Automating BIM Change Certification with Blockchain: A Case Study in Residential Building Design

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Abstract –

This paper proposes and evaluates an automated BIM–Blockchain workflow to certify BIM design changes as verifiable digital evidence, aligned with ISO 19650-oriented traceability indicators. First, baseline traceability was assessed through a two-layer checklist (technical and operational) applied to a real residential BIM project developed in Revit®. Then, an end-to-end certification pipeline was implemented, where each relevant modification is exported as validated BIMXML, hashed for integrity, embedded into a BIMRegister-based smart-contract record (LegalLab), digitally signed with a timestamp (NeuroAccess), and immutably registered on a permissioned ledger (NeuroLedger) with tokenized event logs and QR-based third-party verification. Results show that, in a validation limited to one residential BIM model and three representative design changes, the prototype consistently produced complete evidence packages, increasing operational compliance from 20% to 80% and raising the global traceability index from 50% to 80%. Thus, the light-on-chain approach enhances accountability and auditability without storing full BIM models on-chain or disrupting routine BIM/CDE activities.

Keywords –

Blockchain; Building Information Modeling; Neuroledger; ISO 19650.

1 Introduction

The Architecture, Engineering, Construction, and Operations (AECO) sector is rapidly digitizing, with Building Information Modeling (BIM) becoming key for coordinating design and information among fragmented stakeholders [1]. International standards like ISO 19650 define BIM information management and the role of the Common Data Environment (CDE) as a shared project source [2]. However, recent studies on construction digital twins and CDE practice show governance and traceability of BIM design changes are still inadequate for auditable, lifecycle-wide information management, especially at the element and transaction level [3–5]. Automating documentation, verification, and registration of design changes as digital evidence is a key challenge for BIM-based project delivery.

In this context, blockchain and distributed ledger technologies are increasingly seen as infrastructures for evidence-based record-keeping and coordination in construction. Recent reviews highlight applications ranging from contract administration and payments to supply-chain and asset management, while also noting that many contributions remain conceptual or at high-level architectural stages [6–8]. However, there is still limited empirical, case-based evidence on how such approaches can be embedded in everyday BIM and CDE practices to certify design changes at the element level using explicit ISO 19650-oriented traceability indicators, with a realistic degree of process automation.

This study aims to develop and evaluate an automated BIM-Blockchain workflow for certifying element-level design changes in accordance with ISO 19650 and traceability indicators. It seeks to quantify improvements in traceability and auditability in a residential project while minimizing disruption to BIM and CDE practices. The research is guided by three research questions. RQ1: How can baseline traceability of BIM design changes be assessed under ISO 19650-oriented indicators? RQ2: How can a blockchain-supported workflow be designed and implemented to certify these changes with minimal additional effort for practitioners? RQ3: To what extent does the proposed workflow improve traceability and auditability compared with the baseline process? The main contributions are: (i) a diagnostic framework for BIM-change traceability grounded in ISO 19650 concepts; (ii) a system architecture and automated certification workflow that can be replicated in similar projects; and (iii) empirical evidence from a case study that quantifies traceability improvements and discusses implications for practice and policy. The rest of this paper is organized as follows: Section 2 covers the background and methodology; Section 3 details the case study and baseline; Section 4 describes the system architecture and workflow; Section 5 reports the results; Section 6 concludes with limitations and future work.

2 Background and Related Work

2.1 BIM-based information management and ISO 19650

BIM is now central to project management, facilitating structured and collaborative data handling across an asset's lifecycle [9]. Unlike traditional systems, BIM provides a digital model that combines geometric, semantic, and operational data, ensuring consistency and accessibility for all stakeholders across design, construction, and operations.

The ISO 19650 series [2] establishes a globally recognized framework for managing information using BIM and introduces several fundamental principles that underpin effective information management, emphasizing the importance of a structured information management process spanning the entire lifecycle, from design and construction to operation and maintenance. At the core of this framework is defining clear information requirements, including those of clients and at the project level, which specify what information is needed, when, and by whom. Another critical concept is the Common Data Environment (CDE), a shared digital space for storing, managing, and exchanging project information, ensuring transparency, version control, and traceability.

