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Master's Thesis

"Blockchain Applications in Real Estate: Challenges and a Proposed Framework"

Master of Science in Management of Built Environment

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Abstract

Blockchain technology is witnessing growing use cases in many different industries. In recent years many academic papers have proposed using blockchain technology to dramatically change the slow and inefficient process of real estate transactions, the problem, however, is that these propositions lacked empirical data, mechanism, or idea of how this shift can be implemented and what would be the challenges of that.

The goal of this research is to explore the possibilities of Blockchain technology for the real estate industry, identifying and analyzing the adoption challenges of this technology, and proposing a general framework to suggest how blockchain applications can be implemented together to create a base foundation for developing blockchain-based platforms by real estate sector.

This aim was achieved by conducting interviews with promising startups, studying case studies, white papers, and relevant academic research. The paper argues security, transparency, and faster transactions are the underlying reasons for adopting blockchain-based practices in the real estate sector.

The novelty of this thesis is proposing a cross-blockchain framework suggesting a scheme in which blockchain-based real estate transactions and applications could take place. In this framework, the applications such as NFT, Tokenization of properties, and real estate transactions via smart contracts are foreseen. It also attempts to enhance the ID verification process, by introducing a self-sovereign ID verification system on top of proposing ways to make smart contracts law enforceable by offering pre-defined model smart contracts and by including real estate intermediaries in the blockchain process by employing oracles in the framework.

Keywords: blockchain, real estate, tokenization, framework, smart contracts, self-sovereign identity, adoption, smart law, blockchain challenges

Abstract (in Italian)

La tecnologia blockchain, sta assistendo a casi d'uso crescenti in molti settori diversi. Negli ultimi anni molti articoli accademici hanno proposto di utilizzare la tecnologia blockchain per cambiare drasticamente il processo lento e inefficiente delle transazioni immobiliari, il problema, tuttavia, è che queste proposte mancavano di dati empirici, meccanismi o idee su come questo cambiamento possa essere implementato e cosa sarebbero le sfide di questo.

L'obiettivo di questa ricerca è esplorare le possibilità della tecnologia Blockchain per il settore immobiliare, identificare e analizzare le sfide di adozione di questa tecnologia e proporre un quadro generale per suggerire come le applicazioni blockchain possono essere implementate insieme per creare una base di base per lo sviluppo piattaforme basate su blockchain per settore immobiliare.

Questo obiettivo è stato raggiunto conducendo interviste con startup promettenti, studiando casi di studio, white paper e ricerche accademiche pertinenti. Il documento sostiene che sicurezza, trasparenza e transazioni più veloci sono le ragioni alla base dell'adozione di pratiche basate su blockchain nel settore immobiliare.

La novità di questa tesi è proporre un framework cross-blockchain suggerendo uno schema in cui potrebbero aver luogo transazioni e applicazioni immobiliari basate su blockchain. In questo quadro sono previste le applicazioni come NFT, Tokenizzazione di immobili e transazioni immobiliari tramite smart contract. Tenta inoltre di migliorare il processo di verifica dell'identità, introducendo un sistema di verifica dell'identità autonomo oltre a proporre modi per rendere applicabile la legge sugli smart contract offrendo contratti intelligenti modello predefiniti e includendo intermediari immobiliari nel processo blockchain impiegando oracoli nel quadro.

Parole chiave: blockchain, real estate, tokenizzazione, framework, smart contract, identità sovrana, adozione, smart law , sfide blockchain

1. Introduction

Why is the transition from traditional RET (Real estate transactions) to a blockchain platform necessary? The shift may result in significant improvements to the financial aspects of real estate transactions.
This thesis investigates the potential use of Blockchain as a decentralized platform for the real estate market. Examining the potential benefits and difficulties for governments and citizens of European countries, as well as methods for adapting to these new transformations.

The two primary characteristics of real estate assets are their heterogeneity and immobility. Because of these two factors, the market for buying, selling, and leasing real estate tends to be illiquid, localized, and highly segmented, with privately negotiated transactions and high transaction costs. (Ling and Archer 2013).

Despite technological advancements in the world, the current real estate transactions system is slow due to numerous reasons, whereby the major one is the validation process. Many transaction documents are signed on paper. The primary benefits of a blockchain based platform includes accelerating the transaction process, enhancing security, lowering the cost of transactions, and tokenizing RE assets. In contrast, centralization contributes to a variety of governance issues, including abuse of power, corruption, ineffective governance, significantly high costs, slow and time-consuming processes. As a result of the platform's automation and removal of number of intermediaries, the government's role does not reduce but rather radically shifts, as land cadaster institutions must not be market monopolists.

Deloitte (2017) and Lifthrasir (2016) believe that Blockchain has the ability to overcome the inefficiencies and errors that now exist in the real estate industry. These include applications that would decrease transaction costs and investment barriers while increasing liquidity in this segment, many of which have been assessed in the future chapters. Although this sector has many inherent characteristics that could at the very least, cause problems for the mass and easy adoption of this technology in this sector.

One of the main areas of doubt for many stakeholders is the legal obstacles that are inherent to this heavily regulated sector. These include but are not limited to a) the identity verification of the involved parties b) the need for controlling the legality of the

contracts which would include intermediaries and a central unit of governance c) difficulty in involving the property rights such as the right to build, the right to use, temporal ownership or shared ownership in the smart contracts, d) the need for reversibility of transaction in case of misuse operational errors, or breach of a contract. As per (Sparkes et al, 2016), these are all the functions of the notary which is seen in the Latin Notary System that is applicable in western continental countries. These problems may seem in contrast with some of the principles of smart contracts and blockchain technology such as Anonymity, decentralization, irreversibility, and elimination of intermediaries. This paper will discuss these problems and will assess solutions in the adoption chapter.

1.1 Literature review

Dr. Oleksii Konashevych, paved the way for blockchain adoption in political level.
in 2021 he was invited to speak at the Australian Senate. Conclusions of his research about a new generation property registry were put as recommendations of Senate 'Fintech' Select Committee to National Cabinet to run a blockchain pilot project with land registry. This thesis owes credits to his paper “General Concept of Real Estate Tokenization on Blockchain” (Oleksii Konashevych_2020) for introducing smart laws and Model smart contracts.

Next, a study which was conducted as a part of the MIT Digital Currency Initiative (Tokenized Security & Commercial Real Estate_2019) was helpful to shape the tokenization sector of this research. The paper conclusion “Offers a general framework that can be used to perform future research on the tokenization of other types of assets and their related securities.”

Another paper that became a basis for the legal adoption section of this study was (Legal challenges and opportunities of blockchain technology in the real estate sector,Garcia Teruel, R.M.) in this paper the authors examined potential challenges, limitations, and opportunities in the real estate sector, as well as how traditional intermediaries must confront the potential implementation of this technology. In a typical European-wide real estate transaction, these agreements are typically time-consuming and add additional complications to cross-border transactions.
Using a legal framework, the authors analyzed the current intermediaries in the European Union (EU) real estate industry, their functions, and how blockchain can enhance the security of these transactions while reducing their duration.

The white paper of the TYKN company also provided the basis for explaining the notion of Self sovereign Identity, which is a trustless, centralized database provided by a blockchain aiming to replace classic Identity verification and registration processes.
Our findings revealed that, transaction speed, security and transparency are among the reason for adoption of blockchain systems which was in line with the findings of (Hoxha, V. and S. Sadiku 2019) and (Pankratov, E., V. Grigoryev, and O. Pankratov 2020) and ([Ahmad, I., et al. 2021).

Based on the current literature, we proposed a framework that would include real estate intermediaries in the blockchain-based real estate transactions, due to the essential role they play in the real estate transaction process as highlighted by (Garcia Teruel, R.M. 2020). The problems with the land registry were also highlighted in our interview and our study as also discussed in the works of (Shuaib, M., S. Alam, and S.M. Daud) and (Konashevych, O. 2020)

A lot of debates in the literature were surrounded the idea of the presence of central authority in the future of blockchain based practices in the real estate, stemming from the fact that, at least in the first sight, it seems contradictory with the decentralize characteristic of blockchain, this paper argues that the central authority remains an essential part of the real estate sector for the foreseeable future.

1.2 Theoretical Framework and Methodology

This is a multidisciplinary research including technical studies of blockchain technology, smart contracts, and other new technology with Policy and Legal Studies and Information Science. Our thesis draws conclusions from different sources:
1) Academic research papers
2) Global surveys provided by companies, namely: JLL, Deloitte and Gemini.
3) technical analysis from forums and open industry platforms, Such as white papers of projects namely Ethereum and Bitcoin, and Propy company.
4)focused group interviews with 2 active company in this industry.
5) Participating in Blockchain events such as 6th European blockchain convention.

We chose qualtative approach, as As numerous researchers (Ines and Jansen, 2017), (Allessie et al., 2019), (Alketbi, Nasir, and Talib, 2018), and (Konashevych, 2020a) highlight the fact that projects in blockchain industry are in their early phases and observation and empirical data collection are yet to be generated, the academic knowledge on this matter is based mostly on theoretical materials.
consequently, this research accumulates knowledge of the previous and most recent studies on the subject, plus studying the of the first company which used blockchain technology as their core business for RET in USA, and also interviewing their European competitor “Forsale company”, which at the time of writing this paper was in its early phase of development.

Though this paper is distinguished from observational and descriptive research with its proactive research outcomes by proposing a systematic concept for implementation, further research, and improvement. The paper bridges the complex matter of technologies to social science: law, governance, and macro economics. The research can be used by policymakers, researchers and computer developers to design a useful application.

1.3 Research Structure

The research consists of five sections, it begins with the introduction, literature review and the main research questions. In the next chapter we analize the underlying reasons to adopt blockchain technology in the real estate. In the next chapter we lay the foundation by defining the main concepts in blockchain and its applications in the RE sector. In chapter four we evaluate the legal and technological challenges to the mass adoption of Blockchain-based practices in the real estate and finally in chapter fice we provide a general framework which we believe provide a solution to the aforementioned challenges.

1.4 Research questions

1- Is there a need for a shift to blockchain platforms for the real estate industry?

2- What are the main legal and technological barriers to the widespread adoption of blockchain in real estate?

3- What are the possible solutions to the legal and technological shortcomings in blockchain-based real estate practices?

1.5 Glossary

The purpose of this study is to introduce the notion to a broad range of readers from diverse domains: academic researchers, information systems developers, policymakers, and the general public. The multidisciplinary character of the topic may make it difficult to grasp details. The thesaurus that follows offers the terms and concepts used in this paper and seeks to fill up the technical knowledge gap, at least to the extent that it is sufficient to understand this research. Nevertheless, this terminology is intended to define the author's point of view and strategy for additional reading in order to address academic debates in the field:

- Distributed ledger technology (DLT) -

A digital system for documenting data such as asset/money transactions that keeps the records in multiple places at the same time

- Blockchain -
  A distributed ledger technology (DLT) that keeps transactions in cryptographically connected blocks with a decentralized consensus. Blockchain is differentiated from "permissioned," "private," "federated," enterprise," and other centralized distributed ledger technologies (DLTs) by the fact that the ledger's immutability is not dependent on a single entity's will but on public peer-to-peer interaction.
- Token -
  A record on DLT that is associated with a user's blockchain address (public key) and is managed by the user's private key via blockchain transactions.
- Proptech -
  PropTech, also known as property technology, is the application of information technology (IT) to the management and purchase of real estate by both individuals and businesses. PropTech leverages digital innovation to meet the needs of the real estate industry, just how FinTech focuses on the use of technology in banking.
- REITs -
  Real estate Investment Trust, is a company that owns, and in majority of cases operates, income-producing real estate properties.
- RET-
  Real estate transactions; purchase, sell, rent and loans

- NFT: Non-fungible Token -
  A non-fungible token (NFT) is a type of financial security made of digital data kept on a distributed ledger called a blockchain. As a result of the ownership of an NFT being recorded in the blockchain and transferrable by the owner, it is possible to buy, sell, and trade NFTs. NFTs can be created by everyone, it most cases it does not require any coding skills to create.
- DApps -
  Decentralized applications, referring to new kind of applications which no central authority or company is in charge or have inclusive access to the data of users.
- DAO -
  “Decentralized Anonymous operation, is an organization constructed by rules encoded as a computer program that is often transparent, controlled by the organization's members and not influenced by a central government, in other words, they are member-owned communities without centralized leadership”
- white paper -
  “A white paper is a report or guide that informs readers concisely about a complex issue and presents the issuing body's philosophy on the matter. It is meant to help readers understand an issue, solve a problem, or make a decision. A white paper is the first document researchers should read to better understand a core concept or idea.”(wikipedia.com)
- Mining -
  “Blockchain "mining" is a metaphor for the computational work that nodes in the network undertake in hopes of earning new tokens. In reality, miners are essentially getting paid for their work as auditors. They are doing the work of verifying the legitimacy of Bitcoin transactions.”(investopedia.com)
- Proof of work-
  “Proof of work (PoW) describes a system that requires a not-insignificant but feasible amount of effort in order to deter frivolous or malicious uses of computing power, such as sending spam emails or launching denial of service attacks.” (investopedia.com)
- Zero-knowledge proofs (ZNP) -
  A zero-knowledge proof, also known as a zero-knowledge protocol, is a technique used in cryptography to allow a individual, known as the prover, to convince another, known as the verifier, that a particular statement is true while withholding all other information. The fundamental idea behind zero-knowledge

proofs is that it is easy to demonstrate that one has knowledge of a certain piece of information simply by exposing it; the trick is to demonstrate such knowledge without disclosing the information itself or any extra information.

- Off-chain

  Off-chain transactions are ones that take place on a cryptocurrency network and shift value outside of the blockchain. Off-chain transactions are becoming more common since they have no or little cost, especially among big participants. On-chain transactions contrast from off-chain transactions in a number of ways.

2. Blockchain

2.1 Why Blockchain?

2.1.1 Ledgers; the starting base of transactions

This section will briefly explain the role of trust in every kind of human transaction. Considering the history of human transactions, the first key element to bear in mind is: Ledgers.

For over 1000 years, ledgers have been critical to the development of civilization. The trinity of writing money, coins, and letters enabled humans to do commerce outside of their familial groups and therefore from larger communities. And, while both money and writing are valuable contributions, ledgers are typically only known to those who have studied the dull science of accounting.

Roughly 3000 BC, can be addressed as the time of creation of ledgers in ancient Mesopotamia (present Iraq). Among tens of thousands of clay tablets that are remained, most of them are ledgers, including: tax records, payments, workers pay, private wealth, etc. How come measurements have been very critical throughout history? Exchanges of products and services have been instrumental in the expansion of societies, but only if people could keep track of the transactions.

Once humans began exchanging money across distances, tokens' capacity to perform this record-keeping role deteriorated. There was no mechanism for the payer to physically convey the tokens to the payee without relying on a courier who could easily take them. The answer came with the invention of a new kind of bookkeeping known as double entry bookkeeping, which was pioneered, as we'll discuss later, by a group of renaissance bankers. By adopting this bookkeeping, they incorporate banks into business payments, which has served to significantly improve the capacity for human exchange for ages. It may not be an exaggeration to argue that this concept of banking

set the foundation for the modern world. However, it worsened an issue that has troubled ledgers for centuries: can society trust the record-keeper?

Bitcoin addressed this issue by redesigning the ledger. It brought up the subject that bankers are not always trustworthy and may defraud customers through hidden fees and opaque charges. Bitcoin accomplished this by delegating responsibility for confirming and maintaining the ledger of transactions for the first time to a community of users who verified one another's work and agreed on a single record to represent their shared approximation of the truth. A decentralized network of computers, controlled by no single organization, would thereby substitute the banks and other centralized ledger-keepers defined as "trusted third parties" by Nakamoto, "the mysterious person or group of persons who designed Bitcoin." The ledger that was created is now widely known as the Blockchain.

2.1.2 Economic crisis 2008; Lehman brothers bank

On January 19, 2008 the Wall Street firm Lehman Brothers recorded its financial statement for the fiscal year of 2007. It had been a great year for Loman despite some ramblings in the stock market and a downturn in the housing market which had been red-hot for years and a major source of revenue for investment and commercial banks. The firm, founded 167 years earlier in Alabama and one of the bedrock institutions of Wall Street, posted record revenue for 2007, $59 billion, and record earning, $4.2 billion. Compared to just four years ago, it's more than double what the company had brought in and earned, An unbelievable performance.

Nine months later Lehman brothers was out of business.
Lehman Brothers can be taken as a manifestation of the breakdown of trust in the 21st century. Known as a star of Wall Street, the firm was revealed to be a bit more than a debt ravaged shell, kept alive only by Shady accounting. In other words, the bank was manipulating its ledgers. Sometimes, manipulation involved moving debt off the books as reporting season came around. Other times, the company credited hard-to-value assets as high values on their balance sheets.

How is it possible that a business could earn **$4.2 billion** one year and be out of business the next year? The reason is not just because Lehman Brothers was manipulating its ledgers but because it was taking advantage of the trust invested in it by shareholders, regulators, and the public at large. On the accounting side, Lehman resorted to myriad tricks to bolster its books, those all-important financial documents that investors and other stakeholders depend upon to ascertain the risk of dealing with an institution.

Lehman's accountants would move billions of dollars' worth of debts off the bank's balance sheet at the end of a quarter and stash them in a temporary accounting facility called a repo transaction, a device that's supposed to be used to raise short-term capital, not hide debt. When it came time to report, the company didn't appear to be overly indebted. Once the report was in, the company brought the debt back on the books.

In Reality, it was as if the company was maintaining two sets of books-one it showed the public, one it kept private. Most people accepted what was reported in the public-facing books, Lehman's version of "the truth." Just how severely skewed Lehman's books were would become clear in September 2008. But the problem really started with the public's trust, in the blind faith given to the company's numbers.

The 2008 financial crisis exposed the majority of what we might refer to as the Wall Street confidence game; a massive manipulation of ledgers. The recorded worth of their assets, especially those confusion and chaos credit default swaps, proved to be mostly weak and shallow. The shocking point of Lehman wasn't very much about its crash, but that even the majority of experts relied so much on the ledgers till it was too late.

Governments and central banks around the world spent trillions to clean up the mess, but what they really did was restore the old order, because they may have misdiagnosed the problem. The accepted wisdom was that 2008 was a crisis of liquidity, in which the market broke down due to lack of short-term funding/liquidity. A simple example would be, being short a few hundred dollars/euros to cover the monthly bills.

The reality, in ‘Michael J. Casey and Paul Vigna’s point of view is: “banks were sitting on trillions of purportedly valuable assets they could not even remotely value in the real world. They’d simply assigned poorly substantiated values and put them on their books. Other stakeholders and the general public believed them because they trusted them, they trusted what was assigned in the ledger. The real problem was never really about liquidity, or a breakdown of the market, it was the failure of trust. When that trust was broken, the impact on US society — including on the US divided political culture — was devastating.”

2.1.3 The need for change

Before addressing details of the concept, let us consider the prerequisites for this discussion. Why may stakeholders be interested in considering the shift from the old-fashioned centralized database to public ledgers?
Many countries use electronic cadastral systems for years, but at the same time, they still heavily rely on paper transactions. As a matter of fact, none of the countries enabled electronic peer-to-peer transactions with title rights yet.

Even though in such registries title rights and property rights are recorded in electronic form, these records are secondary and subsequent towards the transactions that happen in the paper form. Parties perform the typical deal as a [paper] title deed, which the land authorities acknowledge and record in the electronic database, i.e., land, cadastral, or real estate registry.

Apparently, there is a great role of the government and intermediaries who are either authorized by the government or licensed to conduct professional services for landlords and interested parties. All this infrastructure of regulations, authorities, and intermediaries is called to establish certainty in “who owns what.”

However, centralization is a source of risks of data loss, corruption, and abuse of power. Inevitably, from time to time, it leads to conflicts of a different scale. Specifically, for information systems, centralization means control over the database, which is a single point of failure. The maintenance of such a system is costly and difficult. This is one of the reasons why citizens do not interact online, performing peer-to-peer transactions with the government database. When there is a chance of losing or corrupting critical data, the government chooses to be on the safe side by restricting any direct interaction.

2.2 Platforms

This section will explain what a platform is and what multisided platforms are. Next, what advantages, disadvantages, and challenges are of a platform. This section will end by explaining why organizations and people are willing to participate on a platform and what incentives could be thought of. This will contribute to the following sub questions:

1. *What are the advantages and disadvantages of using a platform?*
2. *What motivators make participating on a platform attractive for users?*

2.2.1 What are platforms and multisided platforms?

Today many companies in different industries are using platforms for selling their products. A classic example is the form of a shopping mall: the mall developers must attract retailers and shoppers. The internet is providing a next level to the use of platforms. Well-known examples are Uber and Airbnb who do not own any assets like cars or hotels anymore. However, for this specific research, there is no product sold on a product on a platform, it is more like a service platform.
The literature has many definitions for platforms, for example:
“Platforms can be conceptualized as interfaces—often embodied in products, services, or technologies—that can serve to mediate transactions between two or more sides, such as networks of buyers and sellers or complementors and users.” (Eisenmann T., 2008)

“Platforms provide building blocks that serve as the foundation for complementary products and services.” (Gawer & Cusumano, 2012)
When there are more sides on a platform, then it is called a multi-sided platform (MSP). MSP’s enable interactions between multiple groups of consumers and ‘complementors’ (Boudreau & Hagiu, 2008). The direct interactions are the primary way in which platforms can create value. This means that the value created by the platform must be the ability of the customer to directly interact with one or more other types of customers. This terminology of platforms is most suitable for this research.
In connection with platforms, the term network effects are mentioned, this appears when users create value for other users. Alstyne & Parker (2017) explain: “The larger the network the better the matches between supply and demand and the richer the data that

can be used to find matches". Inside a single company, it is not possible to get these network effects on a large scale. The biggest change of platforms in the past years is that information technology can reduce the transaction costs and you do not need to own the physical infrastructure and assets. The most important asset of a platform is best defined as its network of producers and consumers together (Alstyne & Parker, 2017).

According to Eisenmann (2008), platforms have the following roles:

- End-users; the demand-side Complements; the supply-side
- Provider; the point of contact
- Sponsor; the designer & IP rights holder

The platform provider is a mediator for transactions. It is the supply of components with the rules of the provider. The sponsor has the right to modify the technology of the platform. The sponsor also decides who may participate in the network as users and platform provider sponsors could be one firm or multiple firms. (Eisenmann T, 2008).

Platforms can have an open or closed environment. Eisenmann (2008) explains: "A platform is "open" to the extent that:

1) no restrictions are placed on participation in its development, commercialization, or use;

2) any restrictions. When the platform provider chooses a too-closed environment, it is possible that there are not enough participants to generate network effects. If the provider chose a too open environment, there might be value-destroying effects. To be open and ensure quality the platform can use ratings and feedback. With an open platform, it is possible to add new value to the platform without negotiating with the owner. When multiple firms develop a platform and they collaborate on the used technology, this is called a shared platform (Eisenmann T. , 2008). When there is the definition of a platform in this research, it will mean a shared platform and a multi-sided platform.

