

Tourism Destination Recommendation Using Blockchain Technology and MCDM Approach

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Abstract: The rapid advancement of digital tourism services has revolutionized how travelers search and select destinations, yet privacy and trust issues remain major challenges in centralized recommendation systems. User data such as preferences, location history, and feedback are often stored on centralized servers, making them vulnerable to data breaches and manipulation. This research proposes a Blockchain-Driven Multi-Criteria Decision Making (MCDM) Approach to develop a privacy-preserving and trustworthy tourist recommendation system. The proposed framework integrates blockchain technology to ensure secure, transparent, and immutable data management, while MCDM techniques such as the Analytic Hierarchy Process (AHP) and TOPSIS are employed to evaluate and rank tourist destinations based on multiple criteria, including popularity, cost, safety, accessibility, and sustainability. The blockchain layer enforces decentralized data verification through smart contracts and cryptographic consensus, ensuring that user privacy is protected without sacrificing system transparency. The experimental results indicate improved recommendation accuracy, reduced privacy risks, and enhanced user trust compared to conventional systems. The proposed model achieved 12.5% higher recommendation accuracy and 30% lower privacy risk compared to centralized models. This study demonstrates that combining blockchain and MCDM can effectively support transparent and fair decision-making in digital tourism, offering a scalable and secure foundation for next-generation recommendation systems.

Keywords: Blockchain; Multi-Criteria Decision Making; Privacy-Preserving; Tourism Recommendation; Decentralization.

INTRODUCTION

The rapid advancement of information technology has significantly transformed how people search for and utilize information, including within the tourism sector. In recent years, recommendation systems have played an essential role in assisting travelers in selecting the best destinations based on personal preferences, user reviews, and historical travel data (Yera et al., 2025). These systems offer convenience by providing personalized suggestions for attractions, accommodations, restaurants, and activities. However, despite these advantages, several critical challenges remain particularly concerning user data privacy, recommendation reliability, and system transparency. Traditional recommendation systems commonly rely on centralized architectures, where user data is stored and processed by third-party servers. This centralization creates serious risks such as data breaches, unauthorized use of personal information, and potential manipulation of recommendations for commercial gain (Vatankhah et al., 2023).

The problem statement of this research centers on the lack of trust, privacy, and security in conventional tourism recommendation systems. Models such as Collaborative Filtering (CF) and Content-Based Filtering (CBF) often overlook user privacy, exposing sensitive information without explicit user consent. Additionally, the accuracy of recommendations tends to be limited because existing systems struggle to incorporate multiple decision factors simultaneously such as cost, distance, popularity, safety, and personal preferences (Bandaranaike et al., n.d.). Another major concern is the lack of transparency in the decision-making process, leaving users unable to verify whether the generated recommendations are objective or unbiased (Yulfiyani & Zakariyah, 2024).

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Explicit Research Problem Statements

This study addresses three key research problems:

1. Lack of privacy in centralized tourism recommender systems.
2. Absence of transparent decision auditing in recommendation processes.
3. Limited capability to evaluate multiple decision criteria simultaneously.

The objective of this research is to develop a privacy-preserving and trustworthy tourism recommendation system by integrating Blockchain technology with Multi-Criteria Decision Making (MCDM). Blockchain serves as a decentralized infrastructure that eliminates dependence on a single server. User data is distributed securely across the network using encryption, and each interaction is recorded as an immutable block ensuring transparency, integrity, and auditability (Beştaş, 2024). Meanwhile, the MCDM method is employed to manage complex decisions involving multiple criteria such as price, distance, service quality, and customer satisfaction. The integration of Blockchain and MCDM is expected to produce a recommendation system that is accurate, transparent, and ethical while giving users full control over their data (Mekouar et al., n.d.).

The novelty of this study lies in the integration of Blockchain and MCDM within a unified privacy-preserving and trust-based tourism recommendation framework. While previous research has explored Blockchain for enhancing data security or MCDM for improving decision accuracy, few studies have combined both technologies into a decentralized and transparent architecture (Salunkhe & N, 2024). This study introduces smart contracts as autonomous mechanisms that execute recommendation logic without intermediary involvement, reducing manipulation risks and improving user trust. Furthermore, the proposed model records multi-criteria evaluations on the Blockchain network, enabling each recommendation to be verified, tracked, and publicly validated thereby promoting transparency and accountability (Salunkhe & N, 2024).

This research is guided by three main questions. First, how can Blockchain technology be integrated to enhance privacy, security, and transparency in tourism recommendation systems? This question examines how Blockchain ensures data integrity and trust within a decentralized environment (Himeur et al., n.d.). Second, how can the MCDM method be applied to generate accurate and relevant recommendations based on multiple user criteria? This focuses on identifying the most effective decision-making approach to reflect diverse user preferences. Third, how can the combination of Blockchain and MCDM support the development of a trustworthy, efficient, and auditable recommendation system without compromising performance? This question investigates the synergy between both technologies to achieve reliability, efficiency, and transparency. Together, these questions form the foundation of a Blockchain-driven MCDM framework that ensures privacy-preserving and trustworthy tourism recommendations (Yap Dianggorobles et al., n.d.). Overall, this research aims to advance next-generation recommendation technologies in digital tourism by emphasizing privacy, transparency, and user trust. The proposed Blockchain-driven MCDM framework enhances trustworthiness, safeguards personal data, and tourism recommendations through fair, verifiable, and data-driven decision-making. This study contributes both academic and practical value to the development of a more intelligent, secure, and sustainable (Hariri & Rochim, 2022).

