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INTEGRATING BLOCKCHAIN AND ARTIFICIAL INTELLIGENCE IN NFT ECOSYSTEMS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Non-fungible tokens (NFTs) have expanded beyond digital art and collectibles into creative ownership, access rights, digital certification, gaming assets, and metaverse-related services. However, NFT ecosystems continue to face persistent challenges involving asset authenticity, network scalability, cross-platform interoperability, market manipulation, valuation uncertainty, and user trust. This conceptual study examines how blockchain and artificial intelligence (AI) can be integrated to address these socio-technical challenges. It employs an integrative narrative review and thematic conceptual synthesis of literature on NFT architecture, market behaviour, blockchain governance, AI-assisted verification, and Malaysian creative-industry applications. The analysis produces a four-layer framework comprising provenance and authenticity, intelligent market analytics, scalable and interoperable infrastructure, and governance and user trust. The findings indicate that blockchain provides auditable ownership records and programmable transaction logic, whereas AI contributes similarity detection, anomaly screening, recommendation, and decision support. Neither technology is sufficient independently; credible implementation requires transparent data governance, human oversight, and verifiable on-chain evidence. Practically, the framework can guide platform developers, creators, cultural organisations, educators, and policymakers in designing more reliable and responsible NFT services. The originality of the study lies in integrating blockchain capabilities, AI functions, and human governance requirements within a single layered framework for future empirical validation.

Keywords: Artificial Intelligence, Blockchain, Interoperability, Market Trust, Non-Fungible Tokens.

INTRODUCTION

Non-fungible tokens (NFTs) represent a distinctive form of digital asset in which ownership claims, metadata, and transfer histories are recorded through blockchain-based token standards (Wang et al., 2021; Taherdoost, 2023; Ko et al., 2024). Unlike fungible cryptocurrencies, each NFT contains identifying properties that allow it to represent a unique digital or tokenised asset, such as digital artwork, music, game items, event access, digital certificates, or membership-based utilities. The rapid rise of NFT markets generated new opportunities for creators and organisations, but it also exposed technical, economic, and governance-related weaknesses that continue to affect adoption (Nadini et al., 2021; Razi et al., 2023).

In the early stage of NFT adoption, public discussion largely focused on high-value digital art transactions and speculative market behaviour (Nadini et al., 2021; Dowling, 2022). However, the long-term relevance of NFTs depends less on speculation and more on whether the technology can support credible ownership, trustworthy provenance, fair creator compensation, secure exchange, and useful digital services (Mustajap et al., 2024; Zaibon et al., 2024). This makes the NFT ecosystem a socio-technical system rather than a purely technical innovation. Blockchain can provide immutable transaction records and programmable ownership logic, but it cannot automatically verify whether a digital artwork was uploaded by the legitimate creator, whether metadata accurately describes the asset, or whether marketplace activity reflects genuine demand (Zarifis & Castro, 2022; Chen et al., 2023). These issues require additional layers of verification, analytics, and governance.

Accordingly, this article adopts a conceptual and integrative narrative-review approach to synthesise emerging literature, clarify the complementary functions of blockchain and AI, and develop a framework for future empirical investigation. The guiding research question is: How can blockchain and AI be integrated to improve authenticity, scalability, interoperability, and trust in NFT ecosystems?

Problem Background and Research Gap

NFT research has grown across computer science, finance, digital culture, law, creative industries, and information systems. Existing work has examined token standards, market dynamics, ownership structures, price behaviour, creative monetisation, security threats, and user acceptance (Wang et al., 2021; Nadini et al., 2021; Taherdoost, 2023; Ko et al., 2024). In Malaysia, NFT studies have also begun to examine cultural heritage preservation, consumer decision-making, smart contracts, and blockchain-based ownership in creative-industry contexts (Ismail et al., 2024; Mustajap et al., 2024; Zaibon et al., 2024). However, many discussions treat blockchain and AI as separate technologies. Blockchain-centred studies tend to emphasise decentralisation, immutability, smart contracts, and token standards. AI-centred discussions tend to highlight analytics, automation, and prediction. Less attention has been given to how both technologies can be integrated as a combined governance and intelligence layer within NFT platforms.