The next section will argue why mitigation towards platforms can be useful and what the advantages, disadvantages, and challenges are.

2.2.2 What are the advantages of platforms?

Before pointing out the advantages, disadvantages, and challenges of shared platforms this section will start with why a platform could be useful. The five drivers of migration toward platform-centric business models are described in this table:

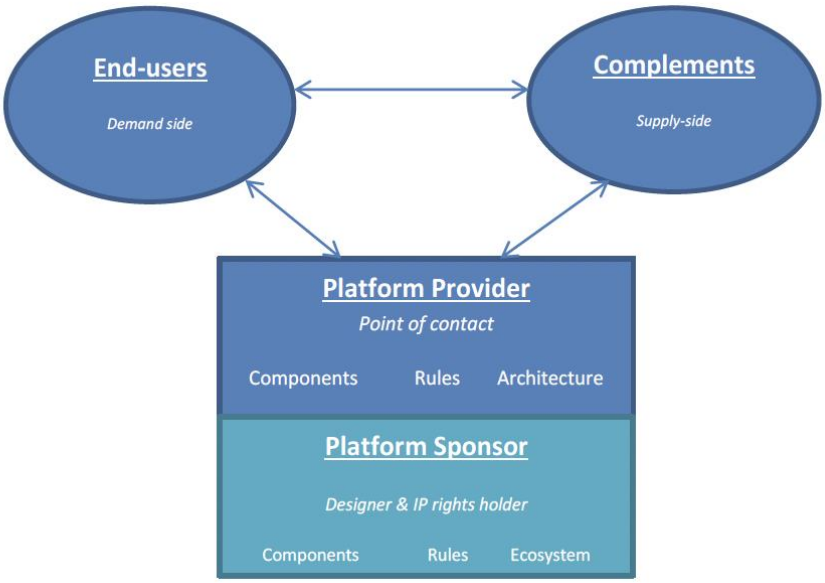


Figure 1. Platform concept

Gawer and Cusumano (2012) argue: “not all products, services, or technologies can become industry platforms. To convince firms to adopt a platform, the platform must (1) perform a function that is essential to a broader technological system, and (2) solve a business problem for many firms and users in the industry.” These theories are important because it explains why moving to a platform is necessary and how to convince firms to adopt a platform. The theory of Table 1 will be used to explain how this will be applicable for this research and why the platform theory is chosen.

Disadvantages

When a platform requires a big investment, it can be a problem when implementing this with many parties. Proprietary providers have an advantage doing the investment and produce the platform more quickly (Eisenmann T. , 2008). It could be possible to start with a consortium where costs and revenues can be equally split. Cost and revenue

sharing is often difficult when partners in the ecosystem do not know each other well and so not trust each other. Blockchain technology might be a solution for this problem that will discussed further in section 4 of this research.

Advantages

When there is one platform owner, the owner could influence and benefit from the behavior of the users. The goals might be getting as much profit as possible instead of increasing value in the ecosystem (Boudreau & Hagiu, 2008). Producing a shared platform has the advantage that there would be no monopoly with aggressive price increases. Because it is a shared platform, the users' concerns about lock-in and hold-up risks will decrease. Platforms affect dynamics and innovation at the ecosystem level. When opening the platform this stimulates innovation on the complements of the platform and make money from the investments made (Eisenmann T. , 2008).

Challenges

It is difficult for platform architects to make sure peers earn enough profit to warrant participation. It is possible to make use of a membership and make the cost reduction visible to mitigate this. Due to conflicting strategic agendas, shared platform providers usually find it hard to agree on diversification and vertical integration initiatives (Eisenmann T. , 2008). It is important to know these conflicts at an early stage and govern the platform where it is possible to manage these conflicts. When the split of costs in investment is a difficult point on the agenda it could be possible to make the manner important for the government to invest. They play an active role in shared platforms when social priorities are at stake. Meyer and Lehnerd (1997) already defined a platform as a set of common components from which a stream of derivative products can be efficiently created and launched. It could be useful to start with one component and add more components later. This is a challenge to keep the platform small from the start and build upon a good basis instead of expanding to fast (Meyer & Lehnard, 1997).

2.2.3 Ecosystems

In business, a network of organizations – including suppliers, distributors, customers, competitors, government agencies, and so on – involved in the delivery of a specific product or service through both competition and cooperation is called an ecosystem. Investopedia (2018) describes the idea: “each business in the "ecosystem" affects and is affected by the others, creating a constantly evolving relationship in which each business must be flexible and adaptable to survive, as in a biological ecosystem.” (Investopedia, 2018). In order to create a platform which solves a business problem like Gawer & Cusumano (2012) explaining in their theory (page 17), the members of the ecosystem around it are important.

Adner (2006) states: *“An ecosystem is working well as it allows firms to create value that no single firm could create alone”.* This theory explains mistakes that are made most common in ecosystems. One of those mistakes is that a manager takes his position in the ecosystem too early and is acting with haste to create and defend their role in delivering an integrated product or service. It is important when a company goes to the market ahead of their rivals that the timing is perfect and that they are ready for the implementation. When an innovation is very dependent on other developments, it would have less control over its own success (Adner R. , 2006).
Another important factor is that innovation and investment emerge within the timeframe. The location where the innovation positions in the ecosystem can either enhance or erode the firm’s competitive advantage from technology leadership (Adner & Kapoor, 2010). It could be interesting to be the technological leader in the ecosystem or just collaborate with other companies.

In the ecosystem, there could be some mismatch between the slower moving large firms and innovative SMEs (Ritala, Agouridas, & Assimakopoulos, 2013). This study found out that there is a need to invest more in collaborative ecosystem activities in early phases of product development.
The literature defined platforms in several ways; it has a strong connection with the literature of ecosystems. The next section will define why companies and people want to participate on platforms.

2.2.4 motivations for participating in a platform

Previous studies showed that onboarding large numbers of parties on a platform is difficult and needs attention. Most studies focus on the pricing instrument of the platform (Eisenmann, Parker, & Alstyne, 2006). They suggest that the correct pricing will be intermediate between the owners of the platform and the users on an MSP. Pricing the platform is a big challenge for the provider. For two-sided platforms, it is more complicated because the pricing on one side must affect the other side's growth and willingness to pay. Eisenmann, Parker & Alstyne (2006) explain: "When the provider can attract enough subsidy-users, money-side users will pay handsomely to reach them." This theory is called cross-side network effects. It also works the other way around when there are more money-side users this will attract the subsidy-side users. According to the theory of Eisenmann, Parker & Alstyne (2006), a platform provider needs to consider the following factors:

- Ability to capture cross-side network effects
- User sensitivity to price
- Use sensitivity to quality
- Output costs
- Same-side network effects

A participant must make a time investment to participate on the platform. It takes time to learn how to use the platform for example. When the participant must take a membership on the platform this is also an investment that has to be considered (Hagiu & Wright, 2011). An incentive for participating could be earning rewards.

Gawer and Cusumano (2002) defined their non-price instruments as their 'four levers of platform leadership':

- Firm boundaries
- Internal organization of the platform owner
- Product technology
- Relationships with platform participants

Boudreau and Hagiu (2009) identified a conceptual framework for interpreting non-price instruments, which defines the MSP as a private regulator. This means that all the interactions around the platform are regulated by characteristics of technological aspects, legal aspects, and other instruments – including price setting. A two-step approach for a platform owner is conceptualized:
(1) maximize value created for the entire ecosystem; (2) maximize the value extracted. The analysis of Boudreau and Hagiu (2009) suggest the regulation of a platform needs to be evolved over time. It is important to be active and be early in orchestration of the platform according to their research.

An interaction between the players on a platform is a reason to participate in a platform (Alstyne & Parker, 2017). These interactions need to be of equal value for all the parties otherwise they will feel no need to participate anymore. Cusumano and Gawer (2002) provide several strategies that platforms use to motivate and cope with external complementors:

1. Platform standards should remain open in order that complementors continue to invest.
2. The platform owner should not play favorites with news or surprise complementors with changes in strategy.
3. Interests of partners should be treated fairly relative to interests of the leading platform firm.
4. Platforms can share risk by investing along with partners in uncertain innovations.
5. The platform should promote the long-term financial health of partners, especially smaller ones.

2.3 Blockchain Technology

In this section, the aim is to explain blockchain technology in enough detail, as the real estate sector is one of the most important investing classes in the world. Therefore, a well-explained description of this technology is needed for important actors in this sector to consider the shift towards this new technology. This section will contribute to the following sub-questions:

1) What is blockchain technology?
2) How can blockchain be supportive of a real estate platform?

Satoshi Nakamoto was the first person or group (the real identity of Satoshi is still anonymous at the time of this writing) who introduced blockchain technology in 2008 as a part of the bitcoin protocol (Nakamoto, 2008). At that time, the financial crisis began, undermining public trust in banks. [see the section on trust for additional information] Nakamoto claimed that an electronic payment system based on cryptographic proof rather than trust was required. Two parties eager to conduct a transaction can do it directly, without the involvement of a trusted third party.

Gartner placed blockchain technology at the start of the peak of high expectations in 2016. They positioned the technology at the end of the exaggerated expectations in July 2017 and it is still scaling on a 5- to 10-year path until it reaches the productivity plateau (Panetta, 2018). This demonstrates the rapid growth of this technology and explains why it is worth investigating in this research.

Although large financial organizations and banks initially viewed blockchain technology as a danger, they began analyzing it, and once they recognized its enormous potential, they began testing solutions that could adapt to their specific needs.
According to a report by the UK Government's Chief Scientific Adviser (UK Government Chief Scientific Adviser, 2016), the financial system's current infrastructure could be gradually replaced in the future by a system consisting of a number of distributed ledgers connected via blockchain technology. According to a recent paper, "The FinTech 2.0 Paper: Rebooting Financial Services," written by Santander InnoVentures in collaboration with Oliver Wyman and Anthemis group (Santander InnoVentures et al.,

2015), the banking sector will save approximately $15–20 billion per year by 2022 as a result of the adoption of blockchain technology.
Additionally, the major Italian banks (Intesa Sanpaolo, UniCredit, and Banca Mediolanum) participated in R3 CEV, an international consortium, alongside partners such as Bank of America, Merrill Lynch, HSBC, and UBS. R3 CEV, which began operations in the summer of 2015, aspires to develop a shared architecture based on blockchain technology for the financial sector.

The global market for blockchain solutions is expected to reach 6.6 billion dollars in 2021. Spending on blockchain solutions is expected to expand in the next years, reaching about 19 billion dollars by 2024, according to forecasts.

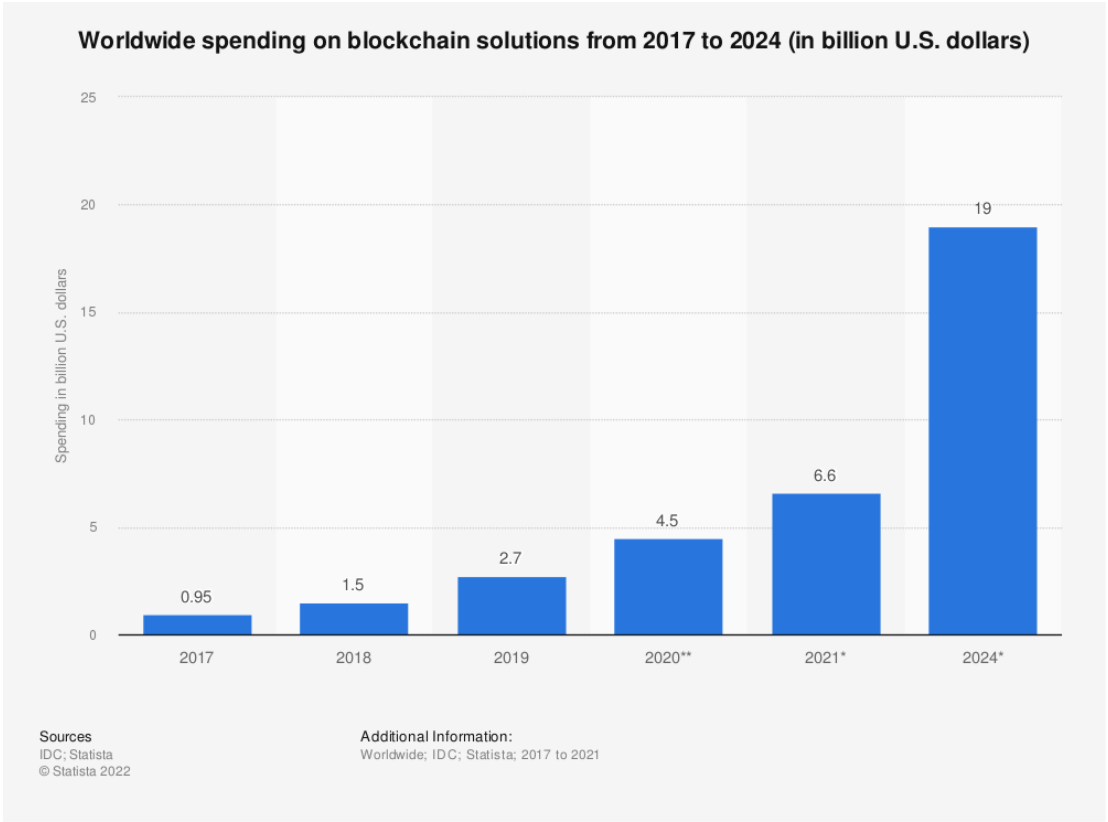


Figure 2. Worldwide spending on blockchain from 2017 to 2024. Source statista

2.3.1 Blockchain description

A blockchain is a decentralized database that is shared among computer network nodes. A blockchain acts as a database, storing information in a digital format. Blockchains are best recognized for playing a critical role in cryptocurrency ecosystems like [Bitcoin], where they keep a secure and decentralized record of transactions. The blockchain's novelty is that it ensures the fidelity and security of the data records while generating trust, therefore removing the need for having a trusted third party.

A key distinction between a traditional database and a blockchain is the way data it's structured. A blockchain connects data in groups known as [blocks] that include sets of data. Blocks contain a limited amount of storage and, when filled, are closed and linked to the preceding block, producing a data chain dubbed the blockchain. All future information is assembled into a newly created block, which is subsequently added to the chain once it's been filled.

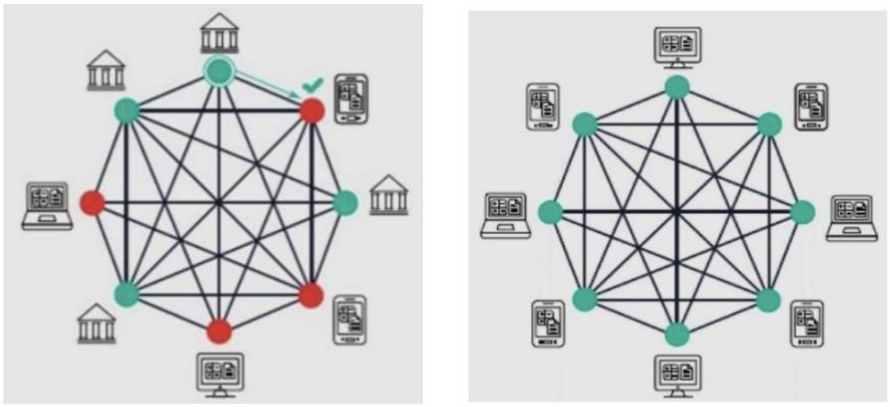
To verify new entries or records to a block, a majority of the processing power in the decentralized network must agree. To prevent hackers from verifying false transactions or [double spends], blockchains utilize a consensus technique such as [proof of work (PoW)] or [proof of stake (PoS). These mechanisms enable agreement to take place even when no single node is in command.

The PoW refers to a system in which validating participants (referred to as miners) compete to solve a computational puzzle. They are required to submit a block of transactions that includes the proper answer. To solve the puzzle, a significant amount of electricity and computer processing power is required. In exchange, the miner receives a reward in the form of a currency(for instance: bitcoin) for sustaining the network. (Bitcoin/cryptocurrency) (Nakamoto, 2008).

2.3.2 Permissioned Blockchain

There are two types of blockchain infrastructure: private blockchain (permissioned) and public blockchain (non-permissioned) (permissionless). In the latter case, all actors might freely participate in the network, validating transactions and blocks while having full access to the public ledger's contents. The chances of malicious actors updating inaccurate data are reduced because of the repeated validation process (as previously

explained). Instead, a private system assigns only specified actors the responsibility of validating transactions, and it is typically characterized by varying levels of data access for different parties. Permissioned blockchain is the model most commonly used by financial institutions who want to maintain complete control over data without releasing sensitive information to a large number of unauthorized parties.



Data source: *Insurance Innovation (EY)*

Figure n3. Traditional vs Blockchain network

There is a concerning issue with Permissioned Blockchains:
Politicians, the media, and public opinion leaders are promoting projects based on permissioned blockchains or DLTs under the name of "blockchain" but without the goal or capability of decentralization.
The research's primary finding is that permissioned and private DLTs offer no decentralization advantages over other centralized databases, or that people who advocate for these technologies did not make a compelling case for them over other centralized registries. This is not to say that the permissioned DLT is worthless. While this can be a useful technology for the private sector, its utility for public administration and public services is debatable. Permissioned networks have a single point of failure, and users are forced to delegate control to the network's owner and rely on their good will. This also applies to other centralized technology, such as more traditional databases, which governments have been using for decades.

2.3.4 Security

Several options exist for blockchain technology to establish decentralized security and trust. To begin, new blocks are always kept chronologically and sequentially. – in other words, they are always attached to the blockchain's "end." After a block is added to the end of the blockchain, it is incredibly difficult to modify its contents unless a majority of the network agrees. That is because each block has its own hash, as well as the hash of the previous block and the time stamp described above. Hash codes are formed by converting digital information to a string of numbers and letters using a mathematical algorithm. If the data is modified in any manner, the hash code is modified as well.

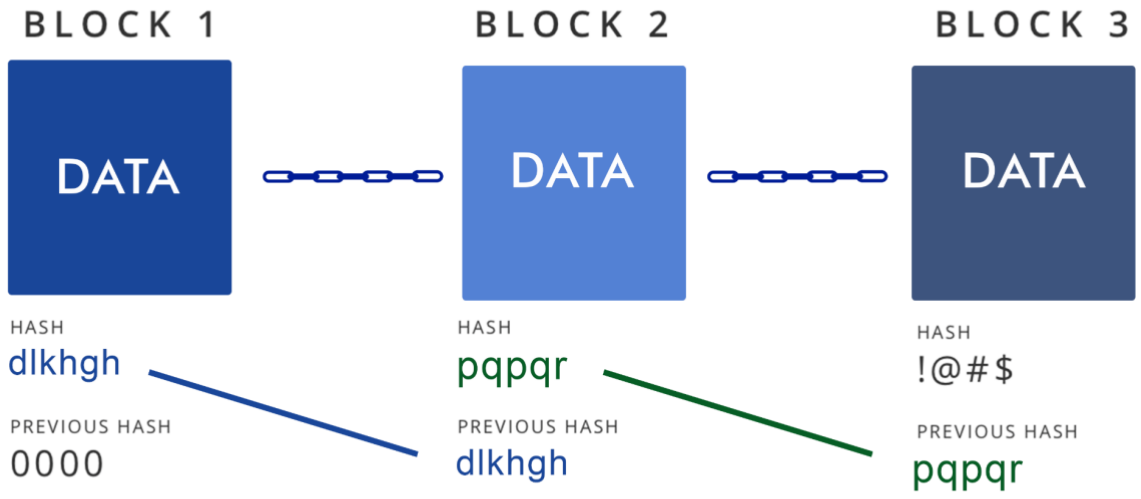


Figure n4. Data blocks creation

An example: Consider a hacker who also operates a node on a blockchain network and wishes to change the blockchain in order to steal cryptocurrency or corrupt the data. If they were to alter their own unique copy, it would become incompatible with the copies of other people's record on the network. When everyone else compares their copies, this one will stand out, and the hacker's version of the chain will be discarded as invalid.

To succeed in such an attack, the hacker must simultaneously control and alter 51% or more of the blockchain's copies, so that their new copy becomes the majority copy and hence the agreed-upon chain. Additionally, such an attack would cost an enormous

amount of money and resources, as they would have to rewrite all of the blocks due to the new timestamps and hash codes.

Due to the scale and rapid growth of many cryptocurrency networks, the expense of accomplishing such a feat would very certainly be unattainable. This would be extremely costly, not to mention it's pointless. Such an action would not go undetected, since network members would witness such significant changes to the blockchain. Members of the network would then [hard fork] to an unaffected version of the chain. This would result in the attacked token's value plummeting, leaving the attack ultimately meaningless, as the bad actor now controls a worthless asset. The same thing would happen if a bad actor attempted to attack Bitcoin's new fork. It is constructed in this manner such that participating in the network is significantly more economically advantageous than attacking it.

2.3.5 Transparency

Transparency is a vital core for the operation of efficient markets. While real estate has long been the world's largest asset class in terms of value, it is now playing a greater role in global investment strategy. As a result, more private individuals are exposed to real estate via their pension funds and insurance policies, as well as through their investments in REITs, publicly traded property firms, and closed and open-ended funds. With an increased need for understanding the impact of investment decisions on the environment and communities, this spotlight on the sector has extended the notion of transparency. “Better transparency is crucial to creating healthy real estate markets which work for all participants, not just a few, and we expect new technologies will accelerate improvements and enable some countries to leapfrog up the ranking in coming years.”(Richard Bloxam, Member of the Global Executive Board Global CEO, Capital Markets JLL, 2020)

To make a successful real estate investment and avoid being swayed by herd behavior and misinformation, a certain degree of transparency around the real estate market is necessary (Schulte et al., 2005). According to the real estate transparency theory, absolute transparency occurs when information is shared with a high degree of equivalency between market players, whereas absence of openness results in market

information asymmetry. Due to the globalization of real estate transactions, the need for real estate data has considerably expanded.(Farzanegan and Fereidouni, 2014).

What's Next for Real Estate Transparency?

The following data are extracted from a recently published report by JLL 2020 Global Real Estate Transparency Index, starting with effects of COVID-19 on the legal and regulatory environment.

COVID-19 creates a fast-changing legal and regulatory environment

• The Transparency Survey was completed in February and March 2020, just as the lockdown of economic activity was underway in the Americas and Europe, having already occurred in East Asia. As a result, the scoring of the fairness, effectiveness and clarity of the regulatory environment took place before many of the hastily enacted regulations intended to address a fast-moving pandemic had started to unfold.

• The COVID-19 crisis is shining a bright light on the transparency of real estate's legal and regulatory systems. New rules to establish how social distancing, virus testing and contact tracing all intersect with existing property and privacy laws are being created in a compressed time frame. As we go to press, sorting out these challenges still lies ahead in the second half of 2020 and in 2021.

