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# **Blockchain, Crypto, Tokens, and Smart Contract Applications to Real Estate Transactions, Portfolios and Capital Markets**

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## ABSTRACT

**Purpose** – This paper aims to present a roadmap for the applications of Non-Fungible Tokens (NFTs) for real estate transactions using blockchain and cryptocurrencies.

**Design/methodology/approach** – Blockchain (unaltered decentralised, distributed, public, digital ledger of records called blocks across computers), cryptocurrencies (a fungible digital currency as a medium of exchange through digital ledger on a computer network), fungible tokens (equivalent and indistinguishable commodity unit can be replaced, but not in same manner) and Non-Fungible Tokens (NFTs) (non-interchangeable uniquely identifiable unit of data-digital files saved to blockchain as a tradeable digital ledger) and smart contracts (computer program-transaction protocol automatically executes-controls-documents of legal events-actions-terms of contract). The research presents an example of a gaming application (*LAND/SAND*) currently being used in the crypto-blockchain environment; and the translation of a movie ticketing system applied to real estate investment transactions using Ethereum (decentralised-open-source blockchain with smart contract acting as permanent-immutable-decentralised tradeable cryptocurrency/NFTs) or Ethereum 2 - Eth2 - Serenity (an improvement in speed, efficiency and scalability allowing for the streamlining of high volume transactions), a cryptocurrency similar to bitcoin (decentralised peer-to-peer verified network of digital currency in a public distributed ledger).

A summary of real estate blockchain and cryptocurrency platforms for real estate transactions are also provided as examples of what the industry has developed so far: RealT, Harbor, Property Club, RealBlocks, Meridio, SMARTRealty, Reasi, Propy, Slice, Bee Token, ShelterZoom, NetObjex, StreetWire, CryptoProperties, Crypto Realty Group, Lending Coin, and Uniswap etc.; and discuss the ability to leverage virtual assets, and market-making activities and the potential of custom and established trading platforms. The paper ends with a discussion on legal and regulatory frameworks.

**Findings** – Current and future real estate transactions can be solved by using ERC-20/721 (simultaneously execute fungible token and smart contract), ERC-1155 (combine fungible token and smart contract), and hyperledger fabric (a flexible and scalable approach to designing, executing, processing, and verifying NFT transactions using smart contracts without cryptocurrency or tokens). The applications of these technologies for potential 1031 property exchanges, recordation systems of title transfer (Wise County Virginia, City of Norton and South Burlington, Vermont), and single-family home sales (Hyde Park, Tampa Florida); and the prerequisites for this NFT market place to achieve institutional capital market development.

**Research limitations/implications** – Blockchain, cryptocurrencies, fungible and Non-Fungible Tokens (NFTs), and smart contracts are rapidly becoming a standard technology, medium of exchange (trading), and unit of account (stored value); however, they are slowly being adopted to

track and verify ownership interests in real estate industries and to trade real estate assets. Since the technology is so new, and the rate of adoption in other industries is so rapid, there is limited literature in their applications to real estate.

**Practical implications** – NFTs are significant in their potential to revolutionise investment in real estate assets. Non-Fungible Tokens are being used to fractionalise-decentralise ownership interest in real assets. If the NFTs and smart contracts are fully adopted by the industry at some point in time this will radically change how real estate ownership interests are held, exchanged, and portfolio managed on a global basis.

**Social implications** – Blockchain and non-fungible tokens are going to rapidly disrupt the way investment managers, institutional and retail investors, debt-equity-mortgage financiers, and property managers and tenants-occupants interact with properties. Potential to create a highly efficient, productive and liquid marketplace for real estate ownership interests could solve the high asymmetric information costs, transaction opaqueness, market inefficiencies, lack of ownership verification and validation, lags in transaction timing, real-time portfolio adjustments, etc.

**Originality/value** – This research focuses on the application of NFTs in their ability to fractionalise and track real estate assets and ownership interests. NFTs are known in the industry in their ability to fractionalise (decentralise) virtual assets such as art, and the blockchain technology allows for the immutable tracking of the ownership interests. There has been limited application of these technologies to real estate, and virtually no discussion on the potential of the blockchain, cryptocurrencies, fungible and Non-Fungible Tokens (NFTs) and smart contract applications to develop a new institutional real estate capital market.

**Keywords** Management, Technology, Machine learning, Artificial intelligence, Institutional investment, Blockchain, Cryptocurrency, Fungible-Non-Fungible Tokens (NFTs), Smart Contracts, Real Estate Technology, Real Estate Transactions, Real Estate Portfolio Management and PropTech.

**Paper type** Conceptual, viewpoint and technical paper

## **Non-Fungible Token (NFT) Real Estate Applications Using Blockchain/Cryptocurrency**

**The use of blockchain and cryptocurrency is expected to revolutionise and modernise the way investors make decisions and hold ownership interests in real estate.**

### **Introduction**

This paper aims to present a roadmap for the applications of Non-Fungible Tokens (NFTs) for real estate transactions using blockchain and cryptocurrencies.

For example, the blockchain is a decentralised-distributed-public-digital ledger of records called blocks across computers; cryptocurrencies are fungible digital currency used as a medium of exchange using the blockchain; fungible tokens for example can be used as a medium of exchange in Initial Coin Offerings (ICOs) similar to an Initial Public Offering (IPO); Non-Fungible Tokens (NFTs) are unique data-digital files saved and traded on the blockchain; and smart contracts are automatic executable programs triggered by a legal event or actions according to the terms of the contract.

This research focuses on the impact of the NFT's ability to fractionalise and track real estate assets and ownership interests; by giving an example of a gaming application currently being used in the crypto-blockchain environment; the translation of a ticketing system for real estate investment transactions using Ethereum; and current and future real estate transaction solutions using ERC-20/721, ERC-1155, and hyperledger fabric.

Ethereum is a decentralised-open-source blockchain with a smart contract acting as a permanent-immutable-decentralised tradeable cryptocurrency or Non-Fungible Token (NFT). Ethereum 2 (Eth2), also known as Serenity, is a second generation Ethereum cryptocurrency that improves speed, efficiency and scalability that allows for the streamlining of high volume transactions. Bitcoin is a decentralised peer-to-peer digital currency that is verified on the blockchain network through a public distributed ledger system.

The Ethereum ERC-20/721 is the combination of a fungible token and a smart contract that is exercised simultaneously. This provides liquidity and the ability to act as a medium of exchange backed by a smart contract.

The next generation of Ethereum based contracts is the ERC-1155; this contract combines the fungible nature of a token with the smart contract. The ERC-1155 is efficient in combining these two attributes and is now becoming the standard for placing and exchanging NFTs on a tradable platform such as OpenSea.

Hyperledger fabric is highly flexible and scalable in its approach to designing, executing, processing, and verifying permissioned and peer-to-peer NFT transactions on the blockchain using smart contracts, and there is no cryptocurrency or tokens involved. Hyperledger Fabric has a high degree of transparency and integrity.

A summary of real estate blockchain and cryptocurrency platforms for real estate transactions are provided; along with the applications of these technologies for potential 1031 property exchanges, recordation systems of title transfer (Wise County Virginia, City of Norton and South Burlington, Vermont), and single-family home sales (Hyde Park, Tampa Florida).

The paper ends with a discussion on legal and regulatory frameworks, and prerequisites for institutional capital market development, leverage and market-making potential.

The future of NFTs is significant as it could radically change investment in real estate assets. Over the last ten years, blockchain and cryptocurrencies have become a standard technology, medium of exchange (trading), and unit of account (stored value), representing the ability to track and verify ownership interests in ways never before applied.

Specifically, non-fungible tokens are being used to fractionalise ownership interest and real assets. In the world of real estate, blockchain and non-fungible tokens are expected to change the way managers, investors, financiers, and tenants interact with properties.