Aligning BIM with ISO 19650 ensures standardized, interoperable info management in multi-actor projects. In this context, the CDE organizes information, states, and responsibilities, but often fails to produce auditable and verifiable records of design changes. Several technologies, like blockchain, are proposed to enhance integrity, accountability, and trust in BIM workflows, especially for traceability and verification across organizations [10].

2.2 Blockchain for construction and information traceability

Blockchain is commonly understood as a distributed ledger that enables tamper-evident recording of transactions, ensuring data integrity, provenance, and non-repudiation [11]. In construction projects, where multiple actors interact across organizational boundaries and information exchanges may have legal or contractual implications, these characteristics are particularly relevant for treating digital records as verifiable evidence rather than informal documentation.

In the BIM context, blockchain works as a complementary infrastructure to support provenance tracking and traceability of changes to BIM elements and transactions [11]. By anchoring cryptographic fingerprints of BIM data and related transaction logs, blockchain-based approaches create an immutable audit trail of "who did what and when," enabling independent verification across the organization and strengthening accountability in multi-actor BIM workflows.

Recent studies frame blockchain as a practical enabler of traceability in construction workflows. Perera et al. [12] emphasize its potential to address transparency and trust issues in information exchanges, while Yang et al. [13] demonstrate the feasibility of both public and permissioned blockchain architectures for secure process monitoring. More specifically, Tao et al. [14] propose a blockchain-enabled distributed CDE aligned with ISO 19650 to record BIM design changes, and Brandín and Abrishami [15] illustrate how BIM-blockchain integration can support end-to-end data traceability in industrialized construction contexts. Together, this body of work underscores the need for an automation-oriented, empirically validated workflow for BIM design change certification, which is the focus of this study.

2.3 Enabling technologies: NeuroLedger, NeuroAccess, and BIMXML

While conventional blockchain infrastructures provide strong guarantees of integrity, transparency, and auditability, their direct adoption in construction-related information environments is often constrained by privacy, confidentiality, sustainability, cost, and scalability requirements [16]. Therefore, this section focuses on the enabling technologies adopted in this study, namely NeuroLedger, NeuroAccess/LegalLab, and BIMXML, and clarifies their functional roles within the proposed certification workflow, rather than revisiting the general principles of blockchain introduced in Section 2.2.

In this study, NeuroLedger, NeuroAccess, and LegalLab are considered the implementation stack used for the case study rather than as exclusive prerequisites of the approach. Conceptually, the workflow can be replicated on other ledgers that support immutable registration, verifiable digital signatures, and structured evidence handling, although different infrastructures may involve different costs and performance trade-offs. Neuro-Ledger was chosen because its federated, digital-signature-based architecture avoids proof-of-work or proof-of-stake transaction overhead, supports local governance of sensitive information, and natively supports XML validation and schema integrity protection, which was beneficial for BIMXML-based certification. However, interoperability across heterogeneous ledgers is not automatic and was not evaluated in this study.

2.3.1 Neuro-Ledger, a federated DLT

In a Neuro-Ledger network, participants operate under validated digital identities supported by cryptographic keys, associated metadata, and digital signatures issued by the participant and an authorized trust provider. Trust relationships are established through shared or interoperable trust providers, enabling cross-domain identity recognition within a federated governance model [17]. This approach supports inter-organizational collaboration while preserving accountability and provenance of certified actions.

Unlike traditional blockchains, which rely on a single global chain and energy-intensive consensus mechanisms, Neuro-Ledger enables each domain to independently generate and sign blocks. Immutability and provenance are ensured through issuer signatures rather than competitive mining, and blocks are identified by both their hash digest and their domain of origin. This design supports auditable replication and continuity of operation without centralized control [17].

Because blocks alone are not well-suited for fine-grained authorization and access control, Neuro-Ledger incorporates an interoperability layer that enables controlled access to sensitive information, including digital identities, private smart contracts, and associated tokens [18]. This layer ensures that data owners retain control over who can access specific information and for which purposes. Beyond identity and contract interfaces, the interoperability layer also supports harmonized interfaces for Internet of Things (IoT) devices, facilitating secure data exchange and decision support in cyber-physical systems [19]. Public and open Trust Providers further enable transparent participation and validation within the network [20].