Disruption leading to innovation and driving transparency

• Technology can contribute to higher transparency, but real estate markets have had trouble
implementing new tech fast enough. The COVID-19 pandemic could help to fast-track digitization and stimulate innovation in the use of technology due to the need for accurate and just-in-time data to keep track of activity – especially relating to health, mobility and space usage.

• The pandemic is leading to an acceleration in new types of non-standard and high-frequency data being collected and disseminated, which is taking transparency to new levels due to its near-real time nature. In the U.S. for example, organizations like the

National Multifamily Housing Council (NMHC) and NAREIT pooled data on rent payments from software firms and property owners within a few weeks of the crisis escalating and have maintained this collaboration with subsequent updates. This has provided visibility into a previously opaque indicator and informed both policymakers and business through the crisis.

Increasing government engagement with prop-tech

• A few governments are now actively engaging and consulting with the proptech sector on how to improve services and make government data more available. Relatively few are doing so in a structured way however, but there are signs of change. The UK's Digital Street program is one of the best examples, running research programs and funding local authorities to trial digital property solutions.

• Despite the hype, governments are still at a relatively early stage in trialing the use of blockchain technology in transactions. **Pilots in Dubai and Sweden** are among the most advanced, while another 30 national governments are engaging with the technology.

• The use of technology will become more important in the record-keeping and forensic work used by governments to combat money laundering and insider trading. Cyber-security regulators in many countries have enhanced their ability to impose penalties and provide enforcement to reduce outbreaks of ransomware or phishing attacks.

(Global Real Estate Transparency Index, 2020, JLL)

According to the table, there are 15 European countries in the top 20 countries of the Real Estate Transparency Index. And as Netherlands is already working on developing a blockchain based application, a unified platform for European countries can be on the horizon.

Global Real Estate Transparency Index, 2020

Highly Transparent	**Key Characteristics** The world's leading investment destinations. These 10 markets are pushing the boundaries of transparency through technology, a focus on sustainability, anti-money laundering regulations and enhanced tracking of alternatives sectors. **2020 Highlights** The UK, the United States and Australia are the most transparent markets. Ireland is one of the top improvers in 2020, while France, Sweden and Germany also advance.	1	United Kingdom	2	United States		
		3	Australia	4	France		
		5	Canada	6	New Zealand		
		7	Netherlands	8	Ireland		
		9	Sweden	10	Germany		
Transparent	**Key Characteristics** European and, increasingly, Asian markets which have strong regulatory frameworks, governance structures and transaction processes. Market fundamentals data and performance measurement are areas for improvement. **2020 Highlights** Switzerland, Finland and Belgium sit on the cusp of 'Highly Transparent', while Singapore, Hong Kong SAR and Japan lead in Asia. Mainland China and Thailand improve and enter the group of 'Transparent' markets.	11	Switzerland	12	Finland	13	Belgium
		14	Singapore	15	Hong Kong SAR	16	Japan
		17	Italy	18	Denmark	19	Spain
		20	Poland	21	Austria	22	Norway
		23	Chinese Taipei	24	South Africa	25	Czech Republic
		26	Portugal	27	Hungary	28	Slovakia
		29	Malaysia	30	South Korea	31	Luxembourg
		32	China – SH/BJ	33	Thailand		

Table N1. Globa; real estate transparency index 2020

Blockchain and real estate applications

Several countries, including the Netherlands, are developing the first blockchain application in real estate to facilitate the documentation of rental contracts. (Veuger, 2018). The project comprises:

1. (1) digitalizing building data;
2. (2) digitalizing the ownership situation;
3. (3) transferring ownership;
4. (4) closing of rental contracts;
5. (5) unlocking contract information for third parties.

"With the help of Blockchain, we can bring together all information about buildings and give access to parties who need the information. It then works as a kind of building passport" (Veuger, 2018).

Blockchain technology enables the digitalization of tangible and intangible assets; this enables the recording and exchange of digitized goods without the use of intermediaries, thereby establishing an economy in which trust is not placed in a central authority or third parties, but in a complex cryptographic code.
The blockchain is precisely an open ledger that assures itself without the involvement of other parties. Additionally, blockchain technology can improve the present transaction process by lowering the time required for due diligence and negotiation, while also encouraging trust between participating parties and information reliability. (Wouda and Opdenakker, 2019)

2.3.5.1 Applying blockchain for CRE transparency

investing entails several stakeholders - tenants, owners, investors, and banks, for example - making it critical for information to be both clear and consistent amongst them. Property DNA uses blockchain technology to update and maintain data about properties from their genesis to the present, thus creating a Carfax for commercial real estate properties. Each property is identified uniquely, and data is accessible via blockchain, which may be accessed and updated by users with varying rights. This connection enables various entities to gain access to a tamper-resistant, single source of truth about an asset's state. The data collected will include title background, brokerage agreements, financial data, debt associated with a property, purchase agreements, insurance-related data, and rental contracts, as well as (potentially) a wide range of other information that was previously unattainable or discovered through multiple different sources. Property DNA's methodology asserts that it can deliver more regularly updated and real-time data than other companies providing data.

Additionally, tokenization of titles (see more on tokenization chapter) are also on the horizon. Numerous blockchain firms are attempting to improve property titling. Namely , Medici Land Governance recently announced a partnership with Mexico to use Medici's blockchain technology to create a digital land record system. The company's major objective is to leverage blockchain technology to construct tamper-resistant proofs of ownership in order to assist individuals in developing countries in establishing official property ownership.

3. Smart Contracts

3.1 Ethereum

Ethereum is a global, open-source blockchain platform for decentralized apps (DApps) that is driven by smart contracts and includes a native digital currency called ether (ETH). The network, which was launched in 2015, was created to complement Bitcoin's basic purpose as a peer-to-peer (P2P) digital currency by including a platform capable of implementing smart contracts and more complicated structures such as decentralized autonomous organizations (DApps) (DAOs).
On Ethereum, programmable conditions can be used to regulate the flow of digital wealth.
Ethereum sparked the second wave of blockchain innovation by expanding on the use cases enabled by Bitcoin and establishing its own distinct place in the digital currency ecosystem. Ethereum's ultimate goal is to be the preeminent platform for smart contract-compatible digital currencies.

Vitalik Buterin, a programmer and co-founder of Bitcoin Magazine, issued a white paper in late 2013 describing a new digital currency-powered technological platform called Ethereum. Vitalik formulated the perspective, as an early adopter of bitcoin, that a digital currency and its accompanying blockchain might enable much more than peer-to-peer electronic value transfer. To realize this greater goal, he set out to build a computationally full virtual environment that would include a global blockchain and a platform for "smart contracts." Both would be fueled by ether, a native digital asset (ETH).

By directly incorporating programming capabilities into the Ethereum protocol, developers worldwide would be able to create a new class of decentralized applications housed on a public blockchain. Through the use of smart contracts, Ethereum-based applications may automate the exchange of information and value under dynamic conditions, enabling the creation of customized business models for the IoT and Machine-Payable Web3. In many aspects, Ethereum was envisioned as the next evolution of operating systems such as Apple iOS or Microsoft Windows, enhanced by blockchain technology.

Ethereum was founded on the same fundamental concepts as Bitcoin: that a blockchain protocol's transaction ledger should be immutable and decentralized.
Many in the digital currency world remain convinced that these principles are necessary for the organic growth and economic viability of distributed blockchain systems.
Vitalik and a non-profit foundation launched Ethereum on July 30, 2015, less than two years after the first white paper was published.

3.1.1 How does Ethereum work

The Ethereum blockchain is essentially a state machine that operates on transactions. In computer science, a state machine is something that reads a sequence of inputs and then transitions to a new state based on those inputs.
We begin with a "genesis state" in Ethereum's state machine. This is equivalent to a blank slate, prior to any network transactions occurring. When transactions are carried out, this genesis state is transformed into a final state. At any given point in time, this final state represents Ethereum's current state.

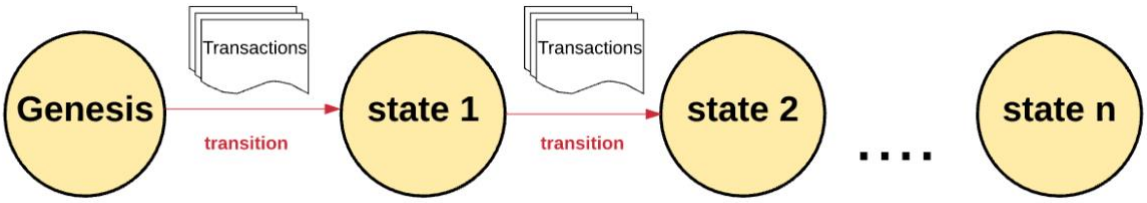


Figure n5. How does ethereum work

Ethereum's state contains millions of transactions. These transactions are grouped together in what are known as "blocks." Each block is composed of a sequence of transactions, and each block is linked to the preceding one.
A transaction must be valid in order to effect a change in state. To be considered valid, a transaction must undergo a validation process called mining. Mining occurs when a collection of nodes (computers) pool their computational resources in order to generate a block of legitimate transactions.
Any node on the network that proclaims itself to be a miner has the ability to attempt to construct and validate a block. Numerous miners from throughout the globe attempt to

simultaneously construct and validate blocks. When a miner submits a block to the blockchain, he or she gives a mathematical "proof" that the block is valid: if the proof exists, the block is genuine.

To have a block added to the main blockchain, the miner must demonstrate it faster than any other miner. "Proof of work" refers to the process of validating each block by requiring a miner to submit a mathematical proof.
A miner that validates a new block is compensated with a certain amount of value for their efforts. Ethereum's blockchain operates on the basis of an intrinsic digital coin called "Ether." Each time a miner successfully validates a block, new Ether tokens are generated and distributed.

3.1.2 Externally owned accounts vs. contract accounts

Ethereum's global "shared-state" is composed of numerous tiny objects ("accounts") that communicate with one another via a message-passing mechanism. Each account is identified by a state and a 20-byte address. In Ethereum, an address is a 160-bit identifier used to uniquely identify any account. Accounts are classified into two categories:

-Externally owned accounts that are controlled via private keys and do not include any code.
-Contract accounts, which are controlled and associated with a contract code.

It is critical to recognize the underlying distinction between externally owned and contract accounts. By establishing and signing a transaction with its private key, an externally owned account can send messages to other externally owned accounts OR to other contract accounts. A message sent between two accounts that are not controlled by the sender is a value transfer. However, sending a message to a contract account from an externally controlled account triggers the contract account's code, enabling it to do numerous activities (e.g. transfer tokens, write to internal storage, mint new tokens, perform some calculation, create new contracts, etc.).

Contract accounts, in contrast to externally owned accounts, are unable to initiate new transactions on their own. Rather than that, contract accounts may only initiate

transactions in response to previously received transactions (from an externally owned account or from another contract account).

3.1.3 Gas fee and Payment

Gas fee is one of the main features of Ethereum. Each computation that occurs as a result of an Ethereum transaction is charged – there is no such thing as a free meal! This fee is denominated in "gas."

Gas is the unit of measurement for the fees associated with a certain computation. The gas price is the amount of Ether you are willing to pay for each unit of gas, expressed in "gwei." The smallest unit of Ether is the "Wei," with 10^18 Wei equaling one Ether. A gwei is equal to 1,000,000,000 Wei.

A sender establishes a gas limit and price for each transaction. The product of the gas price and the gas limit indicates the maximum amount of Wei the sender is ready to pay to complete a transaction. The gas limit indicates the maximum amount of gas for which the sender is willing to pay. The transaction is completed if they have sufficient Ether in their account balance to cover this limit. At the conclusion of the transaction, the sender gets repaid for any unused gas at the original exchange rate.

If the sender does not give the required gas to complete the transaction, it becomes "out of gas" and is deemed invalid. In this situation, the transaction processing is aborted and any state changes that happened are reversed, restoring Ethereum to its pre-transaction state. Additionally, a record of the failed transaction is kept, indicating the type of transaction attempted and the location of the failure. And, because the machine invested effort performing the computations prior to running out of gas, logically, no gas is reimbursed to the sender.

The sender sends the entire amount of money spent on gas to the "beneficiary" address, which is often the miner's address. Miners receive the gas fee as compensation for their efforts in doing computations and validating transactions.

Generally, the higher the sender's willingness to pay for gas, the larger the value derived by the miner from the transaction. As a result, the more probable it is that miners will

choose it. Miners are thus free to decide which transactions to validate or ignore. To assist senders in determining the appropriate gas price, miners have the option of publishing the lowest gas price at which they will complete transactions.

3.1.4 Transaction and messages

Ethereum, as previously stated, is a transaction-based state machine. In other words, transactions between multiple accounts are what change the global state of Ethereum. A transaction, in its simplest form, is a cryptographically signed sequence of instructions issued by an externally owned account, serialized, and then posted to the blockchain. Transactions are classified into two types: message calls and contract creations (i.e. transactions that create new Ethereum contracts).

We learned in the "Accounts" section that transactions — both message calls and contract creation — are always initiated and submitted to the blockchain by externally owned accounts. Another way of looking at it is that transactions are what connect the external world to Ethereum's internal state.
However, this does not exclude contracts from communicating with one another. Contracts that are part of the global scope of Ethereum's state can communicate with other contracts that are part of the same scope. They accomplish this by interacting with other contracts via "messages" or "internal transactions." Consider messages or internal transactions to be equivalent to transactions, except that they are not generated by externally owned accounts. Rather than that, they are generated through contracts. They are non-serializable virtual objects that live exclusively within the Ethereum execution environment, in contrast to transactions.

When one contract transfers an internal transaction to another, the code associated with the transaction is performed on the receiving contract's account.
Notably, internal transactions and communications do not include a gas limit. This is because the gas constraint is set by the transaction's external creator (i.e. some externally owned account). The gas limit specified by the externally owned account must be sufficient to carry out the transaction, including any further sub-executions, such as contract-to-contract communications. If a particular message execution runs out of gas during the chain of transactions and messages, the execution of that message will revert, as would any earlier messages triggered by the execution.

3.2 Smart Contracts

Nick Szabo, a computer scientist, pioneered the concept of Smart Contracts. Many types of contracts, he suggested, can be integrated in computer software and hardware architecture. The vending machine, which is designed to transfer ownership of a good (e.g., a can of soda) for the exchange of money, is an early and simple example of a Smart Contract. Because the vending machine has physical authority over the item, it can execute the "contract," which is known as a "contract with bearer,"[28] since anybody with money can transact with the vendor.

According to Kost De Sevres, Smart Contracts are “self-executing, autonomous computer protocols that facilitate, execute and enforce commercial agreements between two or more parties". Wattenhofer offers another definition of Smart Contracts that focuses on Blockchain technologies: an agreement between two or more parties, encoded in such a way that the correct execution is guaranteed by the Blockchain.” (Wattenhofer_2016)

Szabo proposed that computer code could be used in place of vending machines by extending the logic behind mechanical devices like vending machines. This concept could be used to negotiate more complex transactions, form strategic alliances, and coordinate transactions involving multiple jurisdictions. A Smart Contract might transfer ownership of shares, real estate, or intellectual property rights instead of just a can of Coke. The purist notion Nick Szabo presented in his fundamental paper works well for the simplest transactions (e.g., transferring Bitcoins from one owner to another on the Blockchain ledger), but not for all aspects of more complex contracts.

The definition of "smart contracts" or "self executing contracts" in this paper will apply to a broader range of functionalities which are intended to designate a broader category of technology types, this would include smart contracts as fully automated entities as per the original description by Nick Szabo, but also models that allow human intervention, and broader consequences of a triggering data point beyond simple payment. Hence the definition of smart contracts in this paper does not imply that humans are no longer involved in the process; for complicated contracts, this is neither possible nor desirable, specially in our area of focus, the real estate.

3.2.1 Smart Contracts vs Traditional Contracts

A Smart Contract is not a classic written contract on paper, nor is it merely an online contract. It's called "smart" because it can do more than either of these paradigms, much like a "smartphone" can do more than just make phone calls. It executes itself when electronic data inputs are received in the form of computer code on a Distributed Ledger Technology.(which can be a Blockchain but can also be another sort of DLT such as Corda)8. It adjusts itself or transfers payment or other assets, monitors stock levels, or performs other actions on a DLT in a manner similar to a formula in an Excel spreadsheet cell—it adjusts itself or transfers payment or other assets, monitors stock levels, or performs other actions automatically because that is what it is programmed to do.

Contracts have been concluded on the internet for a long time. Indeed, automated systems are used to trade a huge fraction of all shares in the United States. The fundamental benefit of a Smart Contract is self-execution, which is achieved by a combination of its capacity to react to "live" data triggers and the Smart Contract's access to the value itself. People refer to Blockchain as "the Internet of Value"9 or "the World-Wide Ledger" because of the integration of Smart Contracts with DLT. 10 This combination also makes "Smart Contracts" the most revolutionary Blockchain application at the time of writing, since they enable a new standard of trading—one that is disintermediated, safe, efficient, and without of a central point of potential failure.

An Example of the functionality of smart contracts

The conventional Internet contract outlines what will happen in the form of texts, on an Internet form (typically incorporating a set of long-form General Conditions), but it lacks access to the value that will satisfy the deal. If, for example, an online book reseller fails to deliver a textbook that has been ordered, the purchaser will be responsible for enforcing any legal recourse by initiating a complaint procedure or demanding a refund or compensation using a designated email address. This is usually written out in the General Conditions section, which the buyer must click-and-accept before the sale/purchase agreement is finalized. The bookseller must then either initiate payment from its bank account (on a separate ledger kept by the bank) or issue the buyer with a refundable credit note.

The Smart Contract goes above and beyond the usual internet paradigm. It not only defines the next phase, but also performs it by reordering the textbook from the next supplier and, if necessary, moving value captured on the DLT from seller to buyer to indicate a delay penalty against the bookseller. Because the Smart Contract is embedded in a DLT that captures that value, it has access to it. In fact, the Smart Contract does not need to be embedded on the same DLT as the item to be transferred; all it requires is a command function over it.

With this strategy, the amount of human intervention after a contract is signed will be significantly reduced. The need to enforce rights after the closure will be lessened, for better or worse. Human qualities like generosity and opportunism will be absent from the computer code. It will not be guilty of withholding funds that should be delivered, nor will it relinquish rights of recovery because it cannot be bothered to enforce them, or (more explicitly) because enforcement would be too costly, or because it intends to preserve the parties' relationship.

The computer will simply carry out the instructions it was given at the outset: funds will be transferred from one party to another on the Distributed Ledger, and other remedies will be activated. Naturally, both parties must trust and agree on the data inputs that will trigger contractual acts. Official registers capable of providing electronic messages, the Internet (including the Internet of Things), and other business networks will be examples of such sources, and they will need to be connected to the DLT by "Oracles," which will, among other things, exercise the level of human oversight required.

3.3 Smart Contract Execution

Executing smart contracts can have its challenges, some of which are rooted in the principal characteristics of the blockchain, such as transparency, Limited processing rate and limited complexity of the smart contracts. In this section we will explore those problems and try to represent some of the proposed solutions.

First, we look at the characteristics of blockchains that cause the most challenges to smart contracts:

- *Compulsory publication of smart contracts contents* ; Although most blockchain systems employ pseudonyms to safeguard users' anonymity, the contents of smart contracts must still be made public in order for miners to execute them and all nodes to agree on the final states.
- *Low processing rate*: In the majority of blockchains, a transaction must be verified, performed, and packaged by all miners prior to taking effect, however this redundant and resource-intensive technique severely limits the processing rate. Technically, the processing pace is determined by the blockchain's fundamental properties, such as block size and time interval between blocks. Although modifying these parameters is not difficult, new issues may arise as a result. For instance, a larger block size consumes more capacity, whereas a smaller interval results in frequent and undesired forks. As a result, conventional smart contract systems are incompatible with applications that place a high reliance on processing speed.
- *Limiting Complexity*:To ensure a blockchain's viability, methods to avoid DoS attacks are created. For example, Bitcoin only permits a fixed number of operations, effectively preventing the creation of infinite loops. Ethereum introduces the gas mechanism, which restricts the number of instructions that can be executed in a single transaction. On the one hand, these safeguards ensure the currency's viability, but on the other, they restrict the ability to execute complicated smart contracts on-chain. In other words, applications requiring sophisticated operations and heavy overheads are not suitable with current blockchains.

In the coming sections, an overview is given on the solutions proposed to address these issues, these solutions are further subcategorized into three main categories, namely, *private contracts with added tools, off-chain solutions and extensions on core functionalities*.

3.3.1 Private Contracts with added tools

In the majority of mainstream public blockchains, smart contracts are maintained on-chain, where their content can be viewed and validated by anyone. In other words, in order to process a transaction that triggers a smart contract, all miners will act in accordance with the transaction and contract and will eventually agree on the execution result. Such a technique could create privacy concerns; for example, a business would be curious about its competitor's daily sales and large orders. This will hinder the execution of certain business contracts.

To address privacy concerns with smart contracts, cryptographic algorithms or hardware tools are provided; these solutions are referred to as private contracts with added tools. In the following section, we group these solutions into private contracts based on Secure multi-party computation, Zero-knowledge proofs, and Trusted Execution Environment, and provide an overview of each method.

3.3.1.1 Secure Multi-Party Computation

SMPC and smart contracts both have the purpose of involving several parties that do not trust one another and producing correct execution results. To some extent, SMPC is similar to smart contracts, except that it is virtually almost off-chain. When paired with smart contracts, SMPC has the potential to enhance contract privacy and mitigate some of the issues associated with a blockchain's high latency and limited capacity.

In a secure multi-party computation protocol participants P_1; P_2,. Pn can jointly evaluate a probabilistic polynomial-time function $f(x_1; x_2; x_n)= (y_1; y_2; y_n)$ where xi (resp. yi) is the secret input (resp. output) of Pi (i = 1; 2; n). Additionally, these two properties must also be met; Each Pi gets the correct result and Pi cannot receive any extra information except his own input and output

Smart contracts written in the SMPC protocol format are more versatile and are not bound by the blockchain's underlying execution methods. Typically, these approaches are applied to the application layer, which does not rely heavily on execution mechanisms. They rely solely on existing blockchain functionality to assure the

protocol's security or fairness. For instance, participants may upload witnesses or evidence to ensure that everyone acts honestly. The majority of procedures are performed off-chain. Thus, the contract's contents are disclosed only to participants, ensuring that the procedure is more private than standard contracts.

We note that SMPC-based solutions require all participants to be online for the duration of the calculation procedure, which may be impossible in some instances. Additionally, existing SMPC schemes have a high computational and communication complexity, which may create new barriers to widespread adoption of smart contracts. In comparison, the options with ZKP outlined below may allow for a minor reduction in communication overhead.

3.3.1.2 Zero-Knowledge Proofs

A zero-knowledge proof is an encryption system in which one person (the prover) can demonstrate the veracity of certain information to another party (the verifier) without disclosing further information.

Despite the fact that ZKP is used to enhance the functionality of blockchains, the protocol predates the advent of the decentralized ledger by forty years. Silvio Micali, Shafi Goldwasser, and Charles Rackoff of MIT pioneered the approach in the 1980s.