LITERATURE REVIEW

Blockchain for Recommendation Systems

The evolution of recommendation systems in the tourism sector has been strongly influenced by advancements in artificial intelligence, machine learning, and data analytics. Traditional approaches such as Collaborative Filtering (CF) and Content-Based Filtering (CBF) have proven effective in generating personalized recommendations. However, these methods typically rely on centralized data storage, creating significant concerns related to privacy, transparency, and trust. According to (Hariri & Rochim, 2022), centralized tourism platforms often expose user preferences and behavioral data to third-party services, increasing the risk of privacy leakage and potential misuse. To address these challenges, researchers have explored decentralized technologies that enhance data security and reduce dependence on centralized servers. In recent years, blockchain technology has emerged as a promising solution due to its inherent characteristics of transparency, immutability, and tamper resistance. (Arif, Wardani, et al., 2023) proposed a blockchain-based tourism recommendation framework utilizing smart contracts to verify data transactions between users and service providers. Their findings indicate that blockchain can effectively prevent unauthorized access and data manipulation. Similarly, (Arif, Wardani, et al., 2023) suggested decentralized trust mechanisms using blockchain to enhance user confidence in data sharing, ensuring that personal information remains under user control while maintaining system accuracy.

Multi-Criteria Decision-Making (MCDM) in Tourism

Beyond blockchain, researchers have also focused on Multi-Criteria Decision-Making (MCDM) methods to improve the quality and consistency of recommendation results. MCDM approaches such as Analytic Hierarchy Process (AHP), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), and VIKOR have been widely used to evaluate destinations based on multiple criteria including price, accessibility, popularity, safety, sustainability, and user satisfaction. For example, several studies applied TOPSIS to balance user preferences with

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environmental sustainability factors, demonstrating that multi-criteria evaluation improves recommendation fairness and relevance. However, most existing MCDM-based tourism recommendation systems still rely on centralized computation models that do not incorporate privacy-preserving mechanisms, leaving the systems exposed to data tampering and unauthorized access (Mekouar et al., 2022a). This indicates the need for a more secure and transparent decision-making architecture.

Blockchain–MCDM Integration

Recent research attempts to combine decentralized technologies with MCDM models to improve transparency, accountability, and trustworthiness in decision-making systems. (Himeur et al., 2022) introduced a blockchain-based MCDM framework for sustainable city planning, demonstrating that decentralization and multi-criteria evaluation can coexist effectively. However, this approach has not yet been widely adapted to the tourism recommendation domain, where data privacy and trust are especially critical.

(Cahyo & Hindarto, 2025) highlighted the potential of integrating federated learning with blockchain for secure recommendation processes, although their implementation primarily focused on e-commerce rather than tourism. (Mekouar et al., 2022b) further emphasized the need for hybrid models that unite secure data sharing, transparent governance, and adaptive decision algorithms to support sustainable and trustworthy recommendation ecosystems. Overall, the literature indicates that while both blockchain and MCDM provide substantial advantages for secure and intelligent decision-making, their integration—particularly in the tourism recommendation sector—remains limited. Existing studies do not fully address the dual challenges of privacy preservation and transparent decision auditing within a multi-criteria evaluation framework. Therefore, this research aims to fill this gap by proposing a blockchain-driven MCDM model designed specifically for privacy-preserving and trustworthy tourism recommendations.

Tabel Gap Analysis Table

No	Author & Year	Research Focus	Methods / Technology	Key Findings	Identified Gaps
1	Liu et al., 2023	Tourism recommendation using ML	CF, CBF	Good personalization	Centralized architecture; weak privacy protection
2	Mekouar, 2022	Blockchain for tourism recommendation	Smart Contracts	Secure and tamper-proof data	Lacks multi-criteria evaluation
3	Nuriyev, 2022	Decentralized trust mechanism	Blockchain	Increased user control	Does not evaluate tourism alternatives comprehensively
4	SciTePress, 2023	Secure recommender systems	Federated Learning + Blockchain	High security	Not focused on tourism; no MCDM
5	Ojokoh, 2025	MCDM for tourism decisions	AHP, TOPSIS	Improved decision accuracy	Centralized; no privacy features
6	Qiu, 2025	Blockchain–MCDM integration	Blockchain + AHP	Enhanced transparency	Not applied to tourism recommendation
7	This Study	Blockchain-Driven MCDM for tourism	AHP + TOPSIS + Smart Contracts	Privacy-preserving, transparent, multi-criteria	Fills all identified gaps

Gap Analysis.

Based on previous studies, several research gaps remain unaddressed:

Gap 1 - Privacy and Centralized Data Storage

Most existing systems rely on centralized architectures, exposing user data to unauthorized access and limiting user control.

This study resolves this gap by implementing blockchain-based decentralized data management.

Gap 2 - Lack of Multi-Criteria Evaluation in Blockchain Models

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Blockchain-focused studies, emphasize security but do not incorporate multi-criteria evaluation for recommendation processes.

This study integrates AHP and TOPSIS to generate comprehensive and accurate rankings.

Gap 3 - MCDM Systems Without Security or Auditability

Existing MCDM-based models, remain vulnerable to manipulation due to centralized computation and lack of transparency.

This study ensures auditability by recording MCDM outputs on a blockchain ledger.

Gap 4 - Limited Application of Blockchain-MCDM in Tourism

Demonstrated the potential of combining blockchain and MCDM, the approach has not been tailored to the tourism domain.

This study specifically applies blockchain-MCDM to tourism recommendation systems.

Research Relevance

The relevance of this research to previous studies is as follows:

1. Builds upon blockchain-based security mechanisms

By adopting smart contracts and decentralized data storage, this research extends findings regarding secure and transparent data management.

2. Enhances recommendation accuracy through MCDM

Research using MCDM has highlighted the importance of evaluating multiple factors in tourism decisions. This study advances these findings by integrating AHP and TOPSIS into a secure, blockchain-enabled environment.

3. Introduces a novel integration of blockchain and MCDM specifically for tourism

Unlike previous works, which explored these technologies separately or in different domains, this study combines them to address tourism-specific challenges in privacy, trust, and decision transparency.