## **Technologicalization of Real Estate**

The introduction of new technologies by financial engineers to change the way real estate transactions are conducted and how real estate is owned. New hardware and software technologies running blockchain is altering the way investors are thinking about holding real estate assets.

The real estate industry and owners are not known to embrace rapid changes in technology. Institutional investors also have not fully adopted the application of the blockchain or cryptocurrencies. These technologies are expected to significantly alter the real estate industry, and in particular, the way owners finance and invest in properties.

The adoption of new technology processes faces severe challenges in the real estate industry. Significant problems are found in the assessment, compatibility, interface, acceptance, and implementation phases of technology adoption.

Real estate firms are expected to overcome these problems by changing their management style, database management and interface systems, and implementation of end-user programs.

## **Investment in PropTech Technologies**

A reflection of the change in the real estate industry is Property Technology (PropTech) companies' growth. Property Technology (PropTech) is one of the most popular areas next to Financial Technology (FinTech) for Venture Capital (VC) investment.

These companies (start-ups) use Information Systems and Technology (IS/IT) to improve labour productivity and transactional efficiency surrounding property management, brokerage, investments, etc. PropTech development and investment are multiplying, as reflected in predictive analytics, machine learning, and blockchain applications.

Predictive analytics and Business Intelligence (BI) is the application of statistical tools, techniques and technology for forecasting, testing correlation-causation, and use of big data machine-model learning and mining (artificial intelligence). Machine Learning (ML) or predictive analytics and computational statistics uses algorithms to learn from the data through exploratory mining techniques.

According to Conway (2018) and Columbus (2018), the Compound Annual Growth Rate (CAGR) of the Predictive Analytics & Machine Learning (PAML) market to grow by 21%.

Between 2013 and 2017, machine learning patents CAGR grew 34%, the third-fastest category of all patents granted. Furthermore, Asaftei et al. (2020) at McKinsey Research, demonstrates that machine-learning models for real estate applications are 90% accurate at predicting changes in rent and 60% accurate at predicting other property metrics.

As reported by the United States Census Bureau (2019), the information technology sector totalled 5.2% of total Gross Domestic Product (GDP) in 2015. Between 2008 and 2017, capital investments in the industry rose 53.5%, or \$55.3 billion dollars. According to Oslen and Hammond (2017), in 2010 venture investors spent only \$33 million on real estate technology, however, by 2017, real estate tech related investments rose to \$1 billion.

Furthermore, Fortune Business Insights (2020) predicts the worldwide blockchain sector to grow to \$69.04 billion in 2027, up from \$2.01 billion in 2019. IoT Analytics (2018) forecasts the global Internet of Things (IoT) sector to exceed \$1.5 trillion in 2025, up from \$150 billion in 2018.

The Internet of Things (IoT) are hardware and software applications that run off the internet; and use cloud computations, processing, machine learning, automation, and other telecommunication technologies to deliver services to end users.

As reflected by rising allocation of capital toward new technologies, real estate portfolio managers continue to integrate technologies to increase operational efficiency and improve

investment strategies through such innovations as the blockchain, cryptocurrencies, fungible tokens, and Non-Fungible Tokens (NFTs).

## **Literature Review**

### **Blockchain, Cryptocurrencies, Fungible Tokens, and Non-Fungible Tokens**

Blockchain was introduced in 2008 in a bitcoin white paper by Nakamoto (2008) and is the technology used for cryptocurrencies in their initial development stage. Blockchain is a secure decentralised database across computer network nodes that collects and records information as blocks and is linked to prior blocks using cryptographic codes.

Blockchain technology has the potential to replace existing ways of transacting real estate that currently rely on third-party brokers, as referenced by Beck and Müller-Bloch (2017).

Cryptocurrencies (digital currencies) allow individuals to conduct transparent and verifiable transactions through distributed ledger systems (blockchain). Cryptocurrency is a fungible digital currency as a medium of exchange through digital ledger on a computer network

Bitcoin was the first cryptocurrency to be developed; its utility is in the representation, record, and unit of value reflected in the blockchain. Bitcoin is a decentralised peer-to-peer verified network of digital currency in a public distributed ledger.

However, Ethereum is used to create other types of cryptocurrencies for use in decentralised (compound) applications as illustrated by M. (2020). Ethereum is a public permissionless generic blockchain protocol with smart contracts that allows users to create and deploy programs on the shared blockchain network. Network governance is overseen by Ethereum developers.

Standards are used, written, and agreed upon by the Ethereum developer community, known as Ethereum Request for Comments (ERC), to allow for compatibility across other software systems, as cited by Decentraland (2018).

For example, Ethereum is used in fungible and non-fungible tokens as reflected in the LAND video game and real estate transaction (ticketing) system, as illustrated below. Fungible tokens are used to substitute and exchange an item for an item such as established currencies with crypto currencies or tokens. The Ethereum (ERC-20) is the standard interface for fungible tokens. Non-Fungible Tokens (NFTs) are a secured blockchain-cryptocurrency based token with no direct substitute or one-to-one replacement, creating value by storing unique data within the tradable token.

The following section goes into more detail on the blockchain, cryptocurrencies, fungible and

non-fungible tokens and smart contracts applications.

## **Blockchain**

To understand non-fungible tokens and their numerous applications for the real estate industry, it is vital to understand the concept of blockchain.

Blockchain is a database that collects information known as blocks, once recorded, a new block is created that holds the next block of data. These blocks are linked to prior blocks through a time stamped unique cryptographic code called a hash. Blocks are stored and processed over a decentralised global network of computers owned by thousands of users, making it a secured environment with the inability to be hacked, altered, or modified.

Szabo (1994), Glaser (2017), and Sillaber and Walzl (2017), call blockchain a new currency. These “smart contracts” allow parties that do not know or trust each other to do transactions. Their correct execution is ensured by a consensus protocol, the well-known underlying blockchain and its participating nodes provide consistency.

Blockchains create economic incentives to mitigate perverse behaviour by creating reusable, anonymous, and secure digital identities (public addresses/ identifiers).

Although blockchain and NFT applications in real estate transactions have not yet been fully commercialised, there is a robust, existing framework that we can use to validate the technology’s applications in real estate investment. Over the last ten years, the introduction of fungible and non-fungible tokens has provided ways of raising capital and new mediums of exchange.

## **Ethereum**

According to Buterin (2014), Wood (2014), Christidis and Devetsikiotis (2016), Morabito (2017), and Wüst and Gervais (2017), Ethereum is a public, permission less blockchain protocol, with smart contracts allowing any user to create and deploy programs on a shared global infrastructure. These smart contracts are achieved as the community agrees on multiple application standards, called Ethereum Request for Comments (ERCs).

According to Valenta and Sander (2017) and Bal and Ner (2019), Ethereum is also currently being used on the blockchain, the platform is a generic blockchain with the governance overseen by Ethereum developers; as mentioned above, the operational mode is permission less, public or private, consensus is mining based proof-of-work at ledger level; and smart contracts are based on contract code (Solidify) and currency using NFT via smart contract.



Smart contracts and Ethereum allow blockchains to develop human interaction and collaboration on a large scale across a variety of industries and services, as cited by Buterin (2014) and Wood (2014). These include supply chain management, international payments, international trade finance, real estate, energy markets, and notary services, as written by Christidis and Devetsikiotis (2016), Morabito (2017), and Wüst and Gervais (2017).

Ethereum has developed a high-level programming language compiling into byte code running on virtual machines. The standard Solidity features JavaScript-like syntax as cited by Tikhomirov (2018). The recommendation is to develop the smart contract code for real estate transactions prototype in Solidity. One approach would be to rely on the development framework Truffle; that includes tools for deployment of contracts and the testing library Mocha, as well as ganache-cli, providing a local Ethereum blockchain for testing as cited in Truffle (2019).

