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Towards a Generic NFT-Driven Digital Twin Simulation Platform: A Systematic Literature Review

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Abstract
A new approach to asset management and traceability emerges upon the integration of Non-Fungible Tokens (NFTs) and Digital Twin (DT) technology. While NFTs are widely used in digital art and gaming, their potential for securing real-world assets in DT simulations remains under-explored. A generic NFT-driven DT simulation platform could transform asset management by enhancing traceability, optimizing operations, and fostering sustainability within and across industries. In livestock management, DTs can model individual animals in real time, capturing data on health and growth. Linking this data to NFTs ensures ownership and provenance, improving traceability and accountability. Similarly, in manufacturing, DTs can identify inefficiencies, reducing waste and energy use. It is pressing to improve decision-making and operational efficiencies throughout distinct contexts. A Systematic Literature Review (SLR) was conducted following PRISMA. The goal was to build a solid, unbiased foundation for our research, contribute lasting value to the community, and identify where our work can make the most impact. From an initial set of 114 papers, the authors screened and classified the most relevant. This led to a final selection of 8 papers for full-text reading and in-depth analysis. They are presented in detail and compared in order to depict the current state of the art in the field. Results reveal a significant gap concerning the topic, particularly highlighting the absence of simulation environments that align with the previous proposal presented by the authors: a comprehensive NFT-driven and DT simulation platform that transforms NFT-based asset management from static ownership records to dynamic, provides simulation operational tools, enables real-time monitoring, predictive maintenance, and performance optimization for real-world assets.

Keywords *Blockchain, Non-Fungible Token (NFT), Digital Twins (DT), Traceability, Simulator, Generic*

1. Introduction

The emergence of Non-Fungible Tokens (NFTs) and their integration into Digital Twin (DT) simulation platforms have the potential to revolutionize asset management across various industries. By leveraging the unique properties of NFTs, such platforms can enhance traceability, optimize operations, and foster sustainability. This systematic literature review aims to explore the existing research surrounding NFT-driven DT simulation platforms and their implications for asset management, with a particular focus on how these technologies can transform industry practices.

NFTs serve as digital certificates of ownership, providing a tamper-proof record of an asset's history, which is critical for fostering transparency and traceability in asset management (Caldera et al., 2021). Using blockchain technology in this context aids in establishing the provenance of assets and facilitates real-time monitoring and management, which are vital for enhancing the operational efficiency of asset utilization (Wang et al., 2024). Moreover, frameworks for risk management that incorporate these technologies are increasingly recognized for their ability to mitigate risks associated with asset degradation and lifecycle management (Santosa et al., 2024).

Digital Twins, being virtual representations of physical assets, can significantly improve the management of lifecycle processes by simulating different operational scenarios. Integrating NFT technology with DT frameworks enhances simulations through a detailed lineage of asset data, thus supporting smarter decision-making processes (Papic & Cerovšek, 2019). For instance, the convergence of Building Information Modeling (BIM) with Digital Twins has been documented to improve infrastructure asset management, highlighting how these methodologies can be synthesized to yield better outcomes in various sectors (Garramone et al., 2020).

The challenges of managing physical assets in a rapidly evolving technological landscape need new solutions that promote smart asset management. The strategic integration of NFTs within DT platforms can synchronize asset management practices across diverse industries, leading to improved resource allocation and sustainability. Recent literature indicates that using advanced digital infrastructure, such as an NFT-driven DT simulation platform, can streamline operations and enhance the effectiveness of decision-making frameworks in asset management (Hirschowitz Nel & Jooste, 2016).

Systematic literature reviews (SLRs) play a crucial role in synthesizing existing research and providing a comprehensive overview of a particular field of study. SLRs enable researchers to uncover patterns, identify gaps, and recommend future research directions. This structured approach enhances the reliability of conclusions drawn from diverse sets of literature.

For instance, the systematic review by Semeraro et al. focused on the digital twin paradigm, examining key features and challenges associated with their implementation. The study used a rigorous methodological framework, integrating findings from numerous sources to establish a coherent understanding of current digital twin concepts and applications in various sectors, including manufacturing and healthcare (Semeraro et al., 2021). Similarly, the review conducted by Nunes et al. on NFTs in healthcare elucidates how NFTs can serve as digital representations of healthcare products, ensuring ownership and provenance across the supply chain (Corte-Real et al., 2022). Both studies exemplify how SLRs synthesize existing research, underscoring the potential of NFTs and DTs within their corresponding domains.