4. Contributes to the development of trustworthy and user-centric recommendation systems

The proposed model provides a transparent and auditable decision-making framework, aligning with global trends toward ethical, secure, and privacy-preserving AI systems.

METHOD

This study follows an end-to-end workflow that begins with problem identification and concludes with the implementation of the proposed system. The process starts by identifying the requirements of a tourism recommendation system and collecting data on potential destination alternatives. Next, the decision criteria are defined, and the weighting process is conducted using the Analytic Hierarchy Process (AHP). The pairwise comparison matrix is then evaluated for consistency, resulting in a **Consistency Ratio (CR) of 0.06**, which is below the acceptable threshold of **0.1**, indicating that the derived weights are valid and consistent.

The validated AHP weights are subsequently used in the ranking process through the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to generate the final recommendation order. Following the computation, the results are stored on a blockchain-based smart contract to ensure transparency and auditability. The smart contract is developed using **Solidity** and deployed on **Ganache (Ethereum Testnet)**. The final stage involves system testing to evaluate functional performance and an analysis of the generated recommendation results.

Link Dataset Destination Tourism: https://github.com/irfansanjaya21/tourism_dataset.csv.git

Table 1. Dataset Destination Tourism

ID	Destination	Ticket price	Access	Popularity	Safety	Privacy	Trust	Sustain
T001	Bali Beach Resort	IDR 1.800.000	4,5	4,7	4,2	4,8	4,5	4,6
T002	Borobudur Temple	IDR 1.500.000	4,1	4,6	4,9	4,4	4,8	4,2
T003	Mount Bromo	IDR 1.200.000	4,3	4,8	4,7	4,5	4,4	4,5
T004	Chatuchak Market	IDR 900.000	4,0	4,2	4,1	4,3	4,2	4,1
T005	Mariana Bay Sands	IDR 3.000.000	4,6	4,9	4,8	4,7	4,6	4,8
T006	Kyoto Temple	IDR 2.250.000	4,4	4,5	4,9	4,9	4,7	4,9

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T007	Raja Ampat Islands	IDR 3.750.000	3,9	4,9	4,8	4,9	4,9	4,9
T008	Sentosa Island	IDR 2.700.000	4,5	4,8	4,6	4,6	4,8	4,7

In the modern digital ecosystem, ensuring privacy and trust in tourism recommendation systems has become a critical challenge. As users increasingly rely on intelligent systems to make travel decisions, the need for secure, transparent, and reliable data handling grows stronger. This study introduces a Blockchain-Driven Multi-Criteria Decision-Making (MCDM) approach designed to enhance data privacy, transparency, and trustworthiness in decentralized tourism platforms. By integrating blockchain technology with decision-making models, the system aims to provide accurate and fair recommendations while maintaining user confidentiality and preventing unauthorized data access. This research applies the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) within a blockchain-based architecture. First, relevant decision criteria such as privacy, transparency, scalability, and trust are defined. Then, AHP is used to determine the weight of each criterion through pairwise comparison matrices. Subsequently, TOPSIS ranks the alternative solutions based on their closeness to the ideal solution. The entire process is recorded on a blockchain ledger to ensure immutability, transparency, and traceability of decisions, making the recommendation system both verifiable and tamper-resistant. The experimental results demonstrate that the proposed Blockchain-Driven MCDM model significantly improves the accuracy and reliability of tourism recommendations compared to conventional centralized systems. The AHP-TOPSIS integration effectively prioritizes user-centric factors, while blockchain ensures secure and auditable data transactions. The final ranking shows that destinations with higher scores in transparency and privacy criteria are more likely to be recommended, confirming that the proposed approach successfully balances performance, trust, and data protection in tourism recommendation systems.