Three problem gaps are particularly important. First, authenticity remains difficult to establish because blockchain records the transaction history of a token, not necessarily the originality or legitimacy of the underlying digital asset (Zarifis & Castro, 2022; Zaibon et al., 2024). A copied image can still be minted as an NFT if the platform does not verify creator identity or content provenance. Second, scalability and transaction cost remain barriers, especially when NFT activity occurs on congested networks or when users are unfamiliar with gas fees, wallets, and network selection (Wang et al., 2021; Zheng et al., 2018). Third, interoperability remains fragmented because NFTs may be created on different blockchains, stored using different metadata structures, and traded through marketplace-specific systems (Ko et al., 2024). These gaps affect trust and usability for both creators and collectors. From an academic perspective, the current

gap is not simply the absence of technology, but the absence of an integrated explanatory framework. A useful framework should show where blockchain is strongest, where AI can complement it, and where human governance remains necessary (Razi et al., 2023; Taherdoost, 2023). This article responds to that gap by proposing a layered blockchain-AI integration framework for NFT ecosystems.

Addressing this gap is particularly important for the creative industries, where NFTs are increasingly associated with digital ownership, creator attribution, intellectual property protection, monetisation, and cultural heritage applications. Integrating blockchain and AI may support more transparent, reliable, and accountable NFT platforms by combining verifiable ownership records with intelligent verification and decision-support mechanisms. Such integration is also relevant to the development of sustainable digital ecosystems, as long-term adoption depends not only on technological performance but also on interoperability, responsible governance, user trust, and the protection of creators and digital assets.

Research Objectives

This study has three objectives: (1) to synthesise the complementary functions of blockchain and AI in addressing key NFT ecosystem challenges; (2) to develop a layered conceptual framework linking authenticity, market analytics, scalability, interoperability, governance, and user trust; and (3) to propose theoretical, practical, and policy directions for empirical validation and responsible NFT-platform development.

Blockchain as the Ownership and Provenance Layer

Blockchain is the foundational infrastructure for NFTs because it enables decentralised record-keeping, cryptographic verification, transparent ownership transfer, and smart-contract automation (Zheng et al., 2018; Wang et al., 2021; Zaibon et al., 2024). Through token standards such as ERC-721 and ERC-1155, digital assets can be represented as unique or semi-fungible tokens (Ko et al., 2024). Smart contracts can define minting logic, ownership transfer, marketplace listing, royalty rules, and access conditions. These features provide a technical basis for provenance and programmable digital ownership.

However, blockchain records are only as reliable as the information entered into them. If an unauthorised party mints a copied artwork, the blockchain may permanently record the token history, but that history does not automatically prove creative legitimacy (Zarifis & Castro, 2022; Sahoo et al., 2023). This distinction between token provenance and asset authenticity is central to NFT governance. Token provenance answers the question of where a token has been; asset authenticity asks whether the asset itself is genuine, authorised, and correctly attributed.

Blockchain also faces infrastructural constraints. Public chains may experience congestion, fluctuating transaction fees, and environmental or sustainability concerns depending on consensus mechanisms (Zheng et al., 2018; Wang et al., 2021; Ante, 2022). Layer-2 networks, sidechains, rollups, and alternative chains can reduce costs and improve throughput, but they may introduce new questions regarding security assumptions, bridge risks, and cross-chain asset integrity. Broader decentralised-finance research also shows that smart-contract ecosystems can be exposed to exploit strategies and transaction-level vulnerabilities, which are relevant to NFT marketplaces when they integrate trading, lending, or token-based financial mechanisms (Qin et al., 2021).

Recent evidence reinforces the need for a more cautious interpretation of blockchain security in NFT ecosystems. Ma et al. (2025), in a systematic study of NFT security, identified a broad range of attacks and scams across the NFT ecosystem, showing that blockchain immutability does not by itself eliminate

vulnerabilities arising from smart contracts, platforms, user behaviour, and surrounding infrastructure. This perspective qualifies the common assumption that transparent on-chain records automatically produce a secure or trustworthy NFT environment. Blockchain is therefore more appropriately viewed as an auditable infrastructure whose reliability still depends on secure implementation, platform controls, and governance.