Moreover, the SLR process is particularly valuable in fields characterized by rapid technological advancements. For example, in their review, Coorey et al. highlighted how digital twins can significantly impact precision medicine by enabling patient-specific treatment pathways through continuous monitoring and data integration (Coorey et al., 2022). By systematically collecting and analyzing literature, this review facilitates the identification of emerging trends, benefits, and barriers related to digital twin technologies and their applications.

However, despite the growing body of literature on NFTs and digital twins, there is a notable gap of systematic literature reviews specifically addressing Generic NFT-Driven Digital Twin Simulations. This gap indicates a critical opportunity for researchers to explore how NFTs can enhance digital twin functionality across various sectors. By conducting a dedicated SLR on this topic, researchers could effectively see the intersections between NFTs and digital twins, thus creating innovative solutions that leverage the strengths of both technologies.

As industries aim for more sustainable and efficient asset management strategies, the integration of NFT-driven DT simulation platforms offers a promising avenue. We aim to continue to develop a simulation platform and we need to uncover what is already being done in the world related to this. Specifically, by assigning a unique, immutable NFT to each digital twin, the asset's lifecycle can be securely tracked and verified. This provenance data improves trust among stakeholders and enables more informed, data-driven decisions, reducing waste and extending asset lifespans. It also supports predictive maintenance and resource optimisation by linking real-time simulation outputs to automated workflows, ensuring interventions occur only when necessary. Furthermore, NFT-backed digital twins enhance interoperability. Smart contracts embedded in NFTs can even automate transactions and maintenance processes.

This systematic literature review will critically assess current research to identify current work, technologies used, and future directions in the application of these technologies to foster an evolved understanding of asset management in both a theoretical and practical context. The authors have already proposed the creation of a generic simulation platform NFT-driven and digital twin (DT) simulation platform (Ferreira et al., 2025; Figueiredo et al., 2025). The goal for the SLR is to find related and relevant work that could be used as guidance, comparison and create benchmarks with other projects that integrate these technologies with simulation tools, enable real-time monitoring, support predictive maintenance, and facilitate performance optimization for real-world assets.

2. Methods

We conducted a systematic review that aims to identify and synthesize relevant studies about the connection of Non-Fungible Tokens (NFT) with Digital Twins (DT) and the usage of a simulation environment to replicate real world scenarios where they are used. While conducting the systematic literature review (SLR), the PRISMA methodology was adopted to ensure a structured, transparent, and reproducible process (Preferred Reporting Items for Systematic Reviews and Meta-Analyses and (Page et al., 2021). The review followed the core PRISMA stages of identification, screening, and inclusion, which allowed the collection of relevant studies, the elimination of duplicates and irrelevant records, and the final selection of publications that met the predefined criteria. The eligibility stage, often considered a distinct step in PRISMA, was not explicitly separated in this review. Instead, its function, the assessment of full-text articles against inclusion criteria, was integrated into the screening and inclusion phases. Likewise, the data extraction and synthesis steps, while essential for analysis, fall outside the scope of the PRISMA flow itself and were treated as part of the subsequent review methodology, to streamline the process and reduce redundancy. This adaptation maintains methodological rigour while customizing the process to the specific goals and scope of this study. The workflow is described in Figure 1 (Haddaway et al., 2022).

After conducting some initial research that enabled some pre-adjustments to the conduction of the SLR we selected the keywords ("NFT" OR "Non-Fungible Token") AND "Digital Twin*" AND ("simulator" OR "simulation environment"). These keywords were then used in advanced searches within trusted sources and scientific databases: IEEE Xplore, ACM Digital Library and Scopus. The selection of IEEE Xplore, ACM Digital Library, and Scopus as primary databases is justified by their broad coverage, scientific quality, and relevance to the domains under analysis. IEEE Xplore and ACM Digital Library are the most authoritative sources for peer-reviewed publications in computer science, software engineering, and emerging digital technologies, ensuring access to high-quality and domain-specific research. Scopus complements these with its multidisciplinary scope and extensive indexing of journals, conference proceedings, and book chapters, thus reducing the risk of omitting relevant studies. Together, these databases provide a balanced combination of depth, rigor, and breadth, making them sufficient and appropriate for systematic data collection.