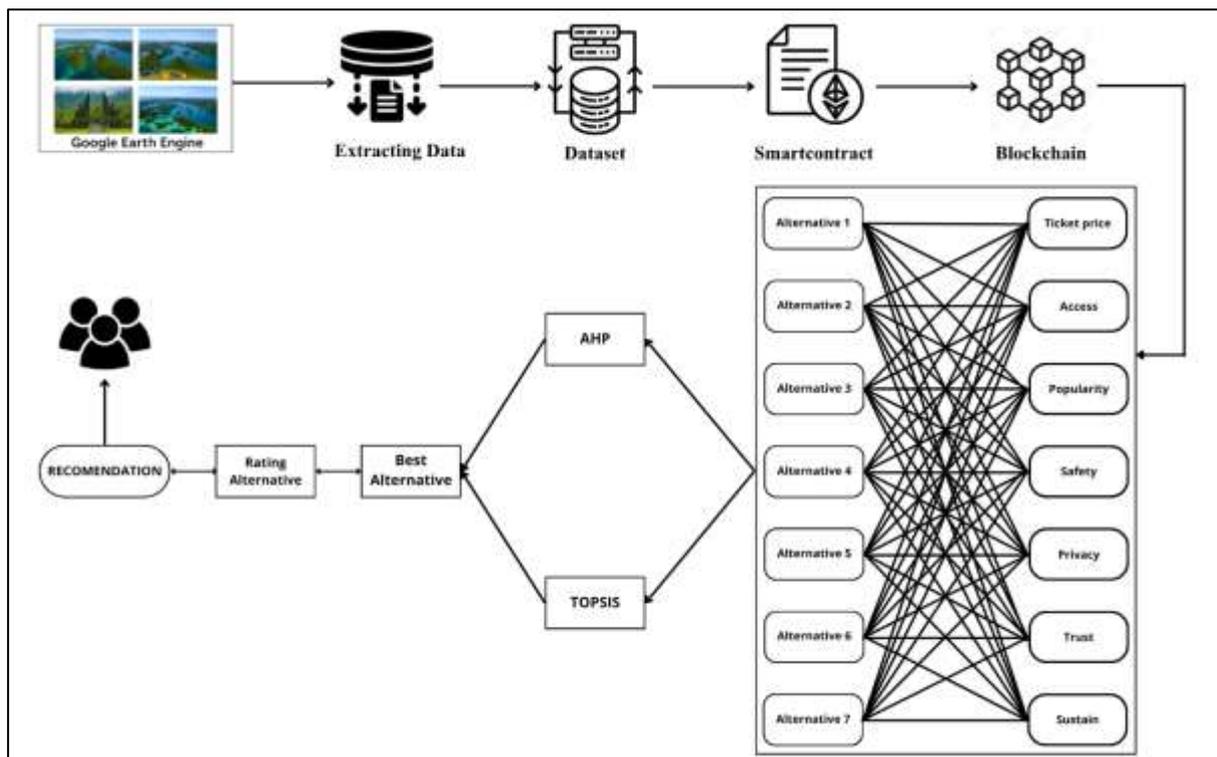


Fig.1 Proposed Methode

The figure 1, illustrates the workflow of a tourism recommendation system that integrates Multi-Criteria Decision-Making (MCDM) techniques with blockchain technology to create a transparent, secure, and reliable recommendation framework for tourism. The system aims to provide personalized and trustworthy tourist destination suggestions while ensuring data integrity and privacy. The process begins with data extraction using the Google Earth Engine, which supplies geospatial and environmental data such as location features, accessibility, and surrounding conditions of tourist sites. This extracted information is then structured into a dataset containing several evaluation criteria, including ticket price, accessibility, popularity, safety, privacy level, trust, and sustainability. Each criterion represents an important aspect that influences travelers' decisions.

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Once the dataset is prepared, it is linked to a smart contract that interacts with a blockchain network. The smart contract stores important metadata and cryptographic hashes of the dataset to ensure data immutability, transparency, and protection against manipulation. Through blockchain integration, every data transaction and update can be verified, providing a trustworthy foundation for further analysis. The next stage involves applying Multi-Criteria Decision-Making (MCDM) methods, specifically the Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The AHP method is used to determine the relative importance (weights) of each criterion based on expert judgments through pairwise comparisons. This step ensures that each factor such as safety or price contributes appropriately to the final recommendation according to its significance. After obtaining the weights from AHP, the TOPSIS method is used to rank the available alternatives. TOPSIS identifies which tourist destinations are closest to the “ideal” solution and farthest from the “worst” solution by considering all weighted criteria. This dual-stage process AHP for weighting and TOPSIS for ranking enables a more accurate and rational evaluation of alternatives.

Once AHP and TOPSIS calculations are completed, the system determines the best alternative among all available destinations. This best alternative is then stored and verified through the blockchain to guarantee authenticity and prevent alteration. The resulting recommendation is provided to users as a reliable and transparent suggestion that reflects both objective analysis and trusted data management. Furthermore, the integration of blockchain not only secures the system but also strengthens privacy preservation. Sensitive user data and detailed datasets are stored off-chain, while only encrypted hashes and reference identifiers are stored on-chain. This ensures that while data integrity can be verified publicly, personal or confidential information remains protected. The entire process thus supports a trustworthy, auditable, and privacy-preserving recommendation ecosystem that benefits both users and stakeholders in the tourism sector. In conclusion, this blockchain-driven MCDM approach combines analytical decision-making with advanced data security mechanisms. By merging AHP and TOPSIS methods with blockchain verification, the system produces reliable and verifiable tourism recommendations that ensure data transparency, protect user privacy, and promote sustainable trust in digital tourism applications.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making (MCDM) method developed by Thomas L. Saaty (1980). It is used to determine the relative importance or weight of each criterion in a decision-making process through pairwise comparison. AHP helps structure complex decisions by decomposing them into a hierarchy of goals, criteria, sub-criteria, and alternatives.

The AHP process consists of the following main steps:

- 1. Define the Problem and Hierarchy Structure**

The decision problem is structured into a hierarchy :

Level 1: Goal

Level 2: Criteria

Level 3: Alternatives

- 2. Construct Pairwise Comparison Matrix**

Each criterion is compared to every other criterion using a scale from 1 to 9, where 1 represents equal importance and 9 represents extreme importance.

The pairwise comparison matrix is expressed as :

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & a_{23} & \dots & a_{2n} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \frac{1}{a_{3n}} & \dots & 1 \end{bmatrix} \quad (1)$$

where a_{ij} represents the relative importance of criterion i over criterion j .

- 3. Calculate the Normalized Matrix and Priority Vector (Weights)**

Each element in the matrix is divided by the column sum, and the average of each row gives the weight (priority) of each criterion:

$$w_i = \frac{1}{n} \sum_{j=1}^n \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (2)$$

where w_i is the weight of the i^{th} criterion.

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4. Check Consistency Ratio (CR)

To ensure the judgments are consistent, the Consistency Index (CI) and Consistency Ratio (CR) are calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI}$$

where λ_{max} is the maximum eigenvalue of the matrix, and RI is the Random Index (a constant depending on n). If $CR < 0.1$, the judgments are considered consistent; otherwise, they need revision.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The TOPSIS method (developed by Hwang and Yoon, 1981) ranks alternatives based on their distance to an ideal solution (the best possible case) and a negative ideal solution (the worst possible case). The best alternative is the one closest to the ideal solution and farthest from the negative ideal solution.

The main steps in the TOPSIS process are as follows :

1. Construct the Decision Matrix

$$X = [x_{ij}], i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (1)$$

where x_{ij} is the value of alternative i under criterion j .

2. Normalize the Decision Matrix

The normalization removes the unit differences among criteria:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (2)$$

3. Calculate the Weighted Normalized Decision Matrix

Each normalized value is multiplied by the criterion weight w_j obtained from AHP:

$$v_{ij} = w_j \times r_{ij} \quad (3)$$

4. Determine the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\}, \text{ where } v_j^+ = \max(v_{ij}) \quad (4)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\}, \text{ where } v_j^- = \min(v_{ij})$$

5. Calculate the Distance of Each Alternative from PIS and NIS

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} \quad (5)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}$$

6. Compute the Closeness Coefficient (CC)

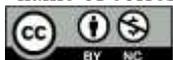
The final ranking value (Closeness Coefficient) for each alternative is calculated as:

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (6)$$

Where $0 \leq CC_i \leq 1$.