As written by Entriken et al. (2018), fungible tokens are based on ERC-20, and a new ERC-721 was introduced in 2017 for non-fungible tokens. This was done to create a new standard to differentiate between fungible and non-fungible tokens. ERC-1155 with the Hyperledger framework standalone or in combination with ERC-721 and ERC-20 could be another future solution for real estate transactions.

According to Simons (2021), for example, the ERC-20 has a current market capitalisation of over \$35 billion and can be used for leverage and adaptive pricing; the ERC-721 is perfect for public title recordation of real property transactions, and has existing in-place backend requirements developed for smart contracts; and the ERC-1155 is a competing solution and can combine both ERC-20/721 attributes in a decentralised finance environment.

### **Fungible Tokens**

According to Decentraland (2018), a fungible token can be used to substitute or exchange an item for an item, like U.S. dollars for bitcoin, or another currency, or bitcoin for a token. Fridgen et al. (2018) state fungible tokens have also reinvented crowdfunding through Initial Coin Offerings (ICOs) in the use of blockchain and token assets.

According to Autonomous (2018) and Vogelsteller and Buterin (2015), by 2018, initial coin offerings totalled \$12 billion, allowing for the Ethereum ERC-20 standards as the interface for fungible tokens, divisible and non-distinguishable. The standards are agreed upon by developers to achieve interoperability and interchangeability at each usage of commodity and by parties in the exchange. Non-fungible tokens are opposite, distinguishable, indivisible, and tracked separately, with unique identifiers and metadata transferred in the transaction (smart contracts), as cited by Voshmgir (2020).

## **Non-Fungible Tokens**

Non-Fungible Tokens (NFTs) and blockchain are crucial innovations that are intended to dramatically alter the real estate investment landscape. Non-fungible tokens are a new type of blockchain-based token introduced in 2017. As cited by Decentraland (2018), NFTs are cryptocurrency tokens with no direct substitute or one-to-one replacement. Its value, therefore, comes from the unique data stored within the token.

Distinct attributes of the token allow for application across multiple use cases, such as real estate, as they digitally represent the uniqueness of the real estate asset as stated in Butcher (2018) and Griffin (2018).

Non-Fungible Tokens (NFTs) use blockchain technology to store unique data. These tokens allow data to be bought, held, and sold. The applications of NFTs for real estate use are immediate and comprehensive. They provide a robust, secure framework for contracts between lessor (seller) and lessee (buyer) while making it easier for real estate owners to monetise their assets. Since NFTs are entirely unique, they provide a legitimate scarcity of assets, and buyers are assured that the assets purchased are, in fact, unique.

The impact of NFTs on the real estate market will change not only its material ownership but also the experience of interacting with the technology, and with the real estate market and how it is used, and how space is consumed. NFTs allow real estate owners to own their digital assets; it gives the real estate owner more control over their area, tenants, and operations. The applications of NFTs will have significant impacts that go beyond the simple ownership interest in a property.

Non-Fungible Tokens are revolutionizing the way we pay for things such as digital art, gaming, etc., and real estate assets. NFTs use blockchain and cryptocurrencies to eliminate financial institutions for intermediation. NFTs allow investors to execute transparent and verifiable transactions through distributed ledger systems (blockchain).

According to Simons (2021), NFTs are provable and immutable and once put on the blockchain, the owner's wallet address and token is known making it highly resistant to censorship and alteration. However, by combining the non-fungible token technical specifications of the ERC-721 creates a tradable asset that represents shares of physical real estate.

The market potential for applications of NFTs to real estate is reflected in the size of the market. According to the National Association of Real Estate Investment Trusts (NAREIT), the total value of commercial real estate in the United States is estimated at over \$16 trillion in 2018. The application of NFTs to real estate ownership interests and transaction volumes, could unlock additional market value on a global basis.

Prototypes are used to illustrate real estate trading systems based on NFTs to tokenize digital real property, preventing fraud and improving transparency over secondary transactions.

The prior section introduced blockchain, cryptocurrencies, fungible tokens, and non-fungible tokens; the following section illustrates applications using NFTs for real estate transactions: gaming application, ticketing system, potential solutions, and current blockchain based real estate platforms.

## **Method Application NFTs to Real Estate Transactions**

The next section illustrates how to use NFTs for commercial real estate transactions. A hypothetical application was created for managing, transferring, and tracking ownership and usage rights; these are powerful attributes to prevent fraud and limit control over secondary transactions, as cited from Waterson (2016).

As written by Hevner et al. (2004), Gregor (2006), and Glaser (2017), this is significant in that it reduces the reliance on third-party brokers for trust in the transactions; this blockchain technology is expected to significantly disrupt the real estate markets. The NFTs decentralised nature and blockchain-based transaction system are designed to replace existing centralised transaction applications. To do this, there will be challenges from a technical and management standpoint.

## **Real Estate Gaming Applications**

Blockchain and NFT applications are limited; however, the use of NFTs to commodify unique virtual real estate in a gaming environment demonstrates a robust framework that is easily transferable to real asset transactions.

According to Animoca Brands (2020), Sandbox is one of the most considerable independent user-generated content and gaming platforms globally, with approximately 40 million downloads and more than one million monthly active users. In Sandbox, players build, own, and monetise their virtual real estate using SAND, the platform's fiat currency, and LAND, a non-fungible token (ERC-721) representing a digital piece of real estate in *The Sandbox* metaverse. There are a limited number of LANDS, 166,464 in total, each with a unique location.

In 2020, *The Sandbox* conducted four successful pre-sales of LAND, worth more than \$1.5 million in all. Most offerings finished within minutes to a few hours due to high demand. Round one of the fourth presale introduced premium LANDS and sold 75 percent of them in one hour on August 4, 2020.

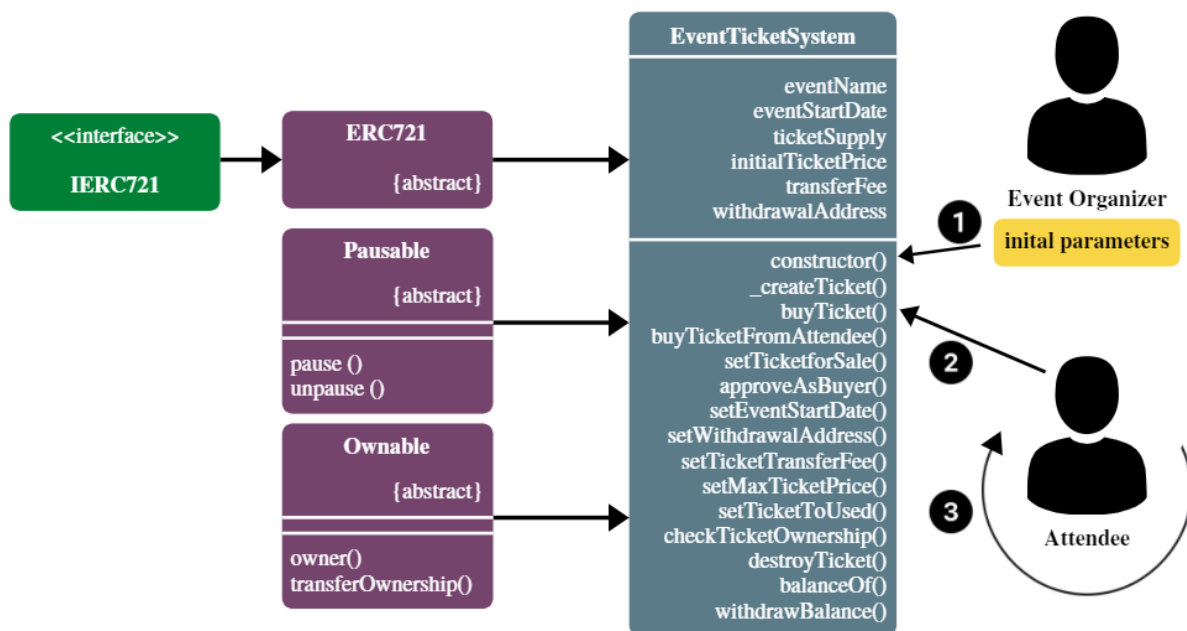
These real estate transactions, though virtual, show how NFTs can be used to facilitate the purchase and sale of unique and scarce assets in today's real estate market as cited by Animoca Brands, 2020.