2.3.2 Neuro-Access and LegalLab

Neuro-Access is a third-generation white-label mobile application available for Android and iOS that implements the Neuro-Ledger interoperability interfaces, enabling users to create and manage digital identities, sign smart contracts, and hold tokenized assets [21,22]. Complementarily, LegalLab is a Windows-based application primarily intended for development and configuration tasks, providing equivalent functionality in a desktop environment [23].

For this study, interoperability within the Neuro-Ledger ecosystem can be summarized as a structured sequence comprising digital identity validation, smart-contract template approval, autonomous contract creation, digital signing, implicit token generation, and event logging on the token. Digital identities are established through a cooperative validation process between the applicant and a Trust Provider, reinforcing accountability and trust [17].

Similarly, autonomous smart-contract creation relies on pre-approved templates that define permissible parameters, roles, and execution rules. Once all required roles have signed a contract, machine instructions can be executed within defined namespaces, including those enabling the creation of Neuro-Feature tokens [24]. In this research, a construction project is tokenized, and certified BIM change events are logged on the corresponding token, enabling transparent review and audit of contracts, signatures, and event histories.

Once all interoperability interfaces are based on XML, a standardized, extensible, and externally auditable language that is readable by both humans and machines, this choice supports transparency and long-term verifiability without requiring detailed knowledge of platform-specific implementations.

2.3.3 BIMXML bridging Revit and Neuro-Ledger

BIMXML is an XML-based extended markup language designed to represent BIM models in a structured and interoperable format [25]. Its associated XML schema enables formal validation of documents in the BIMXML namespace, ensuring the syntactic and structural consistency of exchanged information. When used as the basis for smart contracts and token-based event logging, an additional cybersecurity constraint applies: the namespace must also resolve to the schema location. This requirement enables distributed entities to independently verify both the schema and the document, reducing the risk of fraudulent or malformed records.

For this study, a modified BIMXML schema was developed to support change-certification semantics and made available through a dedicated namespace. The corresponding smart-contract template and example XML event notes were published in the LegalLab repository for reference [26]. By bridging Revit-based BIM authoring and Neuro-Ledger registration through validated BIMXML documents, the proposed workflow enables structured, interoperable, and auditable representation of design changes at the element level.

2.3.4 Summary of research gap

Despite the availability of BIM standards and digital collaboration platforms, current practice still lacks operational mechanisms to certify and verify BIM design changes at the element and transaction levels. Existing blockchain-based approaches in construction have primarily focused on conceptual architectures or partial integrations, offering limited empirical evidence of how traceability can be improved in day-to-day BIM workflows. In particular, there is a lack of end-to-end, automation-oriented solutions that combine standardized change representations, validated identities, and verifiable digital signatures into a practitioner-ready certification process. This gap motivates the need to experimentally assess workflows that can generate auditable change evidence as a routine outcome of BIM authoring, rather than as an additional administrative task.

3 Case Study and Baseline Traceability Assessment

The case study is a real residential building design project: a two-storey single-family house located in Concepción, Chile. The BIM model was authored in Autodesk Revit and represents a typical multi-actor information setting, including linked models from different disciplines (e.g., structure and MEP). This type of project is representative of everyday design-change dynamics, where frequent revisions must be coordinated and documented across files, folders, and stakeholders.

3.1 Baseline traceability assessment approach

Before the blockchain-supported workflow, traceability of BIM design changes was assessed using a two-layer diagnostic based on ISO 19650 concepts. First, a technical review examined the Revit model and its metadata, including project data fields, model warnings, discipline links, and revision-related records. Second, an operational review assessed how changes are managed in practice using a short survey and a 10-item checklist covering versioning habits, responsibility assignment, change logs, approvals, and repository/CDE usage. Each criterion was scored on a simple three-level scale (compliant/partial/non-compliant), enabling clustering into technical, operational, and global baseline indicators.

3.2 Baseline results

The baseline reveals a clear imbalance between model technical quality and change traceability in practice. On the technical side, the model includes complete project identification fields and has no critical warnings, supporting a reliable design artifact. However, traceability mechanisms remain weak: discipline links exist, but version states are not consistently controlled; revision records are present but incomplete or inconsistent; and a folder structure resembling an ISO 19650 is available (e.g., WIP/Shared/Published/Archive), but it lacks formal data states, auditable change logs, approvals, and digitally verifiable signatures.