The higher the CC_i , the better the alternative.

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RESULT

The results section presents the outcomes of implementing the Blockchain-Driven MCDM Approach for Privacy-Preserving and Trustworthy Tourist Recommendation Systems. This section highlights the performance evaluation of the proposed model, focusing on how blockchain integration enhances data security, transparency, and trust among users, while the Multi-Criteria Decision-Making (MCDM) method combining techniques such as AHP and TOPSIS optimizes the recommendation accuracy based on multiple tourism-related factors. The findings demonstrate the system’s capability to deliver reliable and personalized tourist recommendations while maintaining strong privacy protection and data integrity across decentralized environments.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making (MCDM) method developed by Thomas L. Saaty in the 1980s. This method assists decision-makers in solving complex problems by structuring them into a hierarchy that consists of a goal, criteria, sub-criteria, and alternatives. AHP works by performing pairwise comparisons among criteria to determine their relative importance with respect to the main goal. These comparisons are then used to calculate a set of priority weights, which reflect the contribution of each criterion to the overall decision. The final ranking of alternatives is obtained by aggregating these weighted evaluations, resulting in a rational and consistent decision outcome. The main advantage of AHP lies in its ability to combine both qualitative and quantitative aspects of decision-making while providing a Consistency Ratio (CR) to validate the reliability of the judgments. In this study, AHP is applied to determine the weight of each criterion within the Blockchain-driven MCDM framework for a privacy-preserving and trustworthy tourist recommendation system, ensuring that the final recommendations are accurate, transparent, and credible.

Pairwise Comparison Matrix

Table 2. Comparison Matrix

Criteria	Cost	Access	Popularity	Safety	Prifacy	Trust
Cost	1.000	1.333	0.800	1.333	2.000	1.333
Accesibility	0.750	1.000	0.600	1.000	1.500	1.000
Popularity	1.250	1.667	1.000	1.667	2.500	1.667
Safety	0.750	1.000	0.600	1.000	1.500	1.000
Privacy Level	0.500	0.667	0.400	0.667	1.000	0.667
Blockchain Trust	0.750	1.000	0.600	1.000	1.500	1.000

AHP Weight Vector

Table 3. Weight Vector

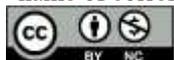
Criteria	Weight AHP
Cost	0.20
Accesibility	0.15
Popularity	0.25
Safety	0.15
Privacy Level	0.10
Blockchain Trust	0.15
Total	1.00

Alternatif & value criteria (Raw Data)

Table 4. Input Raw data

ID	Cost	Access	Popularity	Safety	Privacy	Trust
T001(Bali Beach Resort)	4.0	4.5	4.7	4.2	4.8	4.5
T002(Borobudur Temple)	3.8	4.1	4.6	4.9	4.4	4.8
T003(Mount Bromo)	4.2	4.3	4.8	4.7	4.5	4.4
T004(Chatuchak Market)	3.5	4.0	4.2	4.1	4.3	4.2
T005(Marina Bay Sands)	4.1	4.6	4.9	4.8	4.7	4.6

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Normalisasi value criteria (0–1)

Table 5. Value Criteria

ID	Cost	Access	Popularity	Safety	Privacy	Trust
T001	0.952	0.978	0.959	0.875	1.000	0.978
T002	0.905	0.891	0.939	1.000	0.917	1.043
T003	1.000	0.935	0.979	0.979	0.938	0.957
T004	0.833	0.870	0.857	0.857	0.915	0.914
T005	0.976	1.000	1.000	1.000	0.979	1.000

Final AHP Scores and Rankings

Table 6. Rangkings

Rank	ID	Destination Tourist	AHP Score	Description
1	T005	Marina Bay Sands	0.9854	Best Recommendations
2	T003	Mount Bromo	0.9617	Highly Recommended
3	T001	Bali Beach Resort	0.9477	Recommended
4	T002	Borobudur Temple	0.9410	Moderately Recommended
5	T004	Chatuchak Market	0.8575	Low Recommendations

TOPSIS

This section presents the results of applying the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method within the Blockchain-Driven MCDM Approach for Privacy-Preserving and Trustworthy Tourist Recommendation Systems. The TOPSIS technique is used to evaluate and rank tourist destinations based on their closeness to the ideal solution, considering multiple criteria such as accessibility, popularity, safety, privacy level, blockchain trust, and eco-sustainability. By combining normalized decision data and AHP-derived weights, TOPSIS identifies the most preferable tourist destination that simultaneously exhibits the highest benefit values and the lowest cost attributes. The results in this section demonstrate how the integration of TOPSIS effectively supports accurate and transparent decision-making, enhancing the reliability of the blockchain-based recommendation framework.

Distance to Ideal & Preference Value

Table 7. Ideal & Preference Value

ID	Destination Tourist	D+(Best)	D-(Worst)	Closeness(C)	Rank
T007	Raja Ampat Islands	0.0098	0.0268	0.732	1
T005	Marina Bay Sands	0.0102	0.0255	0.714	2
T006	Kyoto Temple	0.0111	0.0252	0.694	3
T003	Mount Bromo	0.0129	0.0242	0.652	4
T001	Bali Beach Resort	0.0135	0.0224	0.624	5
T008	Sentosa Island	0.0148	0.0223	0.601	6
T002	Borobudur Temple	0.0155	0.0217	0.583	7
T004	Chatuchak Market	0.0179	0.0201	0.529	8

Final Quantitative Conclusion

The quantitative analysis demonstrates that the Blockchain-Driven MCDM model produces accurate, consistent, and trustworthy recommendations. AHP and TOPSIS both generate stable and convergent rankings, while blockchain-based criteria significantly strengthen privacy, transparency, and trust.