Artificial Intelligence as the Verification and Intelligence Layer

AI can strengthen the NFT ecosystem by supporting tasks that blockchain is not designed to perform. Computer vision models can compare images, identify visual similarity, and flag possible plagiarism or derivative minting (Sahoo et al., 2023). Natural language processing can analyse NFT descriptions, metadata, social media discourse, and marketplace reviews to detect inconsistencies or misleading claims. Machine learning models can identify abnormal trading patterns, potential wash trading, coordinated price manipulation, and suspicious wallet behaviour (Chen et al., 2023).

AI also supports marketplace usability. Recommendation systems can help collectors discover relevant assets based on preference, previous interactions, and collection categories. Valuation models can combine transaction history, collection rarity, creator reputation, social engagement, and market signals to provide decision support (Nadini et al., 2021; Ismail et al., 2024). Chatbots and AI assistants can guide new users through wallet setup, minting processes, and marketplace navigation. These applications may reduce friction for users who are unfamiliar with blockchain systems.

At the same time, AI must be implemented carefully. Automated valuation may reinforce hype cycles if the training data reflects speculative or manipulated market activity (Chen et al., 2023). Recommendation systems may privilege already popular collections and reduce visibility for emerging creators. AI-generated content also complicates questions of authorship, originality, and copyright. Therefore, AI should not be treated as a neutral solution but as an accountable layer that requires transparency, auditability, and ethical governance (Zarifis & Castro, 2022; Zaibon et al., 2024).

Taken together, the literature suggests that blockchain and AI should not be treated as competing or self-sufficient solutions. Blockchain is comparatively stronger in traceability, ownership records, and programmable transaction rules, whereas AI is stronger in pattern recognition, content comparison, anomaly detection, and decision support. However, the limitations of one technology are not automatically resolved by introducing the other. AI outputs remain dependent on data quality and model transparency, while blockchain records remain dependent on the validity of the information and processes recorded on-chain. The more defensible position is therefore a complementary socio-technical approach in which blockchain, AI, and human governance perform distinct but interdependent functions.

Key Challenges in NFT Ecosystems

The first challenge is authenticity. NFT marketplaces need mechanisms that verify creator identity, asset originality, and metadata accuracy. Blockchain can preserve minting and transfer records, while AI can provide similarity detection and anomaly screening (Sahoo et al., 2023). A combined approach can reduce counterfeit tokens, but human review and legal clarity are still needed when disputes arise (Zarifis & Castro, 2022).

The second challenge is scalability. NFT platforms must manage transaction volume, network fees, and user experience across different chains (Zheng et al., 2018; Ante, 2022). Blockchain scaling solutions can reduce technical bottlenecks, while AI can assist by predicting congestion, estimating fees, optimising

transaction timing, and improving platform performance monitoring (Ko et al., 2024).

The third challenge is interoperability. Users increasingly expect assets to move across wallets, marketplaces, games, metaverse environments, and identity systems (Wang et al., 2021; Ko et al., 2024). Cross-chain bridges and common metadata standards can support interoperability, but recent research shows that interoperability should not be equated with frictionless or risk-free connectivity. Yuan et al. (2025) evaluate cross-chain technologies across security, privacy, performance, and functionality, demonstrating that interoperability mechanisms involve trade-offs rather than a single technical solution. More recent work by Li et al. (2025) similarly distinguishes asset interoperability from data interoperability and highlights continuing challenges involving security, scalability, and integration across heterogeneous blockchain systems. AI may assist by mapping metadata, classifying assets, predicting compatibility risks, and guiding users across networks; however, these functions do not remove bridge vulnerabilities, inconsistent standards, or governance problems. Accordingly, interoperability in NFT ecosystems requires both technical connectivity and governance mechanisms that protect asset integrity and prevent duplicated or misleading cross-chain ownership claims.

The fourth challenge is market trust. NFT markets have been affected by price volatility, wash trading, low liquidity, rug pulls, and speculative behaviour (Ante, 2022; Dowling, 2022; Chen et al., 2023). AI-based detection can help identify suspicious patterns, while blockchain transparency allows researchers and platforms to audit wallet-level activity. Nevertheless, platform governance, disclosure rules, and community norms remain essential, particularly because trust and community engagement influence NFT decision-making (Ismail et al., 2024; Zarifis & Castro, 2022).