The cutout date was June 1st, 2025. Initial results revealed the lack of work that associated NFTs, Digital Twins and simulators, since some of the sources provided 0 results to the search. Due to this constrain we chose to exclude ("simulator" OR "simulation environment") from 2 of the 3 libraries, keeping the entire search terms for ACM Digital Library. This allowed us to collect results that allow us to understand the work that is currently being conducted with NFTs and Digital Twins and include additional references of simulation environments.

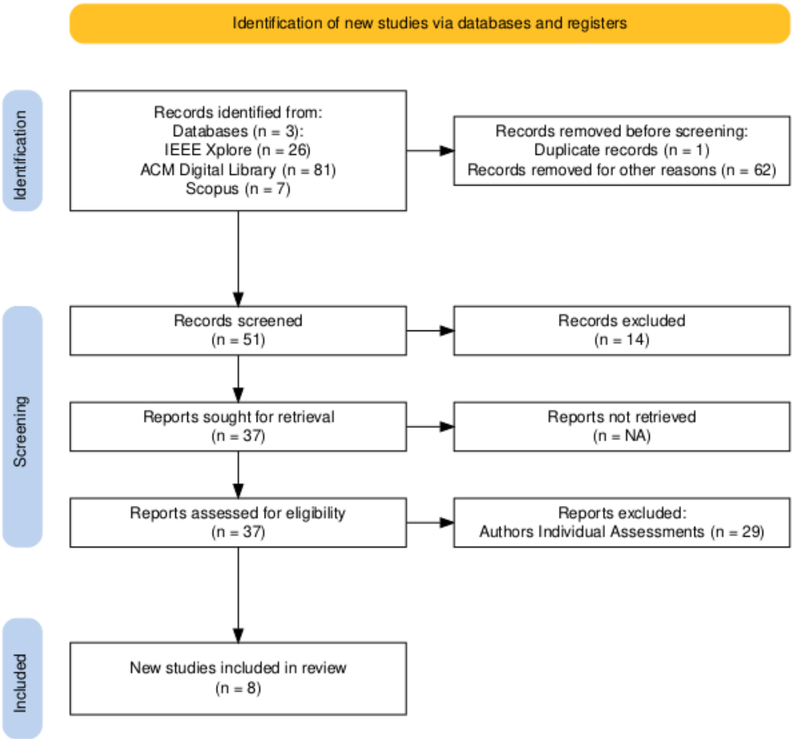

Figure 1. PRISMA Flow Diagram for the SLR

From the first 114 overall results of the searches conducted, we validated that the papers were in English, were peer-reviewed articles or conference papers, and their full-text was available. From the 114, one duplicate was found and 62 proceedings' prefaces that included sparse references to the topics were excluded. This left us with 51 paper references that were used for the initial screening. Both the title and the abstract of the papers were filtered to explicitly find the words ("NFT" OR "Non-Fungible Token") AND "Digital Twin". All of the papers that failed to present the search terms were excluded (n=14).

The remaining 37 papers were sought for retrieval and assessed for eligibility by the authors that used a scale of "-1: off context; 0: neutral; 1: advisable to read and 2: must read" points to classify each one of them for relevance, based on the title and abstract. Appendix A provides a full list of these 37 papers.

Following the authors' individual assessments, we reached consensus on the exclusion of 29 papers due to the lack of relevance: at least one negative or neutral classification (-1 or 0 points); overall classification of less than 4 points out of 8; and, no single classification of 2 points by, at least, one of the authors. The final selection of papers led to the choice of 8 papers that are presented and compared in the Results and Discussion section.

3. Results and Discussion

Selected papers are chronologically distributed across the period from 2022 to 2024, with two studies published in 2022, four in 2023, and the remaining two in 2024. We present them, first, summarized, listed by Authors, in alphabetical order and, later, compare them.

