Tokenizing Building Documentation for Smart Cities: A Digital Twin and NFT Approach

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***Abstract*—In earthquake-prone countries like Italy, the absence of trusted and immutable building documentation poses significant challenges to structural resilience improvements and regulatory authorities oversight. This abstract proposes a decentralized framework that leverages Digital Twins, Smart Contracts, and Non-Fungible Tokens to tokenize critical building documentation such as structural models, project files, and certifications, including those related to seismic compliance. By integrating these assets into a blockchain-based Building Ledger Dossier, the system ensures tamper-proof records, enhances transparency, and enables continuous auditability throughout a building's lifecycle. This approach supports more accountable maintenance, facilitates regulatory compliance, and promotes data integrity in urban resilience initiatives.**

***Index Terms*—Building Ledger Dossier, Blockchain, Smart contracts, Construction, Digital Twin, NFT, IPFS.**

I. Introduction

Italy's seismic vulnerability demands robust traceability of structural retrofits. Earthquakes of Central Italy (L'Aquila 2009 and Amatrice 2016) in particular drained billions of euros to restore private houses and public sites. Building intervention records and related restoration works were often opaque and unverifiable [1], [2], [3]. Tokenizing this documentation using blockchain technologies such as Non-Fungible Tokens (NFTs) and Decentralized Autonomous Organizations (DAOs) can improve control effectiveness by providing auditability, ownership traceability, and public access. Inspired by recent experimental regulation introduced in several regions of Italy known as Fascicolo del Fabbricato (a building ledger to register all of its works and documents), we envisioned the Building Ledger Dossier framework [4]. The idea is to implement a system to track, control and model the building's life using decentralized storage, smart contracts, and digital twins.

II. Methods and Frameworks

The methodology proposed consist in creating a Documental Digital Twin (DDT), which is a comprehensive digital representation of a building that includes both its physical attributes and its complete documentation history (e.g., blueprints, modifications, certifications). Key aspects of the methodology include the tokenization of such documents, every piece of documentation is stored as a NFT to ensure immutability, timestamping, and traceability using blockchain technology. System Requirements are the following: (i) Use of interoperable open data formats to avoid vendor lock-in; (ii) A centralized platform for intervention tracking, photos, reports, and certificates; (iii) Blockchain to guarantee data integrity; (iv) NFT-based storage to timestamp interventions; (v) Remote monitoring to oversee project compliance in real-time, and (vi) Approval workflows involving professionals for validation of works before blockchain registration.

Common structural interventions addressed include (i) reinforcement meshes, (ii) steel plates, and (iii) foundation strengthening. Each intervention is tagged, documented, and validated through a structured four-phase lifecycle: preparation, execution, digital twin creation, and finalization. In particular we modeled the tokenization process in five phases represented in Fig.1: Upload of documents, Metadata extraction, NFT creation, Smart contract minting, and Registration to a public NFT marketplace (we choosed OpenSea[1]). Files

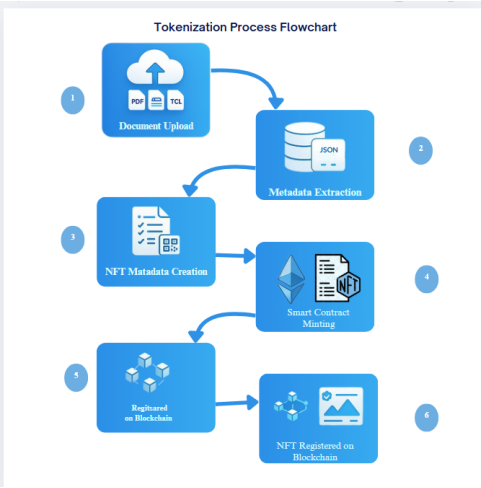

Fig. 1. Tokenization workflow: from upload to NFT registration

involved in the process included project and certification elements (PDF, DWG) and models of the building structure realized with the open format OpenSees (TCL) [5]. They were hashed and uploaded to a remote IPFS system [6]. Metadata

[1]https://opensea.io/, accessed May 2025

included file type, SHA-256 hash, EXIF GPS, uploader ID, and timestamp. Python scripts parse and standardize metadata, then mint tokens using ERC-721-compatible contracts.