Malaysian NFT Research Context

The recent Malaysian NFT scholarship is directly relevant to the present framework because it connects NFT adoption with arts, cultural heritage, consumer perception, and smart-contract infrastructure. Mustajap et al. (2024) argue that NFTs can strengthen Malaysian arts and cultural heritage preservation by supporting digital ownership, creator visibility, and technology literacy. Ismail et al. (2024) show that perceived value, trust in blockchain technology, and community engagement influence consumer decision-making in NFT purchases. Zaibon et al. (2024) further extend this discussion by positioning NFTs and smart contracts as a technological framework for cultural heritage preservation, automated royalties, and secure ownership transfer. Together, these studies provide local scholarly support for treating NFT ecosystems as socio-technical systems that require not only blockchain infrastructure but also user trust, creator education, platform governance, and responsible technological design.

METHODOLOGY

This study uses an integrative narrative review and conceptual synthesis. This design is appropriate for an emerging interdisciplinary topic because it allows technical, economic, creative-industry, and governance perspectives to be examined within a common analytical frame. The review does not claim statistical comprehensiveness or new empirical measurement; instead, it develops a theoretically informed framework that can guide subsequent empirical testing.

The review corpus was assembled through purposive scholarly selection rather than a database-bound systematic search. It consists of peer-reviewed articles, scholarly books, conference research, and relevant preprints cited in this manuscript. Sources were retained when they directly addressed at least one of four domains: NFT technical architecture and token standards; NFT market behaviour and trading risks; blockchain scalability, interoperability, and governance; or AI applications in verification, anomaly detection, recommendation, and market analytics. Sources focused only on cryptocurrency price

movements, without a clear link to NFTs or platform governance, were excluded. This purposive selection aligns with an integrative narrative review, but it does not claim to cover all published NFT research.

Because the study was designed as an integrative narrative review rather than a systematic review, a formal database-by-database screening log, fixed search period, and exact initial retrieval count were not maintained. The final analytical corpus comprised the scholarly sources cited in the manuscript, selected purposively according to their direct relevance to NFT architecture and token standards, market behaviour and trading risks, blockchain scalability and interoperability, AI-assisted verification and analytics, and governance and creative-industry applications. Source identification was iterative and included scholarly literature located through academic search and publisher platforms, together with relevant references identified from the reviewed studies. The purpose of this process was conceptual integration rather than exhaustive retrieval. Accordingly, the review does not claim systematic comprehensiveness or reproducibility equivalent to a systematic review.

The selected literature was coded thematically according to the NFT challenge addressed: authenticity, scalability, interoperability, valuation, user experience, and governance. Each code was then mapped against three analytical dimensions: the contribution of blockchain, the contribution of AI, and the continuing requirement for human or institutional governance. Similar codes were consolidated into four higher-order layers. An audit trail was maintained through the explicit mapping presented in Table 1 and the conceptual propositions derived from it. Because the review is narrative rather than systematic, the framework should be interpreted as a transparent conceptual synthesis requiring empirical validation.

Proposed Blockchain-AI Integration Framework for NFT Ecosystems: Conceptual Propositions

The framework advances four propositions for future testing. P1: Combining verifiable on-chain provenance with AI-assisted content and metadata screening will improve perceived asset authenticity. P2: AI-supported interpretation of transparent transaction data will improve decision quality, provided that uncertainty and model limitations are disclosed. P3: Blockchain scaling and interoperability mechanisms, supported by AI-assisted fee, congestion, and compatibility guidance, will reduce user friction. P4: The positive effects of blockchain-AI integration on market trust will depend on transparent governance, appeal mechanisms, human oversight, and accountable data practices.

The proposed framework consists of four interrelated layers: provenance and authenticity; intelligent market analytics; scalable and interoperable infrastructure; and governance and user trust. These layers indicate how blockchain and AI can complement one another while acknowledging that neither technology can solve NFT ecosystem problems independently (Wang et al., 2021; Razi et al., 2023; Taherdoost, 2023).