Zero-knowledge proofs are classified into two types: interactive and non-interactive. Interactive ZKPs require the prover to conduct a sequence of tasks or actions in order to convince the verifier that they possess specific knowledge. The majority of the needed tasks in interactive ZKPs include mathematical probability ideas. Non-interactive ZKPs do not require interaction between prover and verifier, or the verification can occur afterwards. These additional computers or software are required for these sorts of ZKPs.

All zero-knowledge proofs must satisfy three prerequisites:

Completeness: If a statement is true, the verifier can certify that the prover holds all necessary input.

Validity: the assertion cannot be falsified, and the verifier cannot be convinced that the prover possesses the requisite input when they do not.

Zero-knowledge: the verifier will have no information other than whether the statement is true or untrue. The other parties' information and personal data remain anonymous.

3.3.1.3 Trusted Execution Environment

There are numerous TEE definitions, all of which refer to isolated execution and secure storage in some way. In the simplest terms, it is a section of a computer system that is inaccessible to anyone except those have a trusted agreement.

The TEE runs on the main processor but is not part of the operating system, allowing data to be stored or code to be executed privately and without change. Due to the fact that it controls its own cryptographic keys, it publishes its material only to third parties who meet all of the conditions established to ensure its trustworthiness. It is capable of managing its content through the installation and updating of its code and data and is resistant to both software and hardware attacks on the main system's memory. Additionally, the manufacturer can validate the TEE, confirming that a program is operating on a genuine TEE, even if it is physically situated off-site.

3.3.2 Off-Chain Solutions

To withstand various types of blockchain attacks (e.g., denial-of-service attacks), smart contracts must necessarily entail performance bottlenecks throughout transaction processing. Thus, one way to increase efficiency is to execute contracts off-chain and release only the settling transactions on the blockchain. Additionally, this conceals the terms of the contract and the details of users' conduct throughout data connection. Off-chain channel schemes primarily describe the interactive protocols between multiple parties, ensuring that no one bears an unnecessary loss and that those who misbehave face appropriate penalties. This paper categorizes state of the art off-chain systems into payment and state channels.

3.3.2.1 Payment Channels

A payment channel is a mechanism by which participants can conduct several transactions without submitting them to the Ethereum blockchain. Once the last transaction between the participants has occurred, the beneficiary may collect their funds by sending one final transaction to the blockchain's smart contract. This saves both parties money by avoiding transaction fees associated with several transactions.

The following is a summary of the payment channel process.
A sender creates a smart contract and deposits funds in the contract's escrow account. The beneficiary is guaranteed to get payments since the smart contract holds the Ether in escrow and honors a valid signed withdrawal message.
The sender and receiver agree on the duration of the payment channel. The smart contract includes a timeout, which ensures that the sender will finally recover payments regardless of if the recipient refuses to terminate the channel.

3.3.2.2 State Channels

The updates of smart contract variables can also be performed off-chain, which is the defining characteristic of state channel networks. Off-chain, a state channel updates the states of smart contracts based on established functions and algorithms. In the same manner as PCN, only establishing and settling transactions are handled on-chain. State channel network generalization, usability, efficiency, and privacy are the primary subjects of related study.
Online poker is a typical application of the state channel network. Bentov et al create and execute an effective online poker contract on Ethereum using a feature called secure cash distribution with a penalty, which sends money from losers to winners as soon as the game concludes. The authors also provide evidence of security within the UC concept. The online poker method is essentially a special case of state channel, which may also be utilized for bidirectional payment channels and other smart contract-related applications.

3.3.2.3 Oracle

As previously stated, a smart contract is a collection of computer programming codes that execute automatically when the contract's conditions are met. Using the previously

stated online bookstore example, a code could contain something such as, if the X amount is received, then execute the process of shipping Y; the code could also check automatically for the presence of tangible and intangible goods in order to execute the contract; this could be programmed in a way to only operate if both the customer and the seller are provided with the product and enough funds at the time of the execution of the contract.

Thus, as opposed to traditional contracts, it is the smart contract that holds the value, not the vendor or the vendee. However, there are also more complicated scenarios. What if a smart contract is required to use real-world data? For example, if a farmer is looking to insure his crops against extreme weather conditions, this sort of contract will require data from the outside to verify that an extreme weather condition in a specific area, such as non-stop rains for a few days or weeks of high temperature days, has occurred and consequently damaged the crops. As a result, the execution of these contracts requires off-chain data. External data is used to trigger the start of the smart contract or to output data when it is required by the smart contract on the blockchain. Data from outside the blockchain must be read through an API.
Although blockchain can ensure the validity and correctness of on-chain data,smart contract code can ensure the contract's automatic and accurate execution. Neither can guarantee the authenticity and integrity of off-chain data. This situation puts the blockchain smart contract's execution results in jeopardy. If the accuracy of the initial data cannot be guaranteed, the smart contract's execution result cannot be trusted.

Oracle as a solution for the need of off-chain data

When a smart contract requires external data, Oracle will operate as a data provider, searching and verifying the data based on the oracle mechanism of computability theory and computational complexity theory. After encryption, the data will be sent to the blockchain, which will allow the smart contract to be executed. For blockchain smart contracts, Oracle delivers dependable out-of-chain data. It provides essential data for smart contract execution, providing a baseline assurance for contract execution correctness. Thus, in the earlier example, Oracle will offer real-time off-chain climate data from reputable sources and integrate it into the blockchain code; when the contract's requirements are met, it will create a refund to the farmer in line with the contract's terms.

3.3.3 Extensions on Core Functionalities

The above-mentioned off-chain channels primarily focus on off-chain protocols while keeping the underlying blockchain's original execution mechanisms. In this part, we describe many strategies that enhance the smart contract platform's core functionality. Specifically, the first section introduces extensions on opcodes that add the functionalities that smart contracts could achieve, the second section introduces schemes that improve the security of deployed smart contracts, and the third section describes solutions that enhance the efficiency and privacy of contract execution. All of these extensions and alternatives strive to make smart contracts more universally usable for data communication and value transactions.

3.3.3.1 Extension on opcodes

More appealing functions in smart contracts could be obtained by adding new opcodes, making them better meet daily use. The covenant in Bitcoin refers to a mode in which future fund transfers are prohibited based on user-defined conditions. This feature expands Bitcoin's application possibilities.
(Moser et al. 2013) augment Bitcoin with an opcode that enables the so-called covenant mode, which allows for the tracking of a specific payment's flow. It also allows for the vault transaction, which takes longer to complete than a conventional transaction. Within this period, the vault transaction can be invalidated by the owner of the recovery key, minimizing the financial loss caused by the private key theft and improving the security of the private key. (O'Connor and Piekarska, 2017) offer another opcode that implements the same functionality as a covenant but just includes computational operations and ignores transaction data. They also provide an opcode for enabling vault mode. Both methods appear to necessitate a Bitcoin soft fork.
Smart contracts are also being moved across blockchains to improve performance (which is relevant to the target platform) or simply as a backup.

3.3.3.2 Improvements in security

Because of the tamper-resistant nature of blockchain, smart contracts are difficult to alter, as noted in Section 1. When a defect or vulnerability is discovered in a deployed contract, users and developers have no recourse. (Dickerson et al. 2018) propose the concept of proof-carrying smart contracts (PCSCs) based on the idea of proof-carrying codes to mitigate this danger. Modifying the underlying consensus and execution

mechanism is required for its implementation. Specifically, the blockchain only keeps track of the deployed contracts' critical attributes. As a commitment, the developer first uploads some important contract attributes to the blockchain. The miners then double-check that such important features do not change before and after the update.
Smart contracts might be upgraded in this way without compromising security. Smart contract updates have been a persistent issue for a long time and are a potential study area. We add that auxiliary schemes and tools, such as chameleon hash, are worthwhile to study, as suggested by (Dickerson et al.2018)

3.3.3.3 Improvements in efficiency and privacy: Arbitrum and YODA

Arbitrum introduces a remastered virtual machine to boost performance and privacy during smart contract executions. Users delegate off-chain smart contract executions to trustworthy nodes in Arbitrum. The correctness is ensured thanks to the Arbitrum virtual machine's one-step proof.
This demonstration only exposes a small portion of the privacy, and because the computation is done off-chain, no additional contract information is released.
Arbitrum requires a reasonable incentive and penalty system to ensure that rational parties offer correct execution. Efficiency is enhanced since not all nodes execute the same smart contracts. As stated at the outset of this section, the complexity of smart contracts is restricted by the execution methods (e.g., the gas limit). The execution outcome of typical smart contracts is simple to verify. However, the verification technique for complicated contracts is non-trivial and costs a huge amount of resources, making it hard to complete on-chain.
It is proposed that YODA be used to assist in reaching an agreement on the execution results of such complex contracts. It proposes a non-deterministic off-chain execution approach that uses randomly chosen nodes and a probability model to decide the execution outcome. The most notable characteristic of YODA is that it eliminates the phase of on-chain verification, avoiding the time delay imposed by on-chain settlement.

3.4 NFT

An NFT is a form of digital asset or token that can be proven to be distinct from other digital assets or tokens (i.e., fungible). It's called a "non-fungible token" for this reason. The record of the NFT's uniqueness is usually kept in the form of a cryptographic record on a blockchain, or distributed ledger, which everyone can access. While this isn't always the case, NFTs are more than just digitized data about an asset; they're a digital asset. This is similar to how the internet of value is formed by the blockchain.

To better grasp the notion, consider the difference between an NFT and a fungible token or asset. Fungible tokens, which are the most common in the blockchain world, are tokens that have the same properties as any other and can thus be readily substituted by another token with the same features. Cash is the most common example of a "fungible" asset, as each 10 Euro note can be exchanged for another 10 Euro note. Non-fungible assets, on the other hand, include event tickets, and legal documents of asset ownership such as property titles, as well as artworks or collectibles.

NFTs are generated and deployed on-chain in compliance with specified frameworks or standards. The most popular blockchain for NFTs right now is Ethereum, and the most common Ethereum is ERC-721, which defines certain criteria for NFTs. As a result, NFTs can be managed, traded, and owned in line with the framework or protocol's properties, which have been defined based on their issuance properties.

3.4.1 Characteristics of NFTs

While it's hard to account for every variation and standard, there are some universally accepted and core traits that most NFT deployments share. These include uniqueness, ownership transparency and provability, asset programmability, and record immutability.

1. **Ownership**

Some qualities that may be particularly relevant in the context of NFTs backed by real-world tangible assets include proof of ownership of underlying assets, the potential for fractional ownership, and asset provenance tracking.

2. **Immutability**

This is a feature that all blockchain-based tokens have. Absent a violation of the underlying blockchain protocol, the tokens and the information stored in them are highly resistant to alteration. As a result, there is a high level of trust and transparency.

3. **Programmability**

Many people believe that this is a key distinction that distinguishes NFTs from real-world assets. NFTs, in addition to permitting creative or commercial expression, can be programmed in any way that programmable software can, for example, to ensure that artists receive residuals or moral rights over the life of work, not just the first sale. Furthermore, experimental applications demonstrate how NFTs, like a mortgage, can be utilized as collateral for a variety of DeFi applications.

3.5 Web 3.0

Web 3.0 (or Web3) is a term referring to the next phase or stage in the evolution of the web/internet based on blockchain technology, and it has the potential to be as disruptive and represent a significant paradigm change as Web 2.0. Web 3.0 is based on the fundamental ideas of decentralization, openness, and increased consumer utility.

To put simply, the internet as we are using it today refers to Web 2.0, a paradigm shift in how the internet is used. Web 2.0's interactivity, social connectivity, and user-generated content have overtaken Web 1.0's boring web pages during the last 15 to 20 years. Web 2.0 allows user-generated material to be viewed instantly by millions of people all over the world; this exceptional reach has resulted in an explosion of this type of content in recent years.

However, this exponential growth and interaction of users have been made possible by tech giant companies such as Google, Amazon, Meta (formerly Facebook), and Apple. People are connected to the internet via Massive data centers owned by these companies, and thus all the data generated by users are being monitored and controlled by them.

A bizarre example would be shutting down the Twitter and Facebook account of Donald Trump, when he was the president of the United States during protests and capital attacks in Washington, D.C. Despite the fact that it was right or wrong, this act by Facebook and Twitter showed how powerful these monopoly companies are to shut down the account of the president, while he was in charge. *The influence of the 2016 presidential election in the U.S by Facebook is another example.*

*E*xperts hope that Web 3.0 would take away this power from a few monopolist companies and peno 'kill switch'! This also implies freedom from indiscriminate censorship and surveillance."
Bottom-up design: "Instead of code being written and controlled by a small group of experts, it was developed in full view of everyone, encouraging maximum participation and experimentation." people would be the owner of their own data. Berners-Lee expounded upon some of these key concepts back in the 1990s, as outlined below:

- Decentralization: "No permission is needed from a central authority to post anything on the web, there is no central controlling node, and so no single point of failure.

3.6 Tokenization of Real Estate

In this chapter first, we combine the findings of two important studies on the Tokenization of Real estate, one from (Oleksii Konashevych, 2020), which was also discussed at the Australian senate and many other reputable conferences, and the other one from a working group paper conducted by MIT Digital Currency Initiative, one of the most prestigious technical universities in the world. Afterward, we analyzed and interviewed the 2 active startup companies in 2022, Propy company in the USA and Forsale startup in Europe to portray an outlook of how these theoretical concepts are being implemented in real-world because no practical data on this topic has been covered in previous studies, as these companies are the first ones in applying blockchain into Real estate, including tokenization, and also they are in their early stages.

Tokens can be created and arbitrary data can be inserted using blockchain public repositories. Through public-key cryptography, where the user's private key is used to sign (authenticate) transactions, blockchain creates a system of ownership over tokens, inserted data, and smart contracts.

A token is a monetary unit and a container for a user's data. Tokens are controlled by coin transactions and smart contracts, which let users read, change, update, trade, or destroy data. The chronological nature of transactions kept in the chain of blocks enabled this feature. However, users cannot alter or erase data in the blockchain, but they can agree that the most recent record represents the current situation.

As a result, immutability does not cause legal issues with enforceability; it is the most significant benefit: all records are maintained in the ledger, whether they are authorized or not, valid or not. Everything that happens with property rights in the real world is recorded and then processed by the technology of the cross-blockchain protocol and the framework of smart laws, making blockchain an immutable store of evidence.

The accumulation of these factors lays the foundation for the tokenization of land rights and other property rights. Tokens are created by users to indicate their ownership rights. Users need trusted third parties to validate legal facts that they normally can't accomplish themselves, such as births, deaths, and notary acts. A trusted party is a broad concept here. A land authority, a certificate authority, a trusted service provider (for digital identity), a notary public, a court, or a surveyor are all examples.

The trusted third party issues a token that contains legal information about the user's token. As a result, the user's token is connected to the trusted third party's token. This ensures that the law will be respected. If the user loses control of the token, they can request an update from the trusted party, indicating that the token is no longer valid. They also settle disputes and deal with any other legal problems that may occur.

3.6.1 Tokenization for CRE

This section considers tokenization for the Commercial real estate sector, as several of CRE's existing characteristics make it particularly well-suited for tokenization. By and large, a single CRE transaction is defined by a significant private market investment in an opaque data environment. This results in an investment ecosystem with slow transaction and settlement processes involving a large number of intermediaries (agents, sellers, purchasers, financiers, and insurers, to name a few), redundant verification processes, and duplication or backup data stored in isolated databases and registries. As one goes down the value chain, the problem becomes increasingly complex. Lease management, insurance, maintenance, lessee-lessor payments, lessor-investor payments, and reporting are all time-consuming and labor-intensive operations.

Due to the unique characteristics of the commercial real estate sector (high initial investment, relatively limited short-term liquidity, high management expenses, etc), individual investors are often prohibited from investing directly in commercial real estate. Several financial instruments, on the other hand, seek to decrease the frictions and costs associated with such investors' access to CRE exposure by providing indirect investment options. To name the most popular ones; public and private real estate investment trusts (REITs), real estate crowdfunding, real estate investment funds (REIFs), and real estate exchange-traded funds (ETFs).

With regard to securities that draw their value from actual, physical assets, the tokenization of those physical assets for the purpose of standardized, transparent, and tamper-proof record-keeping has the potential to provide enormous value for investors. This can, for instance, speed up due diligence processes and prevent substantial price dislocations resulting from a lack of transparency on the value drivers of the underlying physical asset (such as occupancy rates and maintenance history). In summary, it's not just about tokenizing securities, but also tokenizing physical assets; we believe that tokenizing both and linking them can provide significant benefits.

The negative impact of tokenization on big players in CRE

Some actors in the space will be harmed by increased data transparency and more efficient debt payment streams:

- In the present setting, larger institutional investors have the ability to conduct more regular physical inspections of properties; smaller players that have access to more data will profit the most from more transparent data.
- Automated payment streams to debt holders are anticipated to have a detrimental impact on debt servicers.
- Brokers are now a primary mediator and holder of information on commercial real estate properties; but, if data transparency is improved, their position and power may be diminished.

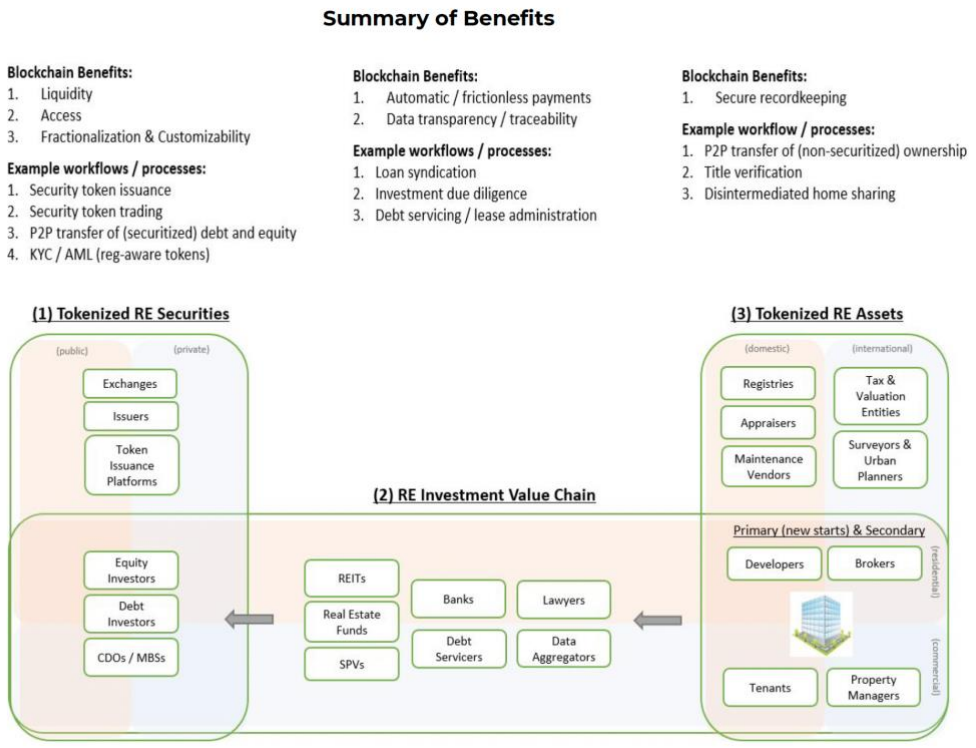


Figure n6. Summary of benefits of tokenization for CRE

- In light of improved record keeping, title insurers and appraisers may be under pressure to cut the cost of their services.

- Law firms that charge a percentage of real estate finance transaction expenses may see their job become increasingly automated as smart contracts become more standardized; newcomers that offer a flat fee may gain a competitive edge.

When considering the tokenization of real estate assets has the advantage of bringing liquidity to this market (liquidity is discussed in the following), an important question arises that how exactly it would differ from REITs? To address this question, first, we analyze REITs.

3.6.2 REITs

Simply put, A real estate investment trust (REIT) is a type of real estate investment business that owns, runs, or funds income-producing real estate.
REITs, which are similar to mutual funds, aggregate the capital of several investors. This enables private investors to receive income on real estate investments without owning, managing or financing any buildings.

- At least 75% of total assets should be invested in real estate, cash, or US Treasury securities.
- At least 75% of gross revenue must originate from rentals, interest on mortgages used to fund real estate, or real estate sales.
- Each year, distribute at least 90% of taxable income to shareholders as dividends.
- Be a corporation-taxable entity
- Be governed by an elected board of directors or trustees

REITs invest in a varied portfolio of assets, generating a diversified stream of income. When a REIT is formed, it issues shares that may be sold in three ways to investors. If the REIT is private, it is offered to qualified investors (accredited investors or Qualified Institutional Buyers) via a private placement. If the REIT is publicly traded and listed on an exchange, it can be acquired via the exchange. If an asset is publicly traded but not listed, it can be acquired through a broker.

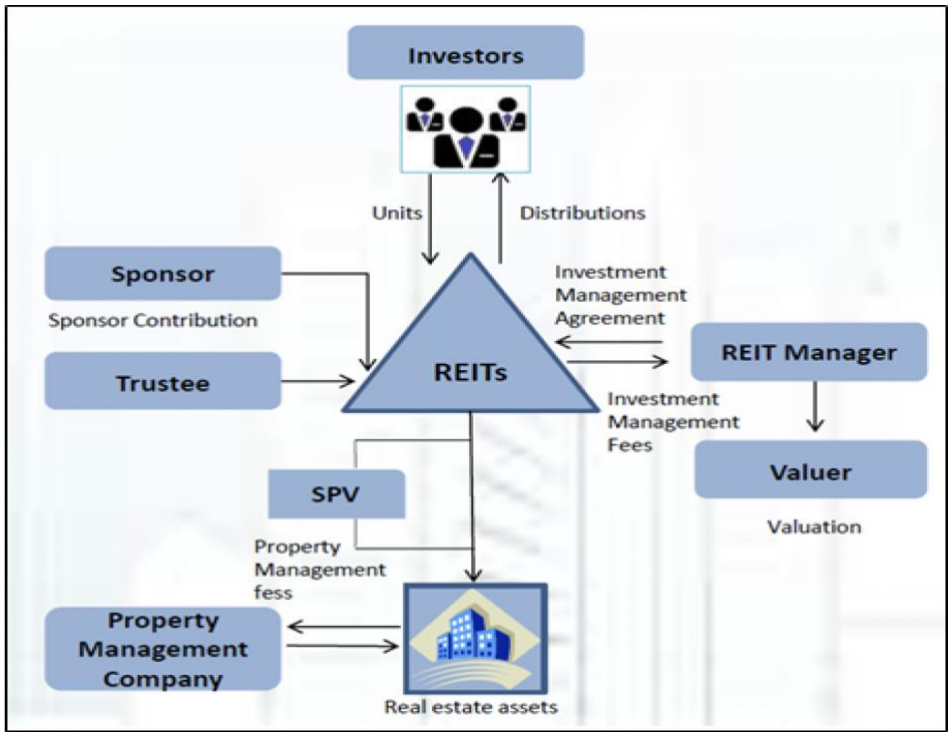


Figure n7. REITs

As an alternative to addressing the informational and structural issues associated with CRE investing, employing blockchain technology to create a token reflecting a financial instrument that invests in real estate is another possibility. Currently, the most often used process is to tokenize all or a portion of the shares in an SPV(special purpose vehicle) that owns all or a portion of a property. The SPV's (Special Purpose Vehicle) shares are kept by a custodian, who is also responsible for overseeing the tokens' initial generation. The tokens are then sold to investors (currently only accredited investors), who will be allowed to trade them in accordance with applicable legislation in the future.