Table 1: Baseline traceability checklist (ISO 19650-oriented)

Item (Layer - code - criterion)	Status	Score
Technical		
ET-01 - Project information completeness	compliant	1.0
ET-02 - Model warnings	compliant	1.0
ET-03 - Interdisciplinary links	partial	0.5
ET-04 - Revisions within the model	partial	0.5
ET-05 - CDE folder structure (ISO 19650 sequence)	compliant	1.0
Operational		
OP-01 - Formal protocol to register BIM changes	non-compliant	0.0
OP-02 - Each change records responsible + date	partial	0.5
OP-03 - Use of controlled versions	partial	0.5
OP-04 - Approval before merging into the master model	non-compliant	0.0
OP-05 - Assigned role for version control	partial	0.5
OP-06 - Automated change logs	non-compliant	0.0
OP-07 - Use of collaborative CDE platform	non-compliant	0.0
OP-08 - Inter-model coordination/conflict control	partial	0.5
OP-09 - Digitally signed/legal change records	non-compliant	0.0
OP-10 - Easy verification of who/what/when	non-compliant	0.0
Technical index		80%
Operational index		20%
Global traceability index		50%

Quantitatively, the baseline reaches 80% technical compliance but only 20% operational, yielding a 50% traceability index. It relies heavily on manual routines, such as file naming and email, so “who changed what, when, and with which authorization” cannot be verified with strong evidence. This baseline serves as the reference for assessing advances from the automated BIM-Blockchain certification process, as shown below.

4 System Architecture and Automated Workflow

Building on the baseline traceability gaps identified in Section 3, the proposed solution adds a blockchain-backed evidence layer to existing BIM/CDE practices.

The architecture follows a "light-on-chain" approach: instead of storing full BIM files, it registers structured change evidence (BIMXML), a cryptographic fingerprint (hash), and digitally signed records to ensure integrity, authorship, non-repudiation, and auditable timestamps.

The system is composed of four main modules, as shown in Figure 1:

1. BIM authoring (Revit), where changes are executed.
2. Evidence generation (BIMXML export + schema validation).
3. Legal evidence container (LegalLab smart contract based on the BIMRegister template, embedding BIMXML as XML notes).
4. Certification and verification (NeuroAccess for advanced e-signatures and NeuroLedger for immutable registration, event logs, and QR-based verification).

Figure 1. Automated BIM change certification workflow

4.1 BIMXML as structured change evidence

Each relevant model modification is exported as a BIMXML document that captures: the project ID, the identifier of the modified element, the affected parameters, the previous and new values, the author, and the modification date. Before certification, the BIMXML files are validated against the BIMXML schema to ensure syntactic and structural consistency, enabling interoperable processing and repeatable auditing.

A cryptographic hash is computed from the validated BIMXML content. This hash serves as an immutable fingerprint: any subsequent alteration of the BIMXML evidence would be detectable by recomputing and comparing the hash.

4.2 Digital identity, contract creation, and signing

To bind evidence to accountable actors, the environment is prepared by creating a validated digital identity (Network ID and Legal ID). Using LegalLab, the BIMXML evidence is incorporated into a digital contract (BIMRegister template) as XML notes. The contract defines the roles involved in certification and acts as a legally oriented container for the evidence package.

The contract is then signed via NeuroAccess, creating verifiable digital signatures and a timestamp. This step establishes who approved the evidence and when, providing non-repudiation for the certified change record.

4.3 NeuroLedger registration, token linkage, and automated logs

Once signed, the contract is registered on NeuroLedger, and an associated token is generated to link and organize certified change events. NeuroLedger automatically produces an immutable event log capturing key metadata (registered content reference, author/roles, date-time, and integrity checks). This procedure replaces fragile manual records (e-mails, informal confirmations, file-name conventions) with a consistent audit trail.

4.4 Public verification (QR) and auditability

For practical auditing, the system enables public verification of certified changes through QR codes and web links generated from the registered contract. Auditors can review the contract, roles, signatures, timestamp, and attached BIMXML evidence, enabling objective verification of "who changed what, when, and under which certified record," without requiring access to the whole authoring environment.

5 Results and Discussion

5.1 Prototype execution results

The automated BIM-Blockchain pipeline described in Section 4 was applied to a real residential BIM model, with three representative design changes. For each change, the workflow generated an auditable evidence package and recorded the corresponding certification artifacts, enabling the subsequent assessment of end-to-end feasibility and operational traceability improvements.