Cao et al. (Cao et al., 2022) presents BDTwins, a comprehensive framework integrating blockchain with digital twin technology (DT) to enhance lifecycle management. It recognizes the increasing complexity and high demand for data-driven strategies in industrial settings, particularly under Industry 4.0, where cloud computing, artificial intelligence (AI), and the Internet of Things (IoT) play relevant roles in smart manufacturing. The authors assert that while the concept of digital twins significantly transforms processes throughout the product lifecycle, from design to operational control, existing research predominantly focuses on earlier stages, often neglecting data processing post-retirement. The framework emphasizes the utility of Non-Fungible Tokens (NFTs) within a seven-dimensional model, ensuring secure data sharing and management throughout the lifecycle of digital assets. Critical to its design is the acknowledgment that stakeholders, often from diverse departments, might not inherently trust one another; thus, the framework incorporates mechanisms for permission control while also recognizing the need for environmental factors (such as IP address and network conditions) to be considered to mitigate security and privacy.

Moreover, the paper underscores the foundational role of data in DT implementations, describing DT as a representation that evolves throughout the asset's lifecycle, ensuring that it accurately reflects current operational states and facilitates better decision-making. Despite the clear advantages presented by the integration of blockchain technology, primarily its decentralization and tamper-proof characteristics, the literature review indicates that prior work has largely overlooked the complexities inherent in post-retirement data management within the digital twin lifecycle, thereby providing a definitive rationale for the authors' focus on this critical aspect.

Elmay et al. (Elmay et al., 2023) investigates the integration of Non-Fungible Tokens (NFTs) and blockchain technologies to enhance the security and management of Digital Twins (DTs) in the maritime shipping sector. The authors recognize the critical need for reliable data traceability and management in shipping container logistics, an area that typically involves numerous stakeholders and complex processes. Traditional methods of managing DTs have often relied on a centralized entity, which may lead to potential data manipulation or tampering, thereby destroying trust among users. The paper addresses these challenges by proposing a decentralized framework that leverages NFTs to tokenize the shipping container DTs and their relevant data. This tokenization allows for the creation of an immutable and transparent ledger using blockchain technology, specifically Ethereum smart contracts.

The authors articulate a framework comprising five modules, designed to facilitate the integration and optimization of DTs throughout the supply chain. These modules encompass the physical supply chain, interface, simulation, optimization, and reporting, thus enabling improved decision-making processes. By implementing such a framework, the authors envision a significant reduction in mistrust and an increase in collaboration between various stakeholders, thereby fostering a more efficient logistics environment.

Gebreab et al. (Gebreab et al., 2022) presents an innovative approach to overcoming traceability issues in the healthcare sector by leveraging non-fungible tokens (NFTs). It addresses significant challenges posed by counterfeit medical devices, which continue to jeopardize patient safety. The authors emphasizes the complex architecture of the proposed system, using NFTs for tracking and managing ownership of medical devices throughout their lifecycle, from production to sale. This is particularly critical given the rising incidence of counterfeit devices that amplify risks within the healthcare supply. The proposed system relies on smart contracts and decentralized storage solutions, such as IPFS (InterPlanetary File System), to record and manage essential documentation about the devices, including certifications, manufacturing dates, and warranty information. This blockchain-enabled approach ensures tamper-proof maintenance of records, thereby enhancing transparency and accountability within the supply chain. Furthermore, the implementation of QR codes and PUF-enabled RFID tags contributes to the validation of product authenticity at a hardware level, which is crucial for post-market surveillance, particularly in cases of device recalls.

The study outlines that unlike other blockchain solutions that provide basic traceability features, the NFT-based system allows for enriched data representation, enabling the integration of multiple product attributes along with a unique digital identification. While the paper presents a conceptual framework and architecture for the NFT solution, it identifies a gap in the technical implementation details, which could delay practical deployment.

Gebreab et al. (Gebreab et al., 2024) investigates the intersection of non-fungible tokens (NFTs), digital twins (DTs), and the metaverse, proposing a novel framework that leverages these technologies to enhance user experiences and facilitate the decentralized management of digital assets. NFTs are positioned as essential elements that offer a secure and verifiable link between the physical and digital realms, allowing the integration of digital artifacts within the metaverse. The uniqueness and traceability of NFTs contribute significantly to ensuring authenticity in digital interactions, which has made them relevant for applications beyond mere collectibles, including the representation and monetization of assets in diverse fields such as healthcare and manufacturing. The paper discusses the potential for NFTs not only to represent ownership but also to facilitate version tracking and real-time updates through dynamic NFTs, which automatically adjust to changes in their corresponding physical entities. This integration ensures that digital representations maintain alignment with their physical counterparts, enhancing the user experience with accurate depictions of physical changes in the metaverse.