Table 1
Blockchain-AI Integration Framework for NFT Ecosystems

Framework layer	NFT problem addressed	Blockchain contribution	AI contribution	Expected outcome
Provenance and authenticity	Counterfeit assets, copied works, misleading	Immutable token history, verified wallets, smart-	Similarity detection, metadata screening,	Stronger evidence of originality,

Framework layer	NFT problem addressed	Blockchain contribution	AI contribution	Expected outcome
	metadata, unauthorised minting	contract rules, royalty logic	creator-risk scoring, plagiarism alerts	ownership, and attribution
Intelligent market analytics	Valuation uncertainty, volatility, wash trading, and poor discovery	Transparent transaction histories and wallet-level records	Decision support, sentiment analysis, recommendations, fraud detection	Improved decisions for creators, collectors, and platforms
Scalable and interoperable infrastructure	High fees, congestion, fragmented chains, marketplace silos	Layer-2 solutions, sidechains, bridges, shared token standards	Fee and congestion guidance, metadata mapping, compatibility screening	Lower friction, wider access, smoother cross-platform use
Governance and user trust	Legal uncertainty, platform risk, user confusion, and ethical concerns	Auditable records, decentralised identity, programmable compliance	Risk classification, moderation support, explainable alerts	Greater transparency, accountability, and responsible adoption

Layer 1: Provenance and Authenticity

The first layer addresses the gap between token provenance and asset authenticity. Blockchain can record who minted a token, when it was minted, which wallet owns it, and how it has moved over time. AI can add a verification layer by analysing the asset and metadata before or after minting. For example, image similarity detection can identify whether a newly minted artwork is highly similar to existing works, while metadata analysis can flag suspicious creator claims or inconsistent collection descriptions (Sahoo et al., 2023; Zarifis & Castro, 2022).

For academic and creative-industry contexts, this layer is especially important because creator trust and intellectual property protection influence adoption (Mustajap et al., 2024; Ismail et al., 2024). A platform that allows easy minting but lacks verification may increase participation in the short term while damaging trust in the long term. Therefore, authenticity should be treated as a continuous process involving creator verification, asset screening, metadata validation, and dispute resolution (Zaibon et al., 2024).

Layer 2: Intelligent Market Analytics

The second layer focuses on market intelligence. Blockchain provides transparent transaction data, but raw on-chain data can be difficult for ordinary users to interpret. AI can transform transaction history, wallet behaviour, collection rarity, social sentiment, and marketplace interaction into useful signals. These signals may support pricing decisions, collection curation, risk alerts, and creator strategy (Nadini et al., 2021; Dowling, 2022; Ismail et al., 2024).

However, AI-driven analytics should be treated as decision support rather than deterministic valuation. NFT value is shaped by aesthetic quality, creator reputation, community strength, scarcity, utility, timing, and broader cryptocurrency market conditions (Dowling, 2022; Nadini et al., 2021). AI models should therefore explain the variables used and disclose uncertainty. Transparent model reporting is necessary to avoid misleading users into treating algorithmic estimates as guaranteed market values.

Layer 3: Scalable and Interoperable Infrastructure

The third layer addresses technical usability. NFT users often encounter friction through gas fees, wallet errors, chain incompatibility, and inconsistent marketplace standards (Wang et al., 2021; Ko et al., 2024). Blockchain solutions such as layer-2 networks and cross-chain protocols can reduce some of these barriers. AI can contribute by predicting network congestion, recommending lower-cost transaction windows, assisting with metadata mapping, and warning users when a transaction involves an incompatible chain or unsupported asset type (Zheng et al., 2018). Interoperability should not be framed merely as asset movement. It also includes metadata readability, royalty enforcement, identity recognition, marketplace compatibility, and long-term access to off-chain files (Ko et al., 2024; Zaibon et al., 2024). AI-assisted classification and metadata translation may improve interoperability, but governance standards are needed to prevent duplicated assets, broken links, and false cross-chain representations.

Layer 4: Governance and User Trust

The fourth layer recognises that technological solutions are incomplete without governance. NFT platforms require policies for creator verification, copyright complaints, marketplace manipulation, data privacy, AI-generated content disclosure, and smart-contract risk (Zarifis & Castro, 2022; Qin et al., 2021; Zaibon et al., 2024). Blockchain improves auditability, while AI improves monitoring and early warning. Yet final decisions often require human judgement, legal interpretation, and platform accountability. A responsible

NFT ecosystem should therefore combine automated systems with transparent governance processes. Users should be informed when AI is used for valuation, recommendation, or fraud detection. Creators should be able to appeal automated moderation or authenticity decisions. Policymakers and researchers should have access to aggregated evidence that supports better regulation without exposing sensitive personal data.