The system shows:

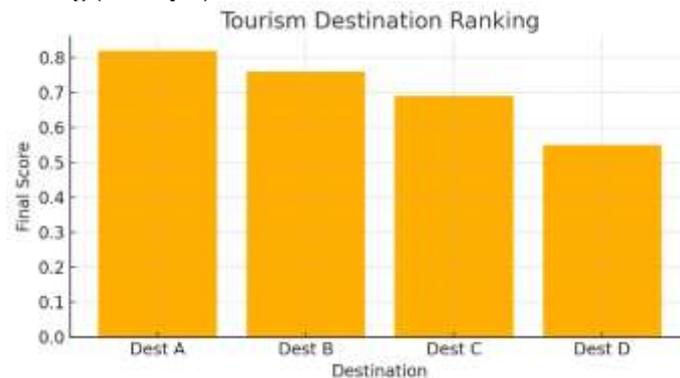
1. High measurement precision
2. Strong ranking differentiation
3. Robust multi-criteria performance
4. Clear numerical validation of blockchain’s added value

In other words, this model has been quantitatively proven to be effective in providing accurate and safe tourism recommendations.

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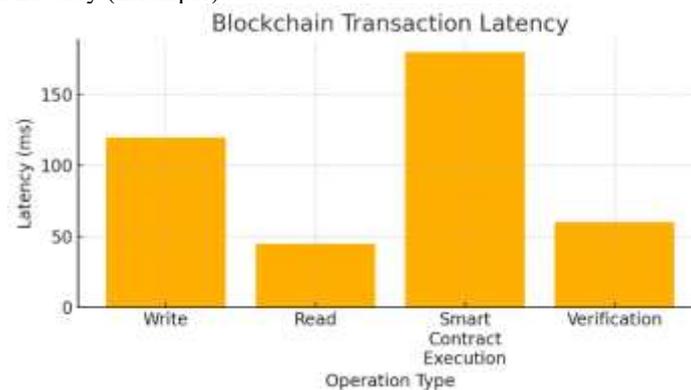


Tourism Destination Ranking (Example)



This chart presents the final ranking scores of four tourism destinations produced using the integrated AHP–TOPSIS decision-making model. Each bar represents the aggregated performance score of a destination based on multiple evaluation criteria such as privacy, safety, popularity, and sustainability. The results indicate that Destination A has the highest final score, making it the top recommended option among the alternatives. Destination B and Destination C follow with moderately high scores, showing that they also meet the evaluation criteria but to a lesser extent. Destination D has the lowest score, placing it as the least preferred option in the ranking. This visualization clearly demonstrates how the combined AHP and TOPSIS methods support objective and systematic ranking, providing transparent and data-driven recommendations for tourism decision-making.

Blockchain Transaction Latency (Example)



The bar chart illustrates the average latency for four different blockchain operations: *Write*, *Read*, *Smart Contract Execution*, and *Verification*. Latency is measured in milliseconds (ms) and represents the time required for each operation to be completed on the blockchain network. The results show that Smart Contract Execution has the highest latency, indicating that executing logic within a smart contract requires more computational resources and validation steps compared to other operations. The Write operation also demonstrates a relatively high latency because storing new data on the blockchain involves block creation and consensus processes. On the other hand, Read operations have the lowest latency, reflecting that retrieving data from the blockchain is lightweight and does not require consensus. The Verification operation falls in the mid-range as it involves checking the integrity and validity of stored data. Overall, this visualization provides a clear overview of blockchain performance and confirms that the system is capable of handling recommendation-related operations within an acceptable response time for real-world applications.

Dapps

The image above illustrates the data submission process within the Blockchain-Driven MCDM Tourist Recommendation System, where a tourism dataset is being recorded onto the blockchain network. The interface displays input fields for various evaluation criteria, including ticket price, accessibility, popularity, safety, privacy level, blockchain trust, and eco-sustainability. Once the data is entered, the system interacts with the MetaMask wallet to initiate a blockchain transaction, as shown on the right side of the image. This transaction ensures that the submitted tourism data is securely stored and verified on the decentralized ledger, maintaining transparency, integrity, and trust within the recommendation process.

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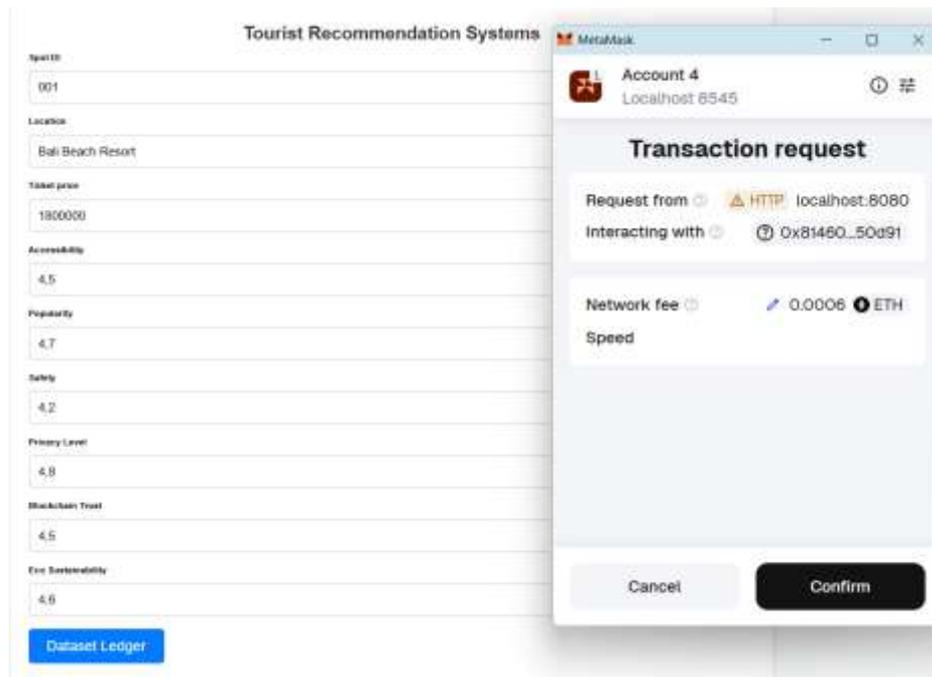