Moreover, the paper identifies existing research gaps, particularly in the secure and efficient integration of DTs into the metaverse ecosystem. While studies have outlined interoperability necessities and explored decentralized service models within the metaverse, they often overlook the practical implementation of secure content exchanges that use blockchain protocols in conjunction with NFTs. As such, this work offers valuable solutions by proposing a structured approach that includes leveraging smart contracts for operations and decentralized storage solutions to uphold data integrity and availability for NFTs.

Gebreab et al. (Gebreab et al., 2023) focuses on using blockchain technology, specifically through the implementation of Non-Fungible Tokens (NFTs), to enhance the traceability and certification processes for refurbished medical devices. The motivation behind this research stems from the increasing reliance on refurbished medical devices as a cost-effective and sustainable option in healthcare settings, particularly because these devices can help mitigate high medical costs while maintaining quality and safety standards. However, the reuse of such devices poses significant challenges, notably the risks associated with quality assurance and potential fraud, such as counterfeiting.

Authors propose a novel framework that leverages the Ethereum blockchain to create a decentralized, immutable record of the refurbishment lifecycle of medical devices. Dynamic composable NFTs serve as digital counterparts to physical devices, maintaining an auditable history of each item's status and any alterations made during the refurbishment process. This ensures that stakeholders can verify authenticity and compliance with safety standards, contributing to the mitigation of concerns regarding the quality of refurbished devices. This solution incorporates smart contracts to automate various operations and ensure transactional integrity, which are essential for maintaining trust among users. And also, reputation-based oracles and InterPlanetary File System (IPFS) for efficient data management. The integration of these technologies enhances the visibility of the supply chain while aiming to establish a secure method for documenting and accessing medical data that preserves individual privacy.

Hasan et al. (Hasan et al., 2023) examines the integration of digital twins (DTs) with non-fungible tokens (NFTs) within the context of smart manufacturing. A digital twin is understood as a precise digital replica of a physical asset that facilitates effective management, monitoring, and control of its real-world counterpart. The evolution of digital-driven manufacturing, propelled by advancements in the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, highlights the increasing reliance on digital technologies in modern manufacturing processes. The uniqueness of NFTs, characterized by their blockchain foundation, provides verification of ownership and authenticity, which is essential when tracking the ownership and lifecycle of DTs. The paper argues that the combination of NFTs and DTs enhances the traceability and accountability of ownership as DTs are created, traded, and transferred among various stakeholders. The authors propose an approach where NFTs represent DTs and their subcomponents, allowing for a dynamic ownership model adaptable to the life cycles of physical assets.

The authors also highlight the potential of smart contracts, enabled by programming languages like Solidity, which allow for customizable interactions tailored to specific marketplace needs. Maintaining a transparent ledger through blockchain technology strengthens trust among stakeholders, fostering an environment with truthful information sharing and cooperation. Moreover, the concept of composability is discussed, indicating that DTs should be designed to accommodate ongoing changes to their physical counterparts over time. This flexibility facilitates the trading of DT subcomponents and creates a framework for multiple ownership scenarios throughout an asset's lifecycle.

Saaed et al. (Saeed et al., 2023) introduces an innovative gaming-based education system aimed at enhancing road safety awareness among children within the context of smart cities. Leveraging immersive technologies such as augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and the Internet of Things (IoT), the system offers interactive simulations that allow children to engage with realistic road scenarios. Authors detail how the integration of AR into this educational framework allows children to visualize virtual traffic signs and signals overlaid onto their real environment, augmenting their practical learning experiences in familiar locales. Furthermore, VR technology immerses them in a controlled yet realistic setting where they can practice critical skills such as safely crossing streets, adhering to traffic signals, and making sound judgments regarding vehicle speeds. The use of digital twins for simulating real-time situations enhances the educational experience, making it both engaging and informative.

Although the work proposes the integration of several technologies, that include DT and a simulation environment, it does not mention the integration of NFTs or any other blockchain related technology.

