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BLOCKCHAIN-ENABLED REAL ESTATE OWNERSHIP TRANSFER IN BELGIUM: A HYBRID INSTITUTIONAL FRAMEWORK

Aishuak Kerimzhanova[1], Theodoros Dounas[2]
[1]University of Antwerp, Antwerp, Belgium
[2]Heriot-Watt University, Edinburgh, Scotland, UK

Abstract

This paper addresses the tension between blockchain's technical potential and the need for legal compliance in highly regulated property markets. Drawing on Institutional Cryptoeconomics, we propose a hybrid governance architecture for real estate transactions in Belgium that complements, rather than replaces, existing legal frameworks. The system combines smart contracts for automated escrow and settlement, an AI-based assistant to reduce ex ante coordination costs, and civil notaries as institutional oracles for legal validation. By embedding algorithms within mandated structures, this "trustworthy" governance model aims to reduce transaction costs while ensuring regulatory alignment, offering a scalable template for adoption in real estate.

Introduction

Real estate transactions are among the most institutionally complex forms of economic exchange, characterised by high asset values, long settlement periods, illiquidity, and substantial information asymmetry (Garmaise & Moskowitz, 2004). As a result, buyers and sellers rely on third parties who perform authentication functions and act as trust intermediaries. Although these intermediaries generate institutional trust, they also impose high transaction costs and cause significant time delays (Nooteboom, 2005).

Blockchain technology has been widely proposed as a technical solution to real estate inefficiencies through its immutable records, transparent distributed ledger, and automated transactions enabled by smart contracts (Konashevych, 2021). Early academic and industry discussions framed blockchain as a "trustless" technology capable of disintermediating traditional institutions (The Economist, 2015).

However, empirical evidence from pilot projects and case studies increasingly demonstrates that fully decentralised models are difficult to integrate with the legal and regulatory frameworks governing real estate markets. Notably, a famous example of the Swedish blockchain and land registry initiative, although technologically successful, has been abandoned in favour of a non-blockchain solution, showcasing that technical feasibility alone is insufficient for institutional adoption (Proskurovska & Dörry, 2022).

Although prior studies have explored the use of blockchain technology in land administration and property transactions, they primarily focus on technical feasibility or propose universal solutions. As a result, limited attention has been given to how such systems can be institutionally embedded to complement, rather than replace, mandatory legal frameworks. This limitation is particularly important, as blockchain-based solutions cannot yet be uniformly applied across jurisdictions; real estate regulations vary significantly even among EU member states. Furthermore, the growing importance of circular real estate and circular construction introduces additional requirements for data continuity and lifecycle management that blockchain can support (Shojaei & Naderi, 2024).

To address this gap, this paper adopts the perspective of Institutional Cryptoeconomics (IC), which conceptualises blockchain not merely as a technical tool but as an institutional technology capable of reducing transaction and coordination costs within an economy (Allen et al., 2020). Drawing on the Transaction Cost Economics (TCE) theory of Williamson (1985), blockchain is viewed as a mechanism that reduces ex post enforcement and verification costs through smart contracts, while some ex ante costs, such as drafting, information processing, and negotiation, remain unresolved.

Building on this theoretical foundation and a gap in the literature, this study develops a hybrid "trustworthy" governance framework for blockchain-enabled real estate transactions in Belgium. The framework aims to provide security, transparency, and automation through blockchain immutability and smart contract execution, while assigning legal certainty and trust to Belgian civil law notaries as institutional oracles. Additionally, the framework introduces an AI-based assistant to reduce ex ante transaction costs associated with bounded rationality and procedural complexity.

Point of departure

This study builds on three interconnected literature topics that together motivate the need for a hybrid, institutionally grounded approach to blockchain-enabled real estate transactions. First, prior research on blockchain in real estate and land administration reveals a consistent gap between technical feasibility and real-world adoption. Second, the literature on trust demonstrates that trust is not merely a social construct or a technological outcome but an institutionally produced condition. Third, IC conceptualises blockchain as an institutional technology that can reduce coordination and transaction costs within an economy. Together, these three topics feed into the central proposition of this study that blockchain-based real estate systems require institutional embedding rather than purely technical design.