The issuer would have total transparency into the ownership of any token at any moment in time under this scenario. Information, payments, and vote requests may all be sent simultaneously to all token holders via their blockchain address. By acquiring property-specific tokens, investors might increase their diversity and customizability. Issuers might develop different tokens for various real estate-related assets (land ownership, usage rights, infrastructure, and leasing cash flows, for example). Additionally, the issuer may define distinct classes within each type of token; for instance, senior tokens for fixed lease payments and junior tokens for variable lease payments. The flow of payments can be hard-coded into the token's contracts, giving a

layer of transparency throughout the token's generation as well as compliance and verification for each payment.

3.6.2.1 Aspen coin: a CRE tokenization example

Elevated Returns LLC is a real estate asset management company, which has issued a token representing ownership of Aspen Digital Inc, a Maryland corporation founded solely for the aim of acquiring the St. Regis Aspen Resort. The initiative raised $18 million, and Securitize (a platform for digital security issuance) served as the token issuer. The principal distribution was administered by Templum, a licensed broker-dealer and alternative trading system, while the custodianship was provided by Computershare (shareholder services). Indiegogo, a crowdsourcing portal, also assisted with marketing.

3.6.2.2 Public-listed REITs

Public REITs have historically underperformed private REITs in terms of returns. In addition, they are often valued higher than the underlying net asset value. As a result, retail investors are left with smaller profits. Furthermore, NAREIT (National Association of Real Estate Investment Trusts, Washington, USA) estimates that the entire value of the CRE market is between $15 and 17 trillion dollars. While the overall market capitalization of publicly-traded REITs is roughly $1.2 trillion.
This means that a large percentage of higher-yielding commercial real estate assets (around 93%) are out of reach for retail investors. Through the tokenization of private deals, it can make them available to a larger pool of investors. Retail investors (middle-class citizens) can have access to this part of the market which formally was only inclusive for accredited and institutional investors, or simply rich people.

Real estate investment trust (REIT) managers make all the decisions for retail investors, who have no say in how much of their portfolios are invested in real estate. If they're looking for a certain asset kind or location, they can't get it through REITs right now. Furthermore, direct real estate investing requires prohibitively huge upfront capital expenditures, which makes diversification almost impossible. On the other side, if real estate is fractionalized, these tokens would give investors the ability to fine-tune their exposure to the underlying. Even without a large amount of money, a retail investor might theoretically be able to own a stake in various properties throughout the world, or at least in countries that have legal agreements.

3.6.3 Crowdfunding platforms

The research paper by MIT (2019) claims that real estate crowdfunding has been a failure for a variety of reasons. The most claimed explanation is unfavorable selection. This occurs when assets that have been unable to attract funds through traditional financing methods wind up on crowdfunding websites. Consequently, despite their stated goal of giving access to the lucrative commercial real estate sector, the majority of these platforms ended up with low-value properties. We are not claiming that blockchain can tackle this issue, but rather that we should keep in mind to avoid repeating past mistakes.

The success of real estate tokenization will be determined by the quality of assets tokenized. Multi-year lock-in terms were another difficulty with crowdfunding. This locks up investor money and limits overall liquidity, even though some platforms provide a secondary market for these assets. Investors can sell their shares after a year on some platforms, but these secondary markets are locked. These assets may only be traded on the site that issued them, and frequently at a significant discount. We require compatibility with blockchain technology, even if the assets are issued on several platforms. To give the access and liquidity that a retail investor demands, we need secondary markets that can trade these assets.

3.6.4 Fractional ownership

A promising feature of tokenization which many refer to as **one of the most impactful potentials of blockchain technology in real estate** is fractional ownership of a single asset/building. Think of owning shares of a company on the stock market, where it's possible to sell it quickly whenever there is a need for it. This case study was also covered in the mentioned group paper by MIT university, and this thesis explores this idea from different viewpoints.

In terms of institutional ownership, MIT researchers believe that fractional ownership has substantial benefits and potential demand. Currently, Professional investors who want to diversify their real estate portfolios to control risk and maturity must frequently engage with many brokers to reach the necessary amount of diversity, incurring charges at each

broker. Professional investors may be able to fine-tune asset exposure and decrease overhead spent on brokerage fees if tokens representing fractional shares of specific assets are available, especially if bought in a peer-to-peer way which will bypass traditional brokers.
However, when it comes to property management, there is an issue. Property managers (either directly or through a third party) are frequently used by direct owners of real estate assets, such as REITs, to guarantee that their investment preserves its value.

Due to knowledge gaps and unbalanced incentives, tensions between owners and property managers are common. Property managers, for instance, are typically more concerned with having repairs completed fast than with doing so in a way that enhances the property's long-term worth as an investment. In the absence of professional institutional investors, the property manager would most likely be checked by brokers or a delegated third party (as individual retail investor monitoring would be extremely expensive), potentially offsetting the intermediaries and cost-saving impacts of adopting blockchain, peer-to-peer fractional share exchange.

The potential for retail investor demand for fractional ownership may not be evident, therefore some threats and advantages are listed below:

Bullish:

- Investors may have first-hand knowledge of buildings they often visit; fractional ownership will provide a mechanism for these people to invest in assets they are familiar with.
- Demographic trends and an aging population will fuel demand for these income-producing alternative investments among retail investors.
- Allowing retail investors to hold a fraction of a single asset makes it easier for them to realize what they're investing in and needs fewer disclosures.
- Some regulators (such as those in the United Kingdom) are more receptive to retail investor ownership of fractional shares in single buildings because of the clear investment value and disclosure requirements, as opposed to REIT investments, which often perform tasks other than pure real estate asset ownership and hence have more difficulty to understand value drivers.

Bearish:

- Demand may be weak, particularly if the absence of retail investor demand for crowdfunded real estate funds is any indicator; yet, demand for landmark building ownership may be strong (such as the Empire Tower)
- Due to the smaller market size, there will likely be minimal liquidity and a significant illiquidity premium for shares in single buildings.
- Even if the requisite data were accessible, most retail investors lack the ability to correctly evaluate real estate assets (and relevant data can be hard to obtain)

3.6.5 Token technology

Tokens are distinct from cryptocurrency. Typically, it is crypto-currency-based. To generate the token, the user needs to spend ("burn") certain coins and run programs based on the technology used. Additionally, cryptocurrency is spent to facilitate additional transactions involving tokens. For example, in Ethereum, Ether coins were required to pay for "gas" used to execute a smart contract transaction (Ethereum Wiki, 2017). Therefore, in these systems tokens can not exist without cryptocurrency.

To begin with token technology, a short description of both tokens and coins in the blockchain would help to better understand the concept, as with high variety in this emerging technology, it is necessary to define the features which are most helpful for title rights.

Beginning with the creation model: both tokens and coins have the ownership feature, controlling with user’s private keys, however, their method of creation is different:

- Coins: Coins are created as a result of competition between independent nodes in the network that employ a mathematical protocol that ensures an element of unpredictability (Konashevych, 2020a) in determining which node earns the right to create the next block, not the user, but the protocol defines the number of coins the node can earn for the block if it wins the mining race.
- Tokens: Tokens can be created freely by any user, and their generation is not dependent on the network's consensus. Nonetheless, the consensus is critical in this case for maintaining the ledger on which such tokens are stored.

In general, regulatory landscape variations may be an important factor that determines whether or not retail investor demand exists (or is even feasible) considering the availability of alternative options to obtain exposure to real estate as an asset class.

3.7 Outline

The blockchain serves as a decentralized, immutable public repository for land titles and other property rights documents. It is not just a secure database, but it also has a method for protecting ownership, as this is an integral part of the technology.

Tokens are digital records representing title and other property rights that are kept on the blockchain. A token is an account unit that is associated with the user's identification. The private key of the user confers exclusive authority over the address. The token is digitally connected to cadastral data (geo-data) and property rights, such as leases, mortgages, surface areas, etc. The connection between title records and real estate and property rights is maintained through blockchain records established by third parties with the authority to validate ownership, deeds, and real estate transactions.

The primary element behind ownership management is smart contracts. Blockchain transactions must include smart contracts. A blockchain transaction is similar to a legal document. The token record is always the outcome of a blockchain transaction, beginning with the token's creation and continuing through its various transfers (such as property rights or title documents) and deactivation if it loses value.

Tokens are distinguishable from cryptocurrency. The latter does not represent any specific quality and is itself a value since it acts as a transaction transmission mechanism, with users paying transaction fees in coins. In a broader sense, cryptocurrency is a reward for miners who construct and maintain the blockchain network infrastructure and ensure the security of the system.

Tokens are digital representations of titles in this scenario. Although title tokens serve as the basis for numerous derivative tokens that are not titles, but are related to them and form new property connections between economic entities, including new sorts of economic activity, they are not themselves titles.

When land titles and property rights are tokenized, there is no need to retain these records in a separate place, such as a traditional land (cadaster) register, because blockchain is a registry system by itself. Although the tokenization process will need early cooperation with land registry notaries, once the title is registered on the blockchain, there is no need to record each time a contract is made; the blockchain serves as a secure database for all transactions that cannot be rejected or changed.

With regard to securities that draw their value from actual, physical assets, the tokenization of those physical assets for the purpose of standardized, transparent, and tamper-proof record-keeping has the potential to provide enormous value for investors. This can, for instance, speed up due diligence processes and prevent substantial price dislocations resulting from a lack of transparency on the value drivers of the underlying physical asset (such as occupancy rates and maintenance history). In summary, it's not just about tokenizing securities, but also tokenizing physical assets; we believe that tokenizing both and linking them can provide significant benefits.

4. Adoption

In the preceding sections, this paper attempted to lay the groundwork for understanding what blockchain is, its benefits, and some of its challenges. In this section, the authors try to provide an overview of blockchain adoption Worldwide and then analyze the technological and legal aspects of mass adoption of this technology. To put it another way, this paper aims to identify the main *legal* and *technological* challenges that the real estate industry is currently facing and to provide solutions to these challenges. While outlining these solutions, the study also analyses the existing real-world projects and start-ups and how they are attempting to solve these challenges.

The first company to use a blockchain-based platform for sales and purchase of homes in the US is briefly studied, as well as their European competitor, Forsale, a start-up company that is accepted by Microsoft for startups founders hub program(receiving $3.5 million funds). We have interviewed the CEO of Forsale company, Alex Fernandes to reflect on his views and predictions for the future of RE transactions, opportunities, and challenges. Furthermore, we highlight the upcoming events, and how big players in the industry such as JLL, BlackRock, and Deloitte viewpoints on using Blockchain for the RE industry.

4.1 Adoption outlook

This chapter presents the most recent data and studies regarding the Blockchain industry, both cryptocurrency adoption and blockchain applications in the Real estate industry. Cryptocurrencies adoption figures are important to study as they are an undivided part of blockchain technology; they are the starting point for almost all blockchain-based projects and higher adoption of them in societies leads to higher and faster adoption of blockchain-based applications for real estate, in terms of educational and legal aspect for both citizens and governors.

A global study by GEMINI, one of the world's most well-known exchanges, among the top 10 in terms of Volume according to coinmarketcap, surveyed around 29,300 people in over 20 countries about their views on cryptocurrency, during the time period of November 2021 to February 2022. factors such as global adoption and barriers to entry are statistically illustrated in the report. The diverse mix of the report is considerable, an important aspect is incorporating people from every continent. Gemini attempted to achieve the most representative view of the adult population in each country, between the ages of 18 to 75, with yearly income of $14000 or more. While this number is considered low for western European countries, it is more common household income for other countries in the list such as Latin American and African countries.

Regarding the time that the survey was conducted, it is very important to analyze the Cryptocurrency market during that time period, as the people's perception of cryptocurrencies is heavily influenced by the state of the market at the time. During the Crypto bull market people are more curious about this industry, Greed indicator is at a peak level and retail investors may have the fear of missing out on the unbelievable gains during this phase of the market, in contrast, the bear market would be 1 to 3 years of downtrends for all crypto-currencies.

According to Coinmarketcap.com, the price of bitcoin at the beginning of November 2021 was over 60,000$, more than double the price of 29,000$ on June 20th, 2021 in just almost 4 months. After hitting an all-time high of 67,780$ on 8th November, bitcoin's price was on a downward trend, dropping to 35,000$ and ending the period at 40,000$. We believe it’s a helpful context to consider before analyzing the actual survey data.

Figure n8. bitcoin price June_Nov 2021

4.1.2 2021: The Adoption year

In this year, the Blockchain industry reached a tipping point, shifting from what many considered a niche investment into a globally recognized asset class, it was the breakout year for the industry. Venture capital investment in cryptocurrencies and blockchain startups has surpassed $30 billion, with more than $10.5 billion invested in Q4 2021 only. The market value of cryptocurrencies has nearly reached $3 trillion, and bitcoin has achieved an all-time high of over $65,000, making crypto the best-performing asset class over the last decade.
The report starts by illustrating the statistics regarding the number of people who bought crypto-currency for the first time in 2021. In the US, Latin America, and Asia almost half of all the people who own cryptocurrency, bought it last year. In details:

• Close to half of all cryptocurrency owners in the United States (44%), Latin America (46%), and Asia Pacific (45%), purchased their first cryptocurrency in 2021.

• More than half of cryptocurrency owners in Brazil (51%), Hong Kong (51%), and India (54%), began in 2021.

• In Europe, 40 percent of cryptocurrency owners began investing in 2021.

The pie chart represents the total number of participants in all countries:

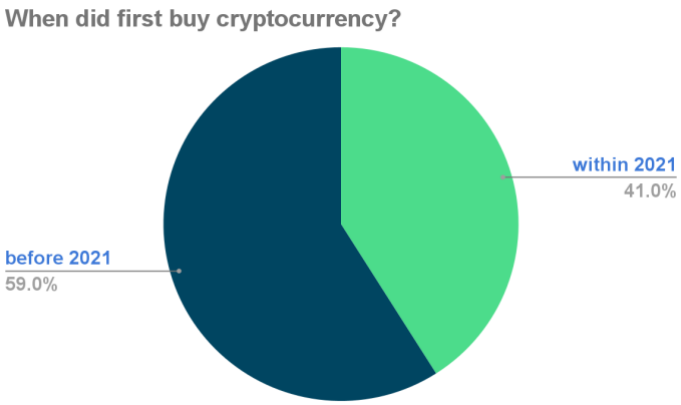
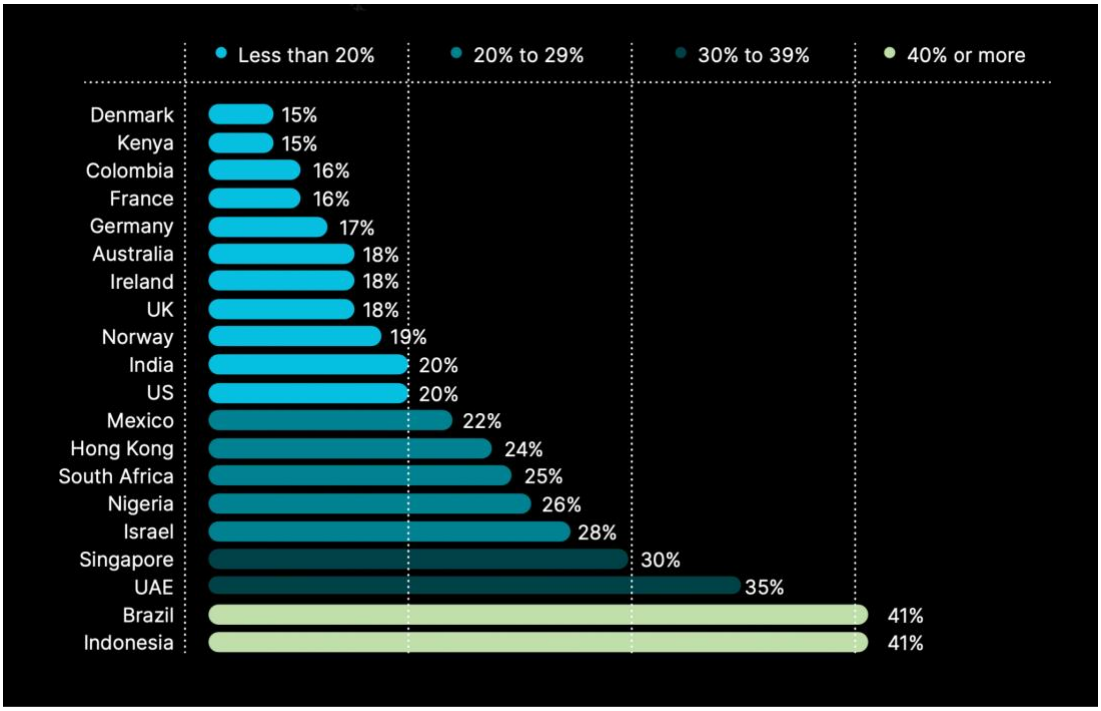
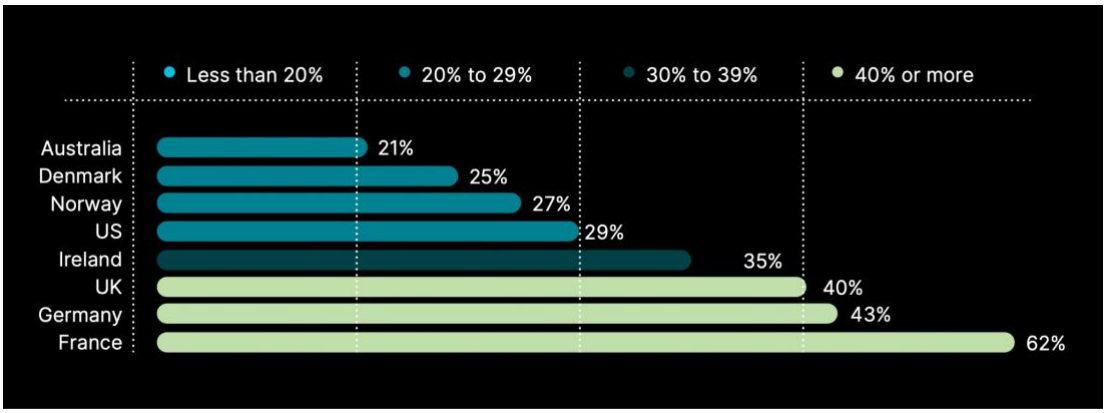


Figure n9. percentage of cryptocurrency acquisition before and within 2021

In the following, the chart illustrates the total number of responders in terms of ownership of cryptocurrency divided by countries:



Graph n1. Cryptocurrency ownership by country

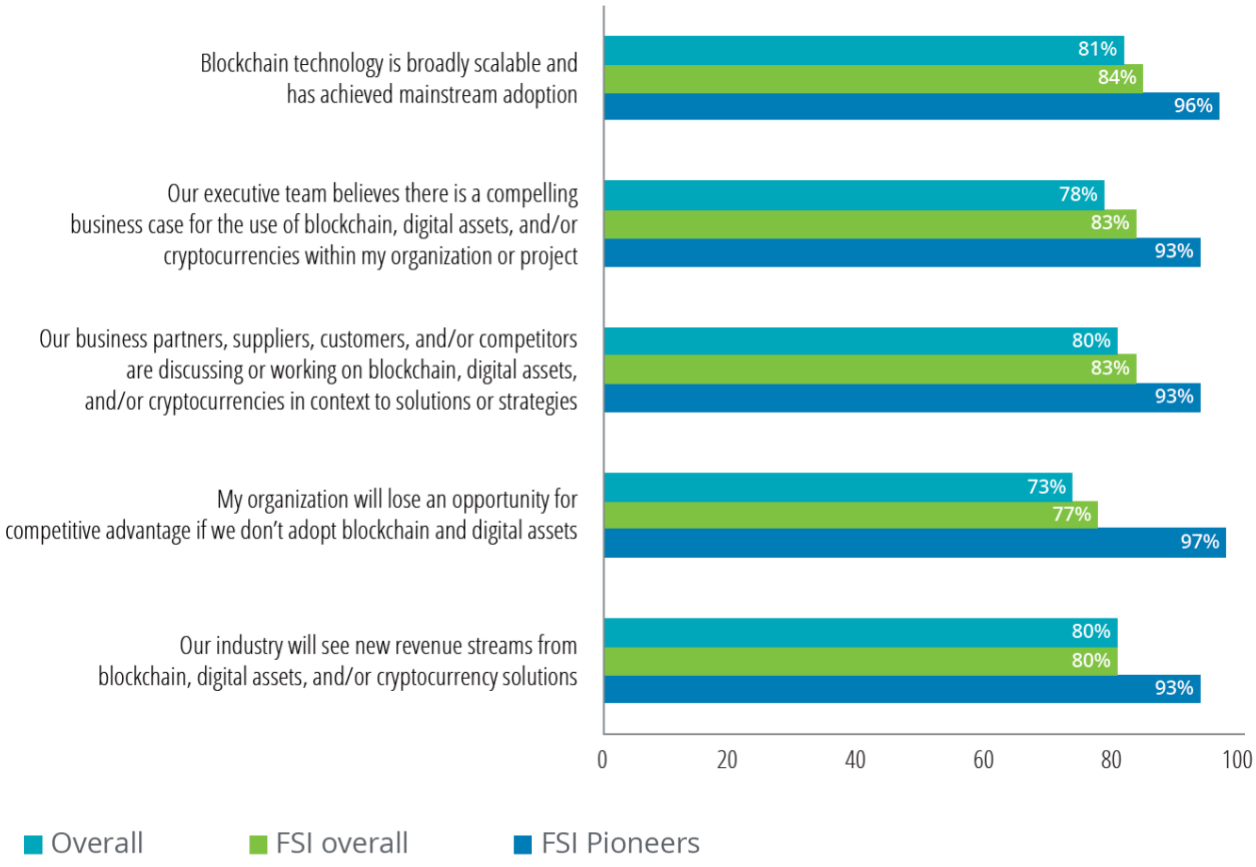


Graph n2. The crypto ownership percentage among high income class in developed countries.

In 2021, Deloitte company, the largest professional services network by revenue and number of professionals in the world, conducted a survey to assess the state of blockchain by professionals in the Financial Services Industry (FSI) who had at least a general understanding of blockchain.

A subset of FSI respondents on the cutting edge has been selected and labeled "Pioneers" based on a deeper data analysis. These are respondents whose firms have already used blockchain technology and/or integrated digital assets into their core operations. The vision of blockchain and digital assets as a top-five strategic goal separates the pioneers. In the poll, FSI pioneers are distinguished from the general population on the basis of their strong convictions regarding blockchain and digital assets' potential.