Sai et al. (Sai et al., 2024) presents a comprehensive exploration of using digital twin technology in the management and support of patients suffering from chronic diseases. Through the development of a novel AI-based and IoT-supported digital twin framework, the authors propose a solution that addresses several challenges in chronic disease management, including patient monitoring, nutrition tracking, and personalized treatment recommendations. At its core, the digital twin serves as a virtual representation of the patient, continuously updated with real-time data from various IoT sensors. This ensures that the model reflects the patient's real-world health status and allows for advanced analysis and optimization of treatment strategies. The proposed digital twin platform incorporates multiple machine learning models to enhance functionality. For instance, one model is dedicated to diet analysis, which monitors patients' food intake and issues alerts regarding unhealthy consumption while offering tailored dietary recommendations. Further, the framework integrates algorithms for drug recommendation and disease stage detection, ensuring that interventions remain personalized and relevant.

This work integrates a NFT-based platform that servers two essential functions: securing medical data storage and health information exchange. The ultimate goal of the digital twin system not only revolves around enhancing patient health outcomes but also motivating patient engagement through innovative approaches.

Table 1 is a comparison table that summarizes the attributes of these papers regarding NFTs, Digital Twins (DTs) and simulation environments (simulator).

Table 1 – Selected Studies Comparison

ID	Use Case	Traceability	Technology	Simulation Env.
(Cao et al., 2022)	generic - management of digital twins throughout their lifecycle	yes	Ethereum Solidity Smart Contracts Cumulus Encrypted Storage System (CESS)	NA
(Elmay et al., 2023)	shipping containers - traceability and management	yes	Ethereum Solidity Smart Contracts Azure Digital Twins Interplanetary File System (IPFS)	NA
(Gebreab et al., 2022)	medical devices - traceability and ownership management	yes	Ethereum Solidity Smart Contracts Interplanetary File System (IPFS)	NA
(Gebreab et al., 2024)	cross-metaverse interoperability and monetization for DT and digital artifacts	yes	Ethereum Polygon Solidity Smart Contracts Interplanetary File System (IPFS) or Ceramic Network or Swarm Oracle (timer)	NA
(Gebreab et al., 2023)	refurbished medical devices - management	yes	Ethereum Solidity Smart Contracts Interplanetary File System (IPFS) or Ceramic Network or Swarm	NA
(Hasan et al., 2023)	generic - management of digital twin ownership and proof of delivery of physical asset	yes	Ethereum Solidity Smart Contracts Interplanetary File System (IPFS) or FileCoin or Swarm	NA
(Saeed et al., 2023)	metaverse - gaming-based education system about road safety	track players	Unity – simulator NFTs – rewards (NA)	yes - Unity
(Sai et al., 2024)	chronic disease patients - monitoring and assisting	track daily activities	Ethereum Solidity Smart Contracts Interplanetary File System (IPFS)	yes

In examining these publications, four aspects emerge: use cases; the presence of traceability as a feature; specific NFT (blockchain), DT and simulation technologies employed; and, the inclusion of a simulator or simulation environment within the respective studies.

3.1. Use Cases

Each paper focuses on distinct domains. Gebreab et al. (Gebreab et al., 2022, 2023) address the healthcare domain, specifically for tracking and managing medical devices and refurbished medical devices (DT). Elmay et al. (Elmay et al., 2023) apply digital twins (DTs) for shipping containers, leveraging NFTs for managing container data and ensuring transparency. In contrast, the work by Sai et al. (Sai et al., 2024) introduces an AI-empowered monitoring framework for chronic disease patients, linking health management with blockchain technology through NFTs that are used to secure patients information and transactions. Saeed et al. (Saeed et al., 2023) presents a game-based education framework for road safety that uses NFTs as a reward system.

Although these varied applications showcase the versatility of NFTs in enhancing traceability and ownership across different industries, three studies provide generic approaches that are meant to be used for any use case. Hasan et al. (Hasan et al., 2023) delve into ownership management of digital twins and asset delivery proof, upon delivery of the physical asset. Gebreab et al. (Gebreab et al., 2024) introduce a cross-metaverse platform that deals with interoperability within blockchain infrastructures and transfer ownership between distinct infrastructures. Finally, Cao et al. (Cao et al., 2022) presents BDTwins, a generic framework used to manage digital twins throughout their lifecycle.

3.2. Traceability

All the selected papers mention a form of traceability in their proposed solution. Only six of them use the inherent traceability characteristic of the blockchain where the NFT is implemented to keep track of the DT that maps a real-world physical asset.