Blockchain technology in real estate and land administration

The application of blockchain technology in real estate and land administration has been a growing topic both in academic research and industry practice. Existing studies suggest that blockchain can address many persistent challenges in real estate, such as inefficiency, fraud, corruption, and high transaction costs (Allessie et al., 2019; Kempe, 2017; Konashevych, 2021). These challenges are commonly associated with unreliable or missing land registrations, lengthy administrative processes, and the structural illiquidity of real estate assets (Shuaib et al., 2020; Wong et al., 2012). Due to the manual, paper-based, and fragmented nature of records, they are prone to errors, fraud, and corruption (Ameyaw & de Vries, 2021).

Distributed Ledger Technology (DLT) has been proposed as a technical solution to reduce these inefficiencies by enabling immutable records and automated transaction execution via smart contracts (Konashevych, 2021). Empirical studies suggest that DLTs can reduce information asymmetries between market participants and improve transparency (Chen & Yu, 2024). Several frameworks have been proposed to operationalise these claims. For example, Shuaib et al. (2020) present an 11-step ownership transfer model, while Verma et al. (2024) and Mohanty et al. (2025) develop blockchain frameworks for property registration and operations, reporting improvements in security, efficiency, and transparency. Bărbuţă & Alexandrescu (2024) further extend the design space by proposing dNFTs as updatable on-chain property representations.

However, recent academic research increasingly highlights that blockchain adoption faces greater constraints from legal and regulatory compliance and the complexity of system integration than from technical feasibility alone (Ajayi et al., 2026; Akhmetbek & Špaček, 2021). Podshivalov (2022) similarly argues that blockchain implementation in real estate registration should be introduced gradually alongside the development of appropriate legal and regulatory frameworks. Case studies of pilot projects show that fully decentralised systems rarely align with the legal frameworks governing real estate markets (Proskurovska, 2023). A notable example is the Swedish Lantmäteriet initiative, which was the first to test blockchain technology for property conveyance but did not advance beyond the pilot phase. Instead, the system was replaced by a non-blockchain platform, Tambur (Proskurovska & Dörry, 2022). Proskurovska (2023) explains that this results from a mix of resistance from existing institutions and incompatibilities with current strategies aimed at financial stability.

These findings thus support a shift from technological optimism toward institutionally embedded adoption strategies. Rather than advocating full-scale disruption, several authors argue for a hybrid approach rather than a full-scale process (Allessie et al., 2019; Bennett et al., 2021; Saari et al., 2022).

Trust

Across the literature, trust was found to influence market confidence and participation directly (Gurun & Booth, 2024), which in turn affects price formation (CFA Institute, 2022). While Nakamoto (2008) introduced blockchain as a technology that does not require trust, in which users rely on cryptographic protocols, consensus mechanisms, and immutable ledgers, subsequent research has challenged this assumption. Blockchain can facilitate a form of institution-based trust by increasing transparency and enabling automated execution (Chen & Yu, 2024; Lumineau et al., 2021). However, it does not eliminate the need for trust altogether. Instead, trust remains embedded in social, legal, and organisational contexts (Szabo, 2017). Furthermore, trust was found to be a crucial prerequisite for blockchain adoption rather than its outcome (Dupuis et al., 2021). Adoption depends on socio-cultural factors (Mutambik et al., 2024), governance structures (Li et al., 2023), and the overall usability of blockchain-based applications (Smits & Hulstijn, 2020).

In land administration, legal and regulatory compliance has been identified as a key factor in stakeholder trust (Ajayi et al., 2026). This suggests that algorithms alone cannot produce trust in blockchain-enabled real estate transactions; they must be anchored in institutional validation and legal enforceability.