III. Architecture and Data Flow

The technical architecture of the proposed system, called the Building Ledger Dossier (BLD) is composed of the following modules: (i) Multi-Agent System (MAS) to coordinate the roles of regulatory authorities, DAOs (Decentralized Autonomous Organizations), and blockchain interactions; (ii) Blockchain Integration, each building's modification history is recorded immutably using NFTs. All intervention data is securely hashed and stored. (iii) OpenSees approach to foster open-source structural modeling of buildings, with scripting in Tcl and Python to define nodes, constraints, and masses; (iv) DAOs for Work Approval, governance is decentralized via DAOs, which manage intervention validation using smart contracts. Participants like Installers and Directors of Work use blockchain wallets to sign and verify actions. We focused on two activities the (a) Plate Installation: Plates installed on buildings are tagged, photographed, geotagged, and documented by Installers; then verified and minted as NFTs by Directors; and (b) Document Registration: Engineers upload essential documents (e.g., permits, structural analyses), which are tokenized and stored on the blockchain. The BLD system is structured into three repositories: (i) Archive stores pre-installed elements and documents; (ii) Cart contains elements ready for blockchain minting; (iii) DLT Network for NFT record storage. As shown in Fig. 2, the architecture connects field inputs, OpenSees models, IPFS data, and smart contract events via an integrated blockchain layer. Installers submit

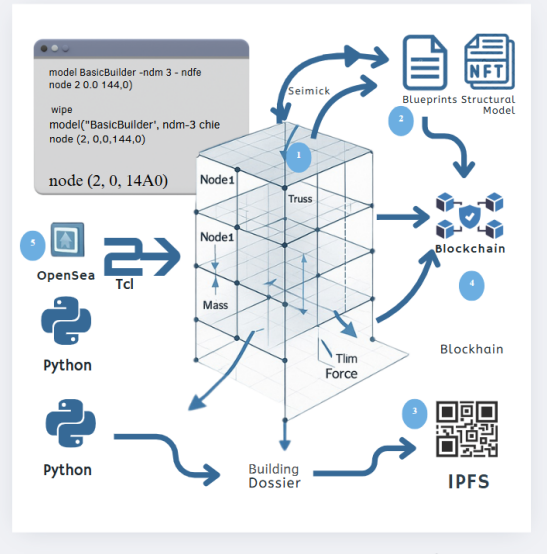

Fig. 2. Architecture integrating digital twin and tokenized Building documents.

records, while Directors of Works (DoW) validate via DAO consensus [7], [8]. GPS-tagged images are parsed via EXIF tools and verified before minting. The validation chain is shown in Fig. 3.

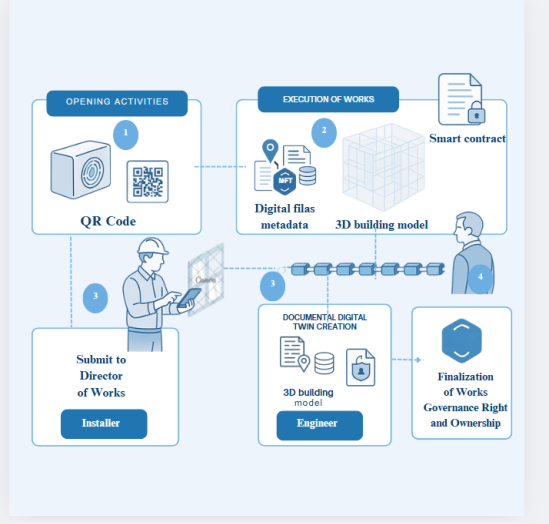

Fig. 3. Restoration Workflow: submission of field data, validation, and minting.

IV. Conclusion

We present a resilient, decentralized document tokenization method tailored for seismic infrastructure. Through NFTs and DAOs, building interventions gain traceability, legal verifiability, and compliance accountability [9], [10]. This architecture can be extended to other civil domains requiring high-integrity records. Future developments will direct to implement a functional demonstrator to evaluate the BLD solution in real scenarios.

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