In the prior section, real estate transactions were illustrated using the Sandbox LAND game based off of Ethereum ERC-721 (NFTs) on the blockchain; and the following section illustrates in detail the use of Ethereum ERC-721 (NFTs) on the blockchain using a developed prototype of a ticketing system to show how real estate transactions work.

## Real Estate Transactions Using NFTs

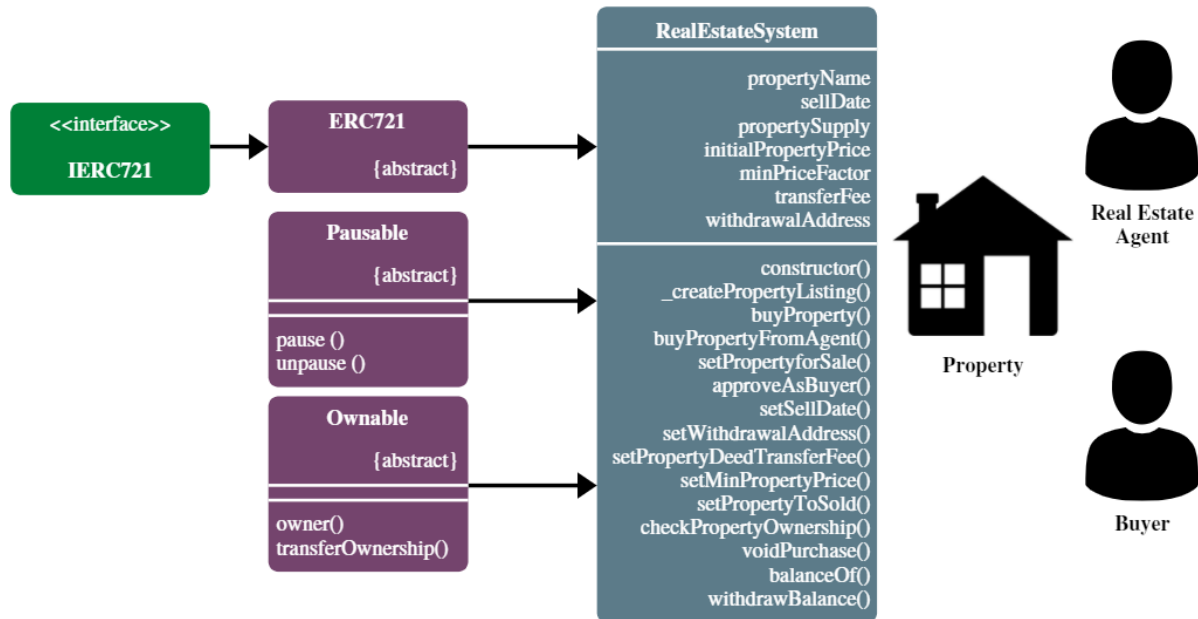
Researchers Regner et al. (2019) created a prototype for the use of NFTs in ticket sales. This prototype, slightly modified, serves as an example of the use of NFTs in real estate transactions. The following section is taken from Regner et al. (2019) article modified for real estate transaction applications.

The figure below outlines the main functions of the original ticketing system prototype.



Source: Regner et al. (2019)

The next figure translates the ticketing system to a real estate transaction prototype.



Also according to Regner et al. (2019), first the real estate owners (sellers/lessors) deploy a smart contract for a specific transaction. Initial parameters, such as the name of the specific property, an initial price, a maximum price factor for the property, the date of sale, and an initial transaction fee for secondary transactions are provided to the `constructor()` as specified in the contract deployment script.

A constructor is a computer science term that refers to inputting parameters for later use in a class or object. In the case of this example, a class or object is a virtual representation of a unique property, identified by unique characteristics added to the constructor. The real estate owner owns the smart contract and can change the parameters later by interacting with the smart contract, and can withdraw the contract and pause the transaction any time.

After the contract is created, lessees/purchasers buy or lease the property until the supply limit is reached, by sending a transaction containing ether (a cryptocurrency) to the payable function `buyProperty()`. The function first checks and verifies the amount transferred and then calls the internal function `createPropertyListing()` to “mint” a new NFT, acting as a virtual representation of the property.

Each property is unique as its id can only exist once per contract, and its ownership can be verified at any time by calling the function `checkPropertyOwnership(id)`. The total number of properties owned/leased can be obtained by calling `balanceOf()`. Once the transaction has been completed, the modifier `TransactionNotStarted()` will prohibit the use of any setter functions.

Thus, no more transactions can be created or transferred after the time specified in `sellDate`. The organiser can call `setPropertyToSold()` to validate a sale at the county/municipal level.

While the scope of this prototype does not feature a front-end for retail users, its full compatibility with the ERC-721 standard enables users to use any compatible wallet or NFT-marketplaces like OpenSea to facilitate peer-to-peer transactions in an easy manner as cited by OpenSea (2019).

The prototype is deployed on the Ethereum test network Ropstenand, thus allows any user with access to an Ethereum node to invoke the smart contract and use it. The source code of the original ticketing prototype, including instructions for deployment, is publicly available on GitHub, and as demonstrated, can easily be modified to suit real estate needs.

In addition, for leasing applications, a secondary market can be established. Property owners can offer their properties for sublet by calling the function `setPropertyForRent()`. They can use the function `setMinPropertyPrice()` to charge any price (rental rate) that does not fall below the minimum price as defined by the property owner.

Any user with access to a blockchain-enabled web browser can lease property from current property owners once approval has been set by the original owner through the call of `approvedAsRenter()`. The sub-letter can now transfer the required amount of cryptocurrency to the payable function `rentPropertyFromLandlord()`, which finally transfers the property space to the renter.

The prior section outlined the two applications using blockchain and cryptocurrencies for real estate transactions. The following section outlines the recommended solutions for developing blockchain and cryptocurrency, along with NFTs and smart contracts, for real estate transactions and capital market making. Other existing platforms are also included.

## **Results of Competing Solutions**

There are three solutions to integrating the blockchain, cryptocurrencies, and smart contracts to real estate transactions and investing: 1) creating an ERC-20 and ERC-721 simultaneously, 2) utilising the ERC-1155, and 3) the Hyperledger Fabric.

### **ERC-20/721**

ERC-20 is currently being used on the blockchain for real estate transactions, ERC-721 is also currently being developed for applications in real estate transactions, and the future will see applications in ERC-1155 and Hyperledger Fabric.

According to Simons (2021), the current solution is to deploy a multi-signature wallet for both the ERC-721 with property information and metadata, and the ERC-20 representing fungible ownership shares of said property. The multi-signature wallet sends the ERC-721 token to the ERC-20 contract making it irretrievable and immutable, for the public and investors to see. This is the point where the title is established.

There is a defect in the ERC-20 token as there is very little verifiable metadata; however, it is fungible and has interoperability with decentralised finance. The pros of ERC-721 are verifiable metadata (smart contract) and censorship resistant (security); however, it is non-fungible.

### **ERC-1155**

The ERC-1155 attempts to combine both the ERC-20 and the ERC-721, but token standards, and a programmer ecosystem, are not yet fully developed for decentralised financial contracts and protocols.

Real estate is an illiquid asset class facing a lack of transparency, hidden costs, and regulations. The market for buying and selling real estate is localised and segmented with private contracts negotiated, expensive transaction costs, due to the number of trusted third parties.

A decentralised auction market is needed to benefit the real estate industry, by making more of the information digitised and available. The investment time cycle of real estate property ownership and transactions is recommended to be transferred to the blockchain, creating systems where properties have digital information on specific assets including title recordation, ownership chains, and sales price history.