Institutional cryptoeconomics and hybrid governance

IC conceptualises blockchain not only as a database technology but also as a new institutional technology for governing the "knowledge commons" (Berg et al., 2019). IC applies the principles of New Institutional Economics (Coase, 1937; Williamson, 2000) to explain how blockchain technology reduces the "costs of trust" and coordination within an economy. The central principle of IC is the reduction of transaction costs (Davidson & Potts, 2022). Transaction costs arise from three primary constraints: bounded rationality, opportunism, and asset specificity (Williamson, 1985). Berg et al. (2019) demonstrate that blockchain technology can be analysed through Williamson's (1985) framework. While smart contracts can reduce ex post costs, such as enforcement and monitoring, through automated execution and transparency, they do not eliminate ex ante costs related to drafting, negotiation, and information processing. Moreover, a smart contract designer might still engage in fraudulent activities during the design process (Davidson & Potts, 2022), giving rise to the so-called "oracle problem" (Caldarelli, 2020). Recent research, therefore, highlights the emergence of hybrid governance models, in which algorithmic mechanisms coexist with social institutions (Bennett et al., 2021; Lumineau et al., 2021; Saari et al., 2022). Such models combine the efficiency of automation with the legitimacy of traditional institutions. In real estate, this hybridisation is not optional but structurally required due to the legal, high-value, and high-risk nature of ownership rights.

Institutional context

EU regulatory framework

The European Commission has adopted several legislative measures to regulate crypto-assets and protect consumers and investors (EU, 2026). Crypto-assets classified as financial instruments are regulated under MiFID II and must comply with the same rules as traditional financial instruments (ESMA, 2025). Other crypto-assets are governed by the Markets in Crypto-Assets Regulation (MiCA). Data protection remains a major concern, especially regarding compliance with the General Data Protection Regulation (GDPR) and the "right to be forgotten" (Zafar, 2025). The European Data Protection Board (EDPB) has addressed this by issuing guidelines on processing personal data through blockchain technologies (EDPB, 2025): storing personal data directly on the blockchain should be avoided, except for identifiers or proof of identity. Personal data should be stored off-chain, with cryptographic proof on the blockchain. This approach allows the "right to be forgotten" to be enforced by deleting data off-chain.

Belgian real estate law

The main regulations governing the purchase of real estate are set out in the Belgian Civil Code, particularly Book 3, entitled "Assets," as of 1 September 2021. Additionally, the transaction process follows the general rules of contract law in Book 5, entitled "Obligations". The real estate ownership and registry system in Belgium was described in detail by van de Werve (2025) in Deloitte's Legal Handbook:

The process of purchasing property in Belgium generally involves two main steps: signing a private sales agreement and executing a deed before a Belgian civil-law notary. Within four months of signing the private sales contract, it must be registered with the mortgage registry office and the land registry (Kadaster). The registered titles in Kadaster are for informational purposes only and do not serve as confirmation of ownership. Civil law notaries play a crucial, legally mandated role in Belgian real estate transactions. Their duties include validating the transfer deed, verifying the identities of the parties, collecting registration fees, ensuring there are no encumbrances, and confirming compliance with urban planning and land use laws. The Royal Decree strictly regulates Belgian notarial fees, which are consistent across regions and are set on a proportionally progressive scale based on the property's value.

The process of real estate purchase and registration in Belgium differs from, for example, Sweden, where real estate transactions do not require notarization (Fjellström, 2025). Instead, their system is heavily dependent on real estate brokers that mediate over 90% of all housing sales in Sweden (Proskurovska & Dörry, 2022). Notably, during the transaction, they are typically granted the power of attorney, which allows them to access and handle personal data of the involved parties (Proskurovska, 2023). These differences underline the importance of national legal systems in the development of blockchain-enabled real estate transaction solutions.

Methodology

This study employs a Design Science Research (DSR) methodology to develop a hybrid governance framework for blockchain-enabled real estate transactions in Belgium. Following Hevner et al. (2004) and Peffers et al. (2007), DSR is appropriate as it focuses on creating innovative artefacts that address identified problems in real-world contexts. This paper covers Phases 1-3: problem identification, objectives definition, and artefact design, leaving development, demonstration, and evaluation for future work.

DSR phases 1-2: problem identification and objective definition

Prior blockchain implementations in land administration, notably Sweden's Lantmäteriet pilot, demonstrate that technical feasibility alone is insufficient for institutional adoption (Proskurovska & Dörry, 2022). The problem is further complicated by three factors: high transaction costs resulting from information asymmetry and intermediary fees, regulatory requirements mandating notarial involvement in Belgian property transfers, and the absence of frameworks that meaningfully integrate blockchain with existing legal structures rather than attempting to replace them.

This phase involved a literature review across three domains: blockchain applications in real estate and land administration, trust mechanisms in property transactions, and hybrid governance models. The review reveals a critical gap between fully decentralised "trustless" blockchain implementations and the regulatory realities of property markets, motivating the development of a hybrid institutional architecture.