Both Saeed et al. (Saeed et al., 2023) and Sai et al. (Sai et al., 2024) report to have tracking features: for the daily activities of patients with chronic conditions; and, for the players of the educational game for road safety. However, none of these features is implemented using a blockchain structure. NFTs in both cases are used to (1) secure patient data and transactions (partially using the blockchain infrastructure) and (2) a rewards system.

3.3. Technology

These studies primarily focus on Ethereum as the base blockchain infrastructure due to its robust support for smart contracts, developed in Solidity. Thus, NFTs are mainly developed using the standard ERC-721, deployed to Ethereum testnets, but with no explicit referral to deployed solutions in the actual Ethereum public network. Additionally, Gebreab et al. (Gebreab et al., 2024) also presents Polygon, a Layer 2 infrastructure that is used for the interoperability assessment they conduct – transfer NFTs from Ethereum to Polygon. Only Saeed et al. (Saeed et al., 2023) do not disclose the infrastructure that supports their NFT reward system.

Regarding the off-chain storage of information, mainly used for storing the metadata for the DT, most of the studies report usage of the Interplanetary File System (IPFS). Some alternatives to distributed and decentralized storage such as Cumulus Encrypted Storage System (CESS), Ceramic Network, Swarm, FileCoin are also presented in some studies (Cao et al., 2022; Gebreab et al., 2022, 2023, 2024).

Only Elmay et al. (Elmay et al., 2023) mention Azure Digital Twins as the specific technology used to manage, create and modify the digital twins. And, only Saeed et al. (Saeed et al., 2023) mention Unity as the simulation environment that supports their game-educational platform.

3.4. Simulation Environment

There is a noticeable gap in explicitly stated simulation environments within these papers. While all papers describe architectural implementation and testing of their frameworks, none sufficiently discuss simulation environments by name or detail their use in demonstrating the operation of blockchain solutions, including NFTs and smart contracts. The absence of this information indicates a potential area for future exploration in ensuring simulated outcomes can be derived before real-world implementations.

In summary, the studies demonstrate a rich landscape of innovative applications using blockchain technologies and NFTs, primarily within the Ethereum ecosystem. They emphasize automated systems through smart contracts while lacking attention to the use of simulation environments, highlighting a unique research opportunity for further development, as the authors already proposed (Ferreira et al., 2025; Figueiredo et al., 2025).

4. Conclusions and Future Work

The results reveal a significant gap concerning the topic, particularly highlighting the absence of simulation environments that align with the previous proposal presented by the authors: a comprehensive NFT-driven and digital twin (DT) simulation platform that transforms NFT-based asset management from static ownership records into a dynamic framework. Such a platform would integrate simulation tools, enable real-time monitoring, support predictive maintenance, and facilitate performance optimization for real-world assets.

Although the present systematic literature review identified only eight studies that satisfied the inclusion criteria, this limited number should not be interpreted as a methodological shortcoming but rather as an indicator of the current state of research in this area. The small corpus of relevant studies reflects a clear and significant gap of literature directly addressing the topic, suggesting that this is still an emerging and underexplored field.

Despite growing interest in NFTs for verifiable ownership and provenance, there is an absence of integrated simulation environments that leverage NFTs and DTs. This highlights the need for continued research and development of platforms that assign a unique, immutable NFT to each digital twin, enabling secure lifecycle tracking and verification. Such capabilities would strengthen stakeholder trust, support informed, data-driven decision-making, and contribute directly to reducing waste.

Moreover, the results show that existing solutions rarely exploit the potential of linking real-time simulation outputs to automated workflows, a crucial step for enabling predictive maintenance and resource optimisation. The limited integration of smart contracts and automation further constrains the transition from static ownership records to dynamic, self-managed asset ecosystems. Addressing these gaps will require moving beyond simple representation toward platforms where NFTs act as active gateways into interoperable digital ecosystems.

As future work, we aim to advance the conceptual architecture and further developing the proof-of-concept platform proposed in earlier stages. This platform integrates NFTs that are linked to real-world physical assets, mapped to Digital Twins, and with real-time simulation capabilities. This includes designing standardized metadata structures, defining interoperability layers between NFT registries and simulation engines, and evaluating performance in industrial case studies. Moreover, research will also focus on trust and governance mechanisms, ensuring data integrity, security and access control across decentralized environments. Through these steps, we intend to bridge the existing gap and provide a foundational contribution toward operationalizing NFT-enhanced digital twins.

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Appendix A

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