NFTs improve this transparency, offering complete records of ownership and investment performance, allowing regulators and assessors, future investors, an improved view of the risks associated with the real estate property, market, and investment potential.

### **Hyperledger Fabric**

Also cited in Valenta and Sander (2017) and Bal and Ner (2019), the next generation of cryptocurrency, blockchain, and NFT applications to real estate transactions to be based on the Hyperledger Fabric. The description of the platform is a modular blockchain platform, governance is the Linux Foundation, the mode of operation is permissioned and private, consensus is based on a broad understanding of consensus allowing multiple approaches at the transaction level, smart contracts use smart contract code such as Go and Java, and there is no cryptocurrency such as Ethereum, currency and tokens that are via chaincode.

Hyperledger Fabric is a modular, permissioned blockchain supporting consistent and on-going execution of distributed applications. This divides transaction flows into three steps: (1)

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transaction execution, (2) ordinal transaction processing via NFT consensus protocols, and (3) transaction validation and verification processes. These steps are performed in a peer environment, significantly different from state-machine replication, allowing for scalability and modular consensus implementation.

Hyperledger Fabric is a permissioned network structure where all nodes are identified and assigned an MSP membership by the service provider, allowing use in an enterprise structure governed by a private organisation to preserve transparency and integrity of the blockchain.

A Hyperledger Fabric is made up of three nodes: peers, orderers, and clients. Peers (real estate counterparties) execute transactions, receiving updates from blocks of the transaction. When receiving the most recent block, peers validate the transaction, adding changes to the local ledger, connecting the blocks to the blockchain. Peers verify and validate the transactions, acting as endorsers, executing the Hyperledger smart contract or "chaincode". They attach cryptographic signatures that are sent back to the clients. Organisations can have multiple parties (peers), and one peer can act as an anchor that collects blocks from the transaction and transfers them to other blocks through peer -to- peer protocols, according to Martijn.

Within the Hyperledger Fabric framework, the counterparties request for all transaction information (orders) in the network, propose new blocks, and seek consensus between counterparties. These orders track the organisations associated with the transaction and provide channels to broadcast the information. Clients act specifically for an end-user, sending transaction proposals received by peers, then sending endorsed transactions to ordering service. A client is related to the peer in its organisation so that it can be notified of committed transactions.

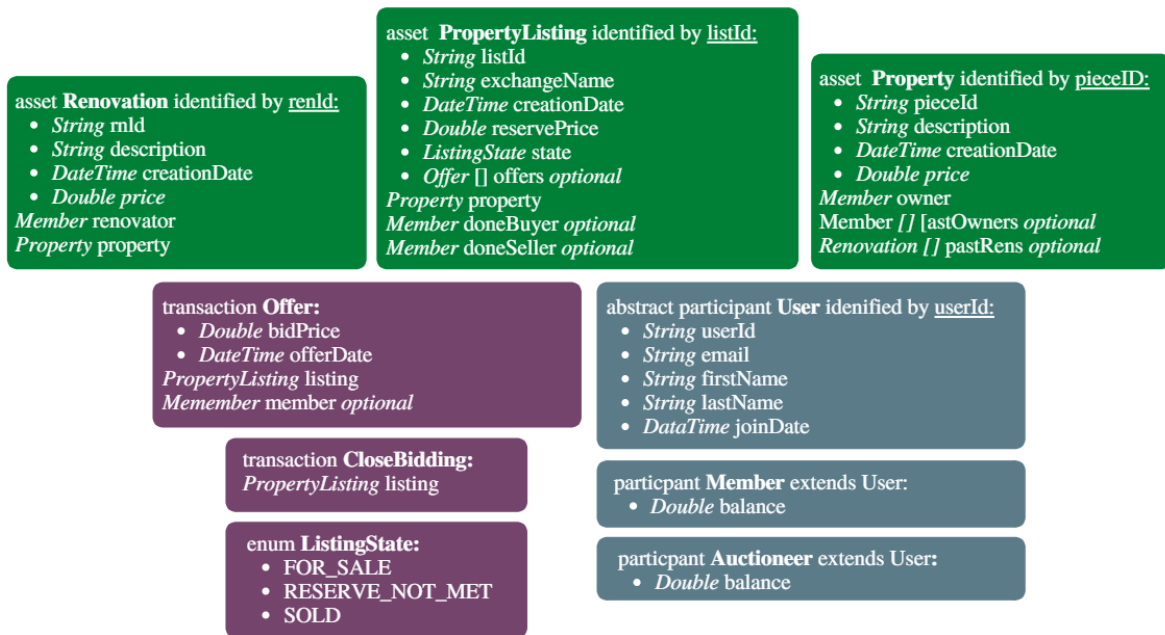
The benefit of Hyperledger Fabric, compared to Ethereum, is if a "client" node wants to communicate a message to other chaincodes, it needs to send to "endorser" nodes that execute chaincodes independently, and determines message's effects on database of chaincode. The "endorsement" adds an endorser's response and digital signature. Once this is done, the transaction is broadcast once the client receives a specific number of endorsements as cited in (Hyperledger, 2019).

A permission blockchain such as Byzantine-Fault Tolerant (BFT) is used under all members of the network. The fabric has member identity serves, these administer user ids, identify users, so members know the identity of counterparties while maintaining confidentiality. Hyperledger Fabric systems architecture differs from others in that you do not need Ethereum or Quorum, these architectures require order execution and consensus protocols, to order and allow peers to execute the transaction.



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The following diagram illustrates real estate transactions using the Hyperledger Fabric platform.



Source: Bal and Ner (2019)

The solution for real estate transactions are implementation of technologies and frameworks described above, with a focus on complete, comprehensive, permissioned, and secured systems using the Hyperledger Fabric blockchain network architecture, thereby allowing real estate transactions to be executed in a decentralised non-fungible token tracking environment, according to Bal and Ner (2019).

The prior sections illustrated the use of the blockchain, Ethereum, NFTs, and the Hyperledger Fabric in the design of a real estate transactions system; the following sections describe other blockchain real estate platforms, give an overview of the legal and regulatory frameworks, discussion of title recordation and transfer system; and ends with a discussion of the potential for NFT applications within the 1031 exchange framework, and the development of an institutional real estate capital market.

## Other Blockchain Real Estate Platforms

Although these are the recommended solutions, there are other platforms currently available. According to Dailey (2020), there are currently 19 blockchain platforms in the market surrounding real estate: RealT, RealtyBits, Property Club, ManageGo, Real Blocks, Meridio, Smart Realty, Reasi, Propy, Slice, Harbor, The Bee Token, ShelterZoom, NetObjex, StreetWire, Cprop, Imbrex, The Crypto Realty Group, and The Lending Coin.

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For example, RealT and several other companies have developed platforms linking real estate and the blockchain. Property Club, Meridido, and Real Blocks are similar to **RealT**, in that it allows institutions and accredited investors to invest into real estate developments and projects, along with a place for them to sell their home shares. RealT illustrates how ethereum is leveraged to develop microscale-controllable security tokens. **Harbor**, on the other hand, attempts to connect real estate portfolio managers to access blockchain tech within their investment platforms, providing liquidity and capital efficiency.

The following platforms were reported by Dailey (2020): **Property Club** is a way for individuals to market, research, buy/sell, and invest in real estate using digital smart contracts and cryptocurrencies (Bitcoin and PropertyClubCoin-PCC); **ManageGo** leverages the blockchain for rental properties using ledger-backed software to process and record payments, tenant credit checks, and maintenance tickets; and **RealBlocks** uses blockchain for real estate investing by fractionalising interests as opposed to individual assets or portfolios through tokenization, accelerating the investment process and enhancing liquidity.

**Meridio** provides commercial real estate owners a platform to sell digital shares by connecting individuals and corporate investors to owners liquidating asset positions; **SMARTRealty** utilizes smart contracts (protocols) to initiate and manage self-terminating investment and rental contracts, along with rent collection, mortgage origination, and residential acquisition; and **Reasi** is a complete escrow transaction platform with secure and streamlined processes that eliminate third party agents.

