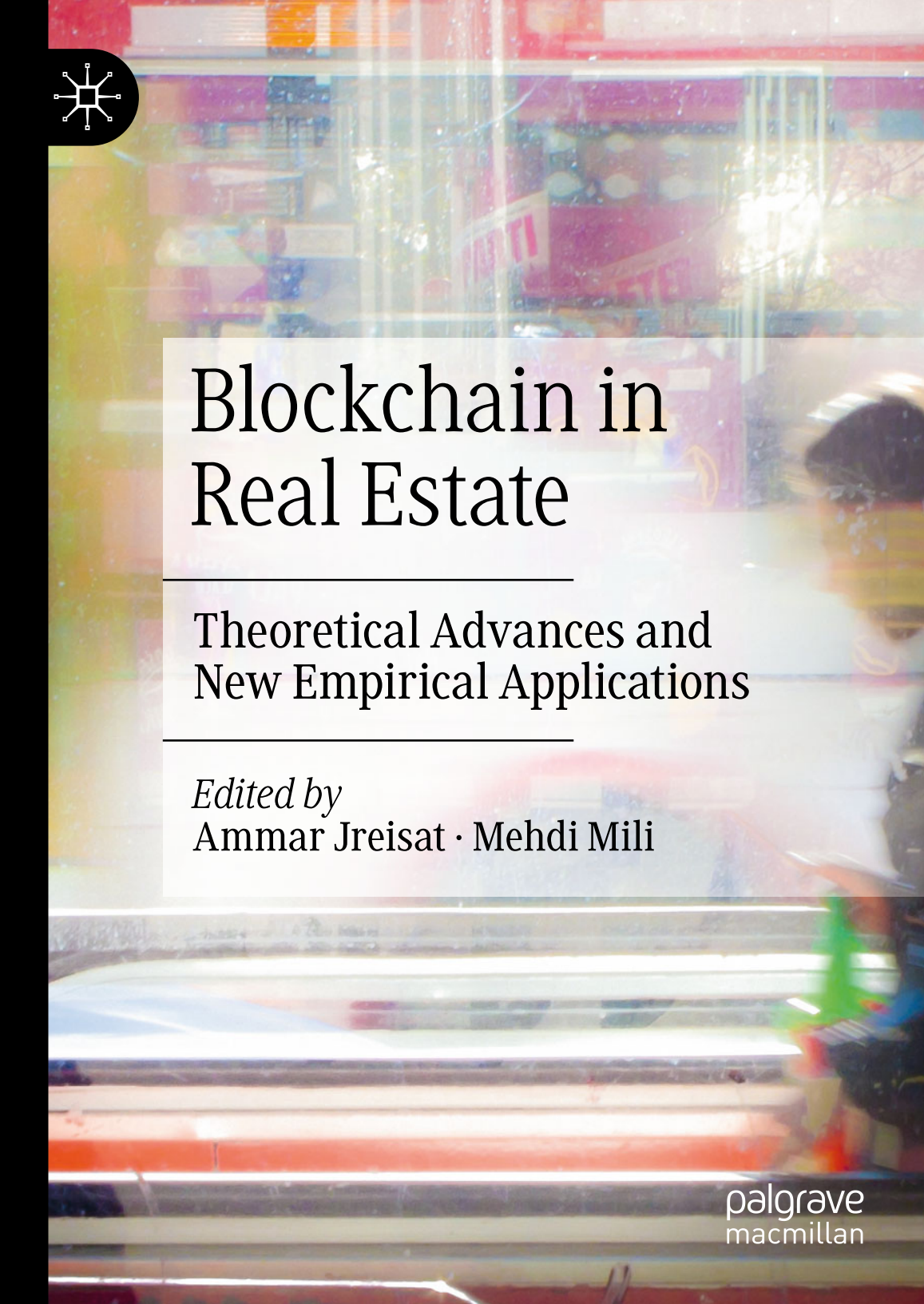
Blockchain in
Real Estate
Theoretical Advances and
New Empirical Applications
Edited by
Ammar Jreisat · Mehdi Mili
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Preface

The use of blockchain, as a new decentralized digital architecture, is of increasing interest to real estate players today, as it would completely revolutionize their profession. This book helps you to understand this technology and offers you a small decryption of the development axes envisaged by this new business model, and you can discover the interest of using the blockchain in real estate.

Blockchain is a protocol, comparable to a recording register, keeping the history of all the exchanges carried out on it. Originally created for crypto-currencies, blockchain makes it possible to carry out transactions, certify information, automate the remuneration of the various stakeholders, and create contracts. The exchanges carried out inside are peer-to-peer, each link in the chain being both the client and the server. In this way, this system allows everyone to verify the validity of the data contained in the blocks. Once deposited, the content based on an encryption method, prohibits any modification of the information.

Since the advent of official document digitization, real estate practices have been disrupted. Blockchain technology is part of this same logic, allowing real estate transactions to be carried out outside the usual processes. Easy to use, fast, and secure, blockchain offers an appropriate response to real estate investments of all kinds. In this way, during a real estate sale, all the elements such as the deed of ownership or the compromise are stored in different blocks, then distributed and duplicated in several copies on different servers.

Blockchain platforms associated with the real estate sector therefore provide a response in terms of speed and security, considerably reducing the risk of fraud. All stages of the real estate transaction are affected by this innovative technology, simplifying the transmission of data and reducing the time between the signing of the compromise and the authentic deed of sale before the notary. In addition, this process is extremely interesting in certain countries where the system is corrupt and where it is difficult to know who really owns a piece of land before buying it. Blockchain is an ideal tool for viewing the status of properties and deeds of sale, with full access to the history of the property or land. Accessible at any time and without time limit, by banks, real estate agencies, buyers, and sellers, the blockchain thus ensures the authenticity of land registers and demonstrates resistance to hacking and data corruption.

This book is written by eminent scholars and international experts to make valuable contributions on the impact of blockchain on the development of the real estate industry. Its originality lies in the desire of contributors to mix as harmoniously as possible theory and practice. Throughout the chapters, the authors present interesting advances in Real Estate Blockchain models. The application areas are illustrated by real and updated applications of blockchain technologies in the real estate industry. Particularly, the topic of this book connects in a significant way with disciplines of research in the field of Blockchain and Real Estate. This book will appeal to a wide readership, from students through researchers to practitioners who want to deepen their knowledge and disclose new advancements in Blockchain and Real Estate professions. Readers will discover diverse perspectives of the contributing authors such as new rigorous extensions of Real Estate models including new Blockchain techniques.

Zalaq, Bahrain

Ammar Jreisat
Mehdi Mili

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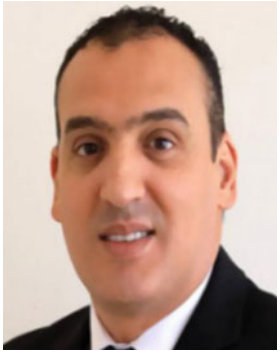
runner-up for the Bates White Prize for the Best Paper at the Annual Meeting of the Society of Financial Econometrics 2022 in the United States of America.



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Blockchain Technology in Real Estate: Potential Future and Challenges

Ammar Jreisat and Mehdi Mili

1 Introduction

The real estate sector is known to be slow to change and relies on traditional methods and approaches for its various segments. The real estate sector constitutes a good portion of the GDP of any country and all governments want to improve and develop this sector. The real estate sector opens important doors for the economy in terms of contribution to GDP and employment generation. Real estate assets are considered as an alternate asset class, and it is used by the investors to diversify their investments and to get alternative sources of income and return. It can be done through direct or indirect investments. Buying real estate assets with the intention of earning income through rental or resale is a method of direct investment in a property. A Real Estate Investment Trust (REIT) is an indirect investment and an investment fund which invests in real estate and pays out rental income to the REIT equity holder. Investors can put money into a collection of properties a REIT company manages which is quite similar to the concept of mutual funds in financial markets. The

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equity holders of REIT will benefit from the dividends earned. Real estate assets have a positive correlation with inflation and therefore provide an inflation hedge. So, the major benefits of real estate investment include passive income, regular cash flow, tax advantages (in some countries), and diversification. Real estate investments also have high transactional costs which include the transfer of ownership fee and legal and brokerage fees. The process of buying property is quite long and has several legal requirements. Another major disadvantage of investments in real estate is that they are difficult to liquidate, and it is not very easy to find potential buyers for the property. Buying and selling any real estate asset is not like the buying and selling of other assets and there are specific laws that govern how it may be bought and sold. The traditional real estate buying and selling process can be time-consuming, challenging, and full of back-and-forth discussions among sellers, buyers, and real estate agents. Renting of various kinds of properties is also an important segment of real estate segment. The whole process of renting or leasing both for the landlords and the tenants is a long and somehow troublesome process. Landlords are always looking for the best tenants and the tenants are looking for a perfect property that can satisfy their needs. Especially for commercial real estate renting and leasing is not just about simply finding a place to run the business but it can greatly impact the business. The right location for the accurate price on precise terms can make the office more productive, which ultimately makes the business more attractive to consumers and enhances profitability.

Till the last few the whole real estate industry was following the traditional methods of buying, selling, renting, leasing, and management but now the role of technology is becoming more prominent in the real estate industry. Therefore, the use of technology and innovation will transform this sector into a smart real estate sector. The most important technology that real estate is adopting is blockchain technology.

Since its introduction, Blockchain technology has become popular in several segments and the potential for the development of this technology is still huge. Blockchain is an information storage method that makes it not possible for the system to be reversed, hacked, or controlled. It is a distributed ledger that replicates and issues transactions across the network of computers which are connected in the chain and helps in the traceability and authentication of multistep transactions. The ultimate advantage of blockchain is that it can provide secure transactions, reduce intermediary costs, and accelerate data transfer processing.

Enabling cryptocurrency was the prime aim of blockchain technology but has since been widely pushed for its potential to transform various industries. Irrespective of the original purpose of blockchain technology, various segments are using it for their own benefits. These segments include the public administration, regulators, traders, healthcare sector, etc. In the domain of business blockchain technology is being used in financial institutions, financial markets, supply chain management, healthcare, media, real estate, and energy. Among all these segments, the use of blockchain in the real estate sector is increasing day by day. The real estate sector is also experiencing the use of blockchain which is being called "proptech" (Nasarre-Aznar, 2018).

2 Use of Blockchain Technology in Real Estate

In the real estate sector, the use of blockchain is possible at various stages of real estate transactions. The use of blockchain in real estate has a number of benefits including an increase of efficiency, reduction of time, reduction of information asymmetry, providing trust, verifiability, and transparency, help to reduce fraudulent transactions, and increase safety and trust as compared to centralized digital solutions of transactions.

In real estate, the term "tokenization" refers to the digitization of various financial instruments. The digital assets can be programmed to bring in ownership rights, transaction description, and rules can be created to guarantee asset issuance, distribution, and transfers follow specific regulations. Digital assets can be altered to fulfill all requirements of the issuer. The blockchain technology can bring alternative financing for real estate. Blockchain-based financial products facilitating investors and providing transparency for the investors. These technological solutions increase investor confidence and unlock access to a wider investor pool all over the world.

In many underdeveloped and developing countries, the land registry departments are engaged in the alleged mismanagement and manipulation of land records. The land registry department in any country can use blockchain technology for ownership transfer/registration of any property and by applying the land registry in blockchain, the security issue is fixed to a greater amount and makes the property transaction more secure. Another big advantage of using blockchain in the land registry process is the reduction of manual effort spent in record keeping. Krishnapriya and Sarath (2020) discussed the use of various algorithms which makes

the information for each transaction more reliable and secure. The Association of Registrars of Spain (CRE) announced the launch of a service called "Regturi" to register properties for tourist use, which is based on a blockchain.[1] Georgia, Sweden, Brazil, India, the Netherlands, Canada, India, the United States, and other countries are already testing and implementing blockchain-based land registration systems.[2] A blockchain ecosystem provides ownership rights efficiently, which eliminates the traditional paperwork and expense while promising transparency.

Infrastructure and construction projects are an important segment of the real estate sector. Blockchain can help infrastructure projects in two ways. One is to help with the funding gap by tokenizing infrastructure securities, either debt or equity and making it more accessible to a number of investors. Secondly, using blockchain for transparency for infrastructure projects. This involves sharing the data of purchase orders and invoicing between subcontractors and contractors and the technology can be used to provide better security, transparency, and management in infrastructure projects. The blockchain in infrastructure market is to reach $725.2 million by 2026 as per estimation as per report by a company IndustryARC.[3] Infrastructure projects can be linked to decentralized land measurement systems through blockchain technology and operational management efficiency is increased primarily by the reduction of time and resources needed to carry them out. In the infrastructure projects, another potential of blockchain technology is in the transportation sector and all tolling transactions may be maintained through the blockchain. Secure and speedy transactions between connected vehicles could lead to excellent advancements. Zhang et al. (2021) discussed that blockchain tokenization has features that can change the capital size of investment in infrastructure projects. The authors also found that the prospective use of tokenization has not yet been fully attained and the prime reasons include

[1] https://www.onlinemarketplaces.com/articles/spain-turns-to-blockchain-to-register-properties-for-tourists/.

[2] https://fcegroup.ch/en/news/text/id411-2022-09-25-how-blockchain-is-changing-land-registration-in-different-countries.

[3] https://www.industryarc.com/Report/18532/blockchain-in-infrastructure-market-research-report.html.

the regulation uncertainties, volatilities in the token market, and the non-existence of the public sector at large. As per report of OECD,[4] the current processes and systems can be improved by the use of blockchain technology by improving the infrastructure value chain.

A smart contract is a computer program that is self-executed and automates the activities required in contract and makes the transactions trackable and irreversible upon their completion. Szabo (1996) introduced the term "smart contract". In the real estate sector, the smart contract is between a landlord of the property and the tenants. The objective of the contract is to confirm that the lease agreement is signed by both parties, payment of lease rental amount is on time and the termination of the lease contract is executed as per contract. Karamitsos et al. (2018) discussed the presentation of the detailed design of smart contract and the authors also used case for examining the smart contracts for renting residential and business buildings.

The term "Smart city" has emerged as a new concept to provide high-quality facilities to the people by optimizing the city resources. Smart cities are being developed and involve excessive networking, service providing, and integration of transactions into the initial city planning. Smart cities provide the finest services for enhancing the daily life of people in certain areas including education, healthcare, transportation, and energy consumption. The use of blockchain technology can resolve the security concerns of smart cities. Blockchain technology is the best way to safeguard smart cities' communications by securing communications routes to guarantee confidentiality. The blockchain technology can also be used to improve the city management and providing of important public services to the people through efficient data collection and analysis. Bhushan et al. (2020) mentioned that the blockchain technology can solve the security issues of smart cities and various facilities like healthcare, transportation, education, and supply chain management, can be improved by the use of blockchain technology along with the improvement of financial systems and data center networks. In their paper, Biswas and Muthukkumarasamy (2016) suggested a security framework by combining the blockchain technology with smart devices to give a communication platform in a smart city which is considered as a secured platform.

[4] https://www.oecd.org/finance/Blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure-key-findings.pdf.

Another prospective use of blockchain technology in the real estate sector is to reduce the fraud and error created by new transactions with an irreversible ledger that tracks all transactions. Traditional methods of property ownership registration are at risk of fraudulent activities and errors by the users. Blockchain offers a reliable and trusted way to store this information. This could help to reduce occurrences of fraud and scams in real estate transactions. The availability of more reliable property records on blockchain ledgers will provide an extremely valuable means for real estate analysts, regulators, and land management officials. The blockchain technology usage in real estate transactions will increase trust and efficiency, reduce corruption and fraud and reduce the cost. Bennett et al. (2021) mentioned the "hybrid approach", which is the concept of integration of blockchain technology with conventional databases in land administration. Saari et al. (2022) determined that existing land registries can be combined by the use of blockchain is a safer first step than replacing them. Implementing blockchain can decrease information asymmetries in real estate buying/selling transactions and will increase trust through verifiability. Goderdzishvili et al. (2018) concluded that blockchain-based ownership registry ensures transparency and reliability for the Georgian real estate sector. Kshetri (2022) mentioned that the digitization of land records can be done through blockchain, and it reduces traditional drawbacks like reduction in inefficiency and corruption in the Indian real estate sector. The prominent use of blockchain in real estate is the online payments and the remittance sector. Blockchain's core strengths can be used for handling a big amount of money changing owners on various property markets every day. The technologies allow for direct transactions between sellers and buyers, without the involvement of a supervising institution which verifies the legitimacy of those transactions. The process can be further strengthened by implementing smart contracts.

If blockchain achieves industry adoption across the whole real estate sector, then the risk of third-party intermediaries will be greatly reduced, and the blockchain-based systems will be able to inevitably validate the legitimacy of the ownership transfer of title. Blockchain platforms can connect sellers and buyers directly and it will eliminate intermediaries like real estate agents, and ultimately reduce the amount of commission given on transactions.

The real estate market can also benefit from joining the rapidly growing tokenization trend. Tokenization implies the blockchain tokens representing digital assets. This process can be applied to real estate assets as it is already used for a number of other asset classes. Tokenizing properties can bring more investors which will increase liquidity and transparency, and make investment in real estate more accessible, among many other benefits.

Another benefit of using blockchain technology in real estate is to manage, secure, and automate financing arrangements. Besides providing a shared ledger for tracking stakes, the blockchain offers smart contract-based mechanisms for stakeholders to participate directly in the project's management.

A big advantage of blockchain usage is in property management. Multinational property management firms experience ineffective management of their global portfolios. Blockchain usage in real estate management firms facilitates secure data sharing, streamlines rental amount collections to the landlords, and provides verification across the international portfolio. This expands operational efficiency and saves time and cost of managing the properties. The decision-making process is also assisted by big data generation due to blockchain technology usage.

Another advantage of blockchain usage lies in the accounting process of real estate assets. The investors and asset owners will get value from the cash flows recorded on-chain and real-time accounting. The annual financial statements can be prepared and conducted with the potential for real-time audits. This gives a huge advantage to various stakeholders of the real estate market and enables numerous developments in accordance with the regulatory supervision.

3 Potential Future and Challenges of Blockchain in Real Estate

The use of blockchain technology in the real estate sector has a number of benefits but at the same time contains a number of barriers. These barriers present challenges to the management of companies that affect the adoption of blockchain technology and innovation in real estate which can be called "smart real estate". Ullah et al. (2021) did a research on Australian real estate sector and concluded that blockchain adoption barriers are complicated. The authors mentioned several barriers that include high software and hardware costs, highly complex technology dissemination

systems, ignorance of government policies, and lack of regulations and standards.

Akhmetbek and Špaček (2021) did the research on real estate market of Kazakhstan and indicated that the key barriers to the potential use of blockchain technology include lack of legislation and also the difficulty of the technical execution of blockchain projects along with integration of technology with the existing systems. Lindholm (2021) did the research on the state of blockchain technology in the Finnish real estate industry and found that there is a disunity both in adoption of blockchain technology and knowledge in the Finnish real estate.

One challenge of blockchain usage in real estate is whether blockchain is necessarily able to perform the functions of land registries, notaries, real estate agents, and lawyers and can ensure a secure real estate transaction. There are some challenges that blockchain technology must overcome to be believed as reliable, legal, and secure system instead of the current real estate usage systems.

4 Conclusion

Real estate is taking a big dive into a decentralized digital world with business leaders and governments discovering and executing blockchain applications including real estate. Blockchain in real estate gives the highest level of transparency and reduces the overall process of transactions. The future of real estate incorporates consolidation of other emerging technologies such as machine learning and artificial intelligence with blockchain and brings an innovative change to the old and traditional real estate processes. The growth and development of the real estate industry is being hindered by various challenges. Nevertheless, blockchain technology can assist in addressing and resolving many of these issues and the application of blockchain in real estate has the potential to revolutionize the entire real estate sector.

Apart from the introduction and conclusion, the book consists of fourteen chapters covering a wide range of issues relating to the Blockchain Technology in Real Estate. The chapter following the introduction is on the blockchain technology transforming the real estate market, the chapter discusses the evolution and implementation of tokenization in real estate projects as well as the potential applications of blockchain in real estate transactions and property management. A key objective of the study is to identify some common themes among existing success and

failure of real estate tokenization projects to assist in developing a case for blockchain adoption across the real estate management process, while highlighting the existing risks and uncertainties associated with physical-metaverse interaction, regulation, registration, compliance, and security. Upon examining the existing evidence, it is evident that blockchain-based solutions will significantly transform the real estate market by automating registrations, fractionalizing property management, crowdfunding, promoting investor outreach, increasing flexibility, customization, administrative simplicity, operational efficiency, and increasing investor demand. In this chapter, it is noted that blockchain technology may provide substantial benefits to the real estate industry, however, there are several challenges facing the sector, such as fractional asset ownership, lack of market depth, overcautious regulation, asset recognition, single-asset tokenization, and cryptocurrency sentiment.

Chapter 3 explores the potential of blockchain technology to transform real estate asset management. This technology has the potential to provide unprecedented opportunities to the real estate sector; however, several challenges and limitations remain significant and require addressing in order to allow for further growth. This chapter provides an overview of these challenges and identifies their origins and discusses ways to address them so that blockchain can be effectively implemented to enhance transaction speed, reduce costs, and ensure data security. In addition to these advantages, a stronger real estate sector would contribute to a stronger and more integrated economy.

Chapter 4 describes in an observational and interpretative way the added value applying blockchain technology can have in the commercial real estate sector. The research goal is to analyze and structure commercial real estate characteristics, map its key stakeholders, their core processes, and how information is being used to answer where and how blockchain technology can add value. The chapter will zoom in on blockchain applications in commercial real estate processes and their challenges. Finally, by concluding the chapter focuses on wrapping up the results from the various studies referred to give a comprehensive overview of promising applications, their opportunities, and challenges.

The fifth chapter is devoted to Blockchain-based Life Cycle Assessment framework for building materials selection. The chapter provides insight into how real estate companies deploying blockchain-based solutions are faced with a plethora of competing technologies, each with a large number of unique parameters that must be adjusted by an expert.

The chapter proposes a Blockchain-based Life Cycle Assessment (LCA) framework to guide construction materials choice. LCA is a multi-criteria evaluation method based on ISO 14040 and 14044 standards and can be applied to additional standards depending on the sector studied and the objectives of the study. It aims to assess the potential environmental impacts of a product or activity. It is characterized by a holistic approach to the problem, considering the entire life cycle of the product studied.

The sixth chapter focuses on cryptocurrency and real estate transactions. This chapter examines the development of financial technology in the twentieth century and its role as a significant feature of contemporaneous technological advancement. Blockchain technology and cryptocurrencies are among the most significant financial innovations within the FinTech sector. It is expected that the use of cryptocurrencies in real estate transactions will reshape the whole market and could be the main game-changer for the industry. Researchers, policymakers, and real estate market participants are currently discussing how digital currencies can potentially benefit the real estate market. The purpose of this chapter is to contribute to the academic literature on the future role of cryptocurrencies in the real estate market in the following ways: Firstly, the chapter provides evidence on the imperativeness of cryptocurrencies and blockchain in the real estate industry. Secondly, the chapter outlines the potential benefits of digital currencies in the context of real estate transactions. Finally, the chapter examines how crypt-based real estate transactions are conducted.

The seventh chapter discusses the potential intersection of real estate and the metaverse, which is a virtual world that has become increasingly popular in recent years. Real estate in the metaverse refers to the ownership of virtual land, which can be used for a variety of purposes such as building virtual homes, businesses, and even virtual amusement parks. This virtual land can be bought, sold, and traded just like physical real estate, creating a new market for investors and developers. The chapter explores the benefits of investing in virtual real estate, including the ability to reach a global audience, reduce costs, and experiment with modern designs and structures. It also discusses the challenges and risks associated with this new industry, such as security concerns and lack of regulation.

Chapter 8 discusses asset tokenization as a new trend in the real estate industry that has attracted the attention of investors, developers, and regulators. It is the process of converting real estate assets into digital tokens that can be traded on blockchain-based platforms. This chapter describes recent developments in asset tokenization in the real estate

industry and examines the empirical methods used to assess its potential benefits and risks. As part of the chapter, the author conducts a review of the current literature and identifies several empirical studies that analyze, among other things, the impact of asset tokenization on real estate markets, investment behavior, and financial stability. Furthermore, the chapter highlights regulatory uncertainty, cybersecurity threats, and potential market manipulation risks associated with asset tokenization. Chapter 9 underscores the importance of distribution of proptech benefits to stakeholders of real estate market, this chapter will focus on the perspective benefits of the adoption of the technology and the distribution of gains to various stakeholders.

The tenth chapter explores the challenges posed by fragmented data in the real estate industry and its impact on transactions. Fragmented data refers to the scattered and disjointed nature of information within the industry, hindering decision-making and impeding transactions. The presence of data asymmetries further exacerbates these challenges, creating an imbalance of power and a lack of transparency. Real-world examples of successful blockchain applications in real estate demonstrate its transformative power. The integration of fragmented data holds immense potential for transforming the real estate landscape, unlocking new opportunities, improving decision-making, and creating a transparent and efficient ecosystem. The continued use of artificial intelligence, machine learning, and blockchain will play pivotal roles in shaping the future of real estate data integration. In the eleventh chapter, the significance of the Digital Building Logbook—the first application of blockchain in real estate—is highlighted. A Digital Building Logbook is the mother use case for blockchain in real estate, hence the need for conducting research to approach this chapter as an exploratory study. Based on my own practical experience, along with scientific and applied research, this chapter will provide a reasoned answer to this question.

Chapter 12 discusses land title administration challenges worldwide, with a summary of the most recent literature. It focuses discussion on five main challenges in land title administration and highlights the importance of blockchain technology in resolving these issues globally, demonstrating how blockchain technology can improve land record system efficiency, transparency, and security, thus making title verification easier. In spite of three major challenges associated with this technology, the adoption of blockchain technology in land title administration can enhance efficiency, resolve issues, strengthen regulators' position, and promote investment

in land. Chapter 13 presents a brief overview of the current situation with respect to tokenized real estate. A comparison is made between the active secondary markets for tokenized or fractionalized assets in developing countries and developed countries in the chapter. An overview of the process involved in tokenizing the real estate industry in the two countries is presented in the chapter. The chapter suggests that organizations involved in real estate tokenization in developing countries should learn how to increase the success of tokenization in the industry based on critical reviews expressed in the media and academic papers.