The respondents answer to the question “ What is your level of agreement or disagreement with each of the following statements”:



Graph n3. respondents to the question

When choosing between the role of digital assets in their organization and projects, pioneers stated the role of Tokenization to be more than 50 percent.

Graph n4. Percentage of respondents choosing " tokenization of assets"

4.2 Technological barriers

4.2.1 Scalability

Ethereum is the first blockchain (that enables smart contracts and has the largest community, projects, ext). As the number of Ethereum users and projects built on it has increased, the blockchain has surpassed its capacity limits. This resulted in a surge in network cost usage, demanding "scaling solutions." There are several solutions being explored, tested, and implemented that utilize different techniques to attain identical objectives yet are being developed, tested, and implemented concurrently.

Figure n10. The Ethereum ecosystem; companies using Ethereum Blockchain.

Scalability's primary objective is to increase transaction speed (rapid finality) and transaction throughput (high transactions per second) without affecting decentralization or security. On the Ethereum layer 1 blockchain, high demand results in slowed transactions and expensive gas rates. Increasing the network's speed and throughput is essential for Ethereum's significant and widespread adoption.

The 2017 bull market was the first time that Ethereum scalability issues had occurred. Many ICOs were launched which led to congestion of the network and a spike in gas fees. In 2020 the network congestion was even more extreme, caused by the popularity of DeFi and Yield farming. leading to gas fees ranging between 60$_100$ per transaction for a few weeks in the heat of the market. Having to pay this amount for a single transaction may be feasible for a large firm, but it’s unreasonably high for retail investors.

Experts would argue that Ethereum became the victim of its own success. Other blockchains are competing to provide a better ecosystem and attract people to build on their blockchain. Among them, the best to mention is the Solana blockchain, which successfully kept the average transaction cost at about 0.00025$ with the speed of about 2000 transactions per second. However, even Solana witnessed network congestion in late 2021, causing serious problems for the network for about 5-6 hours.

Selecting one unique blockchain exclusively for governance would inevitably generate problems. Due to its open nature, blockchain protocol does not prohibit the ledger's publication of spam information. Thinking of a country with an 80 million population, relying on one specific blockchain for RE transactions can lead to a massive disruption of service, considering the fact that most of the blockchains are in the top 10 (in terms of market capitalization) have experienced scalability issues in their history.

4.2.2 Price volatility

Due to speculation, the price may radically fluctuate, resulting in a negative user experience for individuals who use cryptocurrency to pay fees for publishing and managing data, performing smart contracts, etc. In conjunction with the previously described scalability limitations, this makes it impractical for the government to utilize or even declare its desire to use any particular blockchain. It will certainly incentivize agiotage on the market, hence compounding the problem of scalability discussed above. As might be expected, the permissioned DLT ultimately may seem preferable to blockchain due to its centralized character, which is designed to govern and prevent undesirable activities and manually resolve problems.

All in all, the technology has not reached its maturity. Both Ethereum and Solana, along with other competitors are working to solve the scalability problem with planned updates in the coming years, specially Ethereum Layer 2 update is expected to dramatically enhance the network functionality and reduce the gas fees.

4.2.3 Privacy and protection of data

As real estate is a strategic industry for every nation, practically it is a market for the land of that country, which makes it vital to protect this market. Thinking of an international platform that has access to real estate transaction data in different countries can be a serious threat, and also enables the company behind the platform to monopolize this huge pool of data, benefiting billions of dollars/euros with the option to manipulate the market.

Decentralization is one of the key components of blockchain technology, and although the company owner of the platform can not manipulate the ledger, having access to and monopolizing on a huge pool of data seems like going back to square one.
Alex Fernandes, CEO of Forsale company addressed this concern during our interview "*Our approach is to build our platform on Web 3.0 fundamentals. the customers will own their data, and only if they chose to share their data with the platform, they will be awarded. Forsale would not make profit by leveraging the massive data of customers, unlike the giant tech companies which play the intermediary role and monopolize the data of billions of people. As real estate transactions and agreements may be sensitive data and governments don't want these data to be shared with a platform, this approach of using web 3 is the cutting edge technology which guarantees the privacy of customers data.*"

Blockchain, the technology that eliminates and reduces human errors and corruption by creating an irrevocable and immutable ledger, is more competitive than a social contract based only on political promises and goodwill. Considering this fundamental conclusion and the obvious benefits of using blockchain technology to store property rights records, immutability poses difficulties that render this technology inapplicable until a suitable solution is developed.

For instance, in case of loss of the private keys, a coin, a token, or a smart contract will become uncontrollable, with little chance of ever being restored. Even though blockchain can eliminate many ownership conflicts, the imperfect nature of people's interactions will always lead to ownership disputes and the need to resolve them. Because typical retroactivity is impossible and no one save the owner of the asset's private key may make a transaction, blockchain itself does not provide realistic options for enforcing any valid judicial judgments or any rightful acts by authorities. As a result, permissioned DLTs may be justified as the sole viable alternative, but sacrificing the immutability and censorship features which were original values derived from the blockchain.

4.3 Legal Barriers

Real estate is a tangible asset, but it can also be viewed as a “bundle” of intangible rights associated with the ownership and use of the site and improvements. These rights are to the services, or benefits, that real estate provides its users (Ling, D., & Archer, W. (2012)) Thus it is very important to assess the legal challenges of blockchain in the real estate world. As worldwide blockchain investment grows, from 4.3 billion US dollars in 2020 to 14.4 billion US dollars in 2023, so does the number of legal challenges relating to blockchain. Although blockchain has the potential to drastically reduce real estate transaction costs, remove investment barriers, and improve real estate liquidity, many people are concerned about legal roadblocks to widespread implementation. The technology has yet to be fully regulated, raising concerns about its potential use in tightly regulated areas like real estate.

In the 2021 survey by Deloitte, 63 percent of the respondents who were working in financial service institutions chose “regulatory barriers” among the obstacles to the acceptance and use of digital assets globally, While 73 percent of pioneers, - a segment of these respondents who already used some practices of blockchain in their company- chose the same making it the highest voted obstacle by pioneers among different option including cybersecurity, privacy, etc.

In addition, every EU country has its own process and requirements, which is one of the reasons why cross-border transactions are decidedly difficult to accomplish, even taking into account the high number of projects intended to do so, such as the European Land Information Service (EULIS), abolished in 2018, the IMOLA I and II (Interoperability Model for Land Registers), CROBECO, as well as the EU Parliament’s “Cross-border acquisition of residential property in the EU: problems encountered by citizens” (Sparkes et al., 2016). The research in this section is based upon the research by (Garcia Teruel, R.M 2020)

4.3.1 Role of intermediaries in real estate transactions

As intermediaries can be an essential part of the real estate transactions in many countries and problems may arise when trying to complete a transaction through

blockchain, we will evaluate the overall role of intermediaries in different countries in Europe.

Once the transaction has been completed, it may be registered in the land registry, by "the competent authority for registering the transfer of ownership and the creation of interests in land" (Schmid and Hertel, 2005). It provides security of tenure and information to both the administration and individuals, about the object (e.g. a piece of land), the rights over this object (e.g. rights in rem, ownership, mortgage), and about the subjects of these rights (Vos et al., 2017). The land registry is kept by an independent a public authority (PT, ES, BE, NL, and Lithuania – LT), by the courts (DE, PL, Austria – AU, etc.) or by a public authority subject to instructions (CH) (Stöcker and Stürner, 2008). The validity of a real property usually does not depend on the registration (ES, PL, BE), except for some countries that do require this (DE, NL, CH, etc.) or with the possible exception of the creation of a mortgage (in ES, for example, the the mortgage must be registered to be valid).

Although it is an option, the involvement of these professionals is not compulsory in the majority of countries, that is, a transaction can be legally concluded without their participation, which gives room for the use of blockchain. However, regarding real estate agents, the ZERP Study of Conveyancing Services concluded that around 70 percent of transactions were facilitated by them (Schmid et al., 2007).

In addition, in Spain and Poland, a public deed is only necessary if parties want to register their right (which is only compulsory in mortgages), but not when conveyancing real property or when leasing a dwelling (although it is quite common to do so because of the legal certainty that it provides). Also in Italy (IT), Luxembourg (LX), Portugal (PT), FR and BE even oral contracts are valid, but if parties want to register the agreement, they have to obtain a public deed. In Slovenia (SL), Slovakia (SK), AU, and CZ, parties need a certificate that validates their signatures, which is issued by a notary (SL, SK) or by a court (AT, CZ) to register the contract.

When acquiring a property through a mortgage loan, the number of professionals involved increases. Apart from the optional use of attorneys, who draft the contract and to assist the parties, and managers, who are in charge of paying taxes and other bureaucratic paperwork, it requires the involvement of a property valuator and the bank

that grants the mortgage to acquire the property. Furthermore, as commented above, the granting of a mortgage is one of the cases where in some jurisdictions it is necessary to have the agreement documented by a notary and entered into the land registry (e.g. in Spain, art. 145 Ley Hipotecaria 1946[7]). Thus, the granting of mortgages through a blockchain would be a more complex case, as either a connection with current registries or an amendment of existing legislation would need to be implemented.

4.3.2 Stakeholders ID Verification

A public blockchain's inherited features mean that an anonymous user can theoretically sell and buy within the blockchain network, and this feature, as previously stated, helps to ensure the security of the entire blockchain platform. The real estate market, on the other hand, is structured in such a way that is in many cases impossible to perform the transaction without knowing the identity of the parties, some of the reasons are listed below:

- for the financial institutions to be able to give loans and mortgages on houses, they have to know the identity of the loaner so they could verify the financial capacity of the person and to be able to condemn the person in case of lack of repayment of the loan.

- In nearly every legislation of any country, in order for the person to have the right to use the asset and to gain profit from it, it must be known who owns that real estate.

- Individuals must have certain status to be eligible to buy/sell or rent houses in a country, for example, they must be over a certain age or have certain residency status or a certain nationality.
- In order to stop money laundering and certain financial frauds, the identity of the stakeholders involved must be known, as studies show that real estate has reached crimes worth $1.6 trillion annually.

These two sides of the coin can offer some obstacles to blockchain adoption in the real estate industry, and in this section, we'll go deeper into the potential solutions to this problem, the problem of regulating interested parties' IDs.
One of the main solutions proposed to this problem that the authors think has a lot of potentials is the Self-Sovereign Identity which is discussed in detail in the final chapter of this section.

4.3.3 Land Registry

The majority of countries' present land registry systems are paper-based, which results in significant resource loss and time-consuming bureaucratic procedures for registering land. In our interview with Alex Fernández, CEO of Forsale Company, one of the leading startups in the real estate blockchain sector, he cited the land registry as the greatest legal challenge his startup has faced and urged the countries to digitize the land registry process.

In some nations, such as the United States, real estate transactions are conducted peer-to-peer and by deeds, and registration is optional. In other nations, where the central government is required by law to ratify the contract, this issue can result in numerous disadvantages.

Several countries have made significant strides in this area, with the United Kingdom and Sweden attempting to migrate from paper-based to digital registration while Estonia has already accomplished this.

4.3.4 Legality of the contract

In a survey conducted in 2021,(Deloitte’s 2021 Global Blockchain Survey. (2021)), more than 40 percent of people with at least minimum knowledge about blockchain chose “smart track enforceability” among the option that would facilitate the adoption of blockchain.
In some jurisdictions, lawyers, notaries, and even land registries verify that a real estate transaction is completed in accordance with the bare minimum of legal requirements, and they tell the buyer about past encumbrances and rights in rem over the property. For example, they are required to detect and notify parties about potentially unfair terms in mortgage loans, or notaries are in most cases responsible for monitoring transactions to prevent unlawful funding activities. Blockchain, as a distributed database, cannot provide the same level of information about the repercussions of a transaction or do a prior review of the legal requirements on its own. Blockchain and smart contracts, which simply check for the fulfillment of pre-conditions, do not now provide for this control.

The application of smart contracts in real estate is still in its early phases, and since there hasn't been much practice with this technology in real estate contracts, we can't predict how any legal body would react to smart contracts as contracts of real estate.

Although many researchers and experts believe that as long as the contract meets the legal requirements for a contract to be valid, the court should treat a smart contract as a normal contract. For example, in the United States, there are three legal requirements for a contract to be valid and thus enforceable by law, which are the requirements of "offer," "acceptance," and "consideration." If these requirements are met, the contract is legal.

Given that legislation may be a little stricter when it comes to real estate contracts, the presence of a notary in the real estate contract is required by law in some nations, and that tends to add the middle man to real estate transactions that blockchain seeks to eliminate.

In a real-world example, a startup named Velox.re claimed to have successfully transferred real estate via blockchain and, more significantly, to have been able to

legally authenticate the transaction by a central government, in this case, the United States. Although it should be noted that in the United States, counties are responsible for contract registration, and also the registration itself is optional, the law may be a little less strict than in Europe, and each county's legislation may differ slightly from one another.

Intermediaries/ transaction	Real estate agent	Notary	Land registry	Other
Renting a property	Common practice	Not a common practice	Not a common practice	An administrative registry might be compulsory (e.g. registry of bad landlords or registry of deposits)
Purchase a property	Common practice	Common practice (in countries where they exist). If parties intend to register their rights, a notarial deed is usually required to do so (ES, DE)	Common practice. In some countries, registration is compulsory (DE, NL, CH)	In some countries, although registration is not compulsory, parties need to validate their signatures before a notary to access the land registry (e.g. FR, IT, LX, PT)
Purchase a property with mortgage loan	Real estate agents in Nordic countries are usually involved in this process; this is normally due to the shortage of notaries. In other countries, it is common practice to use a real estate agent	Compulsory in some countries	Compulsory in some countries	When mortgaging a property, the participation of a bank and a property valuator is also required

Source: Own elaboration

Table I.
Intermediaries in real estate conveyancing

Table n1.Legal challenges and opportunities of blockchain technology in the real estate sector Rosa M. Garcia-Teruel

4.4 Self Sovereign Identity

In the previous section, we proposed self-sovereign identity as a possible solution to the ID verification problem, and in the later section, we will propose a framework with the self-sovereign ID being a key part of it but first, we will look at how specifically will this technology work.

Let's first look at all the different models of digital identity, Siloed digital identity was the first model of digital identity. A user was given a digital identity credential by each organization in order to use its services. For each new organization with which he interacts, each user needs a new digital identity credential. This results in a bad user experience, we can all recall having to register for every website we wished to use.

The Federated model of digital identification is the second option. Third parties began giving digital identification credentials that allow users to log in to services and other websites as a result of the first model's bad user experience. The "Login with Facebook" and "Login with Google" features are the best examples of this. Companies "outsourced" identity management to huge corporations with a financial stake in gathering large databases of personal information. This, of course, raises issues about privacy and security. Facebook, Google, and others become trusted intermediaries.

With the emergence of Blockchain technology, Decentralized Identifiers, and Verifiable Credentials, a third model of identity emerged: Self-Sovereign Identity.
A Self-Sovereign Identity is one that you have control over. Only you have access to it, as it is stored on your digital identity wallet, and only you determine who gets to "see" it and how much of it they get to see.
So, how is a Self-Sovereign Identity different from the Physical IDs and present Digital IDs listed above? What makes SSI superior?

Between the ID Issuer, ID Owner, and ID Verifier, a safe and digital peer-to-peer channel is established. Even the provider of the Self-Sovereign Identity system has no idea what is being communicated when credentials are transmitted. The process of issuing credentials becomes easier and faster. Through the use of encryption, SSI Credentials are tamper-proof.

They're personal and under your command. The selective Identity Disclosure technique is used by SSI. The ID Owner decides whatever aspects of their identity they want to "display" and maintains complete control over their interactions with ID Verifiers (knowing what data is being shared).

Credentials for Self-Sovereign Identity can be validated anywhere, at any time. Even if the issuer no longer exists (with the exception of cases where credentials were issued using Private DIDs and the issuer's DID was not written on the ledger).
Personal information is not kept on a centralized server. To steal 50 million digital identification records, hackers would have to hack each of the 50 million people individually. Significantly more challenging. Self-Sovereign Identity aims to eliminate the need for several passwords, all you need is your wallet password.

How will this technology work? To better demonstrate the use of this ID we will explain it through one of its current applications performed by TYKN company in Turkey to help the government increase refugee employability by issuing work permit applications digitally through this platform.

In order to hire refugees, (Syrian) business owners must fill out a Work Permit application. This is a time-consuming and paper-based approach at the moment. Several Syrian entrepreneurs went to the Chamber of Commerce to personally verify their identity. The Chamber of Commerce used TYKN SSI Portal to provide them with a digital cryptographic proof, known as a Verifiable Credential, confirming that they are a legitimate business.
Those credentials were saved in the digital identity wallets of Syrian entrepreneurs. SSI's Mobile Wallet is a convenient way to keep track of your money on the go. Entrepreneurs were able to initiate a Work Permit Application without leaving their Mobile Wallet and use their Verifiable Credentials to confirm their identity and that they run a registered business by using their Verifiable Credentials.

Job-seeking refugees may be able to request digital credentials in the future, such as the Work Permit or Residence Permit. They'll be able to store those credentials as Verifiable Credentials in their Mobile Wallet and use them to prove their identity and access services right from their phone. Creating processes that are less time-consuming, bureaucratic, and expensive.

4.4.1 Underlying Technology

The three pillars of Self-Sovereign Identity consist of Blockchain technology, Decentralized Identifiers, and Verifiable Credentials.

4.4.1.1 Verifiable Credentials

The physical credentials we use on a daily basis, such as ID Cards, Driver's Licenses, Health Insurance Cards, and even University Diplomas, seldom have a digital equivalent. How could a digital credential, a digital asset, be as trustworthy as the government-issued physical ID card?

"Verifiable credentials represent statements made by an issuer in a tamper-evident and privacy-respecting way," as stated by the W3C.
In summary, Verifiable Credentials enable the digital watermarking of claims data through a combination of public key cryptography and privacy-preserving mechanisms that prohibit correlation. This has the effect that not only can physical credentials now be safely converted to digital ones, but holders of such credentials can selectively disclose specific information without exposing the actual data for instance proving the legal age for drinking alcohol without representing ID card and third-parties are instantly able to verify this data without contacting the issuer.

The following W3C diagram illustrates the interaction between an ID Issuer, an ID Holder, and an ID Verifier, as well as how a Verifiable Data Registry (the blockchain) is used to verify credential data without contacting the issuing party.

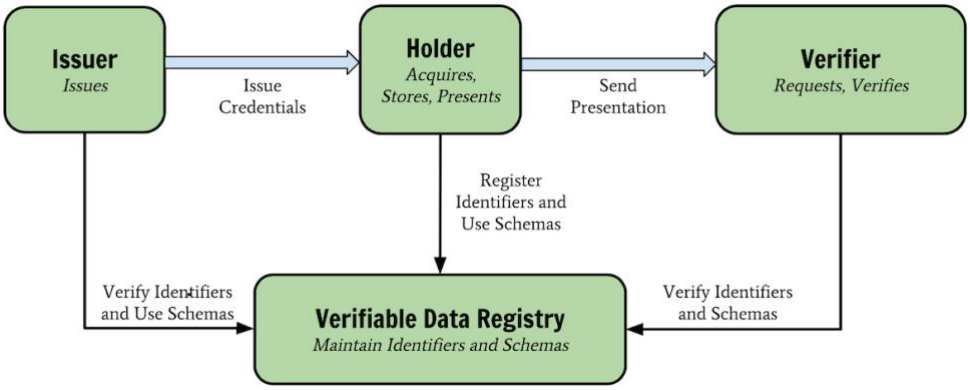


Figure n11. Verifiable credentials diagram

There are two distinct degrees of privacy protection:

4.4.1.2 Selective Disclosure

In selective disclosure, one can construct proofs using only a subset of a credential's properties.
For example, if one needs to confirm his/her age using a Driver's License but do not wish to provide address, it can be done so by omitting the address from the credential.

Zero Knowledge Proof

In ZKP, the attribute of a credential can be validated without revealing its value.
Using the preceding example of a driver's license, it can be demonstrated that the age is older than 18 without disclosing date of birth.
A Zero-Knowledge Proof is a type of authentication that, via the use of cryptography, enables one entity to demonstrate to another entity that it possesses specific information or satisfies a specific criterion without disclosing the actual information supporting that proof. Therefore, the entity verifying the evidence has "zero knowledge" of the facts supporting the proof, but is "convinced" of its validity. This is especially beneficial when the entity proving the information does not trust the entity verifying it but still needs to establish its knowledge.

This is used by Verifiable Credentials and Self-Sovereign Identity to allow an individual to demonstrate that their personal information meets specific conditions without revealing the real information.

One may, for instance, demonstrate that she is older than 18 without providing her actual date of birth.

4.4.1.3 Decentralized Identifiers

DIDs are a fundamental component of Self-Sovereign Identity. It enables the establishment of safe, private, and one-of-a-kind peer-to-peer connections between two parties.

Identifiers from intermediaries such as Google, Facebook, email providers, and mobile network operators are currently used to connect us. This has significant repercussions for our privacy, as we have no control over the (meta)data collected by these parties through our interactions across these links.

Even when utilizing an encrypted messaging service like WhatsApp, Facebook can still observe and gather their client's metadata. This alone might reveal the contacts messaged, when, for how long, at what intervals, from where, and while using which applications.
There are two forms of DIDs: Public DIDs and Private DIDs (also known as "peer", "pairwise", "pseudonymous", and "pairwise-pseudonymous" DIDs).

Private DIDs can be exchanged between two parties to provide a secure, non-public route. This indicates that no third party is aware of what occurs on the channel or who is behind it. The highlight? Without relying on a central authority, many distinct DIDs can be generated for as many distinct associations as one see fit to prevent the correlation of private information. No more unwanted race bike advertisements! (Or election interference, ideally)

In a world where private DIDs are the norm, public DIDs are only used when an individual desire to be publicly known (e.g. a government office issuing passports). Additionally, they might be used to initiate the trade of private DIDs between parties.

So, what does this actually mean? Imagine that the government wants to provide individuals with both a physical and digital passport. An individual intends to secure the physical copy at home and use the digital copy for practical purposes.

The municipal service desk requests to scan a QR code. The DIDs are exchanged at this point, establishing the secure connection. The clerk now offers the individual the digital passport in the form of a Verifiable Credential via this secure connection. He/She accept and store the currency in your (digital) wallet.

If, for example, the individual then decides to purchase a bottle of wine , and the clerk requests identification, a QR-code can be produced from the wallet that verifies the individual's legal drinking age since he/she may have reservations sharing private information with a stranger (e.g., full name, date of birth, place of birth, document number, etc.)

The cashier scans it (again, exchanging DIDs and establishing a secure connection) and checks that this identification is authentic and comes from a valid, government-issued form of identification. All of this is performed automatically on the backend, in part by verifying the public DID of the municipality, together with the schema, credential definition, and revocation registry, which are all registered to the verifiable data registry, or blockchain.