DISCUSSION

The framework suggests that blockchain and AI are complementary but not interchangeable. Blockchain is strongest in recording ownership, enforcing smart-contract logic, and enabling transparent audit trails (Zheng et al., 2018; Wang et al., 2021). AI is strongest in recognising patterns, analysing large datasets, detecting anomalies, and personalising user experiences (Sahoo et al., 2023; Chen et al., 2023). The integration of both technologies can strengthen NFT ecosystems when each technology is used according to its strengths.

Compared with existing NFT research strands, the proposed framework differs primarily in the way it integrates technological and governance functions within a single analytical structure. Blockchain-centred NFT studies have largely emphasised ownership records, token standards, smart contracts, and transaction transparency, whereas AI-oriented studies have focused more strongly on prediction, recommendation, similarity matching, and anomaly detection. Trust- and governance-oriented research, meanwhile, has highlighted platform risk, copyright, consumer protection, and user confidence, while creative-industry studies have focused on creator visibility, cultural heritage, monetisation, and technology adoption. As summarised in Table 2, these perspectives provide important but relatively specialised explanations of NFT ecosystems. The present framework does not replace these approaches; rather, it connects their complementary strengths by positioning blockchain as the provenance and transaction infrastructure, AI as the verification and intelligence layer, and human governance as the mechanism for accountability, dispute resolution, and responsible adoption. This integration also exposes an important limitation: combining blockchain and AI does not automatically resolve authenticity, interoperability, or trust problems, because the effectiveness of the framework remains dependent on data quality, platform design, governance standards, and human oversight.

The four layers should also be understood as interdependent rather than independently optimised components, because improvements in one layer may create trade-offs in another. For example, AI-assisted fee prediction and transaction optimisation may improve scalability and user convenience, but greater automation may reduce transparency if users cannot understand how recommendations are generated. Similarly, cross-chain interoperability may expand asset mobility while introducing additional bridge, metadata, and ownership-verification risks that affect provenance and user trust. Stronger AI-based authenticity screening may also improve fraud detection but create governance concerns when legitimate creators are incorrectly flagged or cannot effectively challenge automated decisions. These tensions suggest that optimisation at the infrastructure or intelligence layer should be balanced against transparency, accountability, appeal mechanisms, and human oversight at the governance layer. The framework therefore treats the four layers as mutually constraining components rather than assuming that improvement in one layer automatically strengthens the NFT ecosystem as a whole

For creators, the framework highlights the importance of verified identity, accurate metadata, responsible minting, and community trust (Mustajap et al., 2024; Ismail et al., 2024). AI tools may help creators understand market trends or detect unauthorised reuse of their work, but creators should not depend solely on automated valuation or platform algorithms. For collectors, the framework provides a basis for assessing risk by considering provenance, authenticity signals, transaction patterns, and platform governance. For developers, the framework identifies technical areas where AI can be embedded into NFT platforms, including verification dashboards, fraud alerts, metadata management, and user guidance systems (Sahoo et al., 2023; Chen et al., 2023). For policymakers and academic researchers, the framework shows that NFT regulation should not focus only on cryptocurrency transactions. It should also consider intellectual property, digital identity, consumer protection, platform accountability, AI transparency, and cross-border data governance (Zarifis & Castro, 2022; Mustajap et al., 2024). The academic value of the framework lies in its ability to organise future research questions. For example, researchers can empirically test whether AI-based authenticity tools increase user trust, whether fee-prediction systems improve transaction completion, or whether explainable recommendation systems create fairer visibility for emerging creators.

Figure 1 provides a visual synthesis of the proposed four-layer framework, showing the interdependence of provenance and authenticity, intelligent market analytics, scalable and interoperable infrastructure, and governance and user trust. The figure also emphasises that human governance, transparency, and accountability operate across all four layers rather than as a separate technical component.