DSR phase 3: artefact design

The artefact is a hybrid governance architecture comprising technical components, institutional interfaces, and procedural workflows, organised into four interconnected activities: Institutional Actor Modelling, Transaction Workflow Architecture, Technical Component Specification, and Regulatory Compliance.

Proposed hybrid transaction architecture

The proposed framework integrates three governance components:

(1) blockchain and smart contracts for automated execution and record-keeping, (2) an AI-assistant for information processing and coordination, and (3) civil law notaries as institutional oracles responsible for legal validation and enforcement. The platform is governed as a permissioned consortium, with node validation rights

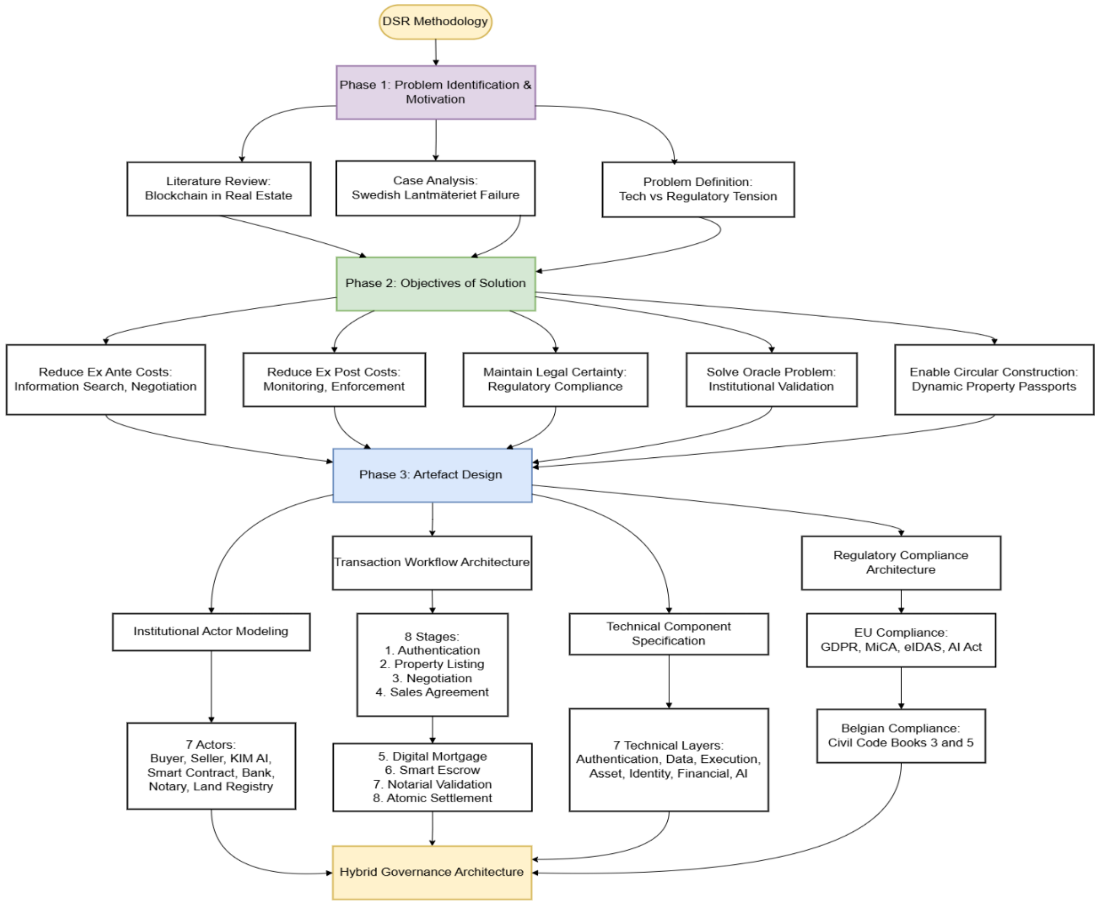

Figure 1: Phases 1-3 of the DSR methodology employed for this paper.

restricted to a defined set of institutional participants. In the Belgian context, the proposed consortium comprises civil law notaries represented through the Federation of Notaries (Fednot), the land registry, and participating mortgage banks. Platform operation and KIM's infrastructure would be managed by a neutral technical operator under contractual obligations to the consortium.