**Propy** uses a series of smart contracts to speed transactions on an international basis used by purchasers/sellers and agents; **Slice** uses ledger technology to offer small international investors access to commercial real estate ownership interests; and **Harbor** tokenises private securities, real estate properties, funds, private REITs, and land to provide liquidity.

**Bee Token** uses a blockchain home sharing platform (like Airbnb) to rent houses and rooms for cryptocurrency; **ShelterZoom** is a blockchain developed to speed up offers and acceptance for real estate contracts in a secured environment establishing and immutable record; and **NetObjex** uses ledger technology-smart contracts specific to real estate companies.

**StreetWire** utilises data provider-controlled encrypted ledger to secure and speed transactions; **CryptoProperties** (CPROP) creates blockchain data systems to identify the problems associated with broker transactions, portfolio management, development, financing, and issuance; and **Imbrex** decentralises and encrypts data on the blockchain, connecting buyers and listing agents using digital tokens as currency, providing transparency and efficiency in the purchase-sale process.

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Lastly, **Crypto Reality Group** is a consulting company designed to bring together crypto escrow and financial consulting firms facilitating the purchase and sale of international, commercial, and residential properties using cryptocurrency; **Lending Coin** is a peer-to-peer financing program on the blockchain, providing fractional interests, and ensures that transactions are transparent and traceable; and **Uniswap** is a trading platform that pinpoints tokens, pricing, yields, buy price, buy difference, buy yield, selling difference, and buy-sell options.

Another decentralized marketplace for trading NFTs is **OpenSea**, the largest marketplace globally, where the Wyvern Protocol allows for peers to search and swap NFT ownership on the blockchain for Ethereum cryptocurrency instantly. And lastly, **Coinbase** (an online platform for secure trading of digital currency with fungible currency) also launched a NFT trading platform.

### **Case Study: RealT**

The following RealT case study section is cited from Simons (2021) and Simons and Simons (2021). This system allows investors to buy units for tokens in specific properties. Investment units offer stated returns and the number of shares offered. A public blockchain is created with an interactive dashboard with data providing maps, rental information and disbursements. The company is only two years old with seven properties, however, the immediate goal is to have 40 properties or more on the platform providing tokenized ownership equity units to investors.

The company structure is as independent LLCs and property transactions appear twice in the public record. First as originator-developer acquires the property at a closing price and second on system at a higher securitised price. The tenant pays rent to the LLC and the property is managed by a property management company. Net funds flow to the RealT blockchain, then to investors through smart contracts. These are legally binding financial agreements between the LLC, tenant, management company, and token buyers. ERC-20 LLC tokens are the smart contract.

The underlying foundation of RealT creates a highly scalable platform, and the company plans to enter 5 cities a year, 30 markets and 900 properties in five years. Expected annual equity returns are targeted at 10%. The upside to this platform is property values could be driven significantly higher as more capital flows to these assets on the platform; and values could be leveraged and credit enhanced through support by Government Sponsored Entities (GSEs), promoting housing policy in the United States through enhanced liquidity, stability, and market making to support the single-family and multi-family housing markets, specifically in Opportunity Zones (OZ).

For example, RealT uses Uniswap as the core application for its secondary market, providing anonymous secondary market transactions. At some point in the future, RealT could use floated funds to buy and sell cryptocurrency for market making. This could lead to a blockchain margin lending system eliminating the third party (clearing house).

## Recent Applications

Recent applications of NFTs used for real estate recordation and transactions are: 1) Wise County Virginia (City of Norton) records system developed by Bloqable, and Propy based South Burlington, Vt. Ethereum-blockchain-property recording system; and 2) a single-family residential property sold in Hyde Park, Tampa Florida.

In June of 2021, Wise County Virginia (City of Norton) recorder's office worked with a company called Bloqable to develop blockchain software to create, validate, store, access, secure and manage smart land records (abstract of title) going back 40 years. Amazon Webservices (AWS) and Amazon Quantum Ledge Database (QLDB) uses Machine Learning (ML) and Artificial Intelligence (AI) to enable automatic generation of title abstractions instantly, as cited by Government Computer News - GCN (2022).

The second case where the blockchain and Ethereum are used for a property recordation system is in South Burlington Vermont using Propy for the pilot project. This system uses Quick Response (QR) codes to allow users to find property title chains, deeds, transactions, information, payments, etc. on the blockchain using Ethereum. The system also provides publicly available information online that is transparent, runs faster because it is digital, is highly secure and verifiable and can be implemented and run alongside existing systems without major disruption. The only limitations to this system could be state laws that prevent new methods of filing deeds, and replacing existing land record software already adopted by local municipalities as cited by Miller (2022).

According to Khoury and Wachtler (2022), from ShepardMullin law firm, on February 10, 2022 there was the first U.S. NFT based single-family residential property (Hyde Park, Tampa Florida) auctioned and sold off of the **Propy** blockchain platform. This is the first use of the blockchain as a digital representation of private property rights. The property sold for \$653,163 using Ethereum (Ether), and an NFT was used to mint the property rights. The way the transaction worked was for **Propy** to conduct the property inspection and title search, the seller-owner transfer the property interest into a Limited Liability Corporation (LLC) created by **Propy**, the LLC ownership was then minted off of the blockchain as an NFT, and then sold-auctioned to a qualified buyer in exchange for Ether (cryptocurrency) delivered to the seller's digital wallet.

The prior section outlined the recommended solutions for executing real estate transactions on the blockchain, along with using NFTs and smart contracts. Other existing platforms were also illustrated. This section concluded with three of the most recent case studies involving the blockchain for property recordation systems. The next section discusses legal and regulatory frameworks, NFT applications to 1031 exchanges, development of institutional real estate capital markets, compound finance, margin lending and market making.

## **Legal and Regulatory Frameworks**

### **OpenLaw Framework**

OpenLaw contracts are legal agreements using smart contracts that reduce the cost and time necessary to create secure legal agreements. Attorneys do not have the basic tools at this time to write dynamic smart contracts in a way that is legally enforceable and understandable to a legal professional.

OpenLaw frameworks are currently being developed to create standardised legal agreements using open source languages and integration with existing Application Programming Interfaces (APIs).

### **Regulatory and Legal Issues**

According to Christidis and Devetsikiotis (2016), the use of blockchain-based systems presents the general challenge of limited legal enforceability. Token owners can rely on authenticity, but are unable to rely on legal ownership and consumption of the private property rights represented by NFTs.

According to Hawlitschek, Notheisen and Teubner (2018), for a blockchain-based system to be truly trust less, legal correctness and legitimacy within the current institutional environment are required. Since NFTs are so new, few legal professionals and investors understand NFTs. In addition, the language used in the blockchain space is very technical and generally not well understood by the public.

### **Smart Contracts & Network Security**

Blockchain technology emerged from the development of bitcoin as a distributed ledger, maintained and verified a network of peers, the real estate industry has explored the peer to peer technology to create decentralised business networks. In permission less or public applications an agent can participate while maintaining anonymous identity. These blockchains include embedding native currency and Proof-of-Work (POW) consensus mechanisms. The benefit of permissioned blockchains is security for a group of entities that do not trust one another but want to achieve real estate transactions.

## **Transferring Ownership Rights Via Title Transfer**

### **Recordation and Transfer of Private Property Rights**

A challenge for NFT applications for real estate transaction recordation and enforcement of private property rights is that blockchain based systems have limited legal enforceability as cited by Christidis and Devetsikiotis (2016). However, token owners rely on authenticity, legal ownership, and consumption of rights as reflected in the NFTs.