In the concluding chapter, the authors establish and emphasize the lack of international (harmonization) in legislation applicable to blockchain applications in cross-border real estate transactions. According to the general theory, blockchains could theoretically address the major problems the real estate industry is experiencing today, including lack of transparency, inefficiencies, fraud and corruption, excessive costs, and also issues surrounding trust. An overview of the legal framework for blockchain applications in international real estate transactions is provided in this chapter. Furthermore, this chapter discusses various legal issues that may arise from blockchain applications, with an emphasis on the smart contract challenges that may arise with regard to the application of the law of contract as well as the potential for blockchain to disrupt the real estate industry.

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How Blockchain Technology Is Transforming the Real Estate Market?

Audil Rashid Khaki, Omar Ali, and Somar Al-Mohamad

1 Introduction

The real estate market has traditionally been considered one with the highest liquidity concerns and is often considered the least liquid asset class. The liquidity concerns in real estate transactions are further aggravated by the paperwork, legal processes, registration formalities, and so on. The investments in real estate market are also characterized by a lack of optimism and lackluster, particularly due to information asymmetry, settlement time, transaction costs, administrative procedures, large capital investment, registration procedures, search processes, regulations, etc. The most prominent challenge for retail investors in accessing real estate investment is the capital constraint or the information on the

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projects. These problems in the real estate sector are increasing the aversion of retail and institutional investors toward investments in the real estate market. As opposed to the suggested optimal portfolio allocation strategies, the institutional investors have allocated far fewer funds to real estate than what the optimal portfolio allocation strategy would suggest (Baum, 2020). While the challenges in the real asset market and property management have been long acknowledged by practitioners, developers, and policymakers, a lot less has been done in transforming the real estate market, probably due to the chilling reminder of the global financial crisis of 2007–2008.

While some of the challenges in real estate investments were, of late, mitigated through real estate investment trusts (REIT) where the investors could buy a fraction of their ownership in a physical asset and enjoy the benefits of the revenues generated by such asset, the governance and agency problems in REITs, yet again, hamper the development and modernization of investment in real estate. The tokenization of real estate and property management on the blockchain could streamline the property management processes and could provide a platform for investors to invest in such assets in a much-simplified manner for a more diversified portfolio. Young and tech-savvy investors have continuously been seeking opportunities to diversify their portfolios away from traditional assets and seek opportunities in non-traditional assets such as cryptocurrencies and other assets on alternative finance platforms (Khaki et al., 2023). Besides providing another asset class in the cryptocurrency ecosystem, it would drastically enhance the liquidity, collateralization, and borrowing mechanism on Decentralized Finance (DeFi) platforms in the real estate markets. Tokenizing physical real estate by using a disruptive blockchain platform is often argued as the future of property management and real estate transactions. Tokenization is described as the issuance of digital assets (referring to an underlying real estate) using distributed ledger technologies (DLTs) on a blockchain platform that aims at democratizing real estate transactions and processes (Chow & Tan, 2022; Swinkels, 2023).

The size of the global commercial real estate market is estimated to be about $35 trillion in 2022; the Asia–Pacific being the largest in size valued at over $12 trillion followed by North America valued at above $11 trillion, EMEA valued at about $11 trillion, and Latin America is just about $1 trillion (*Source* Statista, 2023). The listed real estate market comprises about $3.2 trillion, with North America alone representing about $1.3 trillion (*Source* Statista, 2023). The total value of the

global residential estate has been estimated at more than $200 trillion, exceeding the combined value of equity and bond markets (Savills, 2016). Researchers claim that with such a huge size of the market, tokenization of the real estate sector, and the large-scale adoption of blockchain technology in the real estate sector can bring about a major disruption in the structure, organization, and operation of the real estate markets (Baum, 2021; Cong & Xiao, 2021). Aspen Coin was launched recently in 2018 by Aspen Digital to represent a digital security token for St. Regis Aspen Resort to the value of USD 18 million. Aspen Digital claims to transform the landscape of real estate investment and development by offering a borderless marketplace for investing in real estate by enhancing transparency, liquidity, efficiency, accessibility, and returns on investment (Figs. 1 and 2).

The area of tokenization in real estate is still developing and is gaining traction among developers, policymakers, regulators, investors, researchers, and practitioners. This chapter is an attempt in this direction to examine the landscape of transition to blockchain adoption in real estate transactions and property management and explore the potential of blockchain technology application in the real estate sector beyond the conventional frontiers. The existing literature has largely focused on either Real Estate Investment Trusts (REITs) or the application of

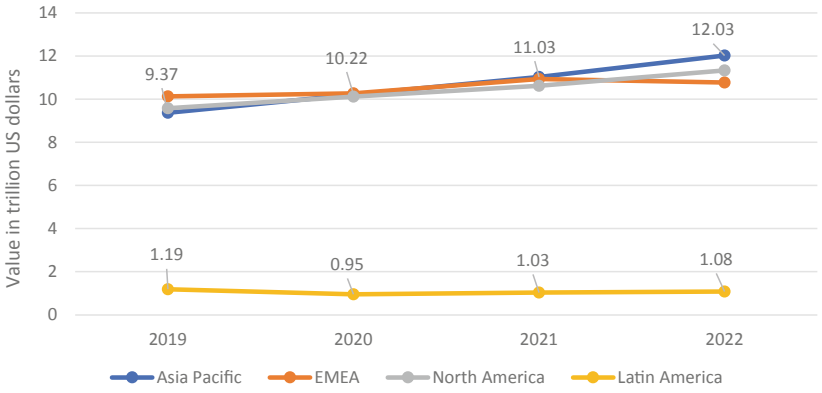

Fig. 1 Value of commercial real estate market worldwide (in USD trillion) (*Source* Statista—2022 [Authors' Illustration]. *Additional Information* Worldwide, 2019–2022, as of December each year)

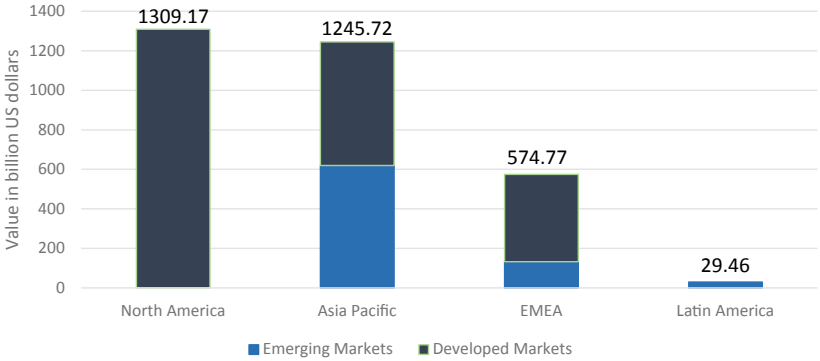

Fig. 2 Value of listed real estate market worldwide (December 2022; in USD billion) (*Source* Statista—2022 [Authors' Illustration]. *Additional Information* Worldwide, AS of December 2022)

blockchain in conventional processes and activities such as property registration, record-keeping, etc. This chapter goes beyond the conventional areas of blockchain application and examines the potential of tokenization in real estate as a solution to the multitude of problems that are paralyzing the real estate markets. The study attempts to shed light on some major challenges in the tokenized real estate market and the opportunities for different stakeholders to explore the advantages of blockchain adoption in developing frameworks, policies, and regulations that aim at enhancing visibility, depth, liquidity, and efficiency in the real estate market transactions. The remainder of this chapter is structured as follows: Sect. 2 presents a brief literature review on the topic, Sect. 3 presents a comprehensive discussion and analysis of the evolution of tokenization in the real estate sector, and a brief conclusion of the study is presented in Sect. 4.

2 Literature Review

The developments in the real estate markets, particularly the adoption of technology have gained considerable interest from researchers, lately. The existing research has largely discussed the conceptual framework for the implementation of blockchain technology, tokenization framework, case studies, and the potential of such disruptions to transform the organization, structure, contracts, administration, record-keeping, etc. in the real

estate market (Cong & He, 2019; Cong et al., 2021; Gupta et al., 2020; Harvey et al., 2021; Konashevych, 2020; Smith et al., 2019; Yermack, 2017). Yermack (2017) examines the application of blockchain adoption on record-keeping and tracking in the real estate market. Cong and He (2019) analyzed the impact of decentralization and smart contracts to mitigate information asymmetry and to enhance competition in the products. Konashevych (2020) supports the belief that traditional real estate has been plagued by poor property management, registry management, and inefficient operations. He argues that decentralization and distributed ledger technologies (DLTs) can considerably enhance property management and registration. Smith et al. (2019) studied the potential benefits to the tokenization ecosystem in real estate by critically examining its potential in the issuance and trading mechanism, representation of real assets by tokenized coins, and the impact/application of tokenization on the real estate investment ecosystem. Zheng and Sandler (2022), in a similar study, support the proposition for tokenization in real estate markets to eradicate the fundamental inefficiencies characterized in the real estate market. They argue that fractionalization has the potential to transform real estate investments by developing mechanisms to provide digital representation to real estate asset ownership and distribution of proceeds from these assets.

A wide section in the existing literature has examined the potential of tokenization in the real estate markets to solve some of the classical inefficiencies in the real estate markets that are hampering investment in the sector, particularly, information asymmetry, liquidity, efficiency, transaction speed, transparency, etc. For instance, Harvey et al. (2021) provide a broader outline of the general applications of DeFi and its potential in solving the fundamental issues of inefficiency, interoperability, illiquidity, and information asymmetry, and elaborate on how blockchain disruption can be scaffolded to drive competitive marketplace with a wide range of applications and benefits. In a similar study, Cong et al. (2021) develop a dynamic asset valuation model to demonstrate the spillover effects of tokenization, particularly, with regard to cost-efficiency, speed, transparency, and subsequent adoption. In a similar study, Krupa and Akhil (2019) support the view that the efficiency and quality of real estate transactions can be considerably enhanced by the adoption of blockchain technology across all its processes. They argue that digitized record-keeping on a distributed ledger improves the speed of transactions and

record-keeping, and facilitates transaction history, rent collection, information dissemination, and distribution of property proceeds. Gupta et al. (2020) examine the issue of liquidity in real estate investments and argue that despite the huge size of the real estate market, the interest of investors is dismal. They further argue that the adoption of blockchain technology could be revolutionary in reviving the sector by enhancing liquidity and transparency in real estate contracts and transactions. In a similar study, Kalyuzhnova (2018) and Pankratov et al. (2020) highlight the potential benefits to the market liquidity, security, transaction volumes, market transparency, and investor interest in real estate assets through tokenization. The impact of blockchain adoption on investors, regulators, issuance platforms, and developers has been studied by Alketbi et al. (2020) and Allessie et al. (2019) and they conclude that tokenization can potentially promote investment in the real estate sector by promoting transparency, regulation, security, trust, and other structural discrepancies, otherwise, so prevalent in the real estate markets. While the literature on the theme is developing to provide a better view of the implementation and adoption of blockchain technologies in the real estate sector, this chapter attempts to contribute to the existing body of literature by further examining the evolving landscape of tokenization in real estate beyond conventional areas.

3 Real Estate Tokenization

3.1 Frontiers of Tokenization in Real Estate

Since the introduction of Bitcoin in late 2018, blockchain-based asset tokens have witnessed explosive growth. Though the legal status of cryptocurrencies is largely debated for numerous reasons, the applications of asset tokenization are poised for revolutionizing the real estate market transactions as we begin to transition and embrace the metaverse in Industry 4.0. Real estate assets are characterized by some prohibitive characteristics that make this sector inefficient, notoriously illiquid, and particularly investor-averse. Recent developments in the tokenization of assets appear to provide a promising prospect to this security class and extend the horizons of the conventional real estate market to explore incredibly novel fundraising mechanisms, enhanced liquidity, hassle-free registration process, tamper-proof ownership and rental history, fractional

ownership, access to broader investor base, streamlined payments, efficient pricing, and a plethora of other benefits. To leverage the benefit of tokenization in commercial real estate, St. Regis Aspen Resort managed to issue one of the very first real estate tokens—Aspen Coin by raising about $18 million through the crowdfunding mechanism. The issue was issued through a special purpose vehicle (SPV) token that represented ownership in Aspen Digital Inc., formed by Elevated Returns LLC, a real estate asset management company, solely for the purpose of floating the issue. Other financial intermediaries in the alternative finance ecosystem were involved in the whole issue with the interactions among other existing cryptocurrencies such as Ether. While the issue offers one of the first examples of tokenization in commercial real estate, it is important to note that the issue offered a wide variety of potential benefits to both the investors and the developers and opened the sector for tokenization.

The current landscape of asset tokenization is still shaping and besides the developers and investors, is characterized by (Smith et al., 2019):

- Issuance Platforms: These platforms allow companies (developers) to tokenize securities (properties) and distribute them as digital assets. They provide the necessary infrastructure to launch tokens and range from private to white-label providers (see Exhibit 1 for some examples)
- Regulation Crowdfunding: The mechanism allows the registered entities to offer and sell securities through crowdfunding through an SEC-registered intermediary. The securities offered through regulation crowdfunding are subject to a 12-month reselling hold, a $5 million cap, and other regulatory provisions (SEC, 2023)
- Compliance Providers: Compliance providers often work together and are integrated with the issuance platforms to provide KYC and anti-money laundering protocols and verification for the investors, streamlining the registration process, and eliminating the whitelist requirements (see Exhibit 1 for some examples)
- Regulators: Regulators are the agencies that provide regulatory oversight over the functioning and classification of securities. In the US, the tokenized securities/assets are regulated by the Securities and Exchange Commission (SEC), while trading in futures and derivatives is regulated by the Commodity Futures Trading Commission (CFTC)

Exhibit 1 Tokenization ecosystem (*Source* Author's Illustration informed from Vertalo [2022] https://www2.vertalo.com/partners/digital-securities-ecosystem [https://www.vertalo.com/partners])

- Broker-Dealers: Brokers and dealers facilitate trading for investors (usually large investors), verify investor eligibility, process deals, and maintain cap tables.
- Trading Platforms: The trading platforms offer secondary trading mechanisms for tokenized securities and are regulated by the Securities Exchange Commission. In order to operate tokenized assets, these exchanges are registered with an Alternate Trading System (ATS) license.
- Legal Firms: These firms oversee the legal arrangement and compliance necessary for the issuance of tokens. These firms act in an advisory role and design special purpose vehicles (SPVs) for token issuance and distribution.
- Custodians: Custodians are the third-party service providers that are meant to safekeeping digital assets on behalf of the investors. Since it is difficult to maintain the custody of digital assets due to complex private key management issues, these providers have evolved to provide custody with keyless operations and without the need for private key management.

Exhibit 1 provides a brief snapshot of the participants in the tokenization ecosystem. The list is meant to provide a general reference to the ecosystem and not an exclusive list of participants operating in the tokenization ecosystem.

3.2 Tokenization: Solutions in Real Estate

Tokenization offers a solution to many prevalent problems in real estate transactions and refers to the digital assets backed by real estate using distributed ledger technologies (DLTs). Each token is identified by and specifies the economic benefits to the holder from the fractional ownership of the underlying physical real estate asset. For instance, the token holders are entitled to the rent income generated on the assets and any appreciation of the value of the property upon realization of the proceeds. Tokenization operates on disruptive distributed ledger technologies and with smart contracts reduces the cost of transactions while incredibly increasing efficiency. While there are still some regulatory drawbacks in upscaling the implementation and usage of tokenization in the real estate sector, without tokenization solutions such as fractional ownership were simply not realizable due to unrealistic administrative processes and transactional costs. Some of the major solutions that tokenization appears to have provided to the real estate transactions so far are listed below:

a. *Fractional ownership*: Fractional ownership has been the major pushback for retail investors to desist from investments in the real estate sector. Real estate assets are essentially indivisible, illiquid, and often require large capital investment; the prohibitive administrative costs deter property owners to offer fractional ownership, and consequently, retail traders are excluded from investment in real estate. The issue of fractional ownership was mitigated through real estate investment trusts (REITs), however, governance problems and agency problems have limited the interest of wary investors in REITs. The evolution of blockchain technology has made it possible to economize on the benefits of fractionalization in real estate assets to tranches and small denominations, which generates a huge interest among investors. The adoption of blockchain technology makes fractionalization possible on an automated distributed ledger with almost no administrative costs.

b. *Customization*: Blockchain technology enables fractionalizing the real asset assets into tokens suitable to investors with different risk preferences and terminal benefit preferences. With fractionalization, the property developers may split the offering into multiple tranches with different minimum investments, rental caps, voting rights, terminal proceeds, etc., for a variety of retail investors. Tokenization takes customization in real estate to another dimension, making it possible for investors to target their portfolios down to a single property rather than the whole sector (Oxford, 2020).
c. *Crowdfunding*: The recent innovation in financing and venture capital has witnessed peer-to-peer lending and crowdfunding as the growing source of financing for start-ups. Crowdfunding has also gained traction in the real-estate markets through the evolution of blockchain technology by raising finance from a broad base of investors beyond geographical boundaries on a distributed ledger. Blockchain technology has the potential to broaden the investor base on real estate projects while also allowing developers to undertake larger and more profitable projects without administrative and agency delays. Crowdfunding in the real estate market has been known to explain about 10–15% of the volumes in the alternative finance ecosystem (Oxford, 2020).
d. *Disintermediation*: Tokenization also offers huge benefits to the project developers, particularly small-scale projects by reducing the floating costs, administrative and regulatory costs, and agency problems as are often remarked in REITs. The benefit of disintermediation trickles down to better proceeds, easy accessibility, low intermediation costs, and better efficiency for retail investors.
e. *Flexibility*: Tokenization has offered and has a huge potential to offer great flexibility to the tokenized securities, particularly by splitting up the characteristically big, lumpy, illiquid real estate assets into customizable units of revenue streams and ownership structures. By fractionalizing an asset can be split beyond geographic boundaries, could be divided and sub-divided where the entitlements could be designed as per the desires and requirements of different investor bases. The tranching arrangements could be designed to provide entitlement interest to rental incomes from the asset, property interest, property usage, joint ownership, syndication, timeshares, etc. with variable rights and legal implications (Oxford, 2020).

f. *Operational efficiency*: The traditional real estate markets have been notoriously popular for 'off-market' deals and administrative and operational inefficiencies. The participants in this sector struggle to give up their dependence on traditional transactional procedures despite huge technological advances, for instance, the purchase of a prime commercial real estate from RFR Holding GmbH in Zurich's Bahnhofstrasse claimed to be among the largest token deal in the real estate transactions supposed to be paid in BrickMark tokens ended up being an off-market transaction (BrickMark Group, 2020). Tokenization in real estate assets has a huge potential to revolutionize transactions in real estate markets and bring about the necessary fluidity, liquidity, transparency, and operational efficiency. The smart contracts supported on the blockchain platform have a tremendous potential to automate processes like pre-issuance eligibility, compliance checks, regulations, record-keeping, history maintenance, KYC/AMC eligibility, collection and distribution, customization of contracts, etc. Automation in real estate through tokenization makes it possible to programmatically distribute proceeds and dividends to investors automatically when due, without any operational drawback.
g. Settlement time: The transactions in traditional real estate assets are subjected to a range of administrative and regulatory processes due to which the settlement time is discouragingly long and the funds remain unnecessarily tied up in the settlement process. REITs resolved settlement time to T+3 to T+1 as in the traditional financial transactions but the funds still remain tied up during the settlement period, thereby leading to some liquidity issues. With the tokenization of real estate assets, the transactions could be instantly settled within minutes or hours upon the corresponding blockchain platform.
h. *Transparency*: Traditional real estate markets are characterized by a lack of transparency. The information about the quality of real estate assets and projects is generally, either outdated or not easily accessible. The unavailability of information and transparency often makes wary investors over-cautious in seeking investment in real estate assets. The delayed and foggy nature of information in real estate projects often makes investors averse to these projects or seek information that is costly and time-consuming to provide. Institutional and professional investors find the information and records

in the traditional real estate assets as spotty and therefore, resort to due diligence in the properties they invest in, which yet again is a costly and time-consuming process. Though REITs resolved some of the issues in the real estate markets such as maintenance history, titles, compliance, insurance, rents, etc., the markets are still far from vibrant and drastically suffer from transparency issues. Blockchain technology has considerable potential in resolving the longstanding transparency concerns in real estate through the tokenization of tiles and deeds, promoting greater visibility of the assets, property management, title history, insurance, rental contracts, debt obligations, and other necessary information, previously impossible in the traditional real estate landscape. The ability to have the information available for investors easily accessible aggregated and integrated within the blockchain platform provides a tremendous potential for governments and developers to leverage their projects a develop strategies for smart cities and communities (Meridio, 2019). The research supports that the cities that rank higher on the transparency index ("Highly Transparent" cities) account for about 75% of commercial real estate investment, globally (Global Real Estate Transparency Index, 2018).

i. *Liquidity*: Despite the huge portfolio diversification benefits of real estate assets in the global portfolios established through the modern portfolio theory frameworks (Baum & Hartzell, 2012), the allocation to real estate by institutional investors has been about less than a quarter of suggested allocations (Oxford, 2020). Real estate assets are traditionally known for illiquidity, slow transaction speed, high transaction costs, and administrative pushbacks, thereby discouraging investors from participating in this asset class. The market is also characterized by what is known as "off-market" transactions which further exacerbates the concerns of fair pricing, democratization, information asymmetry, and demand/supply market forces. Tokenization in the real estate market can potentially benefit the developers in achieving a broader distribution of the offering at an effectively better price. Tokenization may help developers skip the third parties such as brokers and agents as well as secure funding from outside the conventional bank financing, and therefore, raise capital more quickly at a lesser cost and at a much lower risk and fewer covenants (Smith et al., 2019). The tokenization of real estate assets will generate a greater retail investor demand for the tokens

which can further be supplemented by a wider secondary market outreach to enhance the investor demand and the market perception of the asset (and the developer). For instance, Propellr and Fluidity arranged the tokenization of a luxury Manhattan condo with 12 construction units using Ethereum and raised $30 million from a global blockchain platform (Wolfson, 2018)

j. *Access to broader investor base*: The platforms in the tokenized security ecosystem are open and accessible to investors across the globe round the clock, and therefore, allow unhindered access for millions of global investors to invest in tokenized real estate assets without the limitation of geographical boundaries. The platforms also receive huge attention from tech-savvy investors and young investors who are looking for alternative asset classes away from the traditional asset classes to achieve better portfolio diversification benefits (Bakry et al., 2021; Rashid et al., 2023).

3.3 Challenges to Tokenization in Real Estate

Tokenization in real estate has so far been successfully demonstrated by the launch of property tokens by various developers and real estate companies in collaboration with other financial intermediaries like financial advisors, issuance platforms, broker-dealers, etc. Elevated Returns LLC issued Aspen Coin representing ownership of St. Regis Aspen Resort through a Special Purpose Vehicle (SPV). The issue was managed by Templum, a registered broker; Computershare, a custodian; Indiegogo, a crowdfunding platform. The total issue was valued at $18 million. Aspen Digital issue was followed by Blocimmo, Blocksquare, Bolton, Brickblock, BrickMark, etc., demonstrating a huge opportunity and investor interest in this segment. As the regulation around the commercial real estate tokenization infrastructure develops and the inertia to sticking to the traditional practices in the real estate transactions breaks, blockchain technology may potentially impact the commercial real estate landscape in a positively disruptive manner. From crowdfunding, registration, and property management to cryptocurrency-based issuance and secondary market trading, tokenization has a range of benefits to offer to the participants in this relatively lumpy asset category.

A quick reality check on the recent developments in the real estate tokenization ecosystem suggests that after the initial hype in tokenization,

the enthusiasm about real estate tokens has not gained the expected traction among institutional or retail investors. The sluggish demand uptake was further complicated by some failed transactions and issues in the tokenized real estate market. The initial wave of optimism quickly hit the shore when a highly anticipated joint venture between Fluidity and Propellr, a technology provider and the broker-dealer in digital assets, respectively, fell apart. The tokenized commercial real estate market was also characterized by infrequent transaction volumes and undervaluation, despite stimulus from the token developers into their own projects. The market also leads to adverse selection phenomena attracting investors that found no better avenues for placing their funds.

The optimism in tokenized real estate quickly turned into aversion and recoiling to traditional off-market deals with some failed transactions. A student housing project worth $20 million floated by DRW Holdings together with the blockchain partner Harbor and Fluidity and Propellr fell apart. Similarly, the purchase of Zurich's RFR Holding commercial estate by BrickMark took place in an off-market deal in 2020. It has also been argued that many ICOs in the real estate sector were mostly speculative in nature, where the developers were often intrigued to issue the coin before identifying the prospective projects for property development (Smith et al., 2019). The speculative issuance of some real estate tokens has led to some regulatory concerns about tokenization in real estate assets, where the primary issue concerning regulators is about recognizing real estate tokens as digital securities. Besides regulatory recognition, the market is yet also paralyzed by the extreme volatility and turmoil witnessed in the cryptocurrency markets that heavily support the tokenized security ecosystem in real estate. Research suggests that the sentiment in the cryptocurrency market may strongly impact the valuation of real estate tokens (Cong et al., 2021; Kreppmeier et al., 2022; Nadini et al., 2021). The instability in the cryptocurrency markets and the lack of a reliable cryptocurrency to enable smooth transaction mechanism, on one hand, cripples the regulatory agencies from making progress in coming up with regulation that is consistent across different markets and platforms, and on the other hand, discourages investors from exploring this area of investment for portfolio diversification. The recent development, however, insufficient, suggests the position of regulators to recognize real estate tokens as "securities". The regulators are, however, still demonstrating caution by subjecting these securities to stringent listing requirements, legalities, and processes.