Figure 2 illustrates the sequence diagram of the proposed eight-stage transaction workflow. The framework involves the following actors:

- **Buyer (Alice) and Seller (Bob)**: the primary transacting parties.
- **AI-based assistant (KIM - Kunstmatige Intelligentie Makelaar):** KIM operates through a perceive-reason-act cycle without requiring explicit human instruction at each stage. Its agentic capabilities include: (1) independent calls to government APIs, including the Kadaster, soil databases, regional EPC registries, and municipal urban planning systems; (2) multi-source synthesis of retrieved data; (3) document generation, such as standardised property listings and the Private Sales Agreement (PSA). By automating property searches, data retrieval, document preparation, and eligibility coordination, which are currently performed by real estate agents, KIM could reduce their role and, in turn, lower ex ante costs associated with bounded rationality and information asymmetry (Williamson, 1985). Importantly, KIM's outputs are decision support, not autonomous determinations – all binding actions require a notary's authorisation. To ensure compliance with the EU AI Act (Regulation (EU) 2024/1689), KIM is architecturally restricted to a "limited-risk" or "transparency-obligated" AI system.
- **Smart contract (DLT)**: the execution layer that governs the escrow, suspensive conditions, and atomic settlement, deployed on a permissioned consortium blockchain.
- **Mortgage bank**: responsible for credit risk assessment and issuance of MiCA-compliant E-Money Tokens (EMTs).
- **Notary**: acts as an institutional oracle and legal authority.
- **Land registry and mortgage Office**: maintains off-chain records of ownership and encumbrances.

Stage 1: authentication

To ensure non-repudiation and compliance with Belgian AML/KYC requirements, the framework integrates the Belgian digital identity solution, Itsme, as the primary authentication mechanism. Under eIDAS (Regulation (EU) No 910/2014), a Qualified Electronic Signature (QES) generated via Itsme has the same legal validity as a handwritten signature. Both Alice and Bob authenticate via Itsme, each receiving cryptographic credentials derived from their respective Itsme-based verifications. These credentials enable participants to generate zero-knowledge proofs (ZKPs) demonstrating that they are legally authorised to participate in property transactions without revealing their personal data to the platform or the blockchain.

Stage 2: property listing and data verification

Bob submits property information to the platform. KIM verifies ownership status through the land registry's API and retrieves certified property-related data from governmental databases, including cadastral records, energy performance certificates (EPCs), soil reports, and urban planning documentation. Based on these inputs, KIM helps Bob to generate a standardised property listing. For Alice, KIM provides decision support by filtering properties according to her preferences and explains the necessary steps and the legally complex documentation.

Stage 3: viewing and price negotiation

KIM schedules a property viewing for Alice using Bob's preferences, ensuring that both Alice and Bob are authorised participants before the address is shared to reduce security risks. If Alice submits a bid, KIM initiates a privacy-preserving eligibility verification workflow in which Alice interacts directly with the mortgage bank's secure system via Itsme. The Mortgage Bank, after an internal off-chain evaluation, sends the signed via Itsme attestation to the platform, reducing opportunism and lowering risk.

Stage 4: private sales agreement

Once Bob accepts Alice's bid via the platform, KIM generates a Private Sales Agreement (PSA) with the agreed price and conditions. Both Bob and Alice sign the PSA via Itsme. A cryptographic hash of the signed PSA is anchored on the blockchain to prevent both Bob from taking a higher offer after agreeing to Alice's or Alice from lowering her offer at the last minute.

Stage 5: digital mortgage

Alice formally applies for a mortgage. Once approved, the Mortgage Bank issues a conditional payment commitment to the smart contract. Funds are represented as EMTs, ensuring regulatory alignment with EU law.

Stage 6: smart escrow

After the PSA is signed and mortgage approval is granted, Alice sends the deposit to the smart contract escrow in EMTs. The Mortgage Bank transfers the remaining amount to the same smart contract escrow in EMTs. The funds are released only when the notary signs the deed off-chain and authorises execution of the smart contract. This mechanism reduces ex post enforcement costs by automating escrow management while preserving legal safeguards.