DIDs benefit institutions and organizations that issue or verify identification. Their decentralized structure enables identity verification at all times. Unlike a system where identification is stored in a centralized database that could be rendered useless if the database goes offline for any reason, this system does not rely on a centralized database.

The infrastructure of a blockchain allows verifying parties to check the authenticity of the attestation and attesting party (such as the government) rather than the veracity of the actual data in the presented evidence, allowing them to select whether or not to validate the proof.
For instance, when an identity owner presents a proof of residency, rather than checking the residency itself, the verifying party will validate the signature of the government

official who issued and attested the credential, and then decide whether he trusts the government's assessment of the data's accuracy. Therefore, the validity of an evidence depends on the verifier's assessment of the attestor's credibility.

By leveraging blockchain technology, Self-Sovereign Identity fosters confidence between parties and ensures the legitimacy of data and attestations, without storing any personally identifiable information on the blockchain.
This is vital because a distributed ledger is immutable, meaning that anything added to the ledger cannot be changed or removed, and hence no personal information should ever be added.

An example of the Self-Sovereign Identity platform's architecture:

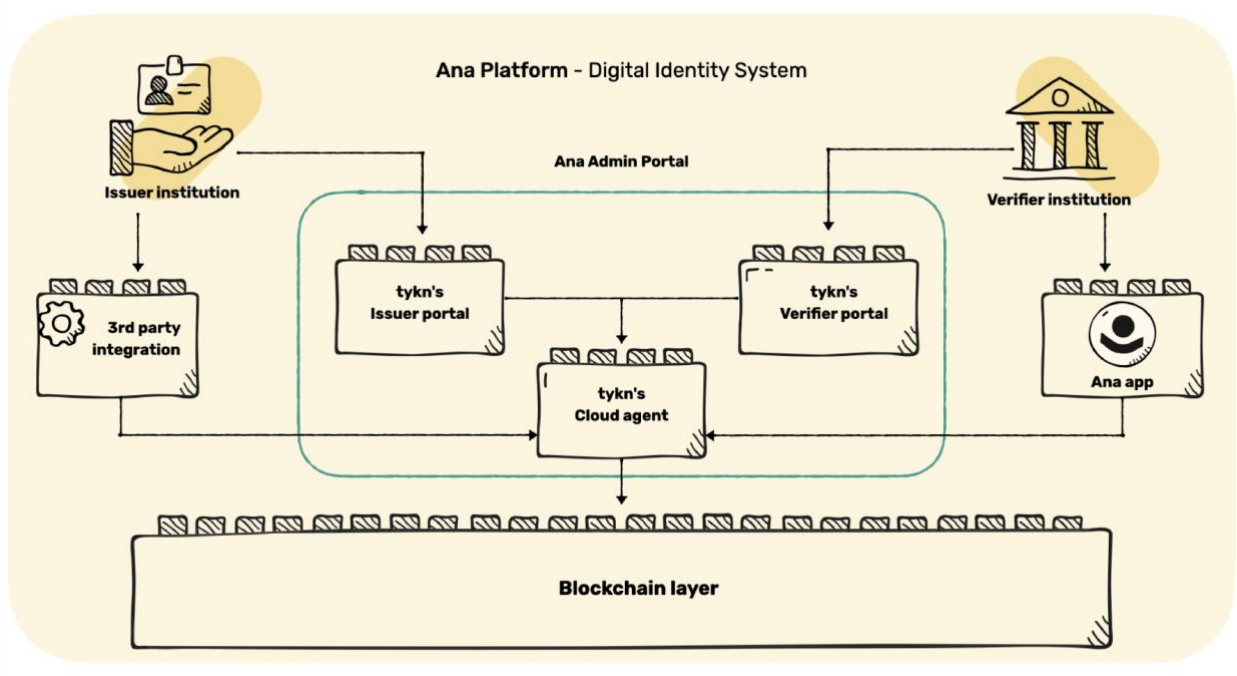


Figure n12. Self-Sovereign Identity platform's architecture

4.4.3 Legal considerations

The legal assessment is still in progress and focuses primarily on the legal implications and relationships of using DIDs and verified credentials (VCs), as well as the alignment of SSI solutions with the eIDAS regulation. In addition, the trust framework raises legal problems about the legal input of the level of assurances (LoAs), governance aspects, conformance, etc.

eIDAS is a European regulation that includes "electronic identification (eID) and electronic Trust Services (eTS), which are key enablers for secure cross-border electronic transactions and central building blocks of the Digital Single Market [...] a landmark to provide a predictable regulatory environment to enable secure and seamless electronic interactions among businesses, citizens, and public authorities." (2015) (EU Commission).

In essence, they standardized and recognized various forms of electronic signatures [simple (SES), advanced (AES), and qualified (QES)] and electronic services in order to harmonize legal aspects of cross-border communication between member state implementations while simultaneously enhancing convenience and predictability for the parties involved.

The significance of eIDAS for SSI stems from the fact that the regulation is the primary basis for electronic identification trust in the EU. It might be extended to include the recognition of eIDs for private sector uses, such as AML/CFT, online platforms, and so forth. It is a technology-neutral strategy that has a significant impact on the international regulatory environment.

This is essential for identity attribute validation. By presenting identification documents recognized in accordance with the eIDAS rule, it is possible to verify the information that will be contained in a verifiable credential. The primary benefit of this approach is that the verifiable credential inherits the level of assurance of the eIDAS electronic identification means, allowing a person with this type of eID to obtain multiple verifiable IDs and leverage their use in the space of decentralized transactions, thereby gaining true privacy.

To be addressed, however, are a number of legal challenges, such as the legal ramifications of on-ledger transactions, the definition of rights and obligations, and the legal consequences of eIDAS and the GDPR for all parties.

5. Proposed Framework and Findings

5.1 Framework

Throughout this research, our goal was to deliver a clear vision of how blockchain-based applications for the real estate industry can be implemented, the main challenges in the way of its mass adoption with a special focus on legal and technological aspects, and finally to propose ideas and findings which could be a solution to the aforementioned challenges.

Based on the foundation we have built in the early stages of this paper, we have covered nearly all the applications of the blockchain in real estate as well as its relevant challenges. We have provided a proposal, a ***base foundation, and a framework for Blockchain based applications*** to develop upon. Later on, a few recommendations are presented with the aim of helping politicians, researchers, and other stakeholders in the decision-making process in this realm.

*The framework includes new ideas, and a combination of our findings to deliver a ***framework*** that clearly provides steps and requirements needed for the development of blockchain platforms and applications. With the broadness and complexity of the real estate industry, and novelty of linking blockchain technology with Real estate transactions, and unique regulations in each country, this framework is intended to be fundamental yet general and as wide-ranging as possible, to cover a global perspective.

Our approach in this chapter is to first present the framework as the whole, and then break down its components and process in detail and steps, as we believe this approach will help with the clarity of context and prevents readers from losing the whole picture.

5.1.1 Current Issues

As discussed in the previous chapters, blockchain applications in real estate face several legal and technological challenges. Including but not limited to:

- ID verification problems due to inherent anonymous characteristics of Blockchain
- Law Enforceability of smart contracts
- The necessity of Notaries in the real estate transaction process

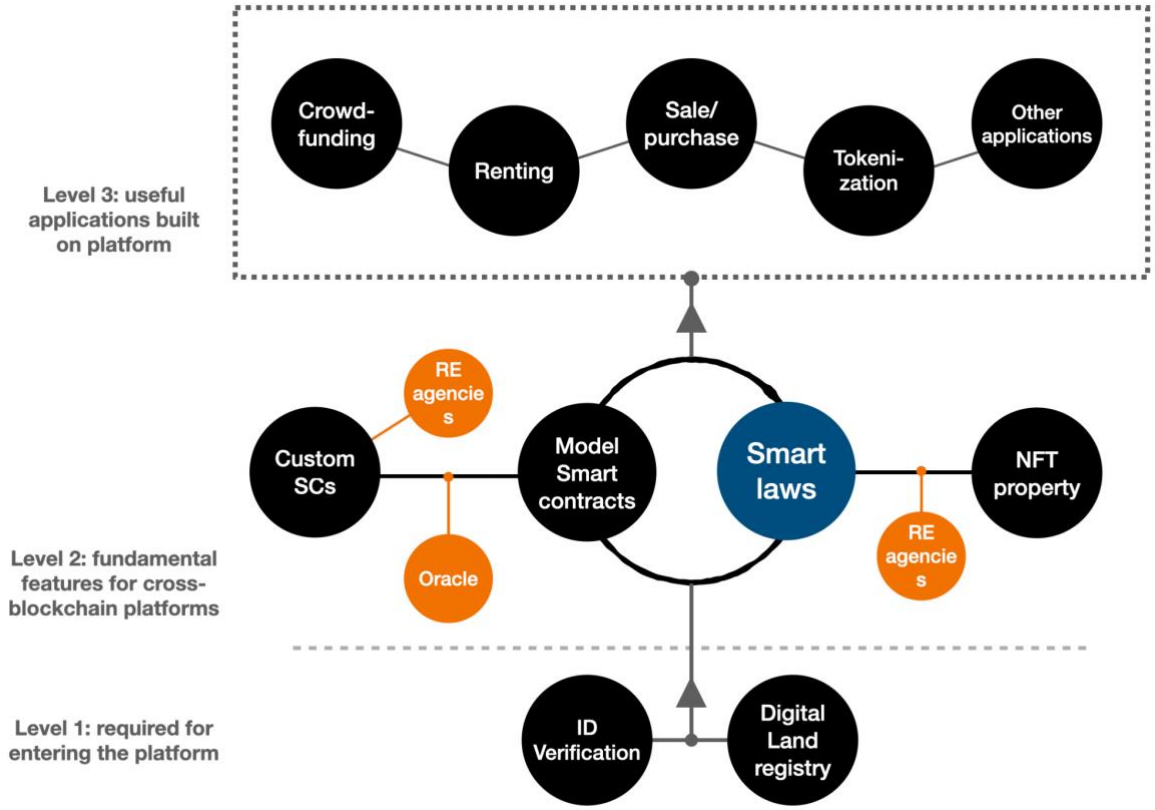
In addition current real estate practices also include procedures that at the very least could use enhancement, some of the current problems are:

- Single point of failure of current central land registry database
- Relatively time-consuming process
- Prone to fraud and corruption
- Illiquidity of the real estate market
- Lack of transparency

Our proposed framework aims to overcome most of the above-mentioned issues.

5.1.2 Framework abstract

Our proposed framework is presented below:



n13. Framework overall diagram

1. In the first level, initial cooperation with land authorities is required, to register the deed on the blockchain. along with a self-sovereign ID proposal which the process is explained in later stages. Once the title and property rights are on the blockchain, *there is no need to keep the record for each transfer and transaction of that title, as the blockchain is the registry itself.* All the data will be recorded in the blockchain forever, even non-eligible transactions are recorded but won't be executed. The data remains in the ledger for any possible conflict in future and legal reasons.

2. Level two is the fundamental infrastructure that needs to be met by ***governments and central authorities, in order to create the base foundation for blockchain platforms to develop upon.*** In our framework, Platforms are almost like the existing RE listing platforms such as Immobiliare, Idealista, Zillow, etc.

Smart laws, which are explained in detail in chapter 5.1.5.2, are a set of rules, programmed into algorithms that monitor transactions and automatically reject illegal or non-eligible activities. Smart laws are to be introduced by governments, and since they're algorithms, they can be adapted to any preferred blockchain.
Model smart contracts are the common rental and purchase/sell paper contracts that are

unique to every nation, turned into model smart contracts, and will fit the majority need of citizens(about 80%). However, these default model contracts can not meet the need of 100% of citizens, that's when customized smart contracts comes in; they can be asked by stakeholders to be done by platform provider or other RE companies active in this area.

NFT-ing a property is also done by a certified RE agency or Land authorities, which can be a paid service for landlords. The NFT will be sent to owners wallet. Issuing NFT for title deeds opens the door for tokenization of the asset, and significantly improves the protection of ownership rights. Moreover, NFT makes double-spending impossible. as during each transaction, the NFT will be locked into the smart contract, and when all the conditions are met and money is transferred from buyer to seller, the NFT which represents the ownership of the title will automatically be transferred to the buyer's wallet.
Lastly, By NFT-ing a property, ownership of the property can be transferred from one wallet to another in a secure manner, as the outcome of a fair auction on smart contracts. Documentation, disclosures, and title insurance are associated with the NFT.

3. Level 2 set the ground for creating Blockchain-based platforms by any RE company which is verified by the central authority of that country. Now, through an open market, RE companies compete to deliver a better platform for the customers, which leads to more innovations and higher efficiency in the market. Just as existing property-listing websites are a platform for RE transactions, these or any other companies can develop blockchain-based platforms and profit from selling their service to customers.

For tokenization of an asset, think of buying shares of a company, but now that liquidity is brought into the RE market. The process of tokenization of a title is done by a certified agency/notary, all data related to the property is recorded in the related smart contract and after issuing tokens, they can be transacted in the platform market. However, we need the RE agents to physically visit properties and evaluate them, including cost and revenue estimations of the property, be held accountable for it, and then list them on their platform. Smart laws make sure all platforms are following the regulations Simultaneously.

Other activities such as renting and crowdfunding are other services that can be provided by the platform provider.
Important note: in this Model, if one company or an operating blockchain shut down or witnesses network issues due to any reason such as technical or other problems, the ledger remains immutable and untouched, As it is distributed among numerous computers. Citizens can immediately switch to another platform provider and the risk of interruption and a single point of failure is avoided in this massive and vital industry.

5.1.3 The Process

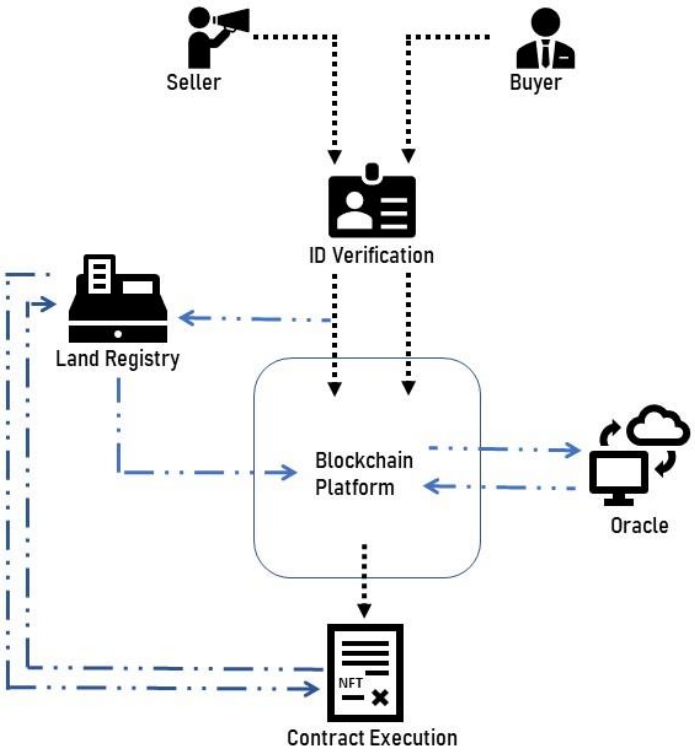


Figure n14. Framework steps diagram

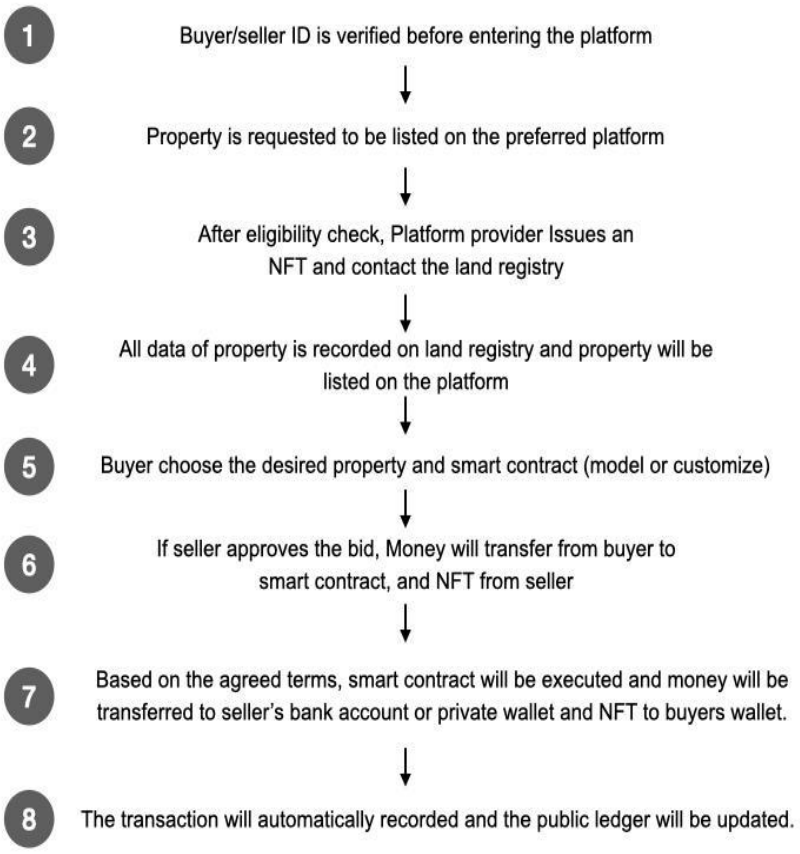


Figure n15. Framework step by step explanation

5.1.4 The Steps

In this section, the process is explained step by step:

1- In the first step, the buyer and the seller are asked to verify their ID using a third party or a self-sovereign ID platform, the Idea, which is explained in detail in the following stages, comprises an Identity wallet, in which people are asked to upload some documents and/or show up in person to verify their ID and the genuinity of the document to the organization that provides the ID wallet or is any other organization that is considered lawful bu government. The wallet acts as a liaison between the person and the government and sends the person's document to respective government sections for

verification. These documents could include birth certificates, passports, residency cards, work permits, licenses, etc.
With these documents verified by the government, the wallet can issue IDs or QR codes based to check the eligibility of a person to perform a certain task. In our example, having all the necessary verified documents in the ID, if the website asks to check if a candidate meets a certain age or residency status to see if he/she is eligible to buy/sell houses in the country, this can be done easily and quickly through this Self Sovereign ID. To conclude the buyer and seller will pass these steps so that their eligibility would be assessed to conduct selling and buying activities.

2- When the seller inputs the title data into the platform, using its verified name in the previous step and the data provided for the house, the platform, sends a request to the registry database to see if the data is valid, and as we discussed before, this validation can be achieved through Zero-knowledge proof so that the platform does not have any access to the registry database. When the validation is complete the property will enter the platform pool.

3- The platform provider which is a certified real estate company/notary, creates an NFT, which is a proof of ownership representing all the data about the property and sends it to the landlord's Wallet. By NFT-ing a property, ownership of the property can be transferred from one wallet to another in a secure manner, as the outcome of a fair auction on smart contracts. Documentation, disclosures, and title insurance are associated with the NFT.

4- The Land registry will be updated by the newly issued NFT and now property can be listed on the platform.

(5)- Buyer choose the desired property on the platform. the options for buying properties are filtered for every individual based on their data which is checked in the first ID verification phase. For example, if an individual is not lawfully eligible to buy a property due to his age or residency status, the options will be filtered out or will be shown as “not available” for that certain individual automatically. the platform will crosscheck automatically based on the smart contract data (clauses of contract), individual’s

personal data, and the legislation of the country to see if the person meets the requirements.

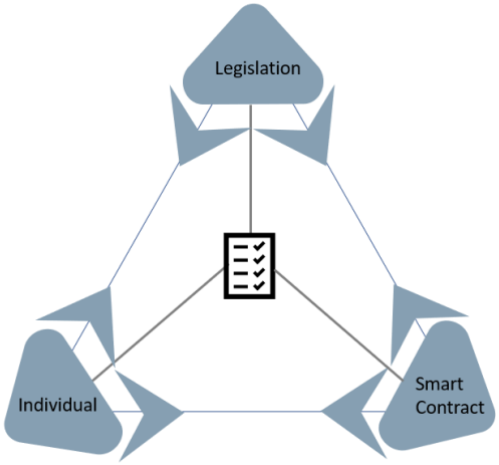


Figure n16. The cross-checking mechanism to contract validation

6- In the case of model smart contracts, the highest bid will win the auction on the platform, and money from the buyer and NFT from the Seller would be locked on the smart contract.

In case of customized smart contract, this will happen after all the terms in the customized smart contract are met. The customized smart contract is written with help of RE companies/notaries and therefore the legibility of the contract is preserved. This action can be done through oracles. As defined earlier, oracles are off chain solutions that can be embedded in a smart contract to check for something outside of the code and to send back the result through codes into the smart contract. In this stage, the RE agencies and authorized notaries can act in the form of oracles, meaning that they are lawfully eligible to check the contract to see whether it aligned with the legislation or not to preserve the stakeholders' rights, and also if stakeholders are interested in having a customized smart contract, they will be providers of this service.

After the notary verified that everything checks out in the contract, it sends its seal online through oracle and it will be sent back to the smart contract and then it can be executed.

7- In this stage smart contract is executed and money will be sent to the seller’s wallet, as well as NFT which will be sent to the buyer's wallet. This process is repeated as the new buyer may wish to re-list the property. With every transaction small fee is paid to the

platform provider for their service, also taxes can automatically be applied to them as in many countries RE transactions are taxed.

8- The transaction is automatically recorded in the ledger, with all data regarding the of

5.1.5 Underlying Technology

5.1.5.1 Verifying the ID through self-sovereign Identity

In the previous section, several reasons were mentioned to explain why in real estate transactions, it is needed that the interested parties have a verifiable Identity, in this part, the authors are proposing a solution to this problem.

Here we build on the concept of Self-Sovereign Identity, we believe it is possible to create a platform where the ID of the interested parties can be checked very fast by central authorities and they would be permissioned automatically to pursue the transaction if they are eligible.

The buyer and the seller should be registered on a self-sovereign identity wallet, this wallet is managed by a central authority (EU or a specific country), in the self-sovereign identity wallet they have registered and verified their nationality, age, residency status, and all the required information needed to legally conduct this transaction, as a central authority, let's say EU has controlled and issued this identity itself, it automatically checks whether the interested parties meet all the criteria to perform this transaction or not, and if all conditions were met, it authorizes the transaction and if not it blocks it.

The technology behind this, as explained in the previous chapter, is based on blockchain and it is much more secure, faster, and private as one gets to decide which portion of his/her identity is shared.

Here is a more detailed look at what happens:
1- Buyers and Sellers interested in purchasing/selling a house physically verify their ID with the central authority (Country/ EU entity). The central authority stores this data and

turns it into codes and either sends the cryptographic proof to the person's wallet or demonstrates that it has received identity, residency, etc documents.

