructure, stakeholder resistance, and implementation costs, which could limit its practical application. In addition, this study adopted a cross-sectional approach, focusing

on the current state of tourism development, tourists' perceptions, and blockchain technology. Therefore, the study was limited in terms of its ability to assess the long-term effects of these factors on environmental sustainability. Therefore, longitudinal studies should be conducted to understand the evolution of these relationships over time. A further consideration is that this study did not fully explore the demographic information of tourists, such as nationality, travel motivation, and budget, which could influence their perceptions and behaviors toward environmental sustainability. Future studies could use segmented or multigroup analyses to uncover how these different tourist traits affect the relationship between the constructs analyzed in this study.

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