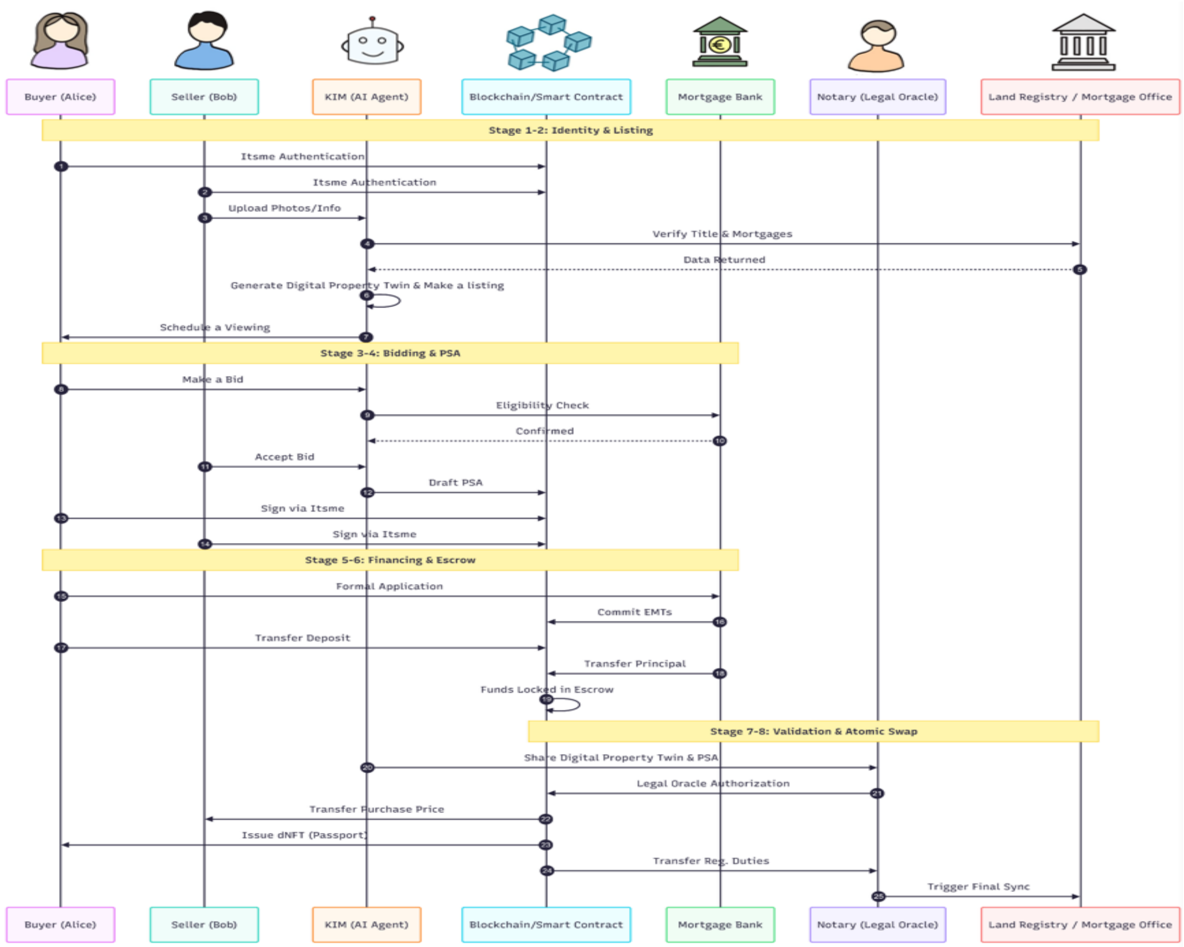

Figure 2: Sequence diagram of proposed property transfer architecture.

Stage 7: notarial validation

The civil law notary receives the "Digital Property Twin" from KIM, stored off-chain via InterPlanetary File System (IPFS). However, the notary remains responsible for verifying the data provided by KIM and performing other mandated checks that require human judgment and institutional authority. Upon completion, the notary issues an on-chain authorisation signal to the smart contract. The oracle problem is addressed through institutional legitimacy.