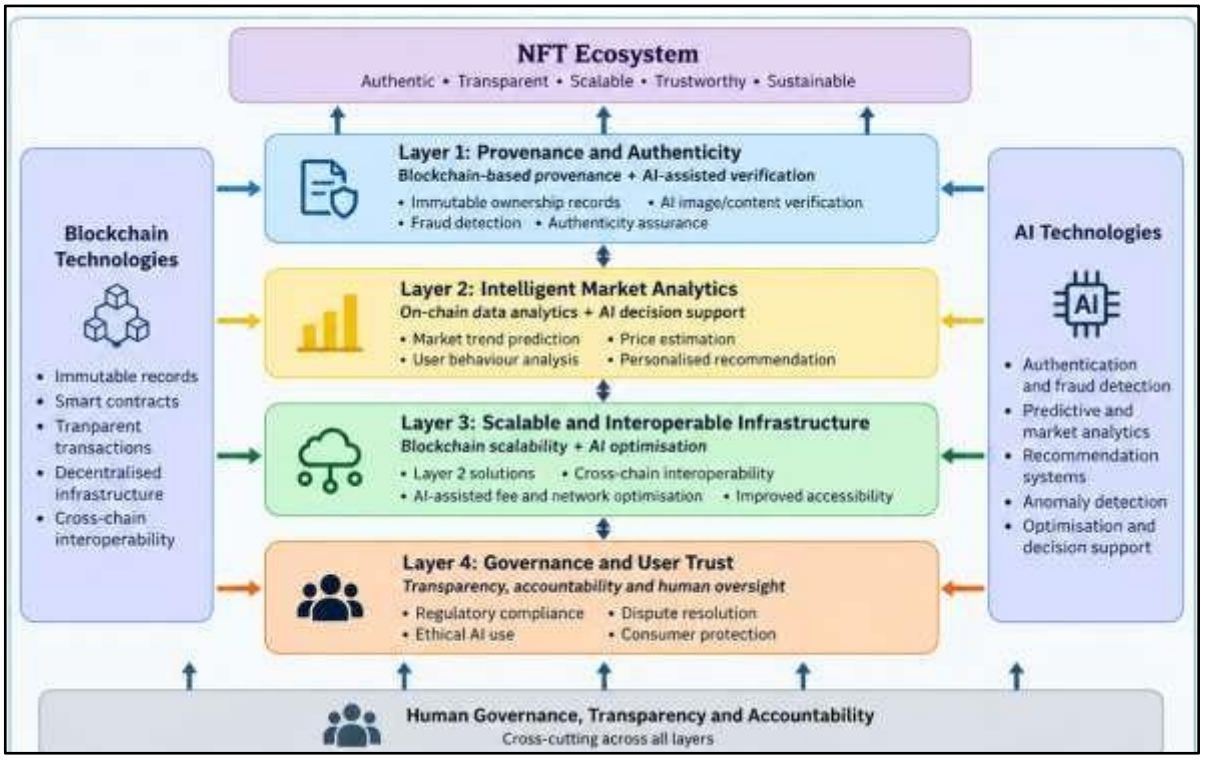


Figure 1. Proposed Blockchain-AI Integration Framework for NFT Ecosystem

IMPLICATIONS

Theoretical Implications

The article contributes to NFT literature by shifting the discussion from single-technology analysis to integrated socio-technical analysis. It clarifies the distinction between token provenance and asset authenticity and proposes a layered framework that links blockchain affordances, AI capabilities, and governance requirements (Razi et al., 2023; Taherdoost, 2023). This provides a conceptual foundation for future studies in information systems, digital creative industries, platform studies, and technology

governance.

The framework extends prior studies in three ways. First, it separates token provenance from asset authenticity, preventing immutable records from being treated as automatic proof of creative legitimacy. Second, it links technical infrastructure with marketplace intelligence instead of analysing blockchain and AI as isolated technologies. Third, it treats governance and human judgment as an enabling layer rather than an external afterthought. This combined socio-technical emphasis constitutes the central conceptual contribution of the study.

The novelty of this study should therefore be understood at the level of conceptual synthesis and framework organisation rather than as the introduction of a new empirically validated theory. Its contribution lies in integrating previously fragmented perspectives on blockchain infrastructure, AI-assisted intelligence, and human governance into a unified layered framework, while distinguishing token provenance from asset authenticity. The framework provides a structured basis for theory development and future empirical testing; however, its proposed relationships and practical effectiveness remain conceptual until validated through empirical research.

