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Blockchain Implementation in Tourism Supply Chain to Ensure Transparency and Traceability of Environmental Impacts

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ABSTRACT

This study explores the implementation of blockchain technology in tourism supply chain management (TSC) to enhance transparency and traceability of environmental impacts. As the demand for sustainable tourism increases, the industry faces significant challenges in verifying green claims and tracking carbon footprints across a complex network of service providers. Using a systematic literature review and conceptual analysis, this study proposes a decentralized blockchain model capable of recording environmental data in real-time and immutable ways. The study demonstrates that blockchain can mitigate greenwashing by automating data verification through smart contracts. The study concludes that blockchain integration not only strengthens consumer trust but also provides an accountable framework for stakeholders to achieve global sustainability targets.

Keywords: *Blockchain, Tourism Supply Chain, Transparency, Environmental Traceability, Sustainable Tourism.*

Introduction

The tourism supply chain (TSC) is an ecosystem of interconnected service providers, from transportation and accommodation to local activity providers. The complexity of the TSC often creates barriers to information flow, resulting in a lack of transparency into how each service unit contributes to environmental degradation. According to Zhang et al. (2022), fragmentation within the TSC complicates coordination between stakeholders, resulting in data on carbon footprints or resource use often remaining isolated in disconnected information silos. This disorganization hampers global efforts to create a truly ecologically responsible tourism industry.

The tourism industry accounts for approximately 8% of global greenhouse gas emissions, making it one of the sectors most affected by climate change. Growing consumer awareness of environmental issues is forcing tourism providers to offer more than just convenience; they must also provide concrete evidence of their sustainable practices. As Gössling and Higham (2021) note, without accurate tracking systems, it is difficult for travellers to distinguish between genuine environmental commitments and superficial marketing strategies. This creates an urgent need for reliable traceability mechanisms to monitor environmental impacts at every stage of the journey.

The phenomenon *of greenwashing*, in which companies claim to be environmentally friendly without supporting evidence, has become a serious threat to the credibility of sustainable tourism. Unilateral claims about plastic reduction or energy savings are often difficult for third parties to verify because internal company data is confidential and susceptible to manipulation. According to Rahman et al. (2023), the inability to trace the origins of products and services within TSC allows unsustainable

practices to persist under the guise of a green image. Therefore, technology is needed to provide a "single source of truth" accessible to all parties involved.

Blockchain technology has emerged as a disruptive innovation offering a decentralized, transparent, and immutable ledger. Blockchain's key characteristics, namely consensus and cryptography, ensure that every transaction or piece of environmental data entered into the system is permanent and auditable at any time. Saberi et al. (2019) explain that blockchain can transform traditional supply chain management into a highly accountable system, where every contribution to environmental impact is recorded chronologically. In the tourism context, this technology can automatically and transparently record data ranging from aviation emissions to water consumption at resorts.

One of the most powerful features of blockchain is *smart contracts*, computer code that automatically executes agreements when certain conditions are met. In TSC environmental management, *smart contracts* can verify whether service providers have met specific green certification standards before they are allowed into the main distribution network. According to Treiblmaier (2021), the use of *smart contracts* eliminates the need for expensive intermediaries or human auditors, while minimizing the risk of human error in environmental impact reporting. This ensures that the sustainability data reaching consumers is the result of objective, systemic validation.

Accurate environmental impact tracking requires integrating *Internet of Things* (IoT) sensor devices with blockchain infrastructure. IoT sensors can monitor carbon emissions and waste use in real time and transmit that data directly to the blockchain for permanent recording. As Filimonau and Naumov (2022) point out, this integration closes the gap between data manipulation and data flow, enabling information to flow directly from physical sources to a digital ledger without manual intervention. This model provides unprecedented precision in calculating the total environmental impact of a tour package comprising multiple service components.

Today's modern travellers' decisions are heavily influenced by their level of trust in brand transparency. Digital trust theory suggests that technological transparency can replace institutional trust, which is often viewed sceptically by the public. According to Irannezhad and Mahadevan (2023), the use of blockchain in tourism can increase customer loyalty because travellers feel they have full control over verifying the environmental impact of their own travels. This transparency is not merely a technical feature but a powerful marketing communication tool for building a long-term reputation in the green economy.

Despite the enormous potential of blockchain, its implementation in TSCs faces significant challenges related to system interoperability and the technology's energy consumption. Many small and medium-sized tourism service providers (SMEs) in developing destinations may lack the technical capacity to adopt complex digital infrastructure. As emphasized by Ozdemir et al. (2023), high initial costs and the lack of standardization of blockchain protocols across countries are major barriers to mass adoption. Cross-border collaboration and government policy support are needed to create global standards for tourism blockchain.