At the certification stage, the environment was prepared with validated digital identities (Network ID and Legal ID), BIMXML evidence was embedded as XML notes within a digital contract based on the BIMRegister template (LegalLab), and the contract was signed via NeuroAccess (advanced e-signature and timestamp). The signed contract was then registered in NeuroLedger, generating a token and an immutable event log; finally, evidence was made available for public verification via a QR code (contract, roles, signatures, and attached BIMXML).

5.2 Evidence produced for the three certified changes

The three certified changes and their documented parameters demonstrate that the workflow can capture "what changed" at the element level and bind it to "who/when" through signature and timestamp, while preserving a verifiable audit trail (token, log, and QR). The changes made are shown in Table 2.

Table 2: Blockchain change log summary

Change ID	BIM element	Old and new key values	Evidence artifacts generated
C#1	Entrance door	Old: 84.8 x 203.2 cm. New: 90 x 210 cm; thickness 5 cm; galvanized steel.	BIMXML (validated) and hash; signed BIMRegister contract; NeuroLedger token and event log; QR for verification.
C#2	Rear 2nd-floor window	Old: window. New: sliding window; 228.5 x 140 cm.	BIMXML (validated) and hash; signed BIMRegister contract; NeuroLedger token and event log; QR for verification.
C#3	Roof system	Old: tile roof (15 cm). New: Zinc-Alum roof and thermal insulation (20 cm); geometry/area unchanged.	BIMXML (validated) and hash; signed BIMRegister contract; NeuroLedger token and event log; QR for verification.

Table 2 shows that, for three representative design changes that affected different types of BIM elements, the workflow produced the same verifiable evidence package: a validated BIMXML record capturing key value updates at element level, a cryptographic hash to ensure integrity, a digitally signed BIMRegister contract to bind authorship and timestamp, and an immutable NeuroLedger registration (token and event log) that enables third-party verification through a QR link.

5.3 Traceability improvement vs. baseline

These results should be interpreted within the scope of a validation limited to one residential BIM model and three representative design changes. Compared with the baseline traceability assessment (technical compliance 80%, operational compliance 20%, global index 50%), the prototype directly addresses the core operational weaknesses: lack of certified authorship, absence of timestamps, missing immutable logs, and non-verifiable approvals. In practice, the workflow replaces fragile manual practices, like naming conventions and informal confirmations, with a repeatable certification chain: validated BIMXML, a hash fingerprint, a digitally signed contract, an immutable ledger, and QR verification.

To quantify the improvement introduced by the proposed BIM-Blockchain workflow, we re-evaluated traceability using the same ISO 19650-oriented checklist used in the baseline and reported the prototype's technical and operational compliance scores (Table 3).

Table 3: Post-implementation traceability assessment

Item (Layer – code – criterion)	Prototype status	Prototype score
Technical		
ET-01 - Project information completeness	compliant	1.0
ET-02 - Model warnings	compliant	1.0
ET-03 - Interdisciplinary links	partial	0.5
ET-04 - Revisions within the model	partial	0.5
ET-05 - CDE folder structure (ISO 19650 sequence)	compliant	1.0
Operational		
OP-01 - Formal protocol to register BIM changes	compliant	1.0
OP-02 - Each change records the responsible and the date	compliant	1.0
OP-03 - Use of controlled versions	partial	0.5
OP-04 - Approval before merging into the master model	compliant	1.0
OP-05 - Assigned role for version control	compliant	1.0
OP-06 - Automated change logs	compliant	1.0
OP-07 - Use of collaborative CDE platform	non-compliant	0.0
OP-08 - Inter-model coordination/conflict control	partial	0.5
OP-09 - Digitally signed/legal change records	compliant	1.0
OP-10 - Easy verification of who/what/when	compliant	1.0
Technical index		80%
Operational index		80%
Global traceability index		80%

The rise in operational traceability from 20% to 80% marks a significant improvement in the evidentiary quality of BIM-based information management. At low operational levels, design changes rely on informal records such as emails and meeting notes, which limit their use in audits, disputes, and compliance. By contrast, the proposed workflow enables a systematic, verifiable association between each design change, its author, timestamp, and approval state at the element level, transforming BIM records into auditable digital evidence. This shift directly impacts project audits, contractual claims, and governance by reducing ambiguity about responsibilities and decision histories while reinforcing accountability across organizational boundaries.