The commercial real estate market is also struggling to scale up due to single-asset tokenization. Barring a few exceptions, real estate token fractionalization for a single asset has not yielded successful results and has often been met by unsubstantial demand and liquidity. The exchanges such as the International Property Securities Exchange (IPSX) that has been catering to the initial coin offering (ICO) and offering the secondary market trading mechanism for single-asset tokens have been struggling to engage sufficient participants to achieve the necessary depth, thereby resurfacing the issues of liquidity yet again. Though IPSX has exceptionally performed well compared to other platforms, the single-asset tokens are doomed to be unsuccessful due to the inherent limitations in the structure and limited breadth of such issues. It has been reported that the single-asset tokens demonstrate poor performance with respect to its NAV, particularly, due to the poor expertise of retail investors to appraise the value of the property under management. Dowling (2022) suggests that the prices of the real estate token may not correspond to the true market value of the property and that these tokens and the non-fungible tokens (NFTs) for virtual property spaces in metaverse may be misrepresentative of the real worth of the assets and not represent the fundamentals of the underlying property. This eventually leads to sluggish demand, low trade volumes, high volatility, less liquidity, and diversion to REITs. Furthermore, the regulation regarding the fractional ownership of assets is still too complicated and not formalized, and therefore, to facilitate fractionalization, tokenization in real estate is possible only through an intermediary Special Purpose Vehicle (SPV) that acquires the direct ownership of the property. An exchange mechanism, hybrid tokens, multiple-asset tokenization, and regulatory flexibility are some of the critical areas which still present challenges to the development of tokenization in the real estate market.

4 Conclusions and Suggestions

Tokenization provides a huge promise in the commercial real estate market by offering solutions that are incredibly innovative and goes much beyond the conventional boundaries of commercial real estate transactions. Tokenization has the potential of and has successfully exhibited how the adoption of blockchain-based solutions can significantly transform the real estate market by offering automation in registrations, fractionalization, property management, crowdfunding, investor

outreach, flexibility, customization, administrative simplicity, operational efficiency, greater investor demand, and so forth. The implementation of technological innovation in real estate may be completely revolutionized by the adoption of Proptech—a combination of the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), and Blockchain. It may be implemented to strip assets and split them to conveniently fit into your investment portfolio to achieve an optimized performance, monitor the carbon footprint of the property, and movement of people in the building, update safety protocols, and property valuations, automation of property facilities, etc. While tokenization has the potential to offer a range of benefits in commercial real estate (CRE), it is still in its early stages of development and is yet to be fully accepted by market participants. The regulation around CRE tokenization is still underdeveloped and has many limitations on engagement in CRE transactions and participant whitelisting. The market is also characterized by the overabundance of single-asset tokenization which does not appear to offer a huge promise in terms of flexibility and scaling capability, besides operational and issuance complexities. Retail investors also lack information on single assets and consider seeking such information as tiresome, therefore, only investors who understand property investments are currently actively engaged in such transactions. Crowdfunding has not been successful for small projects either as investors tend to run after established single-asset tokens and avoid less popular assets.

While the tokenized real estate ecosystem is still evolving and though several cases of successful adoption have demonstrated the potential of blockchain adoption in the real estate sector, there is considerable inertia from the market participants to push back on the evolution of tokenization and recoil back to the traditional practices. The sentiment in the volatile cryptocurrency market is also threatening investor confidence in the tokenized real estate, as well as, reinforcing the dilemma of regulators in the recognition of real estate digital securities and the regulation around them. In a world where the Internet of Things (IoT) is commonplace and where younger generations are embracing digital solutions to world problems, the policymakers, regulators, and developers must recognize the need to develop frameworks and solutions that cater to this tech-savvy community of consumers to provide efficient, convenient, secure, and alternative solutions to conduct their business.

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Blockchain, Asset Management and Real Estate Funds

Mohamed Sraieb, Somar Al-Mohamad, and Audil Rashid Khaki

1 On the Economic Importance of the Real Estate Sector

A wide consensus regarding real estate is that the sector is a strong enabler of economic activity. Due to its high linkage with other economic sectors, real estate is considered as a driving force for the economy. Notice first that the sector provides the infrastructure required for any business. It also provides the accommodations that help agglomerations develop and workers to settle down. Without these catalysts, the economy would be less able to attract talents and capital. In turn, this compromises the potential of the sector to create further economic opportunities. Second, the real estate sector is typically a labor-intensive sector. It is among the most labor demanding activities and provides direct and indirect jobs (engineers, architects, workers, providers of construction, etc.). Job creation extends further to a variegated set of activities including lawyers, financial advisors, surveyors, as well as input suppliers of all types. Third, real estate represents a class of assets by itself. It is attractive for

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many financial intermediaries as it enables them to generate consequential revenues and benefits.

To put things into perspective, recall that the real estate value globally has increased by 5% between 2019 and 2020, reaching an estimated record of USD 326.5 trillion (Tostevin, 2021). The main driver of this performance is the residential real estate accounting for 79% of the global value. Comparatively, real estate value outweighs the value of global equities and debt securities combined. In terms of market size, a report by Grand View Research (GVR-2-68038-354-6) evaluates the global real estate to USD 3.69 trillion in 2021. It grew to $3.97 trillion in 2022. Recall that these figures were affected by the sector's low performances during the COVID-19 pandemic. The stringent pandemic policies including curfews, lockdowns and movement restrictions led to disruptions in new construction projects and consequently to limited sector's performances. This trend is exacerbated further by the war in Ukraine and the plumbing energy prices that put pressure on the economic recovery from the pandemic.

Interestingly, the importance of the real estate sector for an economy stems also from its size as it accounts for 36% of final energy demand in 2017, and nearly 40% of energy-related CO_2 emissions globally (Saari et al., 2022). Furthermore, the sector has a pivotal role in predicting developments in the economy, in terms of macroeconomic conditions and financial stability. This is precisely one of the major reasons for which most central banks are closely following developments and trends in the real estate market. Monitoring real estate helps central banks carry out a comprehensive analysis of the macroeconomic conditions and prospects of the economy. The supervision of the real estate sector also enables screening vulnerable financial institutions; those that are exposed to real estate risks. The role of the real estate sector in forecasting financial conditions and predicting economic conjecture is all the more important that currently the inflationary pressure is high and debt non-repayment risks are large. Therefore, the economy can be caught by the difficulties of the real estate sector, which is precisely what happened in 2008 and initiated the financial crisis. Strikingly, financial markets did not perceive the risks associated with their investments. Furthermore, the development of new financial instruments combined to lose monetary policy implemented by central banks contributed to generate a significant real estate bubble that kept expanding until it burst and led to what is known as the sub-prime crisis. The problem all started in the US (Duca et al.,

2010), but the housing bubble spread by contagion to other countries, via the inter-banks' connections. This ultimately led to a dramatic economic slowdown, at the global level.

It is surprising that despite the size of the real estate sector in the global economy, the literature identified a large contrast between its importance to the economy on the one hand and the low level of digital development characterizing the sector. In comparison, many other sectors of activities with lower impact on the economy benefit from a stronger development in digitalization (Calvino et al., 2018). Interestingly, this limitation points to a possible net benefit for the economy from a higher adoption level of digital technologies in the real estate sector. This higher integration would boost the sector's productivity and therefore the performances of the economy via the strong linkages discussed above. This is precisely the reason for which academic research, at least at the conceptual and theoretical levels, was highly optimistic concerning the ability of blockchain technology—as a digital enabler—to revolutionize the management of real estate and the funds associated with it.

From a general perspective, blockchain is a database shared among connected computers or servers known as nodes allowing them to maintain a common ledger. As its name suggests, it stores encrypted blocks of data that hold sets of information. When the storage capacity of a block is reached, it is closed and then chained to previously created blocks to form a chain of data. Initially, when a user initiates a transaction, a block representing the transaction will be created. This requested transaction is then shared over nodes. Importantly, these nodes will verify the transactions and ultimately can validate them. Transaction can involve any valuable information from any sector including finance, real estate, records on intellectual property rights or health, contracts, etc. The validated transaction forms a secured block that will combine with other blocks and will be recorded in the register of transactions. Verification and validation of transactions are carried out by the network of users. This decentralization of the process confers to blockchain one of its most important characteristics which are transparency to the public, security and immutability (Iansiti & Lakhani, 2017; Xu et al., 2019). As a result, the technology naturally preserves integrity of the transaction, which creates and maintains trust in them (Fig. 1).

Although the first and most cited use of blockchain was in Bitcoin, it is currently rapidly expanding to other fields and new research ideas are being investigated. Among the most important applications fields,

Fig. 1 Blockchain transaction steps

we find supply chain management (Venkatesh et al., 2020). Adopting blockchain in this sector rises efficiencies as it enables cost savings through information collection about the goods produced over all the product cycle from production to distribution and consumption. Another application of blockchain is charity and crowdfunding (Dierksmeier & Seele, 2020). Blockchain technology drastically improves traceability of donations and funds. This increases accountability and transparency, which, in turn, helps solving the classical problem of moral hazard in donations. In tourism and hospitality, blockchain technology enables hotels to reduce their costs as it limits the market power of third parties booking services. Less commissions are paid and hotels cost is reduced. Efficiency in the booking and selling process is improved. Furthermore, as blockchain technology is built on information made publicly available, verifiable and trustworthy, it can help businesses proof that their products are manufactured with absence of social dumping (for instance, child labor) as well as in total compliance with human rights requirements and ecological concerns. In short, blockchain enables businesses to build reputation for sustainability. Among blockchain features, there is also its ability to maintain privacy. The technology relies on an encryption making the information available only to the permitted users. Thanks to this major characteristic, blockchain gained momentum in healthcare sector as it answers ethical and social responsibility concerns. Patient records or clinical trials are secured and made available only to the right persons. Completeness of the data, availability, precision, interconnectedness with other data sources increases cost effectiveness and improves social responsibility.

The real estate sector is another important example of implementation field of the blockchain technology. The guiding principle is that blockchain can, potentially, address some of the inhibitors of an effective development of the real estate sector, such as agency problems in the management of real estate assets leading to fraud, corruption, cost manipulation, lack of confidence, trustworthiness, etc. Strikingly, the growing literature on the real estate implementation of blockchain technology

focused unevenly on land administration as a particular aspect of real estate management (Ferreira, 2021; Saari et al., 2022). A systematic exploration of the advantages and limitations of blockchain integration into the real estate sector that goes beyond particular areas (such as land administration) is missing. Another distinguishing feature of the literature on the topic concerns the disproportionate dominance of conceptual and theoretical studies. Very few papers address the relationship between real estate and blockchain technology through an empirical or quantitative approach (Bennett et al., 2021; Lemieux, 2016, 2017; Veuger, 2020, etc.). The lack of research on the topic encompassing (i) applications to the whole real estate sector and not limited to particular areas, and (ii) quantitative research both contribute to increase further the gap in the literature between applications of blockchain technology in real estate, specifically and applications in general domains. This is precisely the gap that the present work aims to fill. Our objective is to investigate the potential of the blockchain technology for the real estate sector as a whole and the associated efficiency gains in the management of its assets and the administration of its funds. This research also aims to assess the main challenges limiting further development of the real estate sector and to highlight the importance of the sector for the economy.

The remaining part of the chapter is organized as follows. Section 1 introduces the research question and highlights the importance of real estate sector in the economy. An introduction to blockchain technology and its main features is also presented and the benefits of integrating it to the management of real estate assets are discussed. Section 2 characterizes the challenges and limitations inhibiting further development of the real estate sector and assets management. Section 3 elaborates on how blockchain technology can be implemented in the real estate sector. It connects advantages of blockchain applications to the main challenges of the real estate sector. Section 4 presents concluding remarks. It summarizes findings and determines lines of further research.

2 Challenges and Limitations of the Real Estate Sector and Assets Management

Real estate asset management is a complex field, where a variety of protagonists intervene. The nature of the assets and the market conditions create challenges for the sector. The challenges include the design of best practices in the management of the physical assets. These are actions and

plans that ensure the highest possible returns for investors, managers or landlords. Some of these good practices would be ensuring an effective property maintenance in order to keep the value of the asset. Good practices also include effectively managing tenants in order to maximize rental income (screen tenants, resolve complaints and legal conflicts, manage lease agreements, resolve moral hazard and adverse selection problems). Challenges to the real estate sector also include ensuring compliance with local, state and federal regulations. Failure to comply with regulations can result in fines, legal conflict and damage to the reputation. Real estate asset managers are also called to ensure adequate funding of properties and that returns on investments targeted by investors are achieved. This entails proper management of cash flow and would ensure continuous capital provision.

These challenges are all the more sizable when they materialize in presence of global chocks and unfavorable market conditions. Indeed, market volatility is a major issue in this respect. Often, real estate markets are subject to fluctuations, which can have a significant impact on the real estate market, in particular on the value of assets, but the impact can be broader and trigger financial stability as a whole. The relationship between price fluctuations on the real estate market and financial stability has attracted researchers' attention (Cardarelli et al., 2011; International Monetary Fund Report, 2021; Liu et al., 2020; Moscone et al., 2014). In a summary of previous literature, Liu et al. (2020) classify the studies on the topic into three types: those describing the interactions between bank stability and the real estate market, those investigating the relationships between the equity market and the property market and those studying the linkage between the foreign exchange market and the housing market. Liu et al. (2020) extend the analysis to the investigation of the direction of the impact and the potential feedback effect associated with the interaction between financial stability and the real estate market.

The very presence of price fluctuations on the real estate market introduces an additional layer of difficulty to the management of the associated assets. The task of real asset managers becomes even more risky as anticipation of markets movements and responses to these changes are inherently uncertain. Minimizing risk in order to maximize returns is the cornerstone of real estate asset management. This is precisely where technology and innovation can be of great help. The sector has benefited from technological advances (internet, augmented reality, etc.) but blockchain technology is the most important of such technological advances for

the sector. Many consider that blockchain technology is the greatest innovation not only for real estate but also for all sectors since the introduction of the internet. Its variegated applications are creating a new era boosted by the growing security accompanying its utilization and the wide acceptance of its applications among economic actors. These advantages combined to other characteristics made blockchain technology attractive for various sectors, in particular, those where key requirements include speed of transactions, reliability and transparency. These are among the salient features of the real estate sector.

The optimism accompanying the development of blockchain applications for real estate contrasts with the current situation of the sector. The tightening of the monetary policy in many countries (in response to the inflationary pressures) led to higher cost of debt for investments in real estate rendering the cost–benefit of new acquisitions relatively high. Some private equity and institutional investors become reluctant to new investments into the sector and postponed their decision until risk dissipates.

At the intra-sector level, the tight monetary policy conducted by most central banks, combined to the recession, has resulted in a growing interest for less risky assets. Consequently, equity and bond markets as well as the real estate sector experienced turbulences. Indeed, many investors privileged conservative investment policies, focused on insuring themselves against risk through investments in particular forms of real estate assets. Typically, these are first-class buildings generating stable revenues. This self-selection into a restricted class of real estate assets resulted in less investments in other segments of the sector.

Importantly, the projection for the future indicates that the sector will experience a sustained rebound in growth that will continue at least until 2030, with an expected annual compound growth rate of 5.2%. This rebound shows high resilience despite the conjectural challenges. Key to this positive note is the existence of unused investment capacities in the hands of investors that benefited largely from the current situation. These include (i) sovereign wealth funds, particularly in net energy (energy and gas) exporters, whose values have dramatically raised following the shift in energy prices, (ii) unlisted funds accumulating dry powder and (iii) pension as well as institutional funds holding large cash reserves. These idle investment capacities will be activated as soon as the markets recover and investors' confidence reestablishes.

3 On the Role of Blockchain in the Real Estate Sector

Recently, a growing literature investigates the role of innovations in promoting the real estate sector (Dijkstra, 2017; Pankratov et al., 2020; Saari et al., 2022; Wouda & Opdenakker, 2019, etc.). A consensus has emerged on the importance of blockchain technology for the development of real estate sector. As a new technology, blockchain may provide unprecedented opportunities for investors in real estate where blockchain highly improves assets liquidity and their tradability in the market. In turn, this opens up for both a less constrained financing for investors in the sector; and an easier access of this class of assets to the second market, without extra cost. Therefore, the advantages linked to the use of blockchain in real estate stem from the characteristics of the technology itself, namely increased transaction speed, reduction of transaction costs and enhanced security for the transactions. The reduced need for real estate agents, including lawyers and notaries reduces fees and payments to intermediaries. In turn, the possibility of errors by agents or parties to real estate transactions is excluded, as the transactions are automated and managed by the blockchain. This argument will be the driver of the discussion in this chapter. Our main objective is to assess the effects of blockchain on real estate funds and the management of its assets. A detailed discussion of the relationship and its determinants will follow in the text below.

The literature has investigated four broad categories where blockchain technology can add a great deal of value to the real estate sector. These are mainly the system of land administration and asset registration, the ease, rapidity and transparency of the transactions, tokenization, and the system of real estate management.

3.1 Real Estate Asset Registration

The registration of real estate assets and monitoring of the transactions involving them is a complex process. The full history of the property may not be clear or may be highly complex to establish and to verify. This constraint is particularly relevant in less developed countries where land ownership and registration are made based on oral contracts or formal contracts that are registered only locally. In addition, real estate transactions may involve multiple parties that do not necessarily communicate

efficiently or may not know their mutual characteristics, including reliability, record of past transactions, risk of fraud. This introduces an adverse selection problem to the transaction. Adverse selection occurs when one party to the transaction has an informational advantage over the other party and uses it strategically. The characteristics of a real estate asset can be known better by the seller who may use this advantage to foul the buyer or investor. The buyer is disadvantaged as he has no access to information on the asset or the information is not verifiable. This is precisely where blockchain technology can bring advantages as a particularly useful tool in real estate management. Indeed, one of the most striking features of the contractual relationship based on blockchain is the efficiency of the record keeping it initiates. The blockchain could be seen as a register or a database where the information about transactions is visible to all parties but cannot be amended or modified without being checked and validated by the blockchain nodes at every step of the transaction process. The transaction is then recorded and identified by its time stamp and date of creation. It becomes then immutable. This unlimited access to the records and history of the property as well as to the full information regarding payments and all contractual requirements reinforces the verification process of the property status and promotes transparency of the real estate transactions. The two characteristics introduced by the blockchain technology regarding transparency and immutability of the transactions recording process promote fraud prevention and increase trustworthiness between parties including banks, real estate agencies, buyers and sellers. This is valid for the comparison with standard formal registry keeping but extends also to digitalization of records. Indeed, digitalization is often associated with centralization of the real estate transactions and property records that are initially made and kept in the regions where they are located. This centralization means grouping records in one place and may lead to an increased risk of fraud and corruption (Kshetri, 2021). Centralization and digitalization may also make the files prone and vulnerable to cyber threats targeting the center (Bennett et al., 2021).

3.2 Transactions Efficiency

Blockchain-based registration of properties and transactions has multiple benefits. Among the most important there is the ease introduced to data usage. Likewise, blockchain-based registration enhances efficiency in real estate data management. The blockchain technology can be used to

keep and manage large amounts of data, including property information, transaction history and ownership records. The process is secure which reduces errors, and ultimately increases transparency and trust. From an empirical perspective, trust is mainly driven by the fact that transactions, history of properties and their ownership status are at all times verifiable and their records immutable (Bennett et al., 2021; Kshetri, 2021). Likewise, another major benefit of blockchain-based registration of properties and transactions we find increased efficiency under different forms (Alketbi et al., 2020; Bennett et al., 2021; Kshetri, 2021). Efficiency may increase in terms of reduced time for transactions and their registration, simplifying administrative processes, etc. Yet, other benefits include fraud reduction through unlimited free access to data on the blockchain. Corruption prevention is achieved through the verifiability characteristics of the blockchain.

Furthermore, blockchain tends to promote operational efficiency in the real estate sector by facilitating access to data and sharing it securely among operators. Besides, blockchain technology can help to increase efficiency and reduce costs by automating processes and reducing the need for intermediaries, which would make real estate transactions faster, cheaper and more secure (Akhmetbek & Špaček, 2021; Alketbi et al., 2020; Bennett et al., 2021).

3.3 Tokenization of Real Estate Assets

The third pillar where blockchain technology can add a great deal of value to the real estate sector is the process of tokenization; a process by which rights to an asset are transformed into a digital token carrying, on the blockchain, the original rights to the asset. These tokens are then traded on a blockchain-based platform, enabling investors to buy, sell and trade shares of the property, rather than owning the whole asset. In simpler terms, tokenization is the digital representation of ownership of a real estate property. At the heart of the process there is the fractionalization of ownership of real estate assets. Fractionalization refers to the process of dividing the property into tokens, which are digital representations of ownership. These tokens are then listed on a blockchain-based platform, where they can be traded among investors. Therefore, tokenization may result in real estate investments being more accessible to a wider spectrum of investors, creating a more dynamic industry and greater liquidity. In fact, fractional ownership makes it simpler to enter and exit the market

because investors may purchase and sell small amounts of a property (through tokens).

Although the concept of tokenizing real estate has been around for a while, it has only just come to light as a result of the advancement of blockchain technology. The real estate sector could undergo a change thanks to tokenization by making it more accessible, effective and safe. Real estate tokenization is a multi-step process. The property is first evaluated to establish its worth and ownership configuration. The property is then factionalized into tokens after this is finished. Investors can buy and sell these tokens after they are posted on a blockchain-based platform.

Increased transparency is one of the key advantages of real estate tokenization. All transactions are recorded and unchangeable since blockchain technology is transparent by nature. With traditional real estate investments, investors cannot receive the same amount of security and accountability as they do with this. With less paperwork and legal fees, which may add up, real estate tokenization also has the potential to lower transaction costs.

Real estate tokenization is still a relatively new idea, despite its many advantages, therefore there are a number of obstacles to be addressed. Compliance with regulations is one of the major difficulties. Given the strict regulations surrounding real estate investments, tokenization just makes things more complicated. There is still some ambiguity around the legality of real estate tokenization because governments all over the world are still working out how to regulate blockchain-based investments. The absence of standards presents another difficulty. Real estate tokenization can be done on a variety of blockchain platforms, each of which has its own set of guidelines and procedures. This can make it difficult for investors to navigate the market and make informed decisions.

Despite these challenges, real estate tokenization is an exciting development that has the potential to revolutionize the investment in real estate. As blockchain technology continues to evolve and become more mainstream, the expectation is to see more and more real estate assets being tokenized, providing investors with new opportunities to participate in this lucrative market. The many advantages of tokenization would further encourage investors to participate to this market reinforcing acceptance of tokenized real estate assets. Among all advantages related to tokenization of these assets, the one related to facilitating the introduction of smart contracts is strikingly important.

Smart contracts are automated (information) programs that register and/or implement contract terms at a due date without human intervention. These information protocols also check the feasibility and legitimacy of the transaction. Execution of the contract is only carried out if all contract terms are met. Coupled to the blockchain technology, the smart contract benefits from the trustworthiness and transparency characterizing the blockchain to facilitate contract execution. Among the salient features of these contracts is their immutability. This is enabled by the use of the blockchain. Parties to the contract can never modify it unilaterally nor terminate it. Moreover, terms of the contract cannot be altered. As explained earlier, since each new transaction on the blockchain is checked by all members of the network, the smart contract and its implementation will be also checked by all members.

The smart contract works in a decentralized way as it is implemented on a blockchain that is decentralized. Once created, it cannot be modified. Only the occurrence of the event or the realization of the condition specified in the contract would activate its clauses. In general, smart contracts can be of two types: endogenous for which the information is within the blockchain; and exogenous where the information is external to the blockchain and as it is provided by an external source. For the second type of smart contract, a central question concerns the verification of the occurrence of the event triggering execution of the contract. This verification, although automated, is made compared to an information obtained from a predefined and trustworthy but external source. This means that the architecture of the system relies entirely on the trustworthiness of the external source and the truthfulness of the information provided by it. For example, the real estate transaction relies heavily on verification of information provided by an external party. This information, external to the blockchain, includes identity of the buyer/seller and the characteristics of the real estate asset (area, location, etc.). This service of verification is provided by some firms specialized in the conformity of the information to reality of the real estate assets. Yet, this does not ensure the legal validity of the information. This begs the question of the importance to the smart contract of human intervention under the form of public officers (solicitor, notary, etc.). The trust placed in the smart contracts and the confidence in the transactions imply a complementarity between the blockchain and human intervention (Fig. 2).

The implementation of smart contracts in real estate has major advantages for all parties. First, it reduces considerably transaction length and

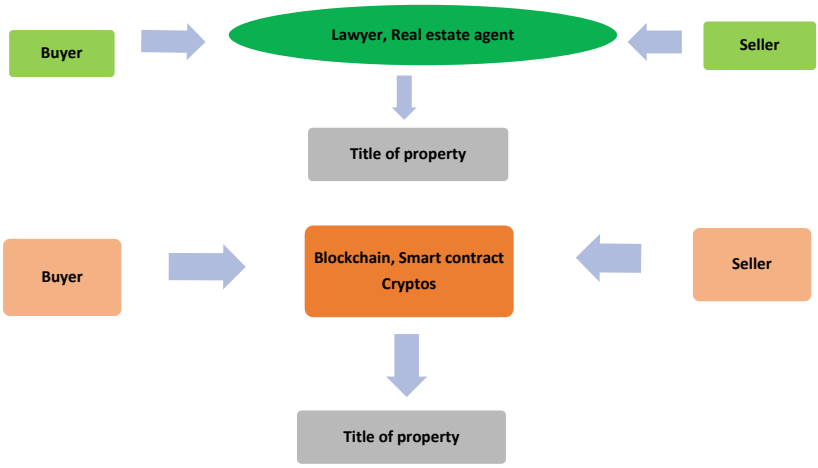

Fig. 2 Standard real estate transaction vs blockchain-based transaction

time. This is enabled by the speed in transmitting the information necessary for the transactions to all parties. The information is also dated which allows to follow up transactions' steps and the progress of operations. This progress is available to all members of the blockchain in a simultaneous way, allowing for higher transparency and boosting trust and security. This is a major advantage for real estate agents as their task can be now more re-focused toward the task they were initially designed for, namely client advisory. Smart contracts are also of high value for public officers as they facilitate the verification task of real estate assets status. The data in the blockchain, including property information, transaction history and ownership records is immutable. It is then made secure which reduces errors, and ultimately increases transparency and trustworthiness. The benefit of smart contracts extends also to future owners as associated risks are reduced and security of their investments is increased.