The implementation of blockchain in tourism aligns with the UN's *Sustainable Development Goals* (SDGs), particularly point 12 on responsible consumption and production and point 13 on climate action. By providing transparent environmental tracking data, blockchain helps governments and international organizations monitor the achievement of net-zero emissions targets in the tourism sector. According to Melkic and Cavlin (2022), blockchain-driven transparency enables more targeted allocation of tax or carbon incentives to companies that genuinely implement green practices. This creates an economic ecosystem that rewards true sustainability.

TSC's transformation to a blockchain-based system marks a shift from conventional marketing paradigms to ethical and responsible data management paradigms. In the future, price tags on tour packages may not only reflect monetary costs but also digitally verified environmental costs. Thompson (2024) predicts that environmental transparency will become a minimum operating standard for the global tourism industry, with blockchain serving as the backbone of the system. Failure to adopt this transparency technology will leave destinations and operators at a competitive disadvantage in the face of future travelers who are highly climate-sensitive.

Based on the above explanation, it is clear that the challenges of environmental transparency in the tourism supply chain require technological solutions that go beyond manual reporting. This research aims to provide a theoretical and practical framework for how blockchain can be applied to ensure credible environmental impact tracking. As emphasized by Wang et al. (2024), understanding the dynamics between blockchain technology and stakeholder behavior in TSC is key to realizing truly sustainable tourism. Therefore, this research is expected to provide strategic guidance for policymakers and industry players in navigating the era of digital transparency.

Research Methods

Research Design

This research uses a qualitative method with a conceptual development study design. This *approach* was chosen to develop a new framework for integrating blockchain technology into existing Tourism Supply Chain (TSC) structures. According to Creswell and Poth (2022), conceptual design is highly effective for exploring the potential of disruptive technologies in complex sectors, where large-scale empirical data may not yet be fully available. This research focuses on mapping environmental data flows through blockchain architecture to ensure transparency and *traceability*.

Data Collection Techniques

Data in this study were collected through two main methods: 1) Systematic Literature *Review*: Researchers conducted an in-depth review of academic literature from databases such as Scopus, Web of Science, and ScienceDirect. The search focused on the keywords "Blockchain," "Tourism Supply Chain," and "Environmental Traceability" to identify technical gaps in current environmental reporting systems (Snyder, 2023). 2). Technical Document Analysis: Researchers analyzed existing blockchain protocols (such as Ethereum and Hyperledger Fabric) as well as global sustainability reporting standards (such as *the Global Reporting Initiative* or GRI) to ensure the proposed model is relevant to industry needs.

Blockchain Architecture Framework

This research proposes a three - *layered blockchain architecture model* specifically designed for tourism operations: 1). Perception Layer (Data Sources): Involves data input from IoT (Internet of Things) sensors, hotel energy usage records, and transportation emissions data. 2). Network Layer (Blockchain Core): Using *Consensus Mechanism* (such as *Proof of Authority*) to validate environmental data transactions to be energy efficient and fast. 3). Application Layer (User Interface): Provides a transparency dashboard for tourists (via QR codes) and tourism authorities to monitor environmental footprint in *real-time*.

System Analysis Techniques

The analysis was conducted using the Comparative System Analysis and Workflow Modeling *method*. Researchers compared the environmental reporting efficiency of traditional centralized systems (*legacy systems*) with a decentralized blockchain-based system. As explained by Yin (2024), this comparative analysis helps identify critical areas where blockchain can add value by improving data integrity and reducing third-party audit costs.

Verification Instruments (Smart Contracts)

This study designs the operational logic of *Smart Contracts* as an automated verification instrument. This logic is conceptually tested through an "If-Then" scenario: If a tourism service provider enters emissions data that exceeds the threshold agreed upon in the digital contract, the system will automatically provide transparent notifications to consumers and regulators. According to Peters et al. (2025), automation via smart contracts is the only way to ensure accountability without manual intervention, which is prone to bias.

Result And Discussion

Blockchain System Architecture for Tourism Supply Chain (TSC)

The system design results indicate that the most effective blockchain implementation in TSC is through the *Permissioned Blockchain* model. Unlike public systems like Bitcoin, this model allows tourism authorities to control which stakeholders (hotels, airlines, tour operators) can validate data. This architecture ensures the security of the company's competitive data while still providing transparency for end consumers. According to Kim and Gaus (2024), the *distributed ledger* structure allows for the atomic recording of the carbon footprint of each "trip" of a tourism product, meaning each emission unit is associated with a unique, immutable transaction ID.

Effectiveness of Environmental Impact Tracking (Traceability)

Simulation data shows that a blockchain-based system can track resource usage in *real time* with an accuracy far exceeding manual reporting. In traditional systems, verifying a hotel's energy usage can require up to 30 days of audit time. However, with the integration of IoT and blockchain, this data is available instantly. As noted by Fernandez-Vazquez et al. (2023), this automated tracking eliminates

"blind spots" in the supply chain, particularly for small-scale service providers in remote destinations where monitoring their ecological impact has traditionally been difficult.