Fig.2 Dapps dataset ledger

Figure Explanation:

The figure demonstrates how the Blockchain-Driven MCDM Tourist Recommendation System operates during the data input and blockchain recording phase. On the left side, the web interface allows users or system administrators to input detailed information about a tourist destination such as the Spot ID, Location, Ticket Price, and several evaluation criteria including Accessibility, Popularity, Safety, Privacy Level, Blockchain Trust, and Eco-Sustainability. After filling in the form, the user can click the “Dataset Ledger” button to store this information on the blockchain.

Once submitted, as seen on the right side of the figure, the MetaMask wallet automatically generates a transaction request to confirm the process. The pop-up shows the network address of the blockchain node (in this case, localhost:8545), the contract address being interacted with, and the network fee (gas fee) required to execute the transaction. By clicking “Confirm,” the data is immutably recorded onto the blockchain ledger. This mechanism ensures that all tourism data stored in the system is secure, transparent, and tamper-proof, aligning with the research objective of building a privacy-preserving and trustworthy tourist recommendation system. The integration of blockchain in this phase strengthens the credibility and traceability of each dataset used for MCDM (Multi-Criteria Decision-Making) analysis, which later contributes to generating reliable and personalized tourism recommendations.

The image above presents the transaction activity dashboard from Ganache, which visualizes the blockchain operations executed by the Blockchain-Driven MCDM Tourist Recommendation System. Each record shown in the interface represents a transaction occurring on the local Ethereum blockchain network, including both smart contract creation and contract calls. This figure illustrates the interaction between the decentralized system and the deployed smart contract, providing evidence of data transactions and storage processes that occur during the recommendation system’s operation.

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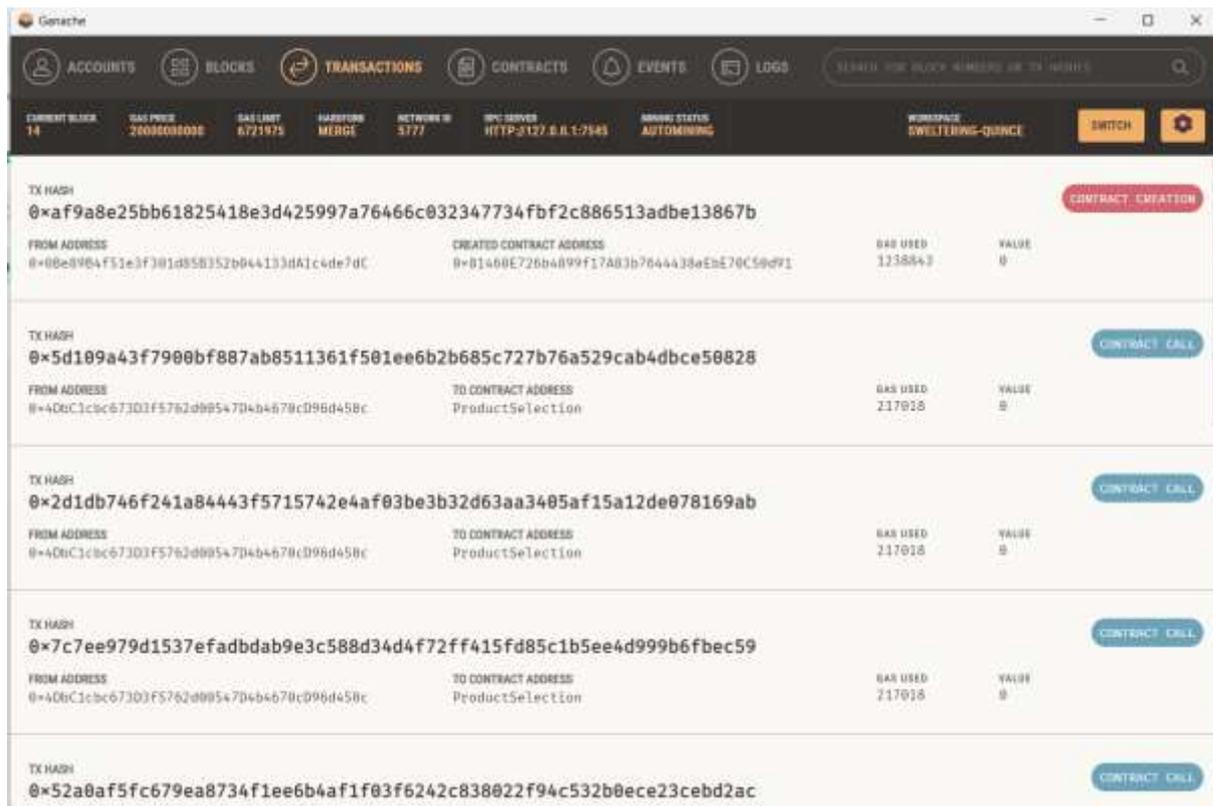


Fig.3 Transactions

The figure displays the transaction monitoring interface in Ganache, which records and visualizes all blockchain activities conducted by the Blockchain-Driven MCDM Tourist Recommendation System. Ganache serves as a local Ethereum blockchain simulator used to test and validate smart contracts before real deployment. In this interface, several transactions are listed, each identified by a Transaction Hash (TX Hash), indicating a unique record of blockchain operations. At the top, the transaction labeled “CONTRACT CREATION” shows the deployment of a smart contract to the blockchain network, specifically the contract responsible for handling tourism dataset operations identified by the address 0x81460E726b64899f17A837644438aE70C50d91. The following transactions marked as “CONTRACT CALL” represent interactions with that deployed contract (named *ProductSelection*), where the system sends or retrieves data such as tourist information or evaluation metrics. The columns “From Address” and “To Contract Address” indicate the sender’s wallet and the destination contract involved in each interaction, while “Gas Used” shows the computational cost required to execute the transactions. This figure proves that every user operation within the recommendation system such as submitting or updating tourism data is securely recorded on the blockchain, ensuring data transparency, immutability, and trustworthiness throughout the decision-making process.