Despite its many benefits, smart contracts in real estate have their own limitations. Part of these contracts rely on a third party to validate the information for a real estate transaction or asset, called also exogenous smart contracts. The information contained in the blockchain triggers the execution of the contract. Therefore, the validity and reliability of this information is key to the idea of smart contract. In some instances,

the legal proofs related to the transaction (property information, ownership records and valuation data) that are stored on the blockchain are incomplete or aren't original. Both situations may lead to problems in the execution phase of smart contracts. Dependency on accurate data is crucial, but obtaining trustworthy data can be challenging. Inaccurate or incomplete data can lead to errors or disputes in the contract execution process. In addition, intervention of an external party for validation of the information is determinant. Importantly, the external party must not be subject to agency problems to guarantee validity and reliability of the information. Limiting supporting documentation to only authentic and original proofs can help reducing this risk. Yet, the risk persists for transactions including supporting documents that are, by nature, changing in time. These include building permits, current situation of the parties, etc. This risk can be reduced if the whole transaction is initiated from biggening on the blockchain as modifications are monitored. Furthermore, the immutability of the contract although a big advantage for trust issue may become problematic in some situations. Indeed, once a smart contract is executed on a blockchain, it becomes nearly impossible to modify or reverse the transaction. While this enhances security, it can pose challenges in case of errors or unforeseen circumstances, requiring legal intervention or complex procedures.

Reliability of smart contracts, if the validation is done properly, would ensure a smooth access to an updated and importantly symmetric information. Nevertheless, the intervention of third party for validation of information shed doubt on the potential for smart contract to shorten transaction times. Acceleration of the process by public officers in charge of the verification task is constrained by the transactions' complexity and number.

4 Conclusion

Recent years have seen a lot of interest in the application of blockchain technology to real estate management and asset ownership, which has the potential to revolutionize the sector. This integration was made possible by the advancement of blockchain technology and its widespread usage. To fully utilize blockchain in the real estate industry, a number of obstacles and restrictions must be overcome, as was covered in this chapter.

There are two broad categories in which to divide the difficulties. Organizational constraints are primarily concerned with how the system works and institutional restrictions that pertain to the enabling environment.

The acceptance of and integration of blockchain into current real estate management systems is one of the main issues. To support the integration and interoperability of blockchain-based solutions, stakeholders—including real estate experts, developers, regulators and government agencies—must work together. A successful implementation requires overcoming resistance to change, tackling technical challenges and building a collaborative ecosystem.

An additional significant obstacle to the widespread use of blockchain technology in real estate management and asset ownership is the murkiness and ambiguity of the legal and regulatory frameworks. To lay a strong foundation for blockchain-based solutions, legislation regarding data protection, smart contracts and property rights must be clear. In order to create supportive frameworks that strike a balance between fostering innovation and safeguarding the interests of all stakeholders, policymakers and regulatory authorities must engage closely with industry experts. The administration of the real estate sector has a number of issues, of which data privacy laws are only one aspect. Maintaining trust and confidence in blockchain-based systems requires careful consideration of security and privacy issues. While blockchain's decentralization and immutability increase security, protecting smart contracts, private keys and personal data is crucial to prevent unauthorized access and ensure data privacy. To enable effective administration of real estate assets, data on the blockchain must not only be safeguarded but also accurate, dependable and consistent across platforms. It is still difficult to find trustworthy and consistent data from a variety of sources, including property information, ownership records and transaction histories. It is imperative to establish data standards, protocols and verification methods in order to guarantee the accuracy and dependability of data on blockchain networks. To address these issues and create a trusted data ecosystem, industry players, technology suppliers and regulatory agencies must work together.

The enabling environment, data quality and security are the foundations for furthering blockchain integration in the real estate industry. However, user experience and education are equally essential for a technology's effective adoption. In order for good, trustworthy and secure technology to be widely used and accepted, it must also be user-friendly.

The other pillar supporting the effective adoption of blockchain technology among real estate professionals, investors and property owners is a simple interface that is user-oriented and intuitively constructed.

In conclusion, despite some difficulties, blockchain technology has enormous potential for asset ownership and real estate administration. The real estate sector can fully utilize blockchain technology by overcoming adoption and integration barriers, creating supportive legal frameworks, establishing mechanisms for data accuracy and standardization, giving user experience and education top priority and improving data security and privacy. In order to overcome these obstacles, parties such as real estate experts, technology suppliers, regulatory authorities and legislators must work together. To overcome obstacles, more research, creativity and cooperation are required.

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Blockchain in Commercial Real Estate

Jo Bronckers

This chapter describes in an observative and interpretative way the added value applying blockchain technology can have in the commercial real estate sector. The research goal is to analyse and structure the characteristics of commercial real estate, map its key-stakeholders, their core processes, and how information is being used to answer where and how in this industry blockchain technology can add value. This chapter extensively refers to other academic research papers, with special mentioning of the research carried out by Dijkstra (2017) and Saari et al. (2022a, 2022b) that provided many valuable insights for composing this chapter. Based on analyses and results of both scientific, applied research and expert-expertise, the chapter will zoom in on the possible applications for blockchain in commercial real estate processes and their challenges. Finally, by concluding the chapter, I will wrap up the results from the various studies referred to give a comprehensive overview of promising applications, their opportunities and challenges, non in the least as input for further research.

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1 When is Blockchain Technology Valuable?

A better understanding of how assessing if Blockchain Technology (BCT) can add value in general will be helpful. A recent study (Witt, 2021) carried out by Josepha Witt at Hohenheim University in Stuttgart focuses on this topic and will be used as reference. Her study provides a state-of-the-art analysis of papers that offer assessments for a Blockchain Technology suitability, based on a pool of 500 studies.

The conclusion of this study is that a potential framework that assesses the suitability of BCT should clearly state: (a) the organizational level (i.e. business model, process, etc.), (b) what to assess (i.e. variables), (c) how to assess it (i.e. measurement and range of values), (d) whether the framework is case-independent, and (e) if and how it would offer value if patterns are outlined to assess a BCT fit more easily.

For this chapter, I will take the freedom to translate these criteria in the following own criteria:

a. The organizational level
b. What framework/variables assessed
c. Opportunities of blockchain implementation
d. Challenges of blockchain implementation

Witt concludes with a statement by Kumalakov et al. (2019) who revealed that decisions to implement BCT in organizations are currently hype-driven and top-down, whereby business cases in the investigated organizations are justified by whitepapers and case studies. Therefore, the relevance of her research is given for practitioners as well as researchers, for whom the literature review can serve as a basis for rigorous research.

In the final part of this chapter, I will use Witt's work and the guidelines when describing the various use cases and their added value for commercial real estate. But before that, let's start with a closer examination of the characteristics of commercial real estate.

2 The Characteristics of Commercial Real Estate

Commercial real estate refers to properties used specifically for business or both direct and indirect income-generating purposes (a building or land), and while the definition varies among different countries, the core offering remains the same. It refers to the process of planning,

building, renting, buying, eventually retrofitting, and finally selling properties. Developers earn a profit by adding value to the land by creating buildings or improvements, and rezoning. The real estate agencies are responsible for guiding their clients through all the related paperwork. In addition, a building is site-specific, with multiple user cycles during its commercial life cycle, either in parallel or consecutively, which in turn requires accurate maintenance with corresponding relatively large financial investments and associated risks that need to be managed. Commercial real estate can as such be further sub-divided in different categories, like residential, office space, retail, warehouses, hotels and resorts, healthcare facilities, and more.

Geltner et al. (2013) discussed that the commercial real estate market can be broken down into two distinct components: the space market and the asset market. The space market is the market for the usage of a particular piece of land or a building, while the asset market deals with the sale and exchange of real estate assets, such as land parcels and buildings. These two markets are closely intertwined; the needs of tenants and the type and quality of buildings available affect the rent for real estate space, while the asset or capital market transactions determine the asset price of space. Ultimately, the space market is the most fundamental since the rents for real estate space create the underlying cash flow needed for determining the value of a property (Fig. 1).

The real estate market is the biggest industry in the world. To get an idea of the size of the global real estate market, market-size estimates from different organizations can be compared. All private houses, high-rise buildings, office buildings, and other properties located in different parts of the world together were valued at a total of $228 trillion in 2017 (Internationalwealth, 2017), where residential property is by far the largest submarket within it at $168tr (74%).

Commercial real estate is the second largest submarket with a global size estimated to measure $35tr (Statistica, 2022), or 15% of all real estate in the world.

> Mind you: If blockchain technology impacts 1% of the commercial real estate market, it is already a $350 billion business opportunity.

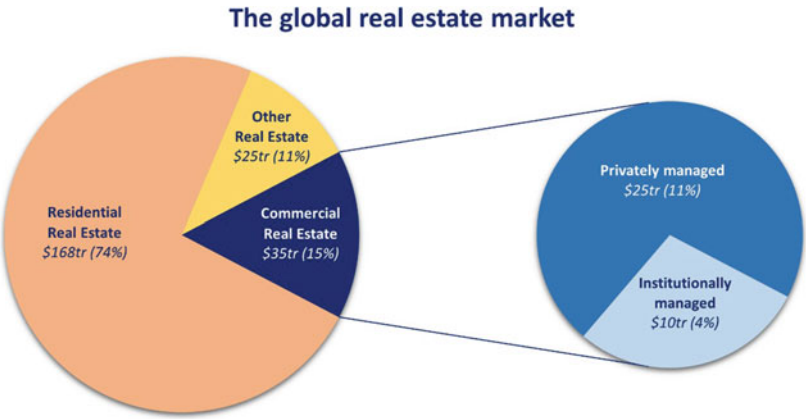

Fig. 1 Commercial Real Estate accounts for 15% of the global Real Estate market

Within this global commercial real estate market, about $10tr (MSCI, 2022), or 29% of all commercial real estate is managed by institutional investors in a professional way. It doesn't mean the remaining $15tr is not being managed in a professional way, but by smaller, non-institutional, private investors.

3 How Information Exchange is Organized in the Real Estate Industry

In PropTech 3.0: the future of real estate (Baum, 2017), Andrew Baum describes the evolution of information technology in the real estate industry. PropTech is about information transactions and management. The internet and mobile telephony have enabled a boom in technology platforms applied to nearly all areas of our lives—jobs, homes, education, health, leisure, finance and even romance. With regard to PropTech 3 main information exchange verticals are identified that are at the core of the digital evolution of real estate:

- *Smart Real Estate*:
  Technology-based platforms which facilitate *the operation and management* of real estate assets,
- *The Shared Economy*:
  Technology-based platforms which facilitate *the use* of real estate assets,
- *Real Estate FinTech*:
  Technology-based platforms which facilitate *the trading of* real estate *ownership*.

The study describes the drivers behind the first PropTech wave of 1980–2000 (PropTech 1.0), describes the conditions which led to the current PropTech 2.0 wave, and explores what the application of advanced technologies may bring in the near future (PropTech 3.0) (Fig. 2).

Real estate sector is ripe for change, being famous for its lack of capacity for deep and continuing innovation. While the industry is still busy implementing PropTech 2.0, more and more PropTech 3.0-solutions are being prepared and introduced to the market. A truly transformative PropTech movement is under construction. New products will bring efficiency and alignment to the market, but they will encounter behavioural obstacles, establishment reaction, and often financial calamity? By citing Ryan Masilello, VTS, Baum warns we must remain realistic:

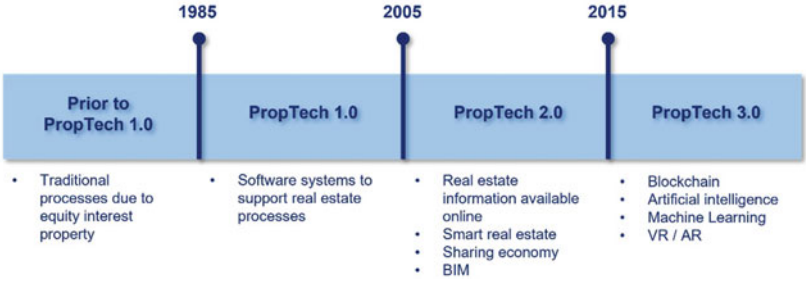

Fig. 2 Evolution of information technology in real estate towards PropTech 3.0 (Baum, A. 2017, personal adaptation)

> The majority of PropTech firms that will succeed are not those that are trying to be disruptive; they are the ones focussed on delivering products that bring efficiency and alignment to the market.

It may be a wise recommendation before reading the remainder of this chapter. We need to make sure that we do not under-estimate the capacity of the real estate industry to resist change, and we need to be aware of the generally uncritical positive spin put out by those tech businesses with vested interests.

Different studies have been carried out to take a closer look at the information exchange process in key processes to commercial real estate. These studies show again how complex and constantly moving the playing field for commercial real estate managers is. While performing their tasks, managers are confronted with decisions and results of other players in their field like governments, banks, other real estate organizations, and more, that impact their market. Real estate managers need to navigate their assets in a prudent way by mapping ahead and anticipating to many constantly changing risks. In general, real estate asset managers identify six different risk types (Henson, 2022):

- Financial Risk: Loan to Value, the relative amount of debt you have taken to purchase a property,
- Structural Risk: related to the financial structure of an investment and the governance structure,
- General market risk: the business cycle, is there a tight, emerging, broad, or declining market? What are interest rates and inflation levels? What key change drivers?
- Asset-level risk: related to the type, age, maintenance and management intensity, the marketability of a property, flexibility in use, energy efficiency, security, availability of parking lots, and more,
- Location risk: urban or rural, ideal for the type of property, upcoming area, proximity of other urban facilities, crime rates, competitiveness, vacancy levels, etcetera,
- Legislative risk: Legal regulations like registration procedures, spatial law restrictions, rent control laws, taxes, tenant laws, governance & disclosure regulation, land title registration, permits, etcetera should be studied carefully before investing. How vulnerable is the investment to possible regulatory changes?

It is no wonder a lot of high-quality information coming from many different sources and on a wide variety of topics is being collected by the asset-manager. High quality means the data is reliable, timely and aggregated in the right way so it can easily be used in conjunction to other available information. To be on the safe side, the commercial real estate manager traditionally makes extensive use of advisers, consultants, lawyers, notaries, appraisers, and other third parties who review information and provide their expert opinion. In other words: with their review these advisers are adding a level of trust to information. In doing so, these advisers typically charge hefty hourly rates. It is exactly at this point where it becomes interesting from a 'blockchain-perspective'. Because if someone is willing to pay a considerable price for high-quality information, it triggers the question how the sourcing, authenticating, aggregation, and verification of this information is organized. And by extension, which ones are homogeneous high-frequent data aggregation processes in this, and which ones are not. What are the gateway moments in decision-making and what set of 'need to have' information is at these moments brought together in which way? Which of these data are important from a legal point of view to compare delivered performance with contractually agreed KPIs? And finally, what information is recorded how from the perspective of good governance and transparency to be able to reproduce and account for decision-making afterwards?

Both Dijkstra (2017) and Wouda (2019) examine the transaction process, its actors, and their roles and data-exchanges, in both the acquisition and disposition phases of the commercial real estate process. Commercial real estate (CRE) transactions have always been collaborations involving multiple parties. Due to the markets' fundamental characteristics—heterogeneity and immobility—real estate transactions face the joint challenges of information inefficiencies and corresponding high transaction costs. The transaction process of an office building is divided into multiple stages, illustrated in Fig. 3. Due diligence phases and negotiations (completion) are carried out to verify and validate information. These processes are a key indicator of the lack of transparency and perceived unreliability of the data used in the transaction process. The decentralized way of working with various 'non-digitized' documents make the process complex and unstructured. Implementing new technologies could lead to an improvement in the transaction of an office building in the future.

Fig. 3 Simplified visualized real estate transaction process (*Source* Wouda [2019])

Figure 4 (Dijkstra, 2017) shows the information exchange during the transfer process. This applies to both the acquisitive and disposition of real estate properties.

The management of Commercial Real Estate is usually a well and structured organized process in which several players fulfil different roles and tasks in relation to each other. Dijkstra (2017) describes the commercial property management process combing theories of Van Driel and Van Zuijlen (2016) and Miles et al. (2007) (Fig. 5).

The commercial property process starts at acquisition, followed by the operation phase, and then the disposition of the asset. Depending on the professionalism and degree of organization of the operation process, it can be further subdivided into strategic portfolio management, tactical asset management and operational property management.

Each level of management in the operational phase thereby performs different tasks. Dijkstra (2017) identifies eight of the most important stakeholders during the operation phase of a commercial building, each with their own expertise, value add and their tasks:

- *Investors*: The owner of a property is responsible for successfully managing the property during its lifecycle on all the three management levels. They often have in-house capacities for strategic and tactical investment management and often outsource their operational property management.
- *Occupiers*: The tenants/users of a building who pay the rent. These are the most important stakeholders during the operational phase of a property. Managing the operational performance of the building and its costs are important to satisfy and keep tenants happy in their housing needs.
- *Funders*: A funder finances a part of the project via a loan with the underlying real estate asset as a security. The investor pays interest

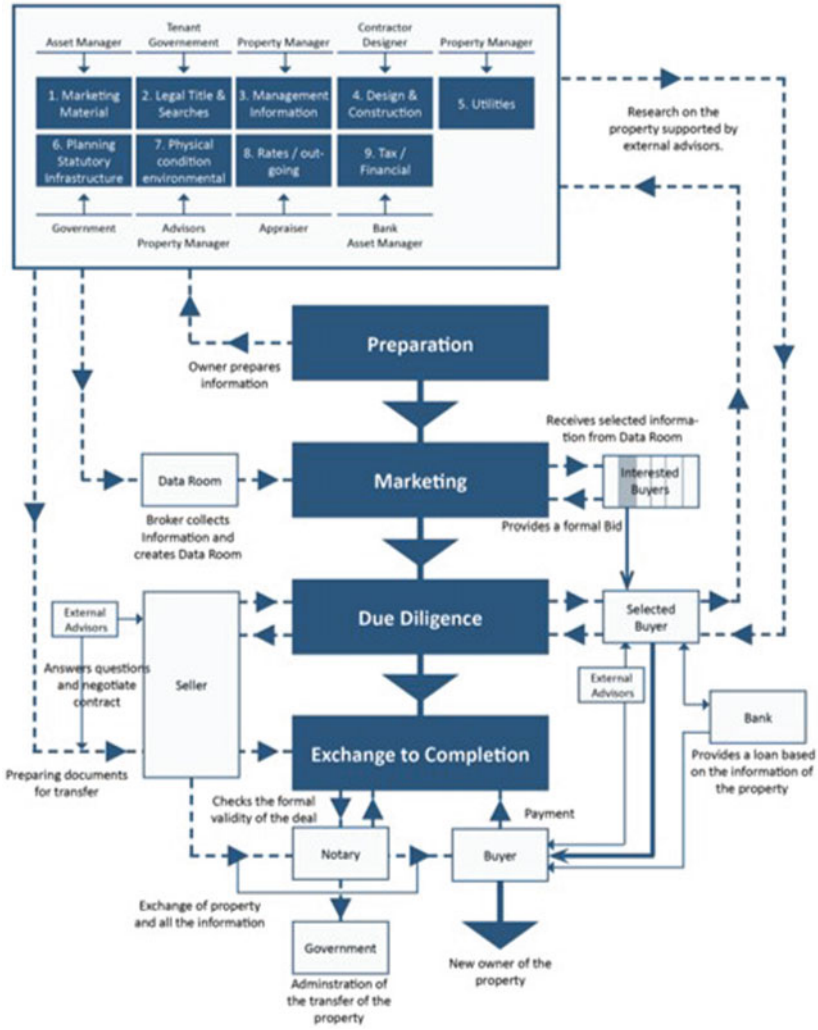

Fig. 4 Information exchange during the transfer process (*Source* Dijkstra [2017])

Fig. 5 The real estate management process and management triangle (*Source* Dijkstra [2017])

rate in return for the loan. The funder wants to obtain frequent information to update his own risk assessments.

- *Brokers*: Brokers play an important role in the buying and selling of properties by assisting the respective parties. They are also responsible for acquiring new tenants and negotiating contracts with existing tenants during the operational phase of the property.
- *Government*: The government is an integral stakeholder in regulation. Property owners may encounter challenges in fiscal, private, and public law, including regulations and taxes. Furthermore, the government bears responsibility for land title registration maintenance and organization, a critical aspect of property management.
- *Designers & Contractors*: The responsibility of physically realizing, maintaining, and improving a property or project lies with the designers and contractors. They possess in-depth knowledge of the materials and designs used in the property, which can be added to the value chain. The delivery of tenant services is handled by a specific group of contractors, which is organized by the investor on behalf of the tenant.
- *Advisors*: Consultants are professionals with diverse expertise that can be deployed at different stages of a project, often supporting, or complementing the stakeholders involved. These stakeholders could

be anyone from construction workers to soil specialists, from valuators to notaries, or legal advisors. The role of a consultant is to provide information and offer their expert opinion based on their specific area of expertise.

Dijkstra (2017) describes how during the operation phase a vast amount of data is exchanged and registered, among which many data needed for the transferring real estate. The most critical information is the contractual relation between tenants, both new and existing, and the owner of the property. Another important set of information relates to the technical and administrative maintenance and the agreements—often in the form of performance agreements—made contractually with the property manager and contractors. To assess the extent to which the agreements made, have been met, data on the performance KPIs are recorded. Figure 6 illustrates at a high-level how these information processes are organized and interrelated in the operation phase.

4 Possible Applications for Blockchain in Commercial Real Estate

Now that the information exchange processes have been mapped, it is possible to examine what applications are seen for blockchain technology in commercial real estate. To this end, findings from several recent academic and applied studies will be presented in this section. What all these studies have in common is that, besides exploring the possibilities, they also address the challenges blockchain application in the real estate sector still faces and are so fitting in the assessment structure derived from Witt (2021).

Baum (2017) suggests that distributed ledgers can pose a risk to the real estate industry by introducing new services and applications that can threaten the market's existing architecture. However, distributed ledger technology also presents an exciting opportunity to establish a robust infrastructure for future use in the industry. To this end, it would be wise for an industry consortium to explore blockchain technology and collaborate with associated sectors such as local and national government, legal professionals, finance (banks and insurance), and regulators. While the implementation of blockchain technology may seem distant, the rapidly changing pace of technology argues against complacency. The real

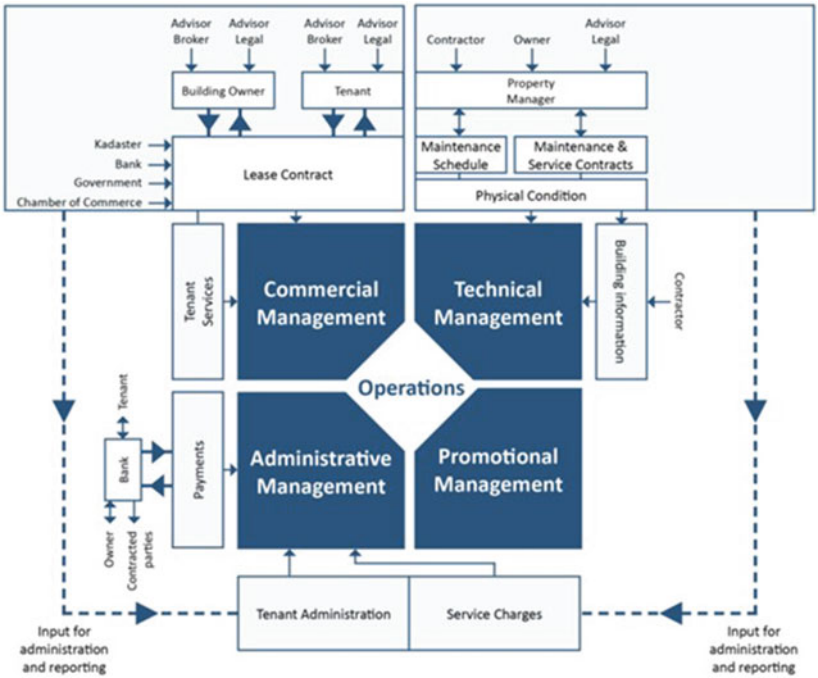

Fig. 6 Information exchange during the operation process (*Source* Dijkstra [2017])

estate industry has the potential to benefit from blockchain or distributed ledger technology by developing applications such as smart contracts. Even if smart contracts do not revolutionize leasing and sales, blockchain proponents argue they will lead to:

- Instantly access more information
- Fewer errors, less duplication, and fewer human inefficiencies leading to significant cost savings
- Greater transparency of prices and contracts through consensus and distribution
- Potentially reduce transaction times
- Greater market liquidity and turnover

Blockchain is also a natural medium for feedback from the Internet of Things and, with advances in machine learning and AI, from big data-driven analytics. The real estate industry uses public sector and private, or proprietary data. To incorporate a shared ledger, the industry needs a public and private system.

Dijkstra (2017) concludes the biggest opportunity for the implementation of blockchain technology is creating *a blockchain-based digital building logbook*, with an immutable, trustworthy ledger which can keep all the relevant documents of a property up to date and easy to access. Creating this digital representation of a property is the core principle for further building blockchain-based applications. He further arrives at four additional opportunities for blockchain in commercial real estate management.

The first is *re-design of real estate transaction processes*. Similar way to how payments between parties are handled using digital currencies, two parties could conduct a transaction immediately, without the need for a trusted third party to verify the transaction.

The next opportunity he sees is to *improve the transparency of real estate markets* with an undisputable public ledger of transactions that would give not only investors but also regulators improved insights into the functioning of the market.

Another point which is argued by literature is *using cryptocurrencies in payments or as deposits*.

Finally, the *deployment of smart contracts* is indicated as one of the opportunities. Smart contracts are inherent to the development of blockchain-based applications. Smart contracts enable self-executing contracts which can automate several processes in real estate.