Blockchain systems can be trust less, legally correct, and legitimate within the current institutional environment as cited by Hawlitschek, Notheisen and Teubner (2018). A further challenge to NFT adoption for recordation and transfer purposes is it remains currently in the innovator stage of the adoption curve, with limited market participants with knowledge of NFT application development and usage, as the coding and technical competencies remain limited. Additional impediments are that it takes time to create tokens.

Based on the first intro the major problem is to track the history of real estate values over time due to fluctuations; and information by governments guaranteeing title deeds or other companies posting tangible entities (Costar/Loopnet, etc.) central information providers (CIP) act as an information source and exchange implying that the information on the platform is secure and accurate.

CIPs are centralised, therefore only one point of failure in the system, if it breaks down, they can be easily breached by various organisations; library techs, malware, or government intervention. The single point of failure is the data servers, various information entered in the system, lack of fact checking, and inability to validate if the information is valid and accurate. There are serious problems in regards to data security and the validity of data.

The solution is to use a blockchain to introduce an NFT tracer or decentralised blockchain solution in a real world and real time environment. For example, we could establish ERC-20/721/1155 for each market as long as the community adopts the standard.

According to Voshmgir (2018), Butcher (2018), and Griffin (2018), the potential use and adoption for NFTs on Ethereum networks to track ownership interests of real estate transactions is significant. Digital assets created by the real estate community could grow significantly over the next five to ten years; and according to Khatri (2018), NFTs will have context in their ecosystem facilitating the tokenization of real estate assets and high volumes of transactions, as cited by Coleman, Horne and Xuanji (2018).

## **Title Transfer and Tradable Assets**

According to Simons (2021), property titles are legally transferred to the entity holding the digital instrument. Ethereum is used with a Multisig wallet, transactions signed when transaction amount approved, creating an authorised, notarised, secure, and signed document. The multi signature wallet along with the authority create ERC-721 with property information, determining the basis for property value, location, as it moves through the legal process to establish title.

NFTs are provable and immutable and once put on the blockchain, the owner's wallet address and token is known, making it highly resistant to censorship and alteration. However, by combining the non-fungible token technical specifications of the ERC-721 creates a tradable asset that represents interests in physical real estate. This provides the opportunity to utilise the 1031 exchange.

## **NFT Applications to 1031 Exchange**

For the NFT applications to real estate transactions (sale and lease), there will need to be some legal clarity in regards to the current and modified enforcement and transfer of private property rights.

For example, one of the major hurdles to implementation is transactions in real estate are conducted at the local level, and title is recorded at the county level. If NFTs are to be considered real property transactions, then NFT transactions will have to be recorded and a chain of title will have to be created using existing or modified purchase-sale contracts.

The local authorities, buyers and sellers, title agencies, and brokers will have to recognise these transfers as legal under current real estate law. If NFT transactions are considered securities, they will have to be regulated under SEC regulatory and security laws/guidelines. The ideal situation would be for these NFT transactions to be considered real property transactions under the IRS 1031 code, which will allow owners of real estate to be able to exchange into NFTs in order to defer capital gains and recapture taxes (upleg-downleg and 45/180-day rules).

Similar transactions, and similar vehicles to NFTs, could be analogous with the tenants-in-common (TIC), Delaware statutory trust (DST), and oil and gas lease-hold interests. These fractional interests are allowed under the 1031 IRS code and could be a structured solution to NFT interests.

For this market to reach institutional status, it would need to meet the criteria for the real estate capital market development and adoption.

## **Development of Institutional Real Estate Capital Markets**

In the next 10 -to- 20 years, an institutional real estate capital market surrounding NFTs will develop. The requirements for institutional capital market development are: standardisation in contracts, confidence in the enforcement of these contracts, liquid and efficient transactions, transferability and transparency in transactions, a broad and deep market, a transactions exchange marketplace, and regulatory oversight.

The use of NFTs in developing a liquid and transparent institutional real estate capital market to meet investment and liquidity needs for institutional investors would have to answer the following questions:

- What are the criteria for efficient NFT real estate capital markets?
- What is necessary for NFT real estate capital markets to develop?
- How long will it take for NFT-based real estate capital markets to reach the early majority adoption phase?
- What are the institutional factors necessary for the development of institutional-grade NFT capital markets?
- What valuation techniques would be used to value the ownership interests?
- How would we develop and pool these interests into a portfolio?
- How would we manage these portfolios?
- Can we structure these portfolios into closed-end private equity funds/ETFs/mutual funds/other institutional and retail investment products?

The criteria for efficient NFT real estate capital markets are standardisation in contracts, tracking of trades between co-parties, liquidity, and market breadth and depth of contract trading, private property rights and enforcement of contracts, institutional and retail (speculators) investor participation, as reflected by contract exchange marketplaces similar to the Chicago Mercantile Exchange (CME), the Chicago Board of Trade (CBOT), NYMEX, etc.

The necessary conditions for NFT real estate capital markets to develop are trust in the system, counterparties, exchanges, regulators, and ability to track, trade, and transfer contracts efficiently at low cost, therefore, the development of a deep, liquid, and transparent secondary marketplace. The ability to apply leverage (margin or mortgage financing), and the eventual development of futures and options contracts on NFT indices, portfolios, and property level interests to help develop the secondary market and provide forward pricing. This also provides risk management strategies and tools for investors and traders.

It will take 5 -to- 7 years for NFT-based real estate capital market applications to move from innovator to the early majority adoption, and 10 -to- 20 years for the marketplace to reach the late majority phase of market development. This is based on prior real estate capital market



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product development cycles as witnessed by limited partnerships in the 1970s, commingled funds in the 1980s, Real Estate Investment Trusts (REITs) and Commercial Mortgage-Backed Securities (CMBS) in the 1990s, and the attempt to develop property derivative contracts in the 2000s.

Institutional factors necessary for the development of institutional-grade NFT capital markets are the establishment or the expansion of a Government Sponsored Entity (GSE) participation in market making, Wall Street and hedge fund participation, public and private equity fund participation, public and private debt fund participation, Registered Investment Advisor (RIA) participation, pension-endowment-sovereign fund participation, commercial and shadow bank participation, and retail investor (Exchange Traded Funds - ETFs) participation.

Valuation techniques used to value NFT fractional ownership interests are intrinsic valuation techniques based on future and projected cash flows (terminal values): simple perpetuity method, constant growth method, multiple approach, Discounted Cash Flow (DCF); and sales comparable approach, income capitalisation approach, and Gross Rent Multiplier (GRM) method. Technical valuation and trading methodologies can also be used to price real estate based NFT contracts by observing bid-ask spreads, contract trading volumes, RSI/MACD momentum indicators, trend analysis, and other techniques.

Once these conditions are met, NFT fractional interests can be pooled into portfolios for management purposes. These portfolio management techniques would adhere to standardised applications in Modern (MPT) and Post-Modern (PMPT) portfolio theory. Based on the development of the marketplace and the ability to build institutional grade real estate based NFT portfolios, and the development of a derivatives market, would allow for synthetic portfolio construction, and the application and development of portfolio insurance. This would provide the necessary conditions to execute on institutional investment and risk management portfolio strategies.

Real estate backed fractional interest portfolios (NFTs) to be managed based on investor preferences surrounding expected nominal and risk-adjusted returns, maturity and duration of holding period, diversification and concentration adjustments, and liquidity and exit capabilities.

These portfolios could be held in single accounts, commingled funds, Real Estate Investment Trusts (REITs), mutual funds, Exchange Traded Funds (ETFs), Tenants In Common (TIC) interests, Delaware Statutory Trusts (DSTs), and other types of structures. ERC-20 and ERC-720 tokens can represent individual properties, portfolios of properties, and shares of real estate funds. In the end, we will be able to structure portfolios and strategies into financial products that meet the institutional and retail client investment needs.

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The following section discusses decentralised and compound finance, lending and liquidity pools, and market-making.

## **Compound Finance**

Real estate blockchain technologies advantages are security, anonymity, and transparency over traditional systems. The real estate market is being targeted for blockchain applications. The benefits could be tax advantages, clearly defined contracts, high liquidity, and integrity protected data storage.