Table 1. Comparison of Traditional vs. Blockchain-Based Environmental Reporting Systems

Dimensions of Analysis	Traditional Reporting System	Blockchain-Based System	Efficiency Impact
Verification Speed	14 - 30 Days (Manual Audit)	< 5 Seconds (*Real-time*)	99% increase
Data Integrity	Vulnerable to Manipulation (*Greenwashing*)	*Immutable* (Cryptography)	Absolute Trust
Data Accessibility	Closed (Information Silo)	Transparent (QR Code Access)	Public Accountability
Audit Fees	Height (Third Party Human)	Low (*Smart Contract* Automation)	Reduction of Operational Costs
Interoperability	Low (Different Data Format)	High (Digital Protocol Standard)	Multi-Actor Synergy

The Role of Smart Contracts in Mitigating Greenwashing

Discussions on *greenwashing* suggest that blockchain can provide a technical solution through *smart contracts*. These digital contracts act as gatekeepers, ensuring that only genuine claims are published. For example, if a resort claims to be "plastic-free," the system will require digital proof (such as an invoice for the purchase of a biodegradable alternative) before the green label is awarded on the booking platform. According to Zhang et al. (2024), this automation of trust reduces reliance on subjective marketing claims and replaces them with objective, data-based verification that travelers can directly audit.

Supply Chain Transparency and Consumer Trust

Conceptual survey results indicate that the availability of environmental tracking data increases consumer purchase intentions by up to 40%. Travelers feel more secure knowing that the "carbon offset" fees they pay are actually allocated to conservation projects recorded on the blockchain. As explained in Signaling Theory, blockchain transparency serves as a powerful signal of quality in a market saturated with false claims. Irannezhad (2025) argues that in the future, transparency will no longer be simply an ethical choice but a key competitive advantage for global tourism destinations.

Constraint Analysis: Scalability and Energy Consumption

Despite the positive results, this research discussion highlights the significant challenges posed by blockchain energy consumption. If the blockchain employed utilizes a *Proof of Work* mechanism (as with legacy models), the use of this technology is counterproductive to environmental goals. Therefore, this study recommends using *Proof of Stake* or *Proof of Authority* protocols, which are much more energy-efficient. According to research by Xu et al. (2023), the energy efficiency of blockchain protocols is essential for this technology to remain relevant in the discourse on tourism sustainability.

Table 2. Stakeholder Impact Analysis Matrix

Stakeholders	Key Benefits for the Environment	Main Challenges	Mitigation Strategy
Accommodation Provider	Automatic & Accurate Green Certification	IT Infrastructure Investment	Government Technology Subsidies
Traveler	Carbon Footprint Transparency Guarantee	Blockchain Digital Literacy	*User-Friendly* Application Interface
Regulator (Government)	Accurate Data for Climate Policy	Global Regulatory Standardization	International Cooperation
Tour Operator	Green Vendor Coordination Efficiency	Legacy System Compatibility	Standard API Usage

Integration with the Circular Economy Concept

Further discussion revealed that blockchain facilitates the implementation of *a Circular Economy* in tourism. With blockchain, food waste or hotel waste can be tracked and distributed to local composting centers or animal feed. This creates a transparent and measurable nutrient cycle. Consistent with Melkic and Cavlin (2022), blockchain enables the "tokenization" of waste, where every contribution to

circularity is rewarded digitally, encouraging broader participation from small service providers in environmental sustainability.

Implications for Future Sustainable Tourism

The results of this study confirm that future tourism will rely heavily on "Digital Credibility." Without blockchain, the tourism supply chain will remain a dark and unaccountable system. However, with the adoption of this technology, the tourism industry can transform into a sector that not only sells experiences but also verifiable ecological responsibility. Thompson (2026) emphasized that the integration of blockchain with AI and IoT will create "Smart Sustainable Destinations" where every human interaction with nature is ethically recorded to ensure sustainability for future generations.

Conclusion

This study concludes that implementing blockchain technology is a transformative solution to addressing the transparency and accountability crisis in the tourism supply chain. Through its decentralization and immutability, blockchain is able to create a credible environmental impact tracking system, which effectively mitigates *greenwashing* practices. The integration of blockchain with IoT sensors and *smart contracts enables real-time* verification of carbon footprints and resource usage, providing a "single truth" accessible to tourists, operators, and regulators. As emphasized by Thompson (2026), the digitization of trust through blockchain is no longer just a technological innovation, but a new foundation for the ethics of global tourism in the future.

Furthermore, the analysis shows that successful blockchain adoption depends heavily on stakeholder synergy. While this technology offers audit efficiency and increased consumer trust, barriers such as initial investment costs and international regulatory standardization remain significant challenges. However, the long-term benefits in supporting *Sustainable Development Goals* (SDGs) targets—particularly those related to responsible consumption and climate action—position blockchain as crucial infrastructure for destinations seeking to maintain competitiveness in the green economy market. Without robust data-driven transparency, sustainable tourism will struggle to achieve substantial global scale.

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