Wouda (2019) developed a data architecture based on literature research and expert opinions. After designing this infrastructure, experts were asked again to pragmatically validate the proposed infrastructure. Based on their feedback, it can be demonstrated that the developed infrastructure is promising and satisfies the expectations of future users. Alongside the benefits of the proposed system, there are some challenges identified. One of the most important will be standardization. How should various types of real estate data such as valuation reports, real estate collaterals, lease information, etc. be connected? To provide a uniform recording of real estate data, consensus must be reached on how to connect various aggregation levels with each other. The question is

how fast the market will come to a consensus, because for all players it is an entirely new and undiscovered realm.

The foundation for international blockchain and real estate expertise, FIBREE, may be considered as the leading global network organization in the niche market that blockchain and real estate is. Since 2019 this organization annually conducts a global survey to the State of Blockchain in Real Estate and publishes the results in their Industry Report. We examined the latest available edition, the FIBREE Industry Report 2022 (FIBREE, 2022). This study report consists of 3 sections, a product database listing all global blockchain for real estate products found with desk research, a country-page section showing the openness of national real estate markets to digitalisation, and the third section articles describing use case experiences, written by the pioneers and researchers in this network. In a large majority of the 32 countries where FIBREE is represented, the real estate market is still mostly paper based and only partly digital. This affects the uptake of blockchain solutions in the real estate market, indicated on the Gartner hype cycle-methodology (Gartner, n.d.), which shows a wider variety between the 32 countries. In two-third of the countries blockchain is still not much more than an innovation trigger, so at the utmost beginning of the hype cycle. The status at the other one-third of the countries is equally spread over the next four stages until leaving the most difficult stage, the 'Through of disillusionment'. When looking at the development of products in the world this report shows that in the earlies edition, 2019, it recorded the largest number of 501 products, followed by a 40% drop towards 297 products in 2020, the lowest amount recorded. Since then, the number increased slowly to a total of 394 products in 2021 and 476 in 2022. Here again, in terms of the Gartner hype cycle, it seems the industry is slowly passing the 'Trough of Disillusionment' towards the 'Plateau of Productivity', like illustrated in Fig. 7.

The annual FIBREE survey shows clearly that the development of blockchain and real estate products is happening all around the world. Europe was in the first edition the leading region, but this position has been overtaken by North America. Asia–Pacific, South America, and Africa also have numerous blockchain and real estate initiatives registered.

When it comes to real estate products, FIBREE categorizes them into eight different categories that are closely related to the real estate life cycle. These categories are:

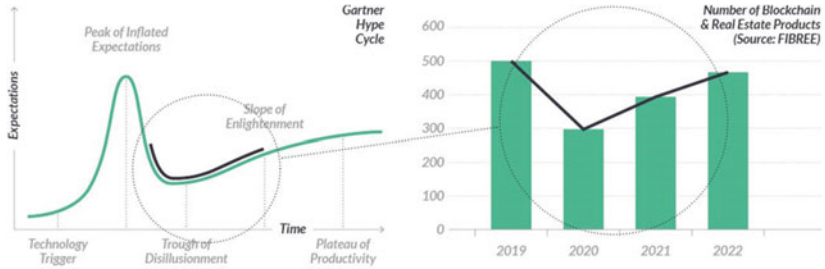

Fig. 7 The state of blockchain in real estate (*Source* FIBREE)

1. Invest & Finance: Products that focus on the investment and loan markets for real estate. This includes fragmented investments in real estate propositions with security tokens, as well as peer-to-peer utility token solutions that support real estate services.
2. Markets & Platforms: Products that list real estate-related products or services and connect market participants' needs. This can facilitate all kinds of markets, from investment platforms to land title records, to reporting platforms for trustworthy data and more.
3. Building Technologies: Products that offer technology and software development to be deployed and embedded in third-party software solutions.
4. Transaction & Escrow Services: Products that support market participants in any kind of transaction. This often involves fully automated micropayments registered in a decentralized ledger.
5. Manage & Operate: Products that are designed to manage and operate buildings or manage real estate portfolios. Examples include facility and property management solutions.
6. Plan & Build: Products that offer architectural or construction services, such as material passports or BIM.
7. Research & Valuate: Products that offer services related to real estate data. A fast-growing amount of hashed data and historical track records create new levels of transparency about the real estate market. This is valuable input for scientific research, as well as for a wide range of purposes in the real estate industry.
8. Smart City Solutions: Products that solve problems for cities and municipalities. This includes digital registration of land titles or building permits, microgrids for sharing utility services between

neighbours, and metaverse solutions that connect building data with adjacent industries, like energy or mobility, to facilitate shared economy solutions.

Expressed in numbers, the invest and finance solutions account for 44% of the products listed, and seem to be the largest category, like Fig. 8 shows. But this doesn't say much about the level of adoption of these products because many of them are still in a very early 'prior to proof of concept' development stage, or many of these products listed in previous editions didn't find their way to the market and already ceased their activities.

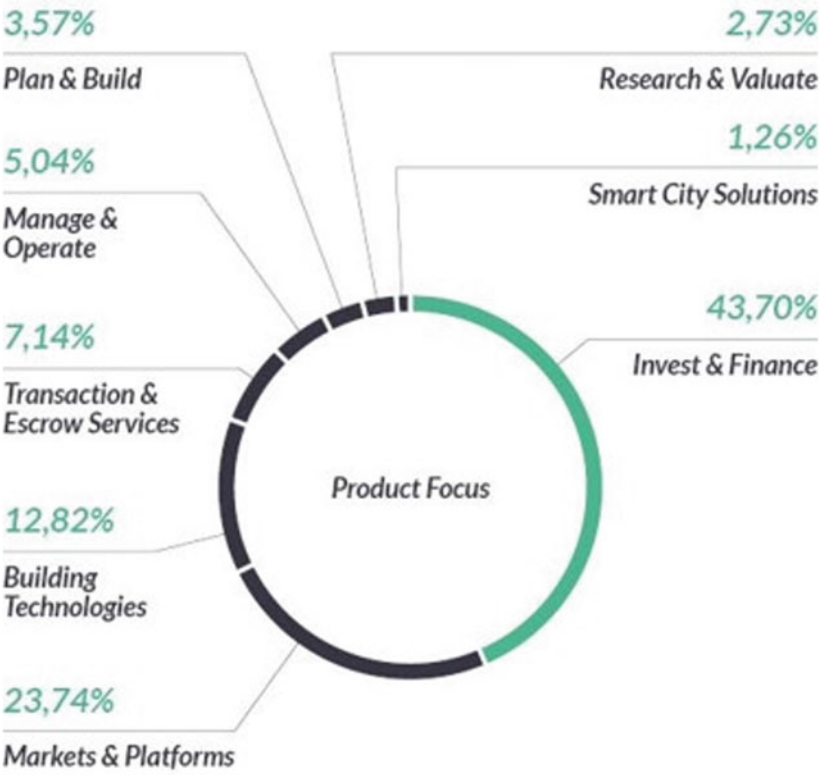

Fig. 8 The distribution of product categories in the total database of 2022 (*Source* FIBREE [2022])

Markets and platforms are with 24% of the runner-up category in 2022. Often these markets are being used in combination with tokenisation because the tokens need to be traded somewhere to find their way to the public. Young generations seem to be getting familiar with having their own crypto wallet. They are getting used to the high volatility of crypto values and are more and more looking to find 'crypto safe havens' to spread their risks. Tokenized real estate is well positioned to offer such a safe haven. The question is still how this may impact commercial real estate. Another way how tokenization may indirectly impact the commercial real estate market is by the introduction of non-fungible tokens (NFTs) that represent virtual real estate in the metaverse. Metaverse is a virtual space that is created to simulate as much as possible a real-world experience to its visitors. Imagine what will be the impact on the need for real world offices or meeting venues if people can easily meet in-person online? Or how can a fast-growing turnover of metaverse shops that are designed to be true flagship-stores with entirely new and mind-blowing customer experiences in the next years impact the need for real world shops? Customers can in the end only once spend their money. Or how is this going to impact the brokerage market if metaverse becomes the place where supply and demand of properties can meet?

The number of products doesn't say all about the adoption in the market. An additional indicator is the acceptance of products in the market.

Figure 9 shows the average level of engagement in the defined product categories estimated by the experts in the regions where FIBREE is currently represented. It becomes clear that Invest & Finance is leading the market again. Not one category is reaching beyond the two lowest levels, which shows wide adoption of blockchain technology in the real estate market still has a long way to go.

The researchers in Tokenisation—The Future of Real Estate Investment? (Baum, 2020) argue that tokenization is still in its early stages and is not yet widely accepted in the real estate market. To assess the potential of tokenization in real estate, one must consider the benefits it provides, and the costs associated with it. If tokenization is to succeed, it must provide enough value to outweigh the costs. If not, it could impede the development of innovation in the sector, such as structured finance, hybrid tokens, and digital fund exchanges.

Empirical studies on the tokenization of real asset markets are necessary to better understand the potential and limitations of this radically

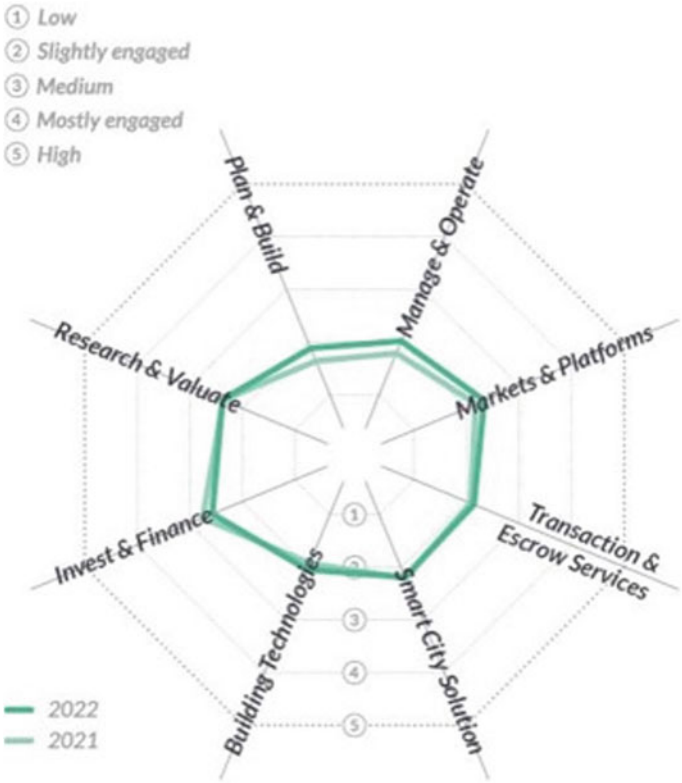

Fig. 9 Level of market engagement for blockchain-based real estate products (*Source* FIBREE [2022])

new organization of financial markets. Laurens Swinkels (2022) is in this perspective worth mentioning because, according to me, he did ground-breaking research with regard to tokenization of real estate. His study is the first to empirically examine the financial and economic consequences of the tokenization of real estate markets using the first experiences of a 58-residential-property sample in the US. However, the study has some important limitations, Swinkels finds that tokenization fulfils its promises and leads to dispersed ownership of properties of modest value, which leads to substantial risk sharing across households. The study documents that token trading in Ethereum adapts within a few days to fluctuations

of the digital currency with the US dollar. In the long run, token prices have been seen to mirror the prices of homes, making portfolios of fractionally owned real estate investments behave similarly to traditional real estate investments. This is mainly attributed to more people being aware of tokenized real estate investments and investing in the tokens, rather than the actual economic value of the house. Thus, the potential benefits of tokenized real estate investments can be realized, which would have a significant impact on the organization of financial markets in the future.

Asset tokenization could be explored further in terms of examining how financial regulation affects the appeal of tokenized assets. Additionally, decentralized finance could be analysed in terms of reducing transaction costs during periods of high Ethereum gas fees. Furthermore, it is uncertain whether the existing governance system can be improved, as fragmented ownership may bring about free riding, which could impede efficient property management. Finally, the proxy used for Detroit housing prices is quite basic, so tokenized residential property prices may be more effective in demonstrating the likeness between token price and estimated property value.

Anniina Saari et al. (2022a)[1] conducted a systematic literature review to explore the recent developments in blockchain technology in the real estate sector, as well as to understand the current real-world applications by collecting empirical evidence from relevant documents. After identifying 262 documents, a thematic content analysis was conducted. Although the blockchain literature presents it as a disruptive technology, the empirical applications suggest that it is being used in hybrid, smaller-scale settings as an additional layer to existing systems. Furthermore, the empirical applications showed that blockchain could bring benefits such as increased efficiency, reduced time, and higher levels of verifiability, transparency, and automation. Additionally, blockchain may help reduce fraud and increase security and trust compared to centralized digital solutions. Finally, the insights highlight the need for a supportive political will, a suitable regulatory framework, access to reliable digital data, public–private partnerships, and educational aspects for successful blockchain applications (Fig. 10).

Saari et al. (2022b) conducted further research to analyse literature by publication year, authors' locations, type of publication, and primary

[1] Saari et al. (2022a, 2022b).

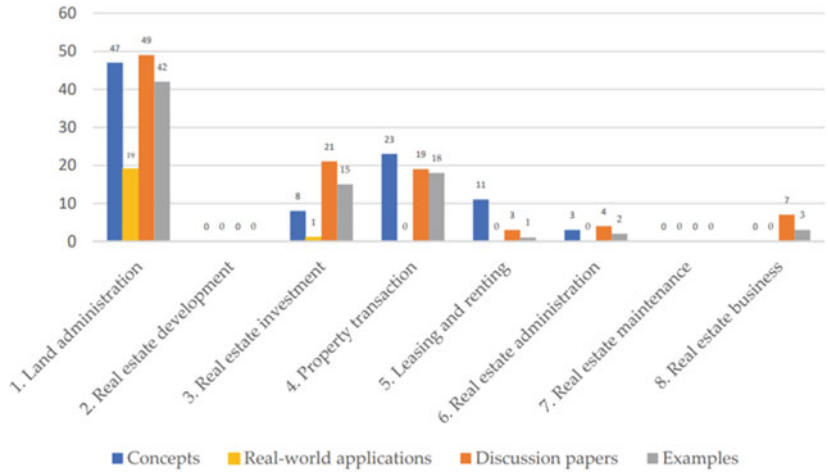

Fig. 10 Document classification by real estate subsectors and paper types by Saari, A. et al. (2022a, 2022b)

publication field. Their findings showed that the majority of the papers (58%) focused on land administration, followed by property transactions (22%), and real estate investments (16%). Leasing and renting, real estate administration, and real estate business accounted for 6, 4, and 4% of the papers, respectively. No documents focused on real estate development or maintenance.

Investigating these topics in greater detail reveals that land administration documents consider blockchain from various perspectives. One stream examined the conditions in different countries, another looked at the legal aspects, and some reports evaluated blockchain in land administration from the public sector's point of view. Blockchain could solve inefficiencies, fraud, corruption, and trust issues. Inefficiencies are often linked to the fact that 70% of the global population lacks official land titles and paper-based records are prone to errors and tampering. Despite many potential advantages, blockchain in land registries remains complicated due to legal, implementation, and technical problems. In addition, blockchain in land administration requires digitalized data of high quality. Additionally, property transactions involve the purchase, sale, exchange, transaction, and valuation of real estate.

The property transaction papers were mainly concepts, followed by reports and examples. Blockchain technology has the potential to revolutionize the property transaction industry, by simplifying the current time-consuming, costly, and paper-based processes, and reducing the role of intermediaries. This distributed data platform would be accessible, transparent, up-to-date, verifiable, and immutable, and could facilitate simultaneous activities, tasks, and formalities. Furthermore, blockchain-enabled smart contracts could help to automate and digitize the process, making transactions faster, less erroneous, and secure. However, the main challenges of applying blockchain in property transactions include regulatory uncertainty, as it would require data standardization and collaboration with many stakeholders, and some of the current transaction processes might be too complex to translate into computer code and algorithms.

The tokenization of real estate investment has been gaining popularity recently. Tokenization is a process of fractionalizing large, traditionally lumpy real estate investments and allowing more investors to join the real estate market. Tokenization also brings about improved liquidity and cost reductions. However, tokenizing real estate assets is not possible in most jurisdictions, and this has led to the development of intermediate structures. Furthermore, the liquidity improvements through primary and secondary markets and fractionalization may lead to a decrease in the illiquidity premium of real estate, thus decreasing returns for large institutional investors. Therefore, these investors are more interested in investing in funds that fit their investment and risk profile.

The literature on leasing and renting is the fourth largest segment and covers topics such as inefficiencies, intermediary dependencies, and trust issues. Mostly, papers focus on apartment rental services. The existing leasing process is labour-intensive, paper-based, and slow, resulting in high costs, lack of transparency, information asymmetry, and fraud. Blockchain technology can address these problems by automating processes via smart contracts, reducing costs by replacing real estate brokers and fragmented information services with a secure blockchain platform, and providing real-time information with distributed access and a MLS.

Managing and overseeing financial, operational, and information services relating to real estate, as well as legal matters regarding real estate, are activities that encompass both Blockchain for Real Estate Administration and Real Estate Maintenance. Real Estate Maintenance furthermore includes energy management, technical services, facility services, waste

management, cleaning services, and maintenance of outdoor areas. The primary blockchain idea in real estate administration and maintenance relates to storing real estate data in the property passport. Devices and monitoring systems could log relevant data automatically to the blockchain data. Storing all the information related to a building and produced during its lifecycle on a blockchain would allow a trustworthy, fraud-resistant, verifiable, single source of validated data that can cut duplicate costs, reducing standalone record-keeping and the role of intermediaries. The main advantages are increased efficiency, automation, and trust.

Finally, there is one more very relevant new global trend, that might create entirely new opportunities for application of blockchain technology in commercial real estate. Given the real estate sector's tremendous environmental burden, it is not surprising that recently, some blockchain applications in green real estate investment have emerged. For example, blockchain-based tokenized securities for green real estate bonds are tied to environmental objectives. By extension, it is also worth mentioning that in the 2020, 2021, and 2022 editions of the FIBREE Industry Report a series of articles written by Roland Farhat (2020, 2021, 2022) explain how commercial real estate companies are struggling to comply with new disclosure and reporting demand from pension funds, governments, and supervising bodies on Environmental, Social and Governance (ESG) issues of their investments and related activities. Since the financial crisis in 2007, authorities around the world have been steadily and consequently increasing requirements on reporting at regulated institutions. The European Commission (EC) introduced new regulations like the Corporate Sustainability Reporting Directive (CSRD) (European Commission [CSRD], n.d.), the Sustainable Finance Disclosure Regulation (SFDR) (European Commission [SFDR], n.d.) or the European Building performance Disclosure Regulation (EBPD) (European Commission [EBPD], n.d.) to strengthen sustainability reporting about buildings. The impact of these new regulations will extend across the globe, as the consequence is that suppliers and the suppliers of suppliers will have to start providing ESG-related data, which the asset manager should consolidate in its disclosures reporting in an aggregated manner. This is expected to create new standards for the construction and real estate industry worldwide in the coming years. In his articles Farhat (2020, 2021, 2022) describes how real estate companies can on the organizational level adopt a data-driven approach to strategy and build

their data streams alongside their investment process. Depending on the scope of the business, data can start with the analysis of macroeconomics for investment decisions. Data then evolves through the whole cycle of managing real estate and investing in the existing portfolio. It is lastly needed to decide on divestments and their execution. Technology solutions automate the data collection by accessing application programming interfaces (APIs) and connecting various databases before preparing the data for measurements, analysis, and reporting.

In a further step, and taking all new regulatory requirements into consideration, companies can execute their disclosures on a risk-based methodology and start with few, most relevant dimensions for their business. These dimensions should be carefully selected in a way that the industry can agree about what are 'good' or 'bad' outcomes, and which can be already measured well. Blockchain can, according to Farhat, be used to establish a professional level of transparency and trust in the reported performances. In a first step, metrics related to the specific risks of each component of ESG can be put on-chain. Applying blockchain technology as a fact, this way also relates to Governance-performance of a commercial real estate organization. The company disclosing that kind of data can then show how it intends to mitigate the risks it has identified and to comply with ESG regulations. The sustainability-oriented investor can subsequently decide about his/her investment, relying on a secured, trusted information offered to him/her on the blockchain and to very low costs. The bigger the public interest and concern, the more public should be the info sharing. The more sensitive the data and its provenance are, the more considered should their accessibility be. The use of Distributed Ledger Technology can enhance the credibility of ESG reporting and sustainability-related information in all cases.

To reach net zero carbon, it is not enough to only reduce energy consumption. Companies need to measure and disclose carbon, as well as improve verification and rigor. Achieving better ESG is an ongoing process. To make sure the journey is successful, new technologies can offer reliable compasses, such as Distributed Ledger Technology (DLT). This technology can help enhance the authenticity of companies' disclosures. Regulations are likely to become more stringent in the future. Investors need to be able to distinguish between ESG risks and metrics in order to make sound decisions. Companies need to close the reporting gap and provide trusted facts and figures about their green products in order to attract investors. DLT can help improve investment performance

by providing reliable decision metrics and building trust with external stakeholders.

Another solution in this ESG-viewpoint is the application of blockchain technology for construction supply chain solutions and circular design & construction solutions. This often involves complex processes, involving not only design, but also logistical planning, mining, and intermediate processing of raw materials to construction materials from, capturing intermediate maintenance and adjustments to the building and materials, up to and including the planning and execution of renovations or demolition and the disposal and reuse of additional building materials. Blockchain can play an important role here to reduce information asymmetry and transaction costs between parties, or to give individual materials their own identity so that corresponding material specifications can be recorded in the materials passport. Challenges here are again overcoming interoperability issues through greater standardisation and improved transparency and accessibility to information, needed at the transaction, operation and again at the disposition phase of the commercial real estate process.

5 Conclusions and Recommendations for Further Research

To investigate the added value of blockchain technology (BTC) to commercial real estate, the following structured assessment framework can be helpful:

- The organizational level
- What framework/variables assessed
- Opportunities of blockchain implementation
- Challenges of blockchain implementation

Commercial real estate refers to properties used specifically for business or both direct and indirect income-generating purposes (a building or land). When examining the organizational level and characteristics of the commercial real estate industry, this shows the market consists of a combination of the space market and the asset market. The space market is the most fundamental since the rent for real estate space creates the underlying cash flow needed for determining the value of a property. Various

studies show how complex and constantly moving the playing field for commercial real estate managers is. Three main information exchange verticals are identified that are at the core of the digital evolution of real estate:

- Smart Real Estate
- Shared Economy
- Real Estate FinTech

While performing their tasks, managers are confronted with decisions and results of other players in their field like governments, banks, other real estate organizations, and more, that impact their market. Real estate managers need to navigate their assets in a prudent way by mapping ahead and anticipating to many constantly changing risks of different types.

A large amount of high-quality information coming from many different sources and on a wide variety of topics is being collected by the asset-manager. High quality means the data is reliable, timely, and aggregated in the right way so it can easily be used in conjunction to other available information.

The management of Commercial Real Estate consists of three main phases:

- Acquisition of the property,
- Operation of the property,
- Disposition of the property.

This is usually a well and structured organized process in which several players fulfil different roles and tasks in relation to each other. The operational phase can be further subdivided in strategic, tactic and operational management. During the operation phase a vast amount of data is exchanged and registered, among which many data is needed for the transferring real estate. Due to the markets' fundamental characteristics—heterogeneity and immobility—real estate transactions face the joint challenges of information inefficiencies and corresponding high transaction costs.

Various studies highlight opportunities and challenges regarding possible application of blockchain technology in commercial real estate. These will be listed below in the structured assessment framework:

Organizational level	*What variables assessed*	*Opportunities of blockchain implementation*	*Challenges of blockchain implementation*
Industry-wide	*Building Technologies* **Better information quality** More information, available instantaneously, less error, less duplication, less human inefficiency, greater transparency, reduced transaction times, greater market liquidity and turnover	Build a robust infrastructure for future use by the industry Facilitating enhanced data-quality and enhanced interoperability	New services and applications can appear from nowhere to threaten the market's architecture
Real Estate Owner	*Manage & Operate* A blockchain-based **Digital Building Logbook**, with an immutable, trustworthy ledger which can keep all the relevant documents of a property up to date and easy to access	The core principle for further building blockchain-based applications The primary blockchain idea in real estate administration and maintenance relates to storing real estate data in the property passport Log relevant data automatically to the blockchain data. Storing all the information related to a building and produced during its lifecycle on a blockchain would allow a trustworthy, fraud-resistant, verifiable, single source of validated data that can cut duplicate costs, reducing standalone record-keeping and the role of intermediaries. The main advantages are increased efficiency, automation, and trust	Implementing blockchain requires good-quality digitalized data and standardization. How should various types of real estate data such as valuation reports, real estate collaterals, lease information, etc. be connected? To provide a uniform recording of real estate data, consensus must be reached on how to connect various aggregation levels with each other

(continued)

(continued)

Organizational level	*What variables assessed*	*Opportunities of blockchain implementation*	*Challenges of blockchain implementation*
Transactions	*Transaction & Escrow Services* Re-design of real estate **transaction** processes	Conduct a transaction immediately, without the need for a trusted third party to verify the transaction Reduction of intermediary-dependent, paper-based, manual, costly, and time-consuming processes that are prone to errors and fraud	Standardization. How should various types of real estate data such as valuation reports, real estate collaterals, lease information, etc. be connected? To provide a uniform recording of real estate data, consensus must be reached on how to connect various aggregation levels with each other
Industry-wide	*Research & Valuate* Improve the **transparency** of real estate markets	An undisputable public ledger of transactions that would give not only investors but also regulators improved insights into the functioning of the market	
Industry-wide	*Transaction & Escrow Services* **Using cryptocurrencies** in payments or as deposits		
Industry-wide	deployment of **smart contracts**	Blockchain-enabled smart contracts could help to automate and digitize the process, making transactions faster, less erroneous, and secure	Regulatory uncertainty, as it would require data standardization and collaboration with many stakeholders Some of the current transaction processes might be too complex to translate into computer code and algorithms

(continued)

(continued)

Organizational level	*What variables assessed*	*Opportunities of blockchain implementation*	*Challenges of blockchain implementation*
Real Estate Owner/ Industry-wide	*Invest & Finance; Markets & Platforms* **Tokenization** of real estate for funding investments Tokenization of real estate for decentralized finance (DeFi) Trading platforms for real estate tokens	Inclusion and efficiency while providing better liquidity and cost reductions Safe haven for crypto investors When popular, several innovations become conceivable, including structured finance, hybrid real estate tokens and digital fund exchanges Many of its predicted conceptual advantages can be realized Major disruptive innovations in the organization of financial markets in the future	Regulatory uncertainty, ambiguity, and terminological differences exist Tokenisation is at an early stage of its development, and real estate applications will take time to develop and become accepted Demand is limited, the economics unconvincing and the obstacles significant Unwanted economic consequences for those parties that dominate the current market Effect of financial regulation on the attractiveness of tokenized assets Whether the governance system in place can be improved is unclear

(continued)

(continued)

Organizational level	*What variables assessed*	*Opportunities of blockchain implementation*	*Challenges of blockchain implementation*
Industry-wide	*Smart City Solutions* NFT-representation of real buildings in **Metaverse** Creating **Web3** solutions in conjunction with adjacent other industries	Create attractive new customer experiences Can be anything, like digital micro grids for sharing utility services between neighbours, to metaverse solutions or at the edge of real estate connecting building data with adjacent industries, like energy or mobility to facilitate shared economy solutions	Decreased need for space in real-world real estate Lack of standardisation and interoperability with other industries
Industry-wide	*Smart City Solutions* Land and **title registries**	Improve worldwide coverage of land title registries Reduce time-consuming processes Less errors and lost documents	Legal, implementation, and technical challenges. Implementing blockchain within land administration requires good-quality digitalized data

(continued)

(continued)

Organizational level	*What variables assessed*	*Opportunities of blockchain implementation*	*Challenges of blockchain implementation*
Real Estate Owner	**ESG-reporting** & disclosure, Evidence-based Green Investments	Solution for current struggling to comply with new disclosure and reporting demand Increasing requirements on ESG-reporting Technology solutions automate the data collection by accessing application programming interfaces (APIs) and connecting various databases before preparing the data for measurements, analysis, and reporting Relying on a secured, trusted information offered to him/her on the blockchain and to very low costs E.g. blockchain-based tokenized securities for green real estate bonds tied to environmental objectives	Access and aggregation cause technical challenges. Implementing blockchain requires good-quality digitalized data
Real Estate Owner/ Industry-wide	*Plan & Build* Blockchain-based solutions for construction supply chain, fostering circular economy solutions	Reduce information asymmetry and transaction costs between parties, or to give individual materials their own identity so that corresponding material specifications can be recorded in the materials passport	Interoperability issues through greater standardisation and improved transparency and accessibility to information, needed at the transaction, operation and again at the disposition phase of the commercial real estate process

The table illustrates where blockchain in commercial real estate stands in 2023. The opportunities and challenges coming from various scientific and applied studies are often assumptions based on theoretical explorations that are still hardly applied in practice, let alone already sufficiently validated. As such, the overview immediately provides good starting points for further research.

With this chapter, I try to make a valuable contribution for the further development of blockchain exploration and adoption in the real estate industry. I would advise anyone starting follow-up research to be aware that unfamiliarity with blockchain and its possibilities may be the biggest stumbling block to validating opportunities and challenges among market professionals. Being a real estate professional still too often does not mean you are also a digitisation professional to some extent. And the market simply needs more digitisation professionals whose leadership will make businesses and the industry ready for the future. I would therefore like to conclude this chapter by strongly encouraging follow-up research, because for better understanding of the potential and added value of blockchain technology in commercial real estate, the following in particular is very much needed: Education, Education, and Education!

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A Blockchain-based Life Cycle Assessment (LCA) Framework for Building Materials Selection

Nesrine Gaaliche and Mohammad Abou Elseoud

1 Introduction

Life Cycle Assessment (LCA) originated in the United States in the late 1960s as part of the National Environmental Policy Act. In real estate it is a global analysis of the environmental impact of products used in the building throughout their life cycle. It analyzes the phases of raw material supply, production, transport, use and disposal. LCA has several advantages, essentially for any building project. According to the United Nations program, buildings and construction contribute nearly 40% of carbon emissions.

Given the complexity of the construction process, from sourcing raw materials to the final finishing touches, LCA was once a time-consuming

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and required process. However, thanks to the proliferation of assessment technologies such as software and scheduling tools, LCA no longer takes months.

LCA has several advantages essentially for any building project. According to the United Nations program, buildings and construction contribute nearly 40% of carbon emissions. As architects become increasingly invested in sustainable buildings, the most important outcome of an LCA is how well it can help select products that have confirmed a structure's environmental footprint. Using building product data, LCA provides valuable insight into a building's environmental weak points, which helps to solve potential problems such as carbon emissions, waste, or energy flows. Additionally, especially if a construction project is taking place in an environmentally vulnerable area, LCA can also help developers deal with issues such as habitat destruction or resource depletion. ACV can significantly reduce costs in the short and long term, in particular by allowing property developers to have an overview of all aspects of their projects. An important detail of a building as such is its energy consumption. If not systematically optimized, energy consumption can eat up a lot of resources during the construction process and beyond. By using a combination of product data, this assessment can also help developers, including comparing different products and materials with the same results in order to choose the most commendable option.

This method remains a comprehensive process that requires many different skills and an interdisciplinary approach. However, by harnessing the right technologies, it is possible to streamline communication between colleagues, in particular to improve the results and reduce the time required for this analysis.

This research develops a framework to guide the implementation of blockchain-based LCA. The blockchain is a distributed ledger maintained by a set of nodes. Users can interact with nodes in order to send transactions to the blockchain. A blockchain ledger takes the form of a collection of blocks containing transactions submitted by users, along with metadata about itself or the ledger. Each block is linked to the previous one by its hash value. In this sense, since modifying a block would alter this value as well as all the other hash values of the following blocks, it is theoretically impossible to alter the content of a block. New blocks are formed by a subset of nodes responsible for aggregating transactions into a block and validating it by implementing different cryptographic

processes depending on the blockchain used, to ensure its validity when added to the blockchain.

The blockchain appeared during the creation of Bitcoin (Nakamoto, 2008), in order to allow users to exchange the cryptocurrency of the same name. Subsequently, many blockchains were able to emerge. Ethereum, the best known, is acclaimed (Wood et al., 2014) for its ability to deploy and interact with smart contracts, housed in the blockchain (Toufaily et al., 2021). Smart contracts for the blockchain allow not only to execute functions directly within it, but also to store states. They therefore benefit directly from the particular properties of the blockchain, which are integrity, decentralization, non-repudiation of transactions and transparency. This gives the blockchain an artificial trusted third-party status, where it is possible to trust the code and the power of the network unlike conventional trusted third parties who ensure the validity of transactions through their status, such as banks or governments.

These characteristics have attracted the attention of industrialists and academics, who see the blockchain as a means of revolutionizing the way of exchanging value between individuals as well as guaranteeing the veracity and integrity of the data stored in it. Indeed, the blockchain would be "a native digital medium for value, by which we could manage, store and exchange multiple goods […] peer-to-peer and in a secure way" (Tapscott, 2016). As a result, there are many relevant use cases of blockchain in the literature in different sectors of activity, such as supply chain management (Cachin & Vukolic, 2017), finance (Ren et al., 2023), network control (Patil et al., 2023), decentralized digital identity (Shari & Malip, 2023) or health (Erol et al., 2023).

However, despite its potential, blockchain faces many barriers to adoption. According to a study carried out by PwC in 2018, companies face problems such as uncertain regulation on the subject, a lack of trust in other actors when participating in a project using blockchain, as well as the difficult management of the intellectual property of the data and goods recorded there. These problems are gradually being resolved thanks to the collaboration of the actors of the blockchain ecosystem and the competent legal and governmental authorities. Nevertheless, companies are still facing a technological barrier, for several reasons. They may encounter difficulties in recruiting collaborators specialized in blockchain, as the technology is still young. They may also find it difficult to integrate blockchain into their existing information systems and business processes, because there are not yet identified and proven best practices in business

by software architects. In order to overcome this problem, studies have been carried out to assist the integration of the blockchain into software architectures. In this sense, a study proposes a collection of architectural models containing blockchain, as well as the different cases where these models are applicable (Xu et al., 2018).

But the main obstacle lies in the design of the blockchain solution as well as its implementation. At this point, developers may have several questions.

Which blockchain to use in a given context, knowing that there are many competing technologies with, for each, their own properties and characteristics? Maybe it is ultimately more reasonable to use a "proven" solution instead of a blockchain (database, microservices…)? Finally, how to configure the various parameters of the blockchain, which have an important impact on the satisfaction of the requirements (performance, resilience, security…) such as the consensus algorithm or the inter-block interval, often requiring the intervention of experts in the field to achieve a result that meets the requirements?

Many studies have been conducted to answer the first two questions and thus facilitate the choice of the blockchain solution, in particular through decision models through various questions. Another study presents a vademecum containing all the information necessary to understand blockchain from a technical point of view, as well as a decision model for blockchain applied to several example scenarios. The proposed recommender systems are often made up of a series of abstract questions, making it possible to answer questions such as "do I need a blockchain?" or "what type of blockchain to adopt?", but not to provide specific recommendations, or go into more detail by considering the choices between many blockchain parameters and properties. Users wishing to obtain a more precise recommendation should therefore turn to the latter. This type of study is relevant for people with good knowledge in the field of blockchain, but it will be difficult for uninitiated people to answer the questions of the decision model precisely. Moreover, many of these studies only focus on blockchain requirements, while users have requirements related to software quality (performance, security, reliability…). The links that connect blockchain attributes to software qualities as defined in engineering are often not very explicit and it is difficult to quantify the impact of a blockchain parameter on the software qualities of the final solution. Finally, when the number of technical attributes considered becomes large, it is impossible to make a choice taking them all into account,

the computational complexity when using the model manually being too high.

To overcome these limitations, we introduce in this chapter an automated decision process that determines the most interesting alternative for a given case study. In it, the preferences or requirements of users regarding the software quality of the solution to be created will be used as input. These will be compared to the different characteristics of the alternatives considered by a multi-criteria decision-making aid method. These characteristics will be contained in the form of a knowledge base and defined using the existing literature (experiments, literature reviews ...), the white papers of the blockchains considered as well as our own results of experiments. We also present an application of our decision process to a relevant use case in the field of supply chain management. This part will be an opportunity for us to validate the results of the decision process, through manual experiments confirming the decisions made by the process.

Section 2 presents the decision-making process. Section 3 applies our approach to building material selection problem. We present the work related to our study in Sect. 4, then we continue with a discussion of our results and our approach in Sect. 5. Section 6 concludes.

2 Construction of the Decision-making Process

In this section, we will present the inputs as well as the operation of the decision process to help the user choose the most suitable blockchain model.

2.1 Input

The accuracy of a multi-criteria decision support algorithm depends mainly on the input data. In this subsection, we present our approach to build a reliable and adapted knowledge base, as well as our method to elicit the weights that will be applied to each of the criteria for the execution of the decision process.

2.1.1 Alternatives and Attributes

To support our decision support process, we built a first version of the knowledge base containing a set of am blockchain alternatives and their respective attributes (Table 1). We have chosen this specific panel

of blockchains because they are considered to be the most widely used blockchains by enterprise blockchain service providers.

Since the objective of our work is to help make decisions about which blockchain to use when selecting building materials without having any particular expertise on how to configure it, we have chosen a set of criteria that can be placed under the different macro-attributes proposed by the ISO 25010 standard, a standard defining the different macro-attributes to be considered in order to guarantee the quality of a system or software during its implementation. We have chosen the attributes that seem relevant to us in the considerations to have when choosing a blockchain, but also for the possibility of transcribing them in digital format. Therefore, our criteria are not specific to blockchain technology, but related to system quality. It is our decision process that will be responsible for translating these system quality attributes into blockchain attributes (such as inter-block interval, consensus algorithm, or block

Table 1 Alternatives and retained attributes

Attributes/ Alternatives	*Bitcoin*	*Ethereum*	*Ethereum*	*Hyperledger Fabric*	*Corda*
Algorithme de consensus	PoW[a]	PoW	PoW[b]	Raft	PBFT[c]
Efficient en	No	No	No	No	No
énergie:	No	No	No	No	No
Gas Emission	No	No	No	No	No
Liquid discharge					
Solid waste					
Tolerant of Byzantine faults	50.00%	50.00%	33.30%	0.00%	33.30%
Smart contracts	No	No	Yes	Yes	Yes
Cryptocurrencies	Yes	Yes	Yes	No	No
Storage element	Basic	Advanced	Advanced	Advanced	Advanced
Computational	No	Advanced	Advanced	Advanced	Advanced
element	Basic	Advanced	Advanced	Advanced	Advanced
Asset manager	No	Advanced	Advanced	Advanced	Advanced
element					
Software					
connector					
Learning curve	Low	Medium	Medium	Very High	Very High

[a]Proof-of-work (PoW)
[b]Proof-of-Authority (PoA)
[c]Practical Byzantine Fault Tolerance

size). Figure 1 presents a diagram showing the relationships between software quality attributes (chosen criteria for our decision process) and blockchain-specific attributes. The values entered for each attribute of alternatives in our knowledge base come from different sources: studies (such as that of Belotti et al. [2019], white papers [e.g. Nakamoto, 2008; Wood et al., 2014]), technical documentation and scientific literature (Rossi et al., 2019). Some of these values are approximate (marked by the symbol ∓), as they are subject to variation in the topology and configuration of the blockchain network as well as the technical characteristics of the nodes that make it up (CPU, RAM, etc.).

Their value is therefore constructed from known attributes, such as the consensus algorithm supported (an algorithm tolerant of Byzantine faults like the algorithm Bitcoin PoW will have lower transaction throughput than a fault-tolerant algorithm, like Raft used by Hyperledger Fabric). Nevertheless, these values can be fixed when the blockchain parameters are known. Our decision-making process having to take into account assets already present in the company (such as the technical infrastructure or the models of business processes), we rely on the performance of performance tests in order to be able to give a fixed value to the variable attributes in depending on the given context. This knowledge base will also vary over time. The values of the attributes of the different

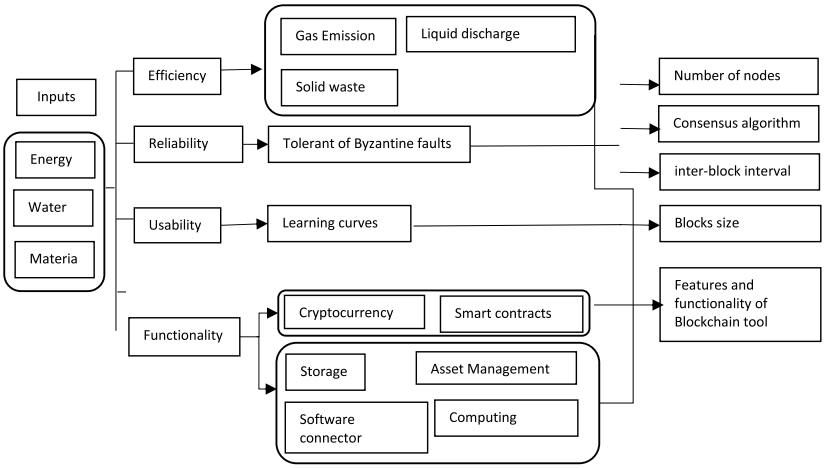

Fig. 1 Blockchain-based life cycle assessment system

Table 2 Likert scale combining labels and preference values

Linguistic variable preference value	Pn
Extremely desirable	4
Quite desirable	3
Desirable	2
Low desirable	1
Indifferent	0

blockchains chosen will be modified if necessary (update of one of the elements of a blockchain). These variations can have an impact on the choice of the best alternative by our decision-making process, it will be necessary to evaluate the age of the knowledge base in order to determine if the recommendation is relevant at a given moment.

2.1.2 User-defined Weights and Conditions

In order to obtain a blockchain recommendation that meets the user's expectations, the automated decision-making process must take into account the user's requirements and preferences. When the user is prompted to enter their choices, they can mark a criterion as Required or Undesirable. During decision-making, an alternative whose attribute does not meet one of these two requirements would be automatically disqualified from the possible alternatives, regardless of its score obtained by the execution of the multi-criteria decision support algorithm.

The user can also indicate their preferences for attributes, through literal variables forming a Likert scale (Allen & Seaman, 2007) (Table 2). The choice of one of these variables makes it possible to obtain a preference value $p_n \in n$ for each of the criteria cn. In order to obtain the weights of each of the criteria ω_n in such a way that the sum of these weights is equal to 1, we must divide each of the preferences p_n for a criterion by the sum of the preferences.

2.2 Internal Logic

First, our decision process performs an initial filtering of alternatives based on user requirements. If a criterion marked as Required or Undesirable is not met by one of the alternatives, it is automatically eliminated, regardless of the score it could have obtained using the decision algorithm that follows. For a Required criterion that is not a Boolean, the user specifies

an extremum value. For example, if a certain number of transactions per second is required, alternatives that do not meet the threshold value will be disqualified.

The automated decision process on the remaining alternatives is based on the use of a multi-criteria decision support algorithm called TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) (Lai et al., 1994). The TOPSIS algorithm is based on the fact that the most relevant alternative am for a given set of choices must be the closest possible to the positive ideal solution A+ and the farthest from the negative ideal solution A−.

The choice of this algorithm was guided by a study presenting a state of the art of studies on the choice of a multi-criteria decision support method (Kornyshova & Salinesi, 2007). This proposes a decision framework including different properties to pay attention to when choosing a multi-criteria decision aid method. We judged that the TOPSIS method was suitable for our decision-making process, in particular because it supports the multi-criteria analysis of many and varied attributes (which is the case when comparing two blockchains) while being simple to implement and precise in the decision. It also allows to take into account weights defined by a user, which is required given the modus operandi of our decision process. Several steps necessary for the execution of the TOPSIS method are detailed in the following.

Construction of the matrix—Let m alternatives a and n attributes c for each of them. Grouping these alternatives gives a matrix $X = \{x_{ij}\}$ for $\{i \in N | 1 \leq i \leq m\}$ and $\{j \in N | 1 \leq j \leq n\}$.

Matrix standardization and application of weights—standardization of criteria with different units and scales is necessary in order to be able to compare them with each other. It is also at this stage that we apply the weights coming from the user's preferences.

$$v_{ij} = r_{ij} \times \omega_j = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \times \omega_j \tag{1}$$

Calculation of the positive and negative ideal solutions and then measurement of the difference with each of the alternatives—By selecting the best and the worst performances of each of the criteria of the weighted normalized decision matrix, we can determine the positive A^+ and negative A^- ideal solutions in order to measure the gap of each of the

alternatives with these two solutions that we will denote S^+ and S^-.

$$A^+ = \left(v_1^+, ..., v_j^+\right) \text{ and } A^- = (v_1^-, ..., v_j^-) \tag{2}$$

$$S_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2} \text{ and } S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \tag{3}$$

Calculation of the relative distance with the ideal solution—This last step makes it possible to give a score to each alternative, which represents its distance with the ideal solution. The ordering of these scores makes it possible to define the best possible alternative compared to the given alternatives as well as the preferences of the user.

$$C_i i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{4}$$

3 Application to a Supply Chain Management Case Study

In order to test the proposed automated decision-making process, we selected a study that proposes to introduce a blockchain system to a supply chain in order to allow data sharing between the different actors (Longo et al., 2019).

In this part, we will detail the scenario proposed by the cited study, then the different attributes required for the blockchain to be implemented which arise from this subject in order to perform our automated decision-making process. Finally, our results are validated using a performance testing tool implemented for this purpose.

3.1 Case: Building Material Selection

Our empirical study consists of a building material selection problem: Brick, Aluminum and Iron. We consider that there is real-time, transparent and reliable data sharing between suppliers of these building materials. Each material has specific features of energy efficiency, storage and supply contracting.

We propose the establishment of a blockchain making it possible to record data linked to the selection of building materials in the form of hash value. The saving of this value makes it possible to certify the consistency and reliability of the data transmitted between third parties, they can now trust each other.

3.2 Building Material Selection Requirements

To be able to recommend using our decision process, it is necessary to identify the quality attributes as well as the requirements and preferences regarding these attributes (Sect. 2). This subsection therefore discusses each of the system quality attributes proposed previously and explains the choice of the value of each of them.

Efficiency—The blockchain-based Life Cycle Assessment System needs to support energy efficiency including: Gas Emission, Liquid discharge and solid waste. Since these attributes are beneficial to the environment, we still chose to set them quite desirable.

Reliability—Since the materials have different features mainly with regard to their supply, it is essential to have a percentage of Byzantine fault tolerance, which indicates that the system is able to function correctly for a certain number of nodes that may have adverse behavior. We have chosen a percentage of at least 33.3%, which makes it possible to guarantee the good continuity of the blockchain network for a number of faulty nodes $f + 1 < \frac{n}{3}$, n is the number of total nodes constituting the network (Saberi et al., 2018).

Functionality—To meet the objectives of the defined subject, the blockchain must be able to take the form of a storage element to contain the data as well as to support the administration of these, de facto through contracts smart. These two attributes are therefore defined as Advanced and Required respectively. The other features are not necessary, they are marked Indifferent.

Usability—Finally, the last attribute chosen is the learning curve: in a context where the blockchain must save costs associated with the supply chain as well as support a low complexity application, using a technology in which it is easy to learn the mechanics can be an asset. We have chosen to mark it as Desirable.

3.3 Results

Performing the automated process eliminates the Ethereum, PoW alternative, as it does not allow smart contract support, as well as the Hyperledger Fabric alternative, as it does not tolerate Byzantine faults. We thus obtain two matrices, one containing the weights and the other the possible alternatives (resp. Ethereum-PoW, Ethereum-PoA, and Corda). Knowing that a weight of 0 for a given attribute makes it insignificant in the calculation of the score of each alternative (Table 3), we can simplify these matrices for the following values:

$$W = \begin{pmatrix} 0.15 \\ 0.85 \\ 0.3 \\ 0.2 \end{pmatrix}$$

$$A = \begin{pmatrix} 160 & 8 & 1 \\ 0 & 1 & 1 \\ 1 & 0.343 & 0.22 \\ 0.4 & 0.4 & 0.8 \end{pmatrix}$$

Table 3 Desired blockchain system requirements for the case study

Attributes	*Requirements*	*Required*	*Value Preferences*
Gas Emission,	None		Quite desirable
Liquid discharge and	None		Quite desirable
Solid waste	None		Quite desirable
Byzantine Fault Tolerant	Required	≥33.33%	Desirable
Smart contracts Cryptocurrencies	Required	Yes	Indifferent
Storage element Calculation element	None	Advanced	Indifferent
Asset manager element Software	Required		Indifferent
connector	None		Indifferent
	None		Indifferent
	None		Indifferent
Learning Curve	None		Desirable

Table 4 Result of the execution of the decision process

Alternative	*Score*
Ethereum, PoA	0.7472
Bitcoin, PoW	0.6836
Corda, PBFT	0.1258
Ethereum, PoW	Disqualified
Hyperledger Fabric, Raft	Disqualified

Our decision algorithm therefore considers the Ethereum-PoA alternative to be the best (Table 4). Indeed, its obtained score is the closest to 1 (positive ideal solution) of the three alternatives.[1]

4 Related Works

Our work is in line with studies carried out to facilitate the adoption of the blockchain by means of decision support between different types of blockchains, or by the decision between using a blockchain or not in a given context.

Sedlmeir et al. (2022) list the main properties of the blockchain (Transparency, integrity, trust…) and propose a decision model on the adoption of the blockchain or not depending on the answer to certain questions (such as: "Are there several third parties involved?" or "Are they trusted?") related to the given case study. They then apply their model to several example use cases. Although there is a study of the blockchain parameters to define the questions of the decision model, the result is of a very high level of abstraction (public, private, permissioned or no blockchain).

It therefore does not allow a precise decision to be made on the blockchain technology to be used as well as these parameters. Ray (2019) carry out a literature review on studies relating to decision models for blockchain in order to build their own model. The results of this one are a little more precise than the previous one, but still do not give a precise recommendation. The authors of (Labazova, 2019) also carried out a literature review while using a DSR (Design Science Research) approach to build their model. This has several levels of decision and takes into account blockchain properties, which allows a user to make a

[1] POA Clique: https://github.com/ethereum/EIPs/issues/225.

choice with increased precision in output compared to previous studies. Moreover, the authors show the dependencies between certain parameters (for example, confidentiality and transparency). However, the input parameters are mostly specific to the blockchain and condition the use of the model by an expert. Another interesting study presents a third approach to decision support by offering a complete detailed work of blockchain fundamentals in the first part of their study, as well as a decision model introducing opposing criteria (such as performance/costs), but also a series of questions to refine the choice ("When to use the blockchain?", "What to use?", "How to use this blockchain?") (Zheng et al., 2017). All these studies help to guide decision-making for a given blockchain project, but do not allow going into more detail (blockchain parameters) because of the limitations of decision models. The lack of automation and the manual resolution of questions does not allow to take into account a large number of input requirements.

Some studies have been conducted to address this issue. As an example, the authors of Tang et al. (2019) propose to use a multi-criteria decision support method called TOPSIS, which is the same as the one used in this study, in order to determine the best solution of public blockchain available from a set of input criteria. The approach is interesting in this context, but does not take into account other blockchains (private, permissioned). In addition, the blockchain technical criteria are grouped under the "basic technology", "applicability" and "transaction per second" criteria, the first being quantified via experts, the recommendations given as a result may therefore lack precision if one considers place from the point of view of the company wishing to start its project.

In Farshidi et al. (2020), the authors built a decision-making system for blockchain technologies based on previous work for other technologies. They carried out a survey of experts to determine the most relevant selection criteria, then filled out a knowledge base containing the values of these attributes chosen for a large set of blockchains (obtained with white papers, studies, performance …) in order to give recommendations via an inference engine. Their tool is very powerful and makes it possible to give precise recommendations, we want to go further by offering something more blockchain-oriented (taking into account specific business processes and architectural models) which is more accessible for non-blockchain experts, through a model that links blockchain and software quality attributes. Thus the user can enter more common requirements than those specific to blockchain technology.

5 Discussions

The prediction obtained, which is to use Ethereum-PoA, seems to us a relevant choice for several reasons. Indeed, all the features that we consider necessary for the proper implementation of the chosen case study are present, while ensuring an optimal cost of it (low learning difficulty and energy saving). However, the method remains sensitive to weight variations. If we had chosen a higher weight for transaction throughput, we might have had a different output result. Sensitivity studies can establish ranges, which serve to indicate how much a weight can vary without affecting the final result. There are also methods, such as that of the determination of weight by entropy, making it possible to limit the impact of criteria with high entropy by reducing their weight (Huang, 2008). Moreover, the Likert scale that we have chosen for the expression of preferences can lead to a bias depending on the perception of the differences between the different values proposed by the user. In order to make the result more reliable, other weighting systems could be considered (AHP).

For our second experiment implementing a performance test of the Ethereum-PoA blockchain, we found that it was no longer able to process 100% of incoming transactions from 400 transactions per second. The monitoring of the execution on each of the nodes shows that this incapacity appears when the CPU of the nodes is no longer able to support the load of transactions received by the Geth client. It is however possible to decrease the inter-block interval in order to increase performance, but too low a value could degrade the quality of the network (difficulty reaching a consensus between authority nodes) and increase the disk space required (each block comprising at least one header of non-zero size). Therefore, we have chosen to keep the default value, but studying the impact of a drop on stability could be profitable. Also, we found during our experiment that the curve faithfully represents the loss of transactions, but we believe that repeating the experiment for each measurement point several times and extending the time of each experiment could greatly refine the results.

6 Conclusion

In this study, we adapted a multi-criteria decision support method to design an automated decision process for blockchain. For this, we selected a relevant panel of blockchains as well as criteria relating to the quality of a

system (ISO 25010 standard) to create a knowledge base, then we chose a list of terms allowing a user to submit his preferences and requirements for the criteria chosen for the decision. Finally, we validated our process on a supply chain management case study and showed that our tool is able to recommend a blockchain aligned with the user's needs. The implementation is in progress, and will be completed and made available in open access on GitHub in future work. This study is a first step to design a more extensive automated decision process, as it could take into account a larger number of inputs (system architecture topology, infrastructure, business processes…). This would allow us, using this information, to run a custom performance test (such as the one presented in Subsection 3.4) for each user before even running the decision algorithm, the goal being to extremely precisely set the values of the varying criteria (transaction rate, latency, etc.). Another avenue for improvement is the use of approaches based on fuzzy logic or Bayesian models which would take into account the subjective aspect of the decision criteria.

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Cryptocurrency and Real Estate Transactions

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1 Introduction

There is pervasive unanimity among economists and research scholars that the real estate is always deemed to be one of the main economic growth engines, and an imperative biometer to indicate the economic strength and well-being of a region or a country. The significant contribution of real estate sector to an economy is derived from various factors, in a nutshell, this sector provides job opportunities to vast percentage of population and contributes in increasing the level of individual and national income alike. According to the United Nations Environment Programme report of 2018, the real estate industry contributes to global total wealth by USD 200 trillion and accounted for almost 40% of global energy demand, also the global real estate investments are almost

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twice the size of investments in stock markets (Miah, 2022). Despite its economic and social significance, the importance of real estate sector has not only been confined on the value creation and money circulation, however, the real estate sector can play a significant role as a trigger for financial crises and serve as a conduit through which economies recover after seismic crises effects simultaneously. For instance, the real estate sector was the main trigger for the global financial crisis in 2008 (initially caused by the burst of U.S. housing price bubble), and on the other hand the sector was the road to economic recovery following the global financial crisis in 2008. Recently, the increase in population and need for residential properties accompanied by the tremendous growth of e-commerce technology have all contributed to the sector's growth. The development prospects of this sectors seem to have considerable temptation to investors and capital providers, according to McKinsey Global Institute Report (2021),[1] the growth of the real estate sector has been more than tripled since 2000, and it is expected to achieve high growth percentage by the end of 2023 as compared to 2022. Notwithstanding, the digital maturity of this sector is consistently considered as being low compared to some other industries, and this signals substantial potentials for enhancing the size of trade alongside with its productivity through the more prevalent adoption of digitalization (Manyika et al., 2015).

The evolution of financial technology (FinTech) in recent years is a main remarkable feature of the contemporary technological advancement in this century. The trajectory of FinTech is mainly propelled by the enhancement in high-speed internet connections and the notorious popularity of mobile applications among youth and financial markets stakeholders. One of the main phenomena of FinTech is the blockchain technology. The blockchain can be described as a series or sequence of digital records lined together through the so called 'cryptography'. Each block is verified, distributed, and managed in a peer-to-peer network. blockchain is a distributed database (Hassan et al., 2022). The blockchain technology enables combining and recording various transactions into secure and decentralized ledger system by establishing a chain of chronological pieces of data. This system allows for immediate authentication of transactions without a need for third party for intermediation. The blockchain application is extended to independent vehicles that rely on

[1] https://www.mckinsey.com/~/media/mckinsey/featured%20insights/mckinsey%20global%20surveys/mckinsey-global-surveys-2021-A-year-in-review.pdf.

machine learning and methods from the field of artificial intelligence, it is proving, day by day, its ability to deliver advantages to trade and investment transactions. It enables creating an encrypted and integrity-protected data storage that can be used to conduct trading transactions in many industries, and the real estate is one of them. With many types of cryptocurrencies subsumed under blockchain technology, the security, transparency, and anonymity of transactions and payment systems can be significantly improved. For instance, in their whitepapers of 2019, Leshner and Hayes have introduced the concept of 'Compound Finance' defined as a set of money market algorithmic protocols that allows investors to lend and borrow assets using the blockchain technology via wrapping cryptocurrencies as a collateral for efficient lending (Leshner & Hayes, 2019). Although the main pervasive and most controversial potential for cryptocurrencies is, primarily, their ability to serve as a medium of exchange, however, empirical examination of cryptocurrencies' use in real estate transactions should come to the fore in the very near future.

The blockchain technology has started gaining attention and recognition across a wide range of market participants. Its impact on financial system in general, and financial service industry in particular has prominently emerged in the last few years. Figure 1 demonstrates the value of investments in proptech companies attributed to venture capitalists between 2008 and 2022, as can be seen, the importance of blockchain adoption in real estate industry has gained a strong momentum since 2017 and intensified in 2022. Although the main aim of blockchain is to provide more developed mechanism for financial system, however it has also been able to break through to reach other industries and functions such as healthcare, management, supply chain, and entertainment. For instance, the current huge wave of cryptocurrency (based on blockchain technology) is tremendously pursuing big impacts on payment system, and foreign exchange transactions. Also, the funds raising and financial market investment are notoriously upended by what so called 'Initial Coins Offering' (ICOs) which can also serve as a venture capital and loan provider to startup businesses. The cryptocurrency, simply, is an assets or value item created by software. It exists digitally, not physically. All types of cryptocurrencies can be exchanged for US dollars, fiat currencies, or for other cryptocurrencies. These digital assets are transferred from one account to another and recorded on specific transaction databases (Silverstein, 2022). The databases pertinent to all sorts of cryptocurrencies' transactions including their inceptions, and change of ownership

are verified and recorded. The cryptocurrencies have become the first assets can be moved and transferred over the internet without a third-party improvement, means from owner to owner, once the transaction is recorded on blockchain ledge, then it cannot be reversed. The cryptocurrency market is currently centralized in terms of market capitalization, wherein bitcoin and Ethereum are the main market dominants, nonetheless, there are thousands of these digital currencies are circulated among investors nowadays.

As a matter of fact, the real estate transactions aren't escaping the blockchain disruption either. Beforehand, the real estate transactions are usually conducted offline based on face-to-face arrangements among various entities. However, nowadays the blockchain technology is opening up ways to change this transaction mechanism. For instance, the introduction and application of smart contracts in blockchain podiums allow real estate assets to be tokenized and traded like cryptocurrencies. It can be obviously noticed that at the real estate market participant, as well as, research scholars and policy makers are currently heating the discussions over the potential benefits can be brought by digital currencies to real estate market, such as facilitating real estate transactions, enhancing the pace and transparency of real estate contacts, promotes the security of transactions' records, and makes homeownership possible for larger population span through tokenization. This chapter attempts to corroborate and contribute to the academic literature on the future role of

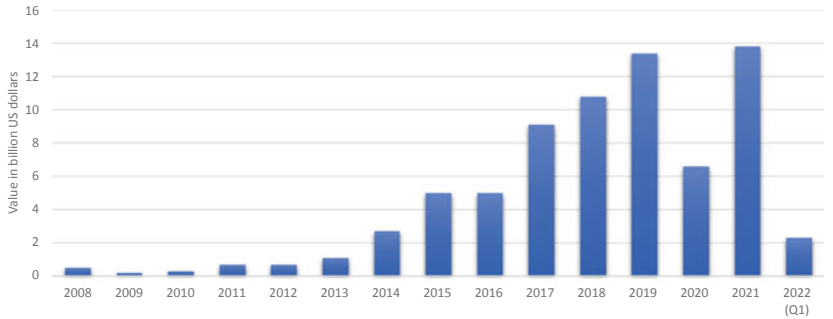

Fig. 1 Value of venture capital investments in proptech companies worldwide from 2008 to 2022 (Q1) (in billion US dollars (*Source* Deloitte, Statista, 2023 [Authors' Illustration])

cryptocurrencies in reshaping and advancing the real estate market. The aim of this chapter is threefold; first, it demonstrates the imperativeness and the potential benefits of digital currencies to enhance the efficiency of real estate market transactions and transparency. Second, the chapter sheds the light on the level of readiness of real estate market's participants and stakeholders for further incorporation of cryptocurrency in real estate contracts. Third, the chapter provides an explanation of real estate transactions using cryptocurrencies. The chapter is organized as follows: Sect. 2 lists the potential benefits of cryptocurrencies and blockchain technology to real estate sector. Section 3 reviews the previous literature and empirical work in the field. Section 4 explains the mechanism of using cryptocurrencies in real estate transactions, and Sect. 5 concludes the chapter.

2 Cryptocurrencies and Real Estate Market: Potential Benefits and Applications

The blockchain technology has recently been hogging the limelight deservedly. That of the types of recent financial innovations, the blockchain technology is by far the most important phenomena gained a ubiquitously traction among real estate market participants including households, investors, real estate developers, brokers, and agents. The residential real estate segment has seen the highest level of blockchain technology adoption due to lower transaction costs and less stakeholders involved compared to typical real estate transaction. Concurrently, mortgage lender, propelled by the aim of expanding their investment portfolios, have started initiating cryptocurrency-based mortgages, where the underwriting service is based on the value of crypto wealth of borrowers and the value of the property of interest. In pursuit of listing the benefits are brought to real estate sector by blockchain technology adoption, we base our discussion on the following:

1. Improve Property Construction and Development, and Enhances Real Estate Assets Management

The property and construction projects nowadays are becoming upended by the arrival of blockchain technology. The typical project requires the involvement of different parties and subcontractors where

the procurement practices and authenticity of construction goods, at their points of origins, should be carefully mentored. The blockchain technology enables the automation of the contract agreements among the project management and subcontractors through smart contracts. It also generates substantially richer data to facilitate better decision making. Moreover, the NFTs (non-fungible tokens) that is a unique digital identifier recorded on a blockchain, allows for proving the authenticity of items and supplies pertinent to construction projects. The adoption of blockchain technology in construction projects enables construction managers to pursue better and more securely track of project accomplishment status and share it with corresponding stakeholders and this increases the project management efficiency. Moreover, the property management companies bear some inefficiencies in their global real estate portfolio management due to the time required to collect money and profit from property renting and trade. The regulatory compliance and access to transactions history are also matters of concern. Blockchain technology facilitates rental collections and payments to property owners and secure data sharing. It also provides extra management capabilities and due diligence across their international property portfolio. The digitization of real assets through tokenization decreases the costs and upgrades the pace of transaction in those assets. This increases operational efficiency and allows for time- and cost-savings.

2. Enhance Liquidity of Real Estate Assets

The real estate assets have long been considered an illiquid asset due to the length of time it requires the owner to convert them into cash. A paramount technological innovation embedded in blockchain technology is the tokenization of real estate assets. Asset tokenization represents an expansion of blockchain, it refers to creating a blockchain tokens acting as a digital representation of fraction of real estate assets. Tokenization at permits digital assets to be traded on blockchains and helps create liquid, transparent, and universally acceptable investments. Nevertheless, the tokenization of properties is still in its inception, where obstacles exist and need to be overcome before the wave of widespread adoption (Sazandrishvili, 2020). The real estate market benefits greatly through the rapid growth of the tokenization technology through increasing accessibility and transparency of real estate acquisition. Tokenizing the physical real

estate assets encompasses dividing up the real estate asset into proportions that can be traded separately using cryptocurrencies and tokens, and this in turn makes the assets readily to use where the asset's owner or seller does not need to find a buyer who can afford to pay for acquisition of the whole real estate asset. International investors and funds always seek to diversify some parts of their portfolios from outside traditional assets such as shares and bonds (Khaki et al., 2023). the blockchain technology enhances the real estate sector's liquidity by promoting the pace of trading processes and enabling the creation of an efficient primary and secondary trading platforms, and this allows investors to improve their portfolio management and diversification through faster liquidize of real estate investment.

3. Facilitate Capital formation and Enhance Real Estate Investment

Analogous to crowdfunding, the application of blockchain technology enables investors with small amounts of capital to pool their capital investment in large-size real estate construction projects. The tokenization technology can convert the real estate properties into financial products by transforming them to digital assets. Through tokenization, investors can simply access multiple trading applications to buy and sell fractions of tokens which represent an ownership claims in real estate assets. Such fractional ownership helps investors save time, cost, and efforts associated with managing their properties themselves such as maintenance costs and any troublesome issues related to dealing with lessees and tenants. Furthermore, the cryptocurrencies which represent a conspicuous feature of blockchain technology can serve as collaterals used to back real estate mortgages. With regard to the real estate investment management, the use of cryptocurrencies is expected to improve the investment income distribution among participants and investors. For instance, the profit generated for equity holders of industrial buildings or multifamily apartments can be more efficiently distributed through stable coins and other types of cryptocurrencies through fast and recorded digital mechanism.

4. Real Estate Mortgage Securitization

The infiltration of blockchain technology into real estate and banking sectors offers banks a secured and single form of digital verification of

information required to initiate real estate mortgages and conduct transactions with more efficient data sharing, secured payment settlements, and immutable monitoring of transaction. This also provides a protection against double-pledging of assets. The digitization of real estate mortgages is programmed to contain related data pieces such as loan payment history and ownership rights to support banking services and decisions. By using smart contracts, banks can gather and distribute payments to beneficiary, and provide up-to-date data and reports to corresponding regulators. This process provides investors with on demand proof of real estate assets' performance and enables for more efficient cash life cycle management by avoiding settlement delays occur due to multiple cash reconciliations across different phases of the transaction's life cycle. The global real estate is worth trillions of dollars however, it is dominated by the wealthy and large corporations and rich investors. The application of blockchain technology enables more households and market participants to perform transactions transparently. Real estate transactions may ultimately become truly direct peer-to-peer transactions with blockchain-powered platforms conduct most of the transactions.

5. Make Homeownership More Accessible

The utilization of cryptocurrencies in property ownership is expected to make homeownership is easier and more accessible to a large sample of households. As a matter of fact, a large proportion of households are deterred from property ownership due to unfavorable conditions of real estate market or lack of credit profile criterion that qualify for a mortgage in a traditional setting. Also, many families and household are normally deterred from homeownership due to a lack of down payment funds or a low credit score. However, as more private lenders and banking institutions are adopting the blockchain technology, the background and credit worthiness checking will be less determining factor in favor of accepting cryptocurrencies of borrowers as a collateral. Hence, this enables the households without all-cash buying abilities to pledge their cryptocurrencies as a collateral and get qualified for mortgages and real estate ownership. It has been claimed that the absence of credit check would lead to increase in interest rate charges on such mortgages with cryptocurrencies pledged as collateral, however, there is a variety of local and international real estate developers along with real estate brokers believe

that the borrowers will still prefer to pay higher interest on real estate mortgages rather than waiting for an unknown time periods as the real estate prices could change drastically.

6. Enhance Due Diligence and Prevent Crises

The blockchain technology improves the due diligence in real estate market through making the background check process faster, and identity verification. It also creates a sequence of recorded transactions with which all information pertinent to properties is kept, it also enables efficient identity verification. verify identities. Thus, the parties involved in a contract or real estate transaction can access it with a personal digital key which enables reducing the likelihood of fraud (Chang & Wang, 2021). It has also been claimed that the adoption of blockchain and cryptocurrency technologies prevents the potential disastrous property bubble burst in future, as they contribute to overcome vital challenges in real estate market such as; reduce suspicious and bad trading practices, promote better property investment arrangements, implement stricter terms and rules on mortgages, control risky derivative trading on secondary markets.

3 Review of Literature

The global real estate industry accounts for a considerable amount of invested capital with almost twice the size of investments in stock markets. This sector is by far considered as a main source of trusted investments since it provides a steady source of income in the form of lease and rents. Hence, a new wave of empirical and theoretical studies have recently emerged in an attempt to provide empirical insights into the benefits and applications of blockchain technologies in real estate transactions. Where a significant portion of these studies have assiduously attempted to explore the potentials for blockchain technology to lead a transition and impose major sectoral changes in real estate transaction and services (Bennett et al., 2019).

A group of studies have measured the role of blockchain technologies in enhancing the quality, speed, and transparency of real estate transactions. For instance, Krupa and Akhil (2019) claimed that the utilization of blockchain technology can enhance the quality and pace of real estate

transactions as it improves the authenticity and confidentiality of operational data generated from lease, sell, and purchase transactions. That multiple information relevant to the same property can be digitized and kept as a decentralized database with lower likelihood of manipulation and fraud. Kalyuzhnova (2018), further identified the potential benefits and advantages of blockchain technologies, through tokenization, the blockchain technology enables cost reduction and improves the investors participation in real estate sector. The outcomes of the paper suggested that information asymmetry dilemma can be considerably eradicated by digital transformation of information which can prevent fraud and ownership manipulation. Similar outcomes were presented by Pankratov et al. (2020), who studied the efficacy of blockchain usage in real estate sector in different countries. They concluded that the time and cost needed for processing real estate transactions with blockchain technology is eradicated sharply, however, the safety and security of transactions can be improved noticeably. Smith et al. (2019) investigated the potential value additivity of blockchain technology to real estate transactions through multiple points of view, including blockchain application in real estate investment and to real estate asset representation. The outcomes of their paper indicate that multiple benefits can be obtained out of blockchain technology adoption mainly through the tokenization of real estate assets which facilitates the real estate trading and transactions. Zheng and Sandler (2022) also attempted to explore the potentials for blockchain tokenization in solving fundamental inefficiencies within the real estate market. They claimed that tokenization is expected to lead to drastic shifts in asset ownership and profits in real estate investments through the fractionalization of real estate property and providing digital representation of real estate assets.

A wide strand of literature examined the role of blockchain technologies in enhancing real estate investment volume through tokenization as a solution for cost reduction and increase market liquidity. For instance, Latifi et al. (2019), found that the employment of smart contract can solve classical deficiencies pertinent to lack of liquidity and number of investors as compared to other financial markets, and they enhance the stability of the real estate market as well. The majority of transactions phases can be fastened to reduce the time between the signing of the preliminary sales agreement before the notary. One of the biggest impacts of blockchain on commercial real estate would be the faster and smoother administration of the contract management process. Gupta et al. (2020),

affirmed that blockchain has potential in enhancing liquidity, transparency, and profit distribution of real estate transactions. They argue that the Ethereum cryptocurrency enhances the efficiency of real estate investment as it facilitates the representation of the value of physical or monetary assets on a digital format. The robustness of cryptocurrencies-based smart contracts can enable the efficient transmission and distribution of income generated from real estate investment among investors. Alketbi et al. (2020) attempted to propose a practical application of suggested blockchain model that can be applied by real estate market participants, as well as regulatory authorities in order to enhance the efficacy of real estate transactions. The outcomes of the paper affirmed that these technologies can promote security and transparency of transactions along with making housing rentals and governance smoother and more transparent. Allessie et al. (2019), have also shed the light on the positive impact of blockchain technology adoption on reducing bureaucracy, enhancing the efficiency of governmental administrative processes. They also shed more light on the need for filling the gap and reducing the incompatibility among the blockchain-based practices and existing legal and organizational frameworks. In the same line, Chand and Wang (2021) argued that blockchain technology helps lower fraud risk and improves trust and efficiency. They also concluded that blockchain technology can bind economic interest and convert legal rights into programmable blockchain-based digital tokens.

A handful proportion of money is circulated in real estate sector is anchored on leasing and renting contracts including land renting, apartments renting, and lease-purchases agreements. The leasing and renting transactions have been always known by intermediary dependencies and inefficiencies due to lack of trust and manipulation. In this respect, literature provides some evidence highlighting the potential combination of blockchain technology and real estate lease and rental services. For instance, Thota (2019), assumes that the representation of real estate property by smart tokens consists of different tiers as general information, technical information, commercial information, and financial information, enables all stakeholders including lessors and lessees to rely on the same datasets without the need for repeated inspection. This in turn improves the due diligence and efficiency of real estate transactions including leasing and rental contracts. Analogously, Kibet et al. (2019), the existing leasing contracts suffer from high transaction cost, lack of transparency, and landlord-tenant conflicts sometimes, in addition to time waste and

inefficiencies due to the involvement of number of intermediaries such as brokers, agents, and other services providers. The outcomes of the paper affirm that the blockchain-based smart contracts can resolve many of these inefficiencies and reduce the housing cost and conflicts through eliminating the middleman in the management and process of transactions. A more recent evidence by Yu et al. (2021), proposes a blockchain-based resolution for real estate rental contracts to achieve peer-to-peer sharing of information in an intermediary-free means. This solution, as they claim, is enabled by the programmatic conversion of traditional lease agreements into smart lease contracts, which in turn advances the efficacy of the leasing transactions, and store records for the leasing process to afford legal protection for tenants and landlords alike. Morena et al. (2020), also attempt to measure the power of blockchain technology in advancing real estate rental services. They found that blockchain through its widespread advantages such as smart contracts, timestamping, secured digital ledger have a great potential to facilitate transactions for individuals with severe disabilities. Research regarding the blockchain and real estate administration has evolved fast in recent years. According to Markunas (2019), blockchain technology can grant a mutual access of parties who operate in the same profession including buyers, sellers, real estate agents, tax officials, banks, and land registries to a network of smart property records. Hence, enables the final field data and notes to be automatically uploaded to the chain for authentication, allows safe keeping and reference, digitizes and uploads hard-copy documentations, stores information models safely that can support decision making, and saves parcels and tax identification of buildings and utilities. Ganter and Lützkendorf (2019) argued that in real estate management, there are some question and issues hover around the market participants minds and thought. For instance, real estate administrators are always concerned about the lifelong and storage of quality data relevant to real estate property. How to assure a high data quality and how to store it over a long period of time, they are also concerned about the traceability of property ownership data at any point of time to manage compliance and legal issues, on top of that what are the main updates in technological models for designers or other service providers? Unless resolved, these questions could remain impediments of efficient real estate management. In response to these questions, the blockchain technology exhibits a potential for enhancing the current approaches regarding documentation retracing and accessibility of real estate properties and life cycle-related information. In the

same line, Shalin (2020), affirmed that the blockchain technology binds together information about specific property and grants access to parties who require this information. Through this binding, all parties interested in the specific property can provide a data input pertinent to the property history, value, and maintenance records. The real estate mortgage providers are enabled though to check the financing more easily and monitor cash flows and income. Lemieux (2017), investigated the role of blockchain technology as a solution to create and preserve trustworthy digital records. The outcomes of the analysis indicate that blockchain technology can be used to address issues associated with information integrity. However, this technology could have several limitations in terms of guaranteeing the reliability of information especially in the long term. Bennett et al. (2019) measured the potential contribution of blockchain technology in property and land administration. The results indicated for a positive prospect for this new technology in making real estate management more efficient and less time consuming.

4 The Use of Cryptocurrencies in Real Estate Transactions

The cryptocurrency can be defined as digital money that is enabled through and exists on blockchain technology. They can be also seen as another application of the blockchain technology for the advancement of money. The Bitcoin and Ethereum are the most popular cryptocurrencies which occupy the top of the market capitalization list of all types of cryptocurrencies. The intersection and connectedness among cryptocurrencies and the real estate industry is considered as one of the most significant innovation in recent years since this sector is known as capital intensive and necessitates pooling of money from different parties. The cryptocurrencies have created a substantial impact on payments, foreign exchange, and real estate transactions. As a matter of facts, the volume of cryptocurrencies-based payments, made by real estate sector participants, for everyday transactions in real estate sector has been increasing sharply in the last two years. The move toward blockchain technology has been observed since 2008 where cryptocurrencies, mainly bitcoin, started being popular. Since then, enthusiasts and cryptocurrencies' developers understood the need for more accessible and flexible financial system distinct from traditional banking system and organizations in order to

process cryptocurrencies transactions. Hence, these enthusiasts and developers started using the blockchain-based smart contracts to create a decentralized financial system, indicated for as DiFi since then. The application and utilization of cryptocurrencies in the execution of real estate real estate transactions goes through multiple phases. The first use of digital currencies in real estate transactions was the case of Aspen Coin, in 2018 the successful real estate issuance on the blockchain representing a mixture of technical innovation and a thorough campaign that raised $18 million for St. Regis Aspen Ski Resort.