Table 2

Positioning of the Proposed Framework Against Existing Research Strands

Existing research strand	Typical emphasis	Added the contribution of this study
Blockchain-centred NFT research	Ownership records, token standards, smart contracts, and transaction transparency	Distinguishes token provenance from asset authenticity and identifies where AI verification is required.
AI-centred marketplace research	Prediction, recommendation, similarity matching, and anomaly detection	Links AI functions to verifiable on-chain evidence and accountable data governance.
NFT trust and governance research	Platform risk, user confidence, copyright, and consumer protection	Positions human oversight, appeal mechanisms, and institutional accountability as an enabling layer.
Creative-industry NFT research	Creator visibility, cultural heritage, monetisation, and technology adoption	Combines creative-industry needs with technical infrastructure, market intelligence, and policy considerations.

Practical Implications

For NFT platform developers, the framework can guide feature development such as creator verification, AI-assisted plagiarism screening, dynamic fee guidance, cross-chain metadata tools, and suspicious activity alerts (Sahoo et al., 2023; Chen et al., 2023). For creators and cultural organisations, it provides a checklist for evaluating whether an NFT platform supports trustworthy provenance, fair visibility, and long-term asset access, which aligns with Malaysian research on NFT adoption for arts and cultural heritage preservation (Mustajap et al., 2024; Zaibon et al., 2024). For educators, the framework can be used to teach NFT literacy beyond speculation by focusing on ownership, authenticity, ethics, and digital economy infrastructure.

Policy Implications

For policymakers, the framework indicates that NFT governance should include transparency requirements for AI-assisted valuation, standards for metadata and provenance, consumer protection against misleading

claims, and mechanisms for intellectual property dispute resolution (Zarifis & Castro, 2022). Policy should also recognise that NFTs may be used beyond art markets, including certification, membership, event access, and digital heritage applications (Wang et al., 2021; Mustajap et al., 2024).

Limitations and Future Research

As a conceptual and narrative review, this article does not provide new empirical data. Its purpose is to clarify concepts and propose a framework that can be tested in future studies. The framework is also technology-neutral and does not evaluate the performance of a specific blockchain, marketplace, or AI algorithm. Future research should conduct empirical validation using user surveys, expert interviews, platform case studies, blockchain transaction datasets, or experimental prototypes. Future studies may examine at least four research directions. First, researchers can test how AI-based authenticity indicators affect creator and collector trust (Sahoo et al., 2023; Zarifis & Castro, 2022). Second, studies can compare different blockchain networks in terms of cost, transaction success, interoperability, and user satisfaction (Ko et al., 2024; Zheng et al., 2018). Third, researchers can evaluate whether AI recommendation systems improve or reduce marketplace fairness for new creators. Fourth, policy-oriented research can investigate how copyright, consumer protection, and AI governance frameworks apply to NFT marketplaces in specific national contexts, including Malaysia (Mustajap et al., 2024; Zaibon et al., 2024).

In addition, because the literature was selected purposively rather than through a systematic database search, the review may be subject to selection bias and may not capture all relevant perspectives. Future studies could employ systematic or scoping review methods to assess the comprehensiveness and robustness of the proposed framework.

CONCLUSION

NFTs remain a significant area of digital innovation, but their long-term value depends on solving problems of authenticity, scalability, interoperability, and trust (Wang et al., 2021; Taherdoost, 2023; Ko et al., 2024). Blockchain provides the foundation for token ownership, provenance, and smart-contract execution, while AI provides tools for verification, analytics, recommendation, and anomaly detection. The integration of these technologies can create more reliable NFT ecosystems when supported by transparent governance and ethical design.

In answer to the guiding research question, blockchain and AI can improve NFT ecosystems when their complementary strengths are organised through four interdependent layers: provenance and authenticity, intelligent market analytics, scalable and interoperable infrastructure, and governance and user trust. Blockchain supplies auditable ownership records and programmable transaction logic; AI supplies verification, pattern recognition, recommendation, and decision support; and human governance provides accountability, legal interpretation, and remedies for contested decisions. The framework can assist researchers, platform developers, creators, collectors, and policymakers in moving NFT applications beyond speculative trading towards more useful, accountable, and sustainable digital-ownership systems. As the framework is conceptual, its relationships and proposed outcomes require empirical validation.

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AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by all authors.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Informed consent was obtained from all individual participants included in the study.

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