2- The buying and selling platform sends a request through the SSI portal, checking if the parties are eligible to pursue the contract based on the verified identical data and the contract clauses using Zero-Knowledge Proof.

3-the permission is granted/blocked based on the provided identity and the requirements of the smart contract.

4- Even if the contract is not smart and written on paper, the identity and eligibility of the person to perform this transaction would be verified.

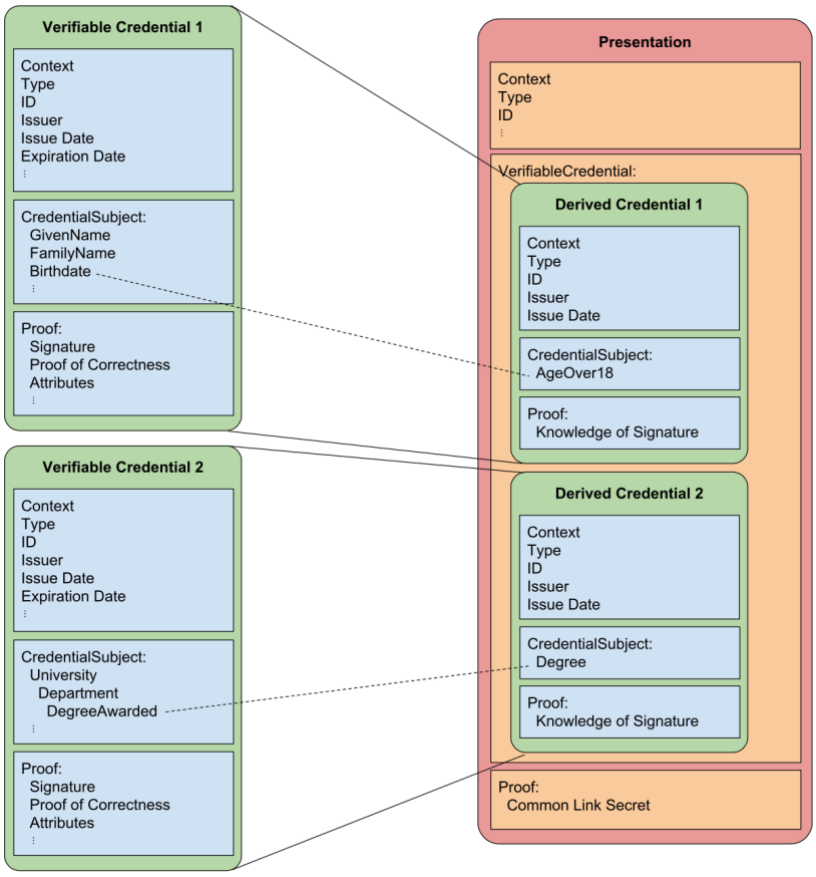


Figure n17. Self Sovereign Identity diagram

5.1.5.2 Model smart contracts and Smart laws

To better explain the smart contracts, we start by specifying what smart contracts are not;
The word "contract" may create confusion among readers as it does not refer to any verbal form in this circumstance. This is a type of machine code that is written in the form of algorithms in a programming language. With respect to smart contracts, there is no human language; everything spoken in words and/or written has a secondary nature. Only algorithms provide legal action and meaning; the smart contract defined in words has no legal consequences.

The smart contract is not only a file, which is the second distinction. Agreements in the form of a text file, as well as their scanned hardcopy, are occasionally included in electronic contracts. The presence of a transaction is the smart contract's second identifying property on the blockchain. In the blockchain, a smart contract is always a transaction. Furthermore, a crypto asset is always involved (coin, token, etc.).

There is a useful method of standardizing papers for legal transactions rather than constantly creating new ones. Many European countries, for instance, created a model charter for companies and eliminated compulsory notarization for company registration between 1990 and 2010. In the United States and many other nations, a similar practice is common. Governments accepted the model charter, and instead of seeing a notary/lawyer, a businessperson fills out a standard application form (usually online these days), which allows them to select a charter. It is obvious that it does not meet all objectives; consequently, the option of creating a customized company charter is also available.

The following illustrates an example of how a model smart contract may be built. For various smart contracts, such as purchases, leases, mortgages, and gift, the government imposes a technical standard. The user can select one of these, design one themselves, or hire an expert to make a unique smart contract for them. Obviously, some governments may impose restrictions on a custom model through licensing or direct prohibition.

To execute a deed, which is the transfer of a token from one address to another, there are two possible contexts:

– moderate, when the user chooses to follow the specified norms; if the user performs a non-compliant transaction, it will be automatically filtered out; therefore, any transaction is possible, but not all will be recognized as genuine (legal); or
– strict, when the transaction won't be accepted by the platform if it is non-compliant.

Online services frequently employ strict regulations. For example, while registering for a forum, the telephone number field might be required and validated against the normal country code. If the user does not meet the condition, they cannot proceed. Likewise, "smart laws" are digitized compulsory laws. Paper rules encoded as algorithms that aid users in remaining inside the legal area when completing a transaction and prevent them from drifting off to the wrong way.

Despite the fact that model smart contracts may suit the great majority of demands, it is nearly difficult to meet 100% of market demand in the diversity of legal relationships. Therefore, the system must continue to support conventional legal transactions. In areas where contract acknowledgment is required, a notary public (a broker, a title agent, etc.) may acknowledge a paper deed and publish the record on the blockchain, which confirms that the acknowledgment was completed properly. The landlord will add a reference to the notary's token in the transaction.

Next, smart laws must be enforceable. To explore this protocol on a more abstract level, let's assume that all paper-based and electronic transactions occur in the nation. The law is a set of rules. As discussed in the ‘legality of the contract’ section, When these criteria are applied to any transaction, the transaction will either comply with the law or not. We may see a set of filters based on the suggested technology of a cross-blockchain protocol and a framework of smart rules. The government develops these standards as blockchain-applicable algorithms. If transactions do not match, they are filtered away.

Compliant individuals will be gathered in a public database. The database is a file that can be retrieved by any user that installs and runs a block- chain node with the filter. The local wallet of the user runs a full node, each new block is verified against these criteria, and transactions that satisfy the algorithms are stored in the local database. The cross-blockchain protocol proposes this method (Konashevych, 2020b).

Consequently, everyone maintains the same version of the public registry, including the government. The government's responsibility is to implement smart laws with model transactions and filters.

It is crucial to note that there is no censorship on public blockchains. Even though the government uses a strict model, it is still possible for individuals who can code a blockchain transaction to create a non-compliant transaction and bypass the smart law framework, therefore pushing such transactions straight into the blockchain. Here, the filter is necessary. It examines each new block; non-compliant transactions are broadcast in the blockchain but are not added to the overlay database as a result of existing these filters. View the configuration of a three-layer system in the following figure.

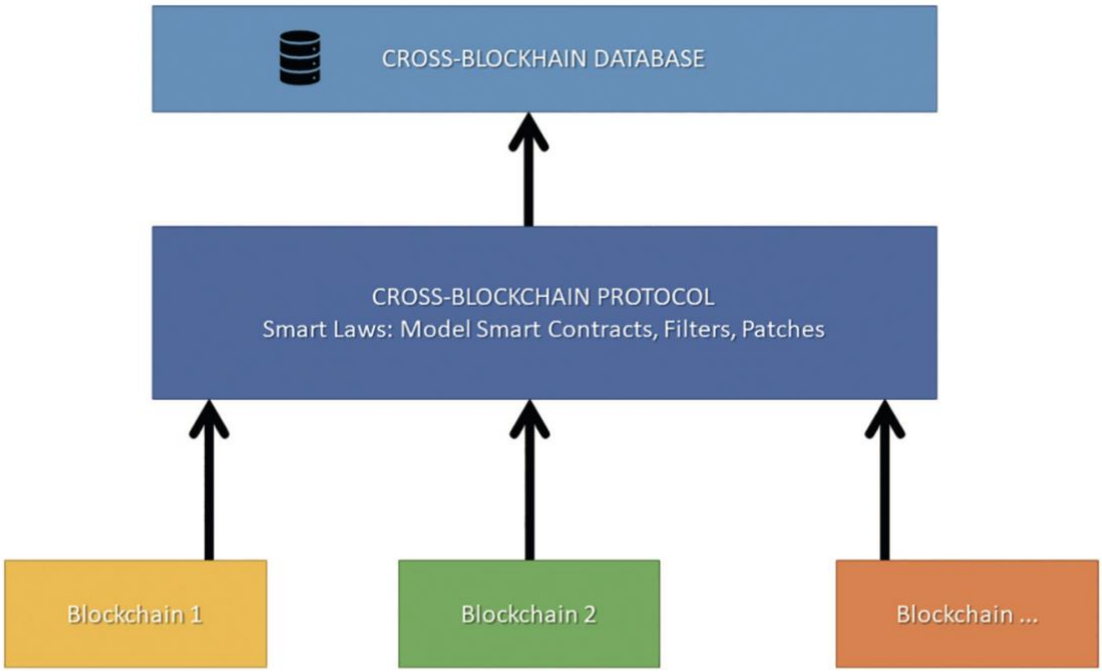


Figure n18. Tiers of a smart legal system.

This filter results in the restoration of power. As previously stated, regular enforcement may be accomplished by updating these records (tokens) on the blockchain, which the government owns and controls with their private keys. They will inform society of which tokens are valid and which are invalid. But if the private key is

compromised, government control is lost. To tackle this issue, they alter the protocol by introducing new filtering rules, new government agency addresses, or by filtering out non-compliant transactions.

The reader could disagree. Government, courts, land authorities, public notaries, etc. have centralized control over this technology. First, we must admit that at least in the Real estate realm, a truly decentralized system cannot exist. There are several circumstances in life that we cannot settle on our own. A person cannot, for instance, verify his/her own death in order to initiate an inheritance transfer. The issue between the two parties must be resolved by a third party. People require trustworthy third parties, such as public servants, notaries public, and judges.

Nonetheless, this method is exceptional because:

- Neither the government nor the user may modify a transaction. Transactions serve as proof of everything that occurs in the actual world, whether legal or illegal. To resolve any legal concern, we do not modify transactions as they occur in the centralized database.
- Government agencies publish their judgments on the blockchain, so all transactions, including those that enforce and resolve legal disputes, are recorded in distributed ledgers. When the government restores access, they do it in a blockchain-based platform/transactions.

Ultimately, it is up to each individual citizen whether or not they trust their government. And at this time, there is no mathematical solution that can answer it.

In conventional words, this is a social consensus or social contract (Friend, 2004). Citizens give authority to the government, therefore it is mandated with power. Obviously, this is a political conversation level. The purpose of this study is not to discuss the political structure of any nation.

Instead, the protocol suggests a variety of alternatives, to name a few:
blockchain voting and any other types of system governance. Consequently, any system may be created in consideration of existing political traditions and systems of government.

With extremely trustworthy public blockchains, society will be shielded against corruption. The system's stability is measured not only by its capacity to endure the danger, but also by its ability to recover after one. Even if the government abuses its authority and breaches civil liberties, the system may be reset by reindexing the blockchain from scratch and applying the appropriate filters.

It is vital to recognize the dependability of blockchains. Physical security of nodes and their owners, as well as the right to free and fair competition in the production of blocks, characterize it. Thus, the police, antitrust organizations, and the court system play a vital role in preventing cartels and other dangerous activities against nodes and miners. In the worst-case scenario, miners would need to pay militaries to defend their lives and interests.

5.1.5.3 Oracles: Including a third-party in Blockchain

There are concerns that the contract or smart contracts are written in the web space can have legal problems, as there is currently no one who checks the legality of the contract and the clauses, moreover, in many countries the role of the notary is required or is common practice to make sure that the contract is in accordance with the country law and the rights of each stakeholder in the contract is preserved, only one of the tasks of notarization, namely the timestamp, is ensured by blockchain, other components of notarization are not automated, therefore to overcome this problem, we suggest the following proposal.

Oracles were discussed in depth in the last section; in essence, they are an off-chain platform that can verify whether or not certain clauses in a smart contract are genuine. What we suggest is an oracle in which third-party notaries check not only whether the contract is written within the scope and following the law, but also whether each party's rights are reserved.

The government can grant permission to these oracles so that contracting parties are aware that they are trustworthy organizations that can be held accountable if they fail to do their jobs properly. If notaries are required by law in a country, this seal of verification by oracle notaries could be added as a mandatory step in the contract. Here is a diagram of how this idea would work.

5.1.6 Value Added

We think that through the use of blockchain and our proposed framework in real estate specifically, we can reduce the corruption and fraud in real estate by a significant amount, through an automated verifiable ID process which we can ensure that all the stakeholders are eligible and legitimate as their documents have been verified by trustable organizations.

Moreover, the legal enforceability concerns of smart contracts would also be diminished by the use of notaries in the form of oracles and also by using predefined model smart contracts.The anonymous nature of the nodes in blockchain systems had caused many to believe that the nature of this platform is contradictory to the real estate market but with Self Sovereign Identity through the use of blockchain, now this concern is eliminated but we also believe that it's a major improvement over current practices in terms of speed, security, and safety.

As the records are registered in the distributed ledgers and are immutable, this will be an enhancement over the current system when all the registry data is kept in a single, central database with the risk of losing all the data if something goes wrong with it. In this way, even if the transaction records are eliminated from everywhere, they will remain in the ledger forever and can be used as a reference if any legal conflict occurred.

The real estate transaction is a relatively slow and time-consuming process, but with the automation offered, we believe the duration could be cut down significantly and thus the real estate asset class could be deemed as a more liquid asset. In addition, by introducing tokenization of properties we will actually have a new and very liquid asset class in the real estate, a class that was hard to imagine just a few years ago with the inherent immovable and illiquid characteristics of real estate.

According to reports, US$2.3 billion was laundered through U.S. real estate over a recent five-year period, through the use of this platform we aim to cut down the fraud and corruption in the real estate sector as the transactions are transparent and have gone through many validation phases.

5.2 Findings

5.2.1 Central authority: Yes or No?

we believe that the central authority cannot be eliminated completely from the blockchain in the real estate sector the reasons for this include but are not limited to

- The term “real estate” denotes the “bundle” of rights associated with the ownership and use of the physical assets “ a property,(Ling & Archer, 2013), therefore it's the central authority that must, in the end, make these laws and the authority to verify them.
- A central authority is needed to verify the ID of the different stakeholders involved in the transaction, in the previous section it is explained why an ID is needed for stakeholders in the real estate.
- There are some occasions in life like birth and death, which there is a need for a third party to verify it, to make an inheritance transfer.
- From distant history up to now, Human transactions were always in need of a third party to play the role of a judge in case of conflicts of interests. This need still remains in our societies and can not be done by smart contracts.

5.2.2 Developing a National Blockchain

As mentioned before, Netherlands, UK, and Australia are among a few countries which have started researching Blockchain technology for their Real estate market.
Our next proposal/suggestion is:

Governments should not consider a private DLT or developing a new Blockchain for their internal market. Rather, working on Model smart contracts and developing smart laws which will have a cross-blockchain effect.

Our reasoning for Decision-makers in this argument is that it goes against one of the core and fundamental values of blockchain, Decentralization.

It may seem confusing at first, previously we claimed total decentralization is not a possibility in Real estate, and we state the fact that a central authority is indeed required for the real estate industry and some actions can not be done anonymously.

Here, we are proposing something in between. True, a total decentralized platform is not possible and beneficial, but creating a DLT or a new blockchain by the government will be not much different from the current state of the RE market and transactions.
Developing a new Blockchain as mentioned in chapter 4.2.2, beyond problems such as extreme price volatility or network congestion, will result in having a single point of failure, as there is only one central entity responsible for the whole network.

The best way to benefit from the enormous advantages of Blockchain in real estate is to define legal ground and framework for further development and create a free atmosphere in which RE companies compete with each other Via different Blockchains, while digital laws and model smart contracts are introduced by the government. Through a free market, competition leads to growth, security, and maturity of this technology, while the failure of one company or blockchain would not result in a total crash of the market.

In 2022 alone, few blockchain companies crashed or witnessed substantial problems. A Famous example is a blockchain named Terra which it’s native token Luna hit all-time-high record of 115$in April 2022 with a market cap of over 40 Billion dollars, and saw a free-fall from 86$ to 0.03$ dollars during the time period of only 7 days, due to highly complex technological and technical issues. Ethereum blockchain also hit hard, dropping more than 75% from its all-time high in June 2022.

5.3 Conclusion

Blockchain is a relatively new technology. Approximately in 2015 first signs of interest in linking Blockchain and real estate appeared in academic research and from 2017 the trend kicked off. They mostly presented futuristic ideas of the revolutionary role of blockchain but very few managed to illustrate how this technology would be implemented.

A key concern was the absence of empirical data and no real-world attempt of mentioned theories. The proposed framework in this thesis is the first attempt of having a clear vision of how we can move towards a blockchain era in real estate, based on the findings of this paper.

We studied and analyzed raw ideas, gathered concepts from a wide variety of research, and empowered our theory with a unique feature: identifying early-stage start-ups in Europe and interviewing the CEO, as well as analyzing their competitor in the US to assess how these theories are working in the real world.

As the result, digitalizing the land registry is identified as the primary and most crucial objective to be addressed, Next on the list legalizing smart contracts.
In the framework, the role of central authorities and RE companies are foreseen with the aim of minimizing legal challenges via smart laws and help of RE companies/notaries through oracles in creating smart contracts for both parties, and maximizing the potential by suggesting model smart contracts and tokenization, in a way that it won't be dependent to a particular platform or blockchain.

This study considers blockchain as a way to turn the page in this industry, although not committing to radical change suggestions proposed in some research. This sector should gradually start to adopt these blockchain-based practices that are more transparent, safer, more cost effective, and more secure. This study analyzes that the central authority is an essential part of real estate and the proposals to eliminate their role completely, are doomed to fail. Having said that, governments could slowly offload their responsibilities to the private sector but set the overall rules to control any miss behavior.

In the proposed framework, a fixed platform or a fixed government-based practice is not recommended but we offer a general framework including a cross-blockchain platform thus enabling healthy competition among private RE companies.
that's one of the reasons supporting our theory of why governments should not consider creating their national blockchain/DLT as it may lead to extreme price volatility, network conjunction, and risk of a single point of failure in having a central database.

Annex

Our Interview with Alex Fernandez, CEO of Forsale company:

Q1. what is the prime goal of your company? Is your company going to be a facilitator between different real estate agencies, providing a shared and secure database via DLTs, or are you going to be a platform that lists properties for purchase and sale like Zillow(USA) or Immobiliare (Italy)?

A: we have two line of business:

1. is selling under the name of Forsale company: at the moment we have our own marketplace(Forsale), where we are onboarding businesses, sellers and constructors.

2. but also we have been asked and we are studying solutions for big customers. Big customers (big companies) want to use the automated services but under their own name, in their own platform and ecosystems. (providing the technical/technological products for other companies to use under their name, not forsale)

Q2- what is the primary legal challenge you have faced in your start-up? (e,g I know some countries require the contracts to be registered in the land registry or some may need a notary etc)

A: number 1 is land registry: they are centralized, demand considerable paperwork, and rely on each country's government regulation. For ownership of a property, the identity of the owner should be taken into consideration. and the whole process of land registry is outdated, except for the UK as its land registry process is digitalized.

Another one is cryptocurrencies and smart contracts. The novelty of blockchain is that it's trustless and so the smart contracts that are based on Blockchain don't need an authority to authorize the contract. Therefore, there is no need for a broker to act as authority to supervise the process, to validate the identity of Person A and Person B, to validate these two persons made an agreement in this location at this date. The identity authorisation will be done By KYC(know your customer) by the platform (Forsale company), the blockchain certifies and automates the tokenized rental or purchase agreement. Regulators need to understand and legalize smart contracts.

In Switzerland only people who hold Swiss citizenship can purchase land or property, therefore a foreigner cannot have access to real estate in Switzerland and this law would be implemented on the platform by KYC. only people whose identity and citizenship are proven through KYC by the platform, have access to listed properties in Switzerland. in

detail, the customer needs to verify his/her ID documents, and also prove of address by providing utility bills. therefore Forsale is able to identify this customer.

Q3. Do you think is it possible to have one united platform for all European countries or each country would have its own platform with their national regulations?

A: Our goal is to have one decentralized worldwide platform, not one platform for every country. Each country has its own regulations, and therefore only eligible user for have access to the real estate market in that country.
Every country needs to protect their land and property and the land registry remains centralized according to regulation of each country. rental and purchase agreements and transactions will be decentralized.

Q4. Regarding the Privacy policies of users, what is your approach to preserving it?

A: Our approach is to build our platform on Web 3.0 fundamentals. the customers own their data, and only if they chose to share their data with the platform, they will be awarded. Forsale would not make profit by leveraging the massive data pool of customers, unlike the giant tech companies which play the intermediary role and monopolize the data of billions people. As real estate transactions and agreements may be sensitive data and governments do not want these data to be shared with a platform, this approach of using web 3 is the cutting edge technology which guarantees the privacy of customers' data.

Q5. Considering your business model, you will not earn money by leveraging the data of users?

No the customers will be the owners of their data and if they want to share the data, they will earn the money for it. Our platform only earns money as a small fee applied to smart contracts that have been made on the platform.

Q6. Which Blockchain would you use for your company? Regarding the network congestion and high gas fees during the high demand which happened to the biggest blockchain networks, namely Ethereum and Solana, what are your solutions for unpredictable problems due to technological shortcomings?

We will build our platform on OASIS protocol blockchain, we obtain the total $3.5 Milion from Oasis x metamind labs accelerator program. We will use USDC as the stable coin

which remained strong during the market crash in early May (2022). There will always be risks, it is not a bulletproof technology, but we believe in it and we try to be prepared for unpredicted problems via frequent risk analysis.

Q7- What are some ways in which the public government could help in order to ease the adoption of blockchain technology in the real estate sector?(introducing laws etc)

A: digitizing the land registry (making it possible to register the land registry on blockchain) - accepting the smart contracts as a valid and legal tender - accepting blockchain technology as a truthless entity.
{our competitor, propy is not providing the real ownership of property, it tokenizes the company and sells the share of the company to customers. They earn dividends based on their tokens and basically it acts more like a REIT on blockchain, but our goal is to provide 100% true ownership of property directly to the customers via NFT technology. This is our novelty and we have been working very hard for months on it and still working.}

Q8- If any party is not happy with the purchase, given that there aren't any laws regarding blockchain, how can this purchase made by a blockchain network enforce any legitimate judicial decisions? To what extent is your platform accountable?
A: the smart contract would have the same legitimate value as the paper contract, it is only digitized. It is the same contract as the paper one and we are not trying to create something new in the legal part.
liquidity is the huge advantage of smart contracts. consider a crowdfunding project that takes few years to build and a costumer buys the presale share of the project. Whenever the costumer felt the need to sell the property, he/she can immediately sell it on the platform. We plan to have crowdfunding projects on the blockchain.
Our platform will work on 3 sections:
presale and rental tokenized agreements - Tokenizing the built property - Crowdfunding

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