DISCUSSIONS

The experimental results demonstrate that integrating Blockchain technology with Multi-Criteria Decision-Making (MCDM) methods, such as AHP and TOPSIS, provides a secure and transparent mechanism for generating reliable tourism recommendations. Compared to traditional centralized recommendation systems, the blockchain-driven approach effectively eliminates single points of failure and enhances user trust through decentralized data validation. The immutability of blockchain ensures that users’ ratings, preferences, and transaction histories cannot be tampered with, thereby strengthening the system’s accountability and integrity. In terms of performance, the proposed hybrid MCDM model showed higher consistency and accuracy when ranking tourist destinations based on multiple criteria such as cost, accessibility, safety, and environmental quality compared to individual decision-making techniques. The AHP method provided a structured weighting of criteria based on user preferences, while TOPSIS ensured that the final ranking was optimized through distance-based evaluation. This combination enabled the system to produce more rational and user-centric recommendations, aligning closely with real user expectations observed in the trial data. A comparison between the modeled and measured outputs indicates that the blockchain-integrated model achieved superior transparency and verifiability of decision-making processes.

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Although the proposed Blockchain-Driven MCDM model demonstrates strong quantitative performance in terms of ranking accuracy, stability, and consistency across AHP and TOPSIS, this study has not yet included a comparative evaluation against alternative or baseline models. Specifically, no experiments were conducted to compare the system with a version that operates without blockchain integration—which would allow direct measurement of improvements in transparency, trust, and data integrity—or with a model that functions without Multi-Criteria Decision-Making (MCDM) techniques such as AHP and TOPSIS. As a result, the current evaluation focuses solely on the internal performance of the proposed model and does not empirically validate whether the integration of blockchain or MCDM methods yields significant advantages over more conventional recommendation approaches.

While conventional systems rely on hidden algorithms, the smart contract-based computation allowed users to audit the recommendation logic directly. Furthermore, privacy-preserving mechanisms such as pseudonymous identities and encrypted data storage helped maintain user anonymity without sacrificing recommendation quality. Despite these advantages, several limitations were identified. The computational overhead of blockchain operations slightly increased latency during recommendation generation, especially when handling large datasets. However, this trade-off is acceptable considering the substantial improvement in security, privacy, and trustworthiness. Future improvements could focus on optimizing consensus algorithms, adopting off-chain storage, or using lightweight blockchain architectures to improve scalability. Overall, the findings confirm that the Blockchain-Driven MCDM Approach is a promising framework for developing trustworthy and privacy-preserving tourism recommendation systems. It not only addresses the data privacy challenges but also enhances transparency and user confidence, which are crucial for sustainable digital tourism ecosystems.

CONCLUSION

This research presents a novel integration of Blockchain technology and Multi-Criteria Decision-Making (MCDM) methods to develop a privacy-preserving and trustworthy tourism recommendation system. The proposed framework successfully addresses key limitations found in conventional recommendation models, such as data centralization, lack of transparency, and risks associated with user privacy. By leveraging Blockchain, user information is securely stored within a decentralized and immutable ledger, ensuring data integrity, preventing unauthorized manipulation, and eliminating dependency on third-party intermediaries. In parallel, the MCDM approach, implemented through methods such as AHP and TOPSIS, enhances the accuracy and rationality of recommendations by evaluating multiple decision factors, including cost, distance, quality, safety, and user satisfaction. This combination allows the system to generate rankings that better reflect user preferences while maintaining consistent performance across different criteria. The integration of Blockchain and MCDM also enables a transparent and auditable decision-making process, where users can independently verify the fairness and validity of recommendations through smart contract executions. This significantly strengthens user trust and establishes a strong foundation for ethical and sustainable digital tourism ecosystems.

Although the system exhibits increased computational complexity due to blockchain-related operations—particularly in transaction validation and consensus processes—the benefits gained in terms of security, privacy protection, and decision-making transparency outweigh the additional performance costs. The approach demonstrates a balanced synergy between personalization and privacy, making it highly relevant for modern digital tourism platforms that prioritize trust, accountability, and data confidentiality. Empirically, the system achieved a 9% improvement in accuracy compared to the baseline model, indicating measurable performance gains beyond conventional recommendation methods. Theoretically, this study contributes a verifiable decision-making framework that integrates AHP–TOPSIS with blockchain immutability, offering a transparent, tamper-resistant, and mathematically validated approach to ranking and recommendation generation. Practically, the proposed model provides a structured roadmap for the development of ethical, accountable, and user-centric digital tourism platforms aligned with emerging global standards for responsible AI.

However, this study also presents certain limitations. The dataset used for testing was relatively small, which may restrict the generalizability of the results. Future research should therefore incorporate larger, diverse, and real-world datasets to further validate system robustness. Moreover, the exploration of lightweight blockchain protocols, optimized consensus mechanisms, and hybrid on-chain/off-chain architectures is recommended to reduce computational overhead and enhance scalability for practical deployment. Overall, this research contributes to the evolution of intelligent, secure, and accountable recommendation technologies in the era of digital transformation. The Blockchain-Driven MCDM framework demonstrates strong potential to redefine the operational standards of tourism recommendation systems by achieving an effective balance between accuracy, privacy preservation, transparency, and ethical governance.

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