According to Simons (2021) and Simons and Simons (2021), compound finance is a part of decentralised finance, what is called self-driving banks for example. DeFi and DeFiPlus aggregates data on financial holdings within a decentralised finance platform, and can use existing platforms such as AAVE, Uniswap and Balancer. Compound finance is a money market for digital dollars and cryptocurrencies pooling continuous markets, and lenders are matching loans to derive a decentralised mortgage finance market.

According to Leshner and Hayes (2019), compound finance is an algorithmic money market protocol allowing users to lend and borrow idle assets on the blockchain, utilising Solidity. For example, Compound Labs created a platform with over \$10 billion on the blockchain as of March 2021. Three stable coins (digital dollars) are used, activating money markets; enabling users to deposit bitcoin, Ethereum, and other assets to borrow or lend on; and allow users globally to leverage investment capital.

One of the main benefits of tokenisation is the ability to put assets on the blockchain is that anyone can interact with the system from any computer; therefore, the platform is censorship resistant, it can use multiple exchanges simultaneously to arbitrage markets. Speed and stability is derived from the distributed ledger system, low barriers to entry, cheap entrance, precision through fractional shares, ability to trade minute-by-minute 24 hours a day 7 days a week, ownership is public and anonymous, provides platform and contract flexibility, access to decentralised exchanges, money markets, and taxes regimes, and is self-regulating as cited by Simons (2021) and Simons and Simons (2021).

## **Liquidity Pools, Margin Lending, and Market-Making**

### **Liquidity Pools**

According to Leshner (2020) and Simons and Simons (2021), compound finance is a standardised example of a decentralised financial ecosystem. For example, margin lending is utilised as parties post collateral (ether) to the platform, requesting a loan for 50% of the collateral, and fees are charged based on the degree of liquidity within the liquidity pool.

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Collateral is managed by a computer system called keepers, ensuring collateral values are safe by communicating with borrowers of liquidity risk. The buyer posts margin, and can call the underlying value at some time in the future.

According to Simons (2021), automatic market makers and the framework for creating liquid pools on the blockchain provide the ability to adjust portfolio weights, positions, and fees. A liquidity bootstrapper allows for the balancing of multiple tokens in a liquidity pool similar to an ETF. Balancer pools are easy to establish with multiple equity tokens and a stable coin or another balancer pool with an equity/stablecoin pairing. This product could be an open-ended redeemable fund.

### **Margin Lending**

The blockchain's margin lending system, backed by a clearing house (compound finance), has no broker or over the counter market making. The counter party system utilises a pre-audited smart contract. Therefore, the real estate exchange transaction is between two investors similar to a credit default swap. Ideally, idle equity can be lent to the investor pool as margin.

For example, compound finance and swap platforms (MakerDao), employ what is called a "self-driving bank" technology. Also, AAVE and Uniswap platforms, specifically identify the asset, the market size, total borrowed, deposit APY, variable and stable borrow APR, and then the ability to either deposit or borrow.

### **Market-Making**

The market-making section below is attributed from Simons (2021) and Simons and Simons (2021). A use case for market making is the DeFi platform. DeFi allows individuals to collectively pool capital that algorithmically unifies market makers. For example, according to Adams (2020), the Uniswap framework allows algorithmic and decentralised exchanges, providing third parties to add/remove liquidity without government regulation. Prices are determined by a constant product formula relying on liquidity providers and arbitrageurs.

Blockchain finance and distributed ledger technology relies on smart contracts allowing funds to be transferred, lent, and sent without manual intervention. The smart contracts code provides user defined parameters for which the funds are to be used, and facilitates over the counter trades, time-locking of funds, promotion of complex trading and lending contracts. One of the main benefits of stable coins is the stability of the digital asset market, compared to the volatility of bitcoin.

Market makers make money off the volume of trading through the platform, by providing liquidity to pools by pledging their assets into a noncustodial fund where traders trade. Market

makers charge a 0.3% fee on the swap. Swap prices are set by a price oracle, a decentralised function providing the highest quality price data. Traders place orders or swap by calling the current market prices and trades with the liquidity pool. The swapper pays the fee to place the trade.

For example, RealT uses Uniswap as the core application for its secondary market, providing anonymous secondary market transactions. At some point in the future, RealT could use floated funds to buy and sell cryptocurrency for market making. This could lead to a blockchain margin lending system eliminating the third party (clearing house).

Stable coins are risk neutral positions as only one trader is going long. For example as prices rise, the long position will receive profits; if prices fall, the margin lender profits. As of July 2020, there was \$2.7 billion in stable coins, up 100% over 3 months; and as of February 2021, rose to over \$31.5 billion according to DeFi Pulse (2021). Markets are visible through the AAVE system, a lending pool now worth \$10 billion. This platform deploys a self-driving bank technology (compound finance).

Other types of instruments that can be developed are Floating Rate Notes (FRN), where we would use interest rate protocols reflecting floating rights of the ERC-20 to provide liquidity. The current market for derivatives is not developed or liquid enough to arrive at forward pricing; however, there are systems trying to price option contracts on Liquidity Pool (LP) tokens.

## **Conclusions**

This paper presented a roadmap for the applications of Non-Fungible Tokens (NFTs) for real estate transactions using blockchain and cryptocurrencies. This research focused on the impact of the NFT's ability to fractionalise and track real estate assets and ownership interests; by giving an example of a gaming application currently being used in the crypto-blockchain environment; the translation of a ticketing system for real estate investment transactions using Ethereum; and current and future potential real estate transaction solutions using ERC-20/721, ERC-1155, and hyperledger fabric.

Real estate blockchain and cryptocurrency platforms for real estate transactions were also provided. We ended the paper with a discussion on legal and regulatory frameworks, applications for potential 1031 exchanges, recordation and transfer of title, and institutional capital market development, leverage and market-making potential.

The future of NFTs, blockchain, and cryptocurrencies to potentially change investment in real estate assets. Over the next 10 -to- 20 years, blockchain and cryptocurrencies could become the standard technology, medium of exchange (trading), and unit of account (stored value) for real estate transactions, representing the ability to track and verify, and leverage and trade ownership

interests, in ways never before applied.

## **Challenges**

Though NFTs and blockchain have enormous potential as innovations in the real estate ecosystem, the adoption of the platform carries certain challenges. The following challenges are the lack of:

- Early majority adoption
- Infrastructure
- Trust and knowledge in the blockchain/cryptocurrency market
- User-friendly interfaces
- Knowledge by institutional/small investors
- Sophistication by real estate investors
- Ability to adopt new tech by real estate investors
- Standardised transactions platform
- Inherent stability of chosen tokens
- Existing market
- Regulatory oversight
- Clearly defined legal standards
- Understanding of enforcement and transferability of private property rights

Lastly, other challenges are:

- Coordinated pushback by insurance/banks/real estate entrenched interests
- High initial start-up costs (learning curve, resources)

Out of the challenges listed above, most are eminently solvable with sufficient time and resources. One of the larger challenges to overcome is the extensive and overlapping legal and contract-based transactions that characterise the real estate industry. The problems of the current systems are: lack of trust, no control over secondary market price, dependence on intermediaries, and no immediate validation.

## **Opportunities**

The opportunities for the use of blockchain and cryptocurrencies (NFTs) are the ability to monetise and liquidise real estate interest in a highly secured environment; this is expected to rapidly drive adoption and the development of new institutional real estate capital markets.

There are currently rapidly emerging crypto and real estate capital markets that can be used as prototypes and models for future platform development. This will require the development of a programmer community and ecosystem around ethereum and hyperledger fabric applications.

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As this marketplace meets the early stage requirements for institutional capital market participation, we envision a multi-trillion dollar global real estate capital market emerging, developing and reaching majority adoption phase within the next 10 -to- 20 years.

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