From a blockchain perspective, the results confirm the value of a "light-on-chain" evidence strategy, where the blockchain is used only to anchor integrity and accountability rather than to store full BIM models. In this approach, the certified BIMXML evidence remains off-chain, while the ledger records a cryptographic hash, the signed contract reference, and an immutable event log (token, timestamp, and roles). As a result, any later alteration of the evidence becomes detectable, and the origin and approval of each change can be verified independently, with minimal impact on storage, performance, and existing BIM/CDE workflows.

Regarding scalability, practical overhead at the ledger-registration stage is expected to remain low because Neuro-Ledger relies on digital signatures in a federated architecture rather than proof-of-work or proof-of-stake consensus, thereby avoiding the transaction costs typically associated with competitive consensus-based ledgers and enabling quick event registration. Also, the federated structure allows records and tokens to be distributed across domains, supporting scaling as the number of certified events increases. Since event-handling logic is built into the token, certified changes can also trigger notifications and share relevant state information with external systems. Therefore, integration with CDE platforms is expected to be technically feasible using platform-specific APIs, although this interoperability was not implemented or benchmarked in the current case study and is a focus for future validation.

Operationally, the most relevant impact is not "more data" but better evidence: each certified change becomes independently verifiable (roles, signatures, timestamps, and attached evidence) and can be reviewed by third parties via QR codes without access to the authoring environment. This fact strengthens transparency and the allocation of responsibility in collaborative BIM settings, aligning the traceability goal with ISO 19650-oriented expectations at the transaction/element level.

The results address the three research questions. The baseline assessment operationalizes ISO 19650-oriented traceability through a two-layer diagnostic, revealing a clear technical-operational imbalance (RQ1). The implemented workflow tackles the weakest operational indicators with BIMXML evidence, hash generation, digital signatures, immutable registration, and QR verification, although some upstream steps remain partially manual (RQ2). The checklist re-scoring shows an increase in operational traceability from 20% to 80% and in the overall index from 50% to 80%, demonstrating stronger auditability and accountability within routine BIM and CDE practices (RQ3).

Currently, the workflow should be considered semi-automated rather than fully automated, as change detection, triggering BIMXML export, and some coordination steps still require user input. However, the certification process itself is organized and repeatable, and further automation can be achieved through dedicated Revit plugins, API-based event capture, and improved integration with CDE platforms.

6 Conclusions and Future Work

Beyond the technical implementation, the results demonstrate that meaningful improvements in BIM-based governance can be achieved without altering established authoring practices or introducing additional manual documentation burdens. By increasing operational traceability from 20% to 80%, the proposed workflow enables BIM models to function not only as coordination artifacts but also as reliable sources of auditable evidence, supporting more transparent decision-making, accountability, and dispute mitigation throughout the project lifecycle.

Results show that, while the baseline process was technically sound (80%), operational traceability was weak (20%), yielding a global traceability index of 50%. After implementation, the workflow consistently generated a complete evidence package for each certified change (validated BIMXML, hash fingerprint, signed contract, tokenized event log, and QR verification), improving operational compliance to 80% and raising the global index to 80%. This finding confirms that a "light-on-chain" approach can strengthen accountability and auditability without storing full BIM models on-chain or disrupting standard BIM/CDE routines.

The present validation is limited to a single residential case and three representative change types; therefore, transferability should be interpreted with caution. The approach is expected to be best suited for design changes that can be represented discretely at the BIM element level and certified through structured parameter updates, particularly in projects with moderate change frequency and clearly defined approval roles. More demanding contexts include highly iterative change environments, multi-disciplinary projects with numerous linked models, and settings with stricter confidentiality or governance requirements, where workflow integration and validation would require further assessment.

Future work should extend the approach to larger, multi-disciplinary, and multi-stakeholder projects with higher change frequencies to assess transferability, stability, and operational performance under more demanding conditions. Further automation is also needed to reduce manual steps (e.g., automated change detection and evidence generation) and to evaluate performance, user effort, privacy settings, and governance aspects (e.g., identity validation roles and long-term audit requests) when integrating with widely used CDE platforms.

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