Stage 8: atomic settlement

Upon notarial authorisation, the smart contract executes an atomic settlement: Bob receives payment, the notary receives the registration fee, and Alice receives a dynamic Non-Fungible Token (dNFT) and a physically signed deed representing ownership. Unlike static hashing, which fails to capture the dynamic nature of a real estate asset, dNFT can be updated and thus functions as a Property Passport. Off-chain data can be erased in compliance with GDPR requirements, while the DLT retains cryptographic proofs. The idea of using dNFTs for real estate assets was mentioned by Bărbuţă & Alexandrescu (2024). Simultaneously, the system notifies the official land registry and mortgage office to ensure synchronisation between the blockchain ledger and the off-chain records.

Discussion and conclusion

This study proposed a hybrid framework for blockchain-enabled real estate transactions in Belgium that embeds blockchain technology within existing legal structures rather than disintermediating legally mandated institutions. Existing research shows that blockchain achieves meaningful impact when integrated into legal and governance frameworks rather than disrupting them (De Filippi & Wright, 2018). By assigning operational and informational tasks to algorithms and validation functions to notaries, the framework addresses specific inefficiencies while maintaining legal certainty. In line with Saari et al. (2022), who emphasised that blockchain implementation in land administration will likely take a hybrid form. The framework employs a permissioned consortium blockchain, restricting validation to civil law notaries represented through Fednot, the land registry and mortgage office, and participating banks. This structure ensures that no single private entity controls the ledger while enabling faster transaction processing and controlled governance (Peters & Panayi, 2016).

Drawing on Williamson's (1985) TCE, the framework addresses both ex ante and ex post transaction costs. In Belgium, real estate agent commissions typically range from 2% to 5% of the property's value, and the average settlement period is three to four months. Ex ante, KIM reduces these costs by automating real estate agent functions, including property searches, data retrieval, document preparation, and eligibility coordination. Importantly, KIM does not require the elimination of real estate agents; buyers and sellers who prefer professional mediation can still choose that option. Instead, the platform lowers the barrier for those who cannot afford or decide not to use an agent, thereby reducing transaction costs more significantly. KIM's outputs are strictly decision support: all outputs are subject to notarial verification, as there is a risk of errors and inaccuracies inherent to LLM-based systems. Ex post, smart contracts and atomic settlement eliminate enforcement costs associated with escrow and manual fund transfers (Davidson & Potts, 2022), while consortium consensus reduces fraud risk and balances efficiency with institutional trust (Kowalski et al., 2021).

The framework proposes a trustworthy environment where algorithmic trust is anchored in institutional trust through notarial oversight. Moreover, the architecture uses dNFTs that, in combination with Digital Twins, could enable longitudinal tracking of construction materials, maintenance logs, and energy performance certificates, contributing to circular real estate and circular construction (Naderi & Shojaei, 2024). Crucially, dNFTs represent a data layer rather than actual ownership and do not require legal equivalence to a notarial deed.

The framework has several limitations. First, it has not yet been tested in real-world deployments, and its performance with high-volume transactions remains unverified. Second, the long-term legal interpretation of the use of dNFTs in property law continues to evolve. Third, relying on notarial oversight might limit scalability in other countries with different legal systems. Fourth, KIM introduces risks specific to LLM-based agent systems, such as outputs that depend on the availability and accuracy of government APIs, residual hallucination risks that cannot be fully eliminated, and user over-reliance on AI-generated documents, which could weaken informed consent. Mandatory notarial verification partly addresses these risks but also creates a dependency on notaries' digital literacy, a skills gap that needs targeted professional development as part of the deployment plan.

Future work will validate the framework through prototype development and multi-dimensional evaluation: (1) technical performance, assessing system reliability, latency, and interoperability; (2) transaction cost analysis, comparing ex ante and ex post costs against traditional Belgian workflows; (3) stakeholder evaluation, conducted through semi-structured interviews with key actors in the Belgian real estate ecosystem, using a protocol grounded in the Technology Acceptance Model (TAM), trust assessment constructs, and perceived adoption barriers (Davis, 1989); and (4) circular construction extensibility, exploring how the dNFT model can support multi-stakeholder material provenance tracking and lifecycle management.

In conclusion, this paper offers a legally grounded template for blockchain-enabled real estate transactions that does not compromise institutional integrity. By embedding algorithms with mandated structures rather than replacing them, this framework provides actionable insights for public authorities seeking to combine technological innovation with regulatory compliance in property markets.

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