4.1 How Does Cryptocurrency Affect Real Estate Transactions?

The process of using cryptocurrencies in real estate transactions begins with a transformation of the ownership title into digital form known as non-fungible tokens (NFTs thereafter). The NFTs are cryptographic assets based on blockchain technology and represent a digital form of ownership right in a business or an asset. These cryptographies are created using a similar type of programming of cryptocurrencies, however, they cannot be exchanged or traded consistently like other cryptographic assets. The NFTs are considered as ideal for use in the digital ownership and trading of real estate. With the help of blockchain technology, NFTs are improving the levels of security, transparency, and ownership rights to the real estate industry. Following the creation of the digital ownership of real estate assets, the second phase of the cryptocurrency-based real estate transactions includes a creation of smart contracts by the seller or the selling agent of the property. The smart contracts can be defined as saved computer programs on the blockchain that can automatically control, document, and execute relevant events and actions on a decentralized network in the blockchain. They also represent prewritten terms agreed upon by corresponding participants in property transaction. These contracts can be used to simplify over-the-counter transactions among investors, and can even ease complex trading and lending market transactions. Once the smart contract is signed by anonymous parties, the gets stored on a secured public ledger. As the triggering event occurs, a simultaneous execution of the contract will take place, where the smart contract transfers the payments among parties and settles the accounts. The utilization of the smart contract through blockchain technology enables for vast potential application of fractional ownership in real estate field. The sellers of the property can use the smart contracts to specify a sequence or set

of actions which trigger the execution of the transactions once the predetermined conditions are met, these conditions in turn can be based on price and/or means of exchange specifications. The smart contracts are considered as a reliable mechanism through which the transactions requiring transparency and trust can be conducted, such as real estate transactions. The smart contracts outline the terms and conditions of the sale of NFTs.

For clarification, assume a real estate company intends to use the smart contracts technology for real estate trade/sell, then the company needs to assure that all partakers agree upon the terms and conditions based on which the smart contract will be initiated. For instance, these terms can be; trade amount, duration of the contract, security deposit, payment deadline, and other terms that will be coded into an agreement. Once all terms are agreed upon by partakers, the company creates a smart contract which regulates the relationship among involved parties. Upon the satisfaction and completion of the coded terms and conditions (trigger), the transaction is automatically executed, and proceeds are transferred to the seller whereas the ownership title NFT is shifted to the buyer. One of the most popular ways real estate market participants and traders are attempting to include digital currencies into real estate transactions is through creating new tokens and currencies for buying, trading, renting, and investing in real estate, without a need to perform traditional transaction. This is more like acquiring shares in a company that owns portfolio of real estate properties. The use of cryptocurrencies in real estate transactions helps also market traders to list properties, where sellers and agents are using bitcoin to create more buzz and attention for their properties, or require for payments split among US dollars and bitcoins. These approaches appeared to be a growing trend since many investors gained profits in cryptocurrency and are looking for converting them into tangible real estate assets. Some other market participants, such as landlords, have started accepting rent fees in cryptocurrencies, especially bitcoin. This approach is becoming increasingly popular for lease and rent contracts. Accepting and sending payments in cryptocurrency will safeguard transaction parties' assets and identities. The conduct of real estate transactions online is more of the norm as a blockchain-based technology continues advancing the digital world. It has been clearly claimed by real estate developers and participating parties that using cryptocurrency in real estate transactions exhibits many advantages such as; easier conducting of local and international and overseas transactions,

enhance liquidity in real estate investing, avoid tax on transferring property rights, and reduce the cost transactions. Another important aspect through which blockchain and cryptocurrency can change the real estate transactions is the tokenization of real estate properties. The tokenization of real estate property encompasses the issue of tokens, representing the right to a part of the property. Such process is called initial coin offering (ICO). Tokenization attracts potential buyers and investors into real estate market and allows involving a larger number of investors and households in the purchase of real estate. In other words, the tokenization represents a joint investment in the development of properties with granting rights to the following acquisition of a part of the asset to the ownership, the use of tokens enables to convert the economic value of property objects into a more liquid form. This can improve the effectiveness of ownership of real estate through including the unemployed resources in the economic turnover. Another way cryptocurrency can emerge in real estate transactions is buying properties in the metaverse, that investors and developers are alike using metaverse platforms to gain real-time insights on the latest trends in real estate market prices and trends prior to investing in real estate properties in real life. The use of cryptocurrencies in real estate transactions can enhance transparency associated with a decentralized network can also cut costs of real estate transactions. There are other costs related to property registration fees, inspections costs, loan fees, and taxes. These can be reduced or even eliminated from the equation as digital platforms automate.

4.2 Challenges Facing the Adoption of Cryptocurrencies in Real Estate Transactions

Despite the potential benefits and upgrades can be brought to real estate transactions, however, there is still a limited adoption of digital currencies in the real estate industry, and this is by far can be attributed to some theoretical and technical weaknesses. For instance, the excessive volatility of cryptocurrencies reduces the interest of real estate market participants to take more initiatives in using digital currencies for real estate transactions. Hence, the need to strengthen the crypto-market is an important part of ensuring the stability of the adoption of blockchain technologies. Furthermore, the cybersecurity-threatening blockchain tools, such as smart contracts, should have a continuing audit to prevent hacks and assaults. Also, the tokenization is yet subject to specific technological

malfunctions. One promising solution for this issue could be by incorporating sophisticated Hi-tech companies into the smart contract, which guarantees a mechanism to attain data from the external sources and assures that all information is updated automatically. The dispute resolution is also arising as a potential obstacle for the speed adoption of digital currencies in real estate transactions. Where the negotiation of asset-based tokens has the potential to result in a disagreement which creates a jurisdictional concern pertinent to determining the specific regulatory authority which has jurisdiction to handle these disputes. The disclosure and licensing requirements also consume a significant amount of tie time and cost to settle. The regulation in many countries, as of now, does not clearly specify the legal framework that governs and organizes the use of cryptocurrencies and tokens. Most countries recognize that tokens are nothing but codes with no legal value. Consequently, the real estate market participants might lack a legal basis to associate themselves with specific pieces of property. Hence advancing the regulatory clarity is necessitated to empower greater access for blockchain technologies and to take big steps forward.

5 Conclusion

In this chapter, we attempt to shed the light on the role of cryptocurrencies and blockchain technology, which are described as one of the main financial innovations fall within FinTech ambit, in the contemporaneous real estate sector. For this purpose, the chapter firstly identified the main benefits of cryptocurrencies inclusion in real estate transactions. The outcomes indicate that various benefits can be brought to real estate from blockchain technology, these benefits include, but not limited to, improve the property development, promote real estate assets' management, enhance the liquidity of real estate market, facilitate capital formation, advances real estate investment, make homeownership more feasible, promotes due diligence and prevent financial crises. The discussion in this chapter demonstrates the main terminologies and variables of real estate transactions using cryptocurrencies. The NFTs can be seen as a main tool through which blockchain real estate operates. The NFTs are cryptographic assets that represent the digital form of ownership right in real estate properties. They are created by similar type of programming of cryptocurrencies. The tokenization of real estate asset also forms a main phase of the transaction, where properties are divided up into equivalent

pieces of digital shares for investment purposes. The cryptocurrencies can then be used as a means of exchange to purchase these fractional digital rights. Consequently, cryptocurrencies assist market traders to list properties, and enable investors and potential households to make payments using cryptocurrencies or split among cryptos and any other fiat currency. These approaches appeared to be a growing trend since many investors gained profits in cryptocurrency and are looking for converting them into tangible real estate assets. On the other hand, the chapter highlighted the main disruptions and potential barriers for blockchain real asset market. These barriers are basically, related to threats of cybersecurity attacks, extreme volatility of cryptocurrencies market, and well as the lack of the fully-fledged legal framework required to govern and organize legality cryptocurrencies in general, and their use in real estate transactions, in particular. Henceforth, the regulatory authorities need to set the proper and well-developed laws in order to enhance and promote the crypto-based real estate transaction in order to help families and households seeking home ownerships, and also to investors and other real estate market participants to enhance national markets and promotes foreign direct investments.

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Real Estate in the Metaverse

Muhammad Abrar-ul-Haq and Farheen Arkam

1 Introduction

The concept of the metaverse has garnered significant attention in recent times, with many futurist scenarios envisioning a future where humanity will exist within this virtual realm. However, the exact nature of the metaverse and the influential forces that will shape it remain uncertain. Currently, it serves as a canvas for divergent visions held by big tech, investors, early adopters, and various other actors. To effectively engage with and understand this evolving technological phenomenon and its future implications, a systematic comprehension of the forces driving its development is essential. Researchers argue for an alternative perspective that recognizes the social dynamics intertwined with emerging technological phenomena (Dwivedi et al., 2022; Kim et al., 2021).

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The metaverse can be understood as a proposed evolution of the internet, transforming it into a unified and immersive virtual world. This transformation is facilitated by the utilization of virtual reality (VR) and augmented reality (AR) headsets. Within the metaverse, users can interact with one another and with digital content in a manner that surpasses the current limitations of the internet, providing a more realistic and engaging experience (Schöbel & Tingelhoff, 2023). What does "Metaverse" mean? Meta describes it as "a set of virtual spaces where you can create and explore with other people who aren't in the same physical space as you." (Bosworth, 2021) Starting from the etymology of the word, the prefix "meta," which signifies "more complete" or "transcending," comes from the Greek language, while the word "Verse" stands for "universe," which signifies a space-and-time container (Gadekallu et al., 2022).

Metaverse was not so popular until October 2021, when Facebook suddenly changes its name to "Meta" leading to its conversion into a Metaverse company, it suddenly catches public attention, becoming the subject of numerous discussions, gaining sympathy, and reaching the peak of its notoriety (Nakavachara & Saengchote, 2022). The metaverse is currently in its early developmental stages, but it holds tremendous potential to revolutionize our internet interactions and social dynamics. One area where the metaverse could make a significant impact is in gaming. Players can enter fascinating virtual worlds, engage in thrilling battles with other players, and complete difficult objectives by using virtual reality (VR) headsets, making for more engaging and dynamic gaming experiences.

Additionally, the metaverse has intriguing social networking opportunities. By using VR headsets, people can attend virtual concerts, parties, and even business meetings, encouraging novel and creative ways of connecting with others. People can interact with one another in creative ways thanks to the extended virtual space, which allows them to transcend geographical borders and create special shared experiences (Mystakidis, 2022).

The metaverse may also transform the way that people learn. Students can go on educational adventures using VR headsets where they can investigate historical locations, conduct experiments in virtual settings, and acquire immersive insights into various cultures. By utilizing the powers of the metaverse, learning is made more interactive, interesting, and accessible, enabling people to learn and develop their talents in exciting and intriguing ways (Hwang & Chien, 2022).

The metaverse can also be advantageous to businesses. Companies may train their staff in precise virtual environments, deliver outstanding customer service, and even enable virtual product sales with VR headsets (Mystakidis, 2022). Through immersive and engaging virtual platforms, the metaverse offers new ways for firms to conduct business while boosting efficiency, innovation, and client engagement. The metaverse is a promising modern technology with the potential to change the way we live, work, and play. As the metaverse continues to develop, it will be interesting to see how it is used by individuals and businesses (Ning et al., 2023).

Currently, the metaverse is made up of a multiplicity of platforms, where you can build everything, "from miniature games in haunted cemeteries to advertising billboards or commercial districts and metaverse HQs for businesses already established in the real world" (Waterworth, 2022). The platforms can be divided into two big distinct categories:

Virtual spaces - These platforms help navigate projects and small areas, which are not placed in an open world, but in virtual rooms where people can visit, play, and interact. This means that each space is disconnected from the others. One of the most famous is Spatial2, which is a virtual and augmented reality platform that lets users create their virtual 3D space/workspace and collaborate inside it (Péruch et al., 2018).

Virtual worlds - A whole different concept of the platform, they are just like digital cities, where it is possible to buy real estate, build projects and interact with the users like in the real world. While a large number of platforms allow the purchase of real estate, the most notable ones are mainly four: The Sandbox, Decentraland, CryptoVoxels, and Somnium Space (Deloitte, 2022; Gadekallu et al., 2022; Waterworth, 2022).

Key Features of Metaverse

- **Technology**: The metaverse relies on several key technologies, notably virtual reality (VR), augmented reality (AR), and blockchain. VR headsets enable users to immerse themselves in virtual environments, while AR headsets superimpose digital content onto the real world.

- **Cost**: At present, the entry cost for the metaverse remains relatively high. VR headsets can carry price tags in hundreds of dollars, and AR headsets tend to be even more expensive. Nonetheless, as time progresses, the cost of these technologies is anticipated to decrease, making them more accessible to a wider range of individuals.
- **Regulation**: The regulatory landscape surrounding the metaverse is currently underdeveloped due to its nascent nature. As a result, issues concerning security and privacy may arise. Nevertheless, governments and industry organizations are actively collaborating to establish regulatory frameworks and guidelines that address the unique challenges of the metaverse. These efforts aim to ensure the responsible and safe development of this emerging technology.

2 Virtual Real Estate

Virtual property is a type of real estate found in a metaverse. The world can be anything from a plot of land to an entire virtual universe. A variety of purposes can be served by virtual real estate, including gaming, socializing, and business activities. The concept of digital real estate exists within virtual worlds, each of which has its own national identity and system of property rights that are clearly defined and irrevocable. Buying virtual land now is similar to buying land in Manhattan a long time ago. It is also safe for People are talking about whether virtual land is worth a lot or not, but more and more people are becoming curious about it. In 2021, a piece of land was sold in Decentraland for $2.4 million Decentraland is a popular virtual world. This is an example of how much people pay for fake land online of the uncertainty caused by COVID in the real estate industry. The value of virtual real estate is still being debated, but there is a growing interest in this new asset class. In 2021, a plot of land in Decentraland, one of the most popular metaverses, sold for $2.4 million. This is just one example of the soaring prices that are being paid for virtual real estate.

3 The Volume of Virtual Real Estate

In 2022, the sale of virtual real estate reached an extraordinary $1.4 billion, which was a staggering increase. These exceptional figures show an incredible increase of 180% when compared to last year's revenues

amounting to $0.5 billion. The minting and secondary sales of vacant land on the other side were a major factor which contributed significantly to overall sales volumes in the second quarter of 2022, becoming an important driver for this increase. Let's examine the top five virtual estate platforms in more detail based on projected sales in 2022 (Fig. 1):

- A plot of land in Decentraland sold for $2.4 million.
- A plot of land in The Sandbox sold for $1.7 million.
- A plot of land in Otherside sold for $1.6 million.

The growth in virtual real estate values may be attributed to a variety of factors, including the metaverse's growing popularity, a scarcity of accessible virtual land, and the market's speculative nature. It is critical to recognize that the value of virtual real estate is very volatile, and investors cannot be confident of generating money. Investing in virtual assets can be risky since their prices can fluctuate dramatically.

Demand for virtual property is expected to rise in the coming years as the metaverse grows in popularity. Analysts expect that the market will be valued at $5.37 billion by 2026. However, it is vital to note that the market has just had a significant cooling-off period. This can

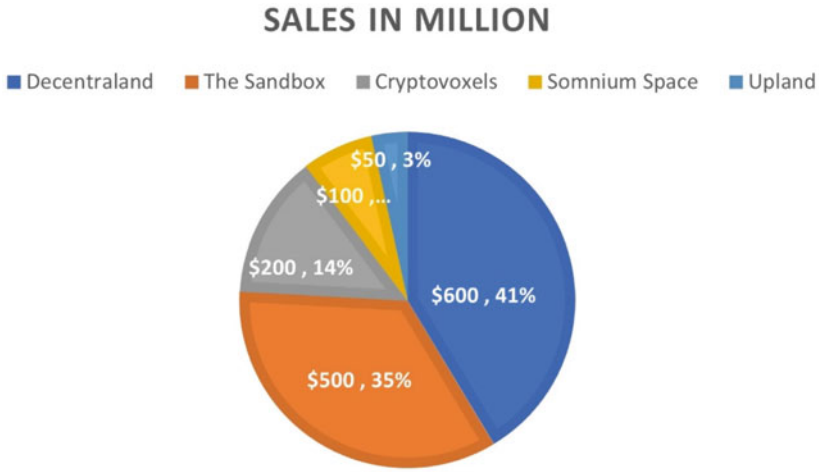

Fig. 1 Top five virtual estate platforms

be attributed to a variety of factors, including a general downturn in cryptocurrency values and the lack of apparent uses for virtual property. Despite the current dip, it is important to remember that the metaverse real estate business is still evolving. The market may rebound in the future as more individuals and businesses begin to use the metaverse. However, it is crucial to approach this market with caution and evaluate the risks associated with investing in virtual real estate.

4 Examples from the Metaverse

Samsung, the widely acclaimed electronics giant, has taken a bold leap into the metaverse by launching a virtual store within the dynamic realm of Decentraland. This groundbreaking step showcases Samsung's entry into the immersive digital landscape, teeming with boundless possibilities and engaging experiences. With its presence in Decentraland, Samsung positions itself at the forefront of the metaverse revolution, captivating the interest and inquisitiveness of global users (Fig. 2).

The Sandbox metaverse has forged groundbreaking partnerships with influential Korean leaders, aimed at amplifying the global influence of K-Culture. As part of the thrilling K-verse LAND Sale, you now have an

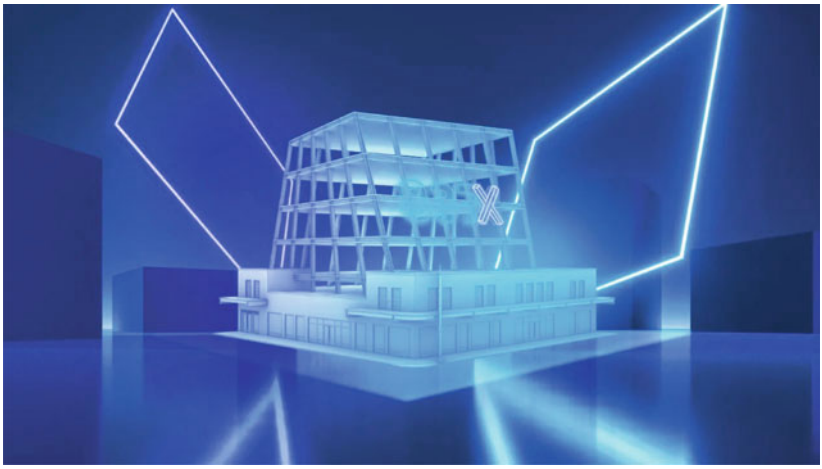

Fig. 2 Samsung's 837X virtual store as it will appear in Decentraland (*Image* Samsung)

exclusive opportunity to acquire adjacent LAND plots for these visionary partners. Prepare to immerse yourself in the expansive and dynamic realm of K-content, where limitless exploration awaits (Fig. 3).

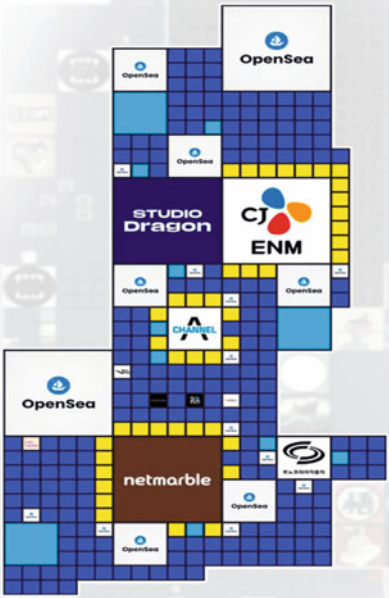

Fig. 3 Hallyu Rising K-verse community

5 Benefits of Investing in Virtual Real Estate

Digital property is now recognized as a valuable thing for investors to consider, and I think it will greatly increase in value soon. Digital real estate has the potential to make big profits and be an effective way to save money, just like real-world real estate and art. This is because more and more people are interested in investing in cryptocurrency.

Users can connect with people virtually in a variety of ways thanks to metaverse real estate. Individuals can use their digital properties for gaming and socializing, while content producers can make money from them by giving their customers exclusive access to online events. Owning virtual land on various web3 games and platforms is now conceivable thanks to the arrival of Web3 technology. These plots are represented as non-fungible tokens (NFTs), and investors in NFTs, Play-to-Earn participants, and fans of the metaverse have grown fond of them. Although some people might find the idea of owning digital land confusing, there are several advantages to it.

When you buy digital real estate on a platform, you take exclusive ownership of that space. The strength of digital ownership enabled by NFTs makes this ownership conceivable (Smith, 2022). You, as the owner, can completely alter and modify your digital asset to suit your tastes. You can also host virtual events, creating new opportunities for promotion, ownership, and business (Cifrino, 2014).

As a result, investors should now give digital real estate serious attention as a valid asset class. It is a desirable investment due to its potential for exponential growth and affiliation with the fast-growing cryptocurrency ecosystem. The metaverse's attraction is further increased by the possibility for individuals and content producers to own and personalize virtual territory (Baur et al., 2018). Its high compatibility with the developing crypto-investment market presents the possibility of large rewards (Dowling, 2022). Additionally, digital real estate in the metaverse enables people to interact, participate in a variety of activities, and investigate business opportunities, making it a significant asset in the developing world of Web3 technologies.

In the realm of futuristic assets, one particular phenomenon has captivated the attention of not just gamers and investors, but also some of the most prominent brands in the world. Adidas, for instance, has recently formed a partnership with The Sandbox, where they acquired a plot of virtual land. The allure of purchasing such virtual real estate stems

from two primary motivations. First, individuals hope to create revenue streams by constructing games or interactive experiences on their virtual land, thereby earning income from visitors. Second, they anticipate the opportunity to resell the land at a higher price in secondary markets like OpenSea, a peer-to-peer marketplace for NFTs. Notably, several renowned companies including Adidas, Atari, PwC Hong Kong, Binance, and South China Morning Post, as well as notable celebrities such as Snoop Dogg and Pranksy, have been reported to own land within The Sandbox. The highest recorded sales thus far have reached a staggering $4.3 million.

The scope for metaverse real estate is broad, brands can use their virtual properties to advertise their services, create product launches, and provide unique customer experiences through VR and AR technology. For real estate investors, these parcels of digitized land offer a lucrative opportunity, in which assets can be developed, flipped, or leased just like in our daily lives. The use cases for metaverse real estate are endless and can be leveraged further through a certain immersive technology known as virtual reality (VR). With the metaverse, these experiences can be developed in conjunction with VR and will provide brands, investors, and other stakeholders with the clarity they need to make informed investing decisions. Another benefit of metaverse real estate is the potential for significant capital appreciation (Anderson & Rainie, 2022). The demand for virtual land and property within the metaverse is rapidly increasing, driving up the value of digital assets. As a result, early investors in metaverse real estate can potentially benefit from substantial capital gains.

Investing in digital real estate offers unique advantages like derivative trades, such as high rewards compared to associated risks, but without the downsides of recourse margin or debt. Also, it serves as an uncorrelated asset class that can help mitigate market volatility effects. While cryptocurrencies, particularly Bitcoin (BTC), were once compared to digital gold, thorough back testing has revealed that crypto assets behave differently from traditional assets like gold, bonds, or equity (Anderson & Rainie, 2022). As a result, investing in digital real estate becomes an excellent tool for diversifying one's portfolio. Although the user base of metaverses currently stands in the tens of thousands, once these virtual worlds attract a substantial number of users, selling real-world items within them could emerge as a highly cost-effective marketing strategy.

Real estate, digital, and art meet dematerialization in the cosmic void under the roof of Mars House, the hyper-futuristic house designed by

Krista Kim and sold exclusively on super rare, in Ntf, for 288 Ether, the second most valued cryptocurrency, for now, after Bitcoin.

Returning for a moment with our feet on Earth and trying to understand, as mere mortals, what happened, we can rewrite the story as follows: the space-accented villa, virtually designed by the artist who founded the Techism Movement, was purchased by the collective "Art On the Internet" on the revolutionary platform dedicated to the trading of digital works of art for a sum equaling $ 514,557.79 (about 431,000 euros). The house is there but it does not exist, it is all true.

6 Reach a Global Audience

One of the key benefits of metaverse real estate is the ability to create a digital presence that can cater to a global audience. According to an article published by Polygon (2022), owning metaverse land provides individuals with the opportunity to create a digital version of their physical business or store, without the limitations of a physical location. This enables businesses to reach a wider audience, without incurring the costs associated with setting up a physical location.

metaverse to reach a global audience:

- **Decentraland** is a virtual world where users can buy, sell, and build land. The company has partnered with several brands, including Atari and Sotheby's, to create virtual experiences for their customers. Decentraland stands out due to its economy built on blockchain technology. Within the game, players can purchase, sell, and construct virtual parcels called "LAND," utilizing the game's native cryptocurrency known as "MANA." The significance of Decentraland's blockchain foundation is evident in the secure and transparent nature of these transactions. With a market capitalization of approximately $225 million, MANA has experienced remarkable growth, increasing more than fivefold since its inception in 2017. An impressive surge of 321% in MANA prices was observed in the preceding year, as of February 2021.

  The ownership of LAND parcels in Decentraland is represented by non-fungible tokens (NFTs) registered on the Ethereum blockchain, adhering to the ERC-721 standard, similar to CryptoKitties. This registration ensures the easy transferability of LAND ownership and provides enhanced protection against fraudulent

activities. The developers of Decentraland have established a fixed total of 90,061 LAND parcels that will ever be created. Each parcel is unique, possessing distinct (x, y) coordinates, further emphasizing their non-fungible nature.

- **Sandbox** is another virtual world that allows users to create and monetize their own content. The company has partnered with several brands, including Adidas and Warner Music Group, to create virtual experiences for their customers. The Sandbox is a game about blockchain. It is its simplest definition, but it also is the one that makes less justice to the complexity of this project, which could impact the virtual real estate industry. Nowadays, The Sandbox is reaching its peak of notoriety and success. The platform is a set of products and services to create, manage, and enjoy experiences and adventures using the blockchain as a permanent ledger to give value and uniqueness to creation. It is difficult to describe everything that can be done on The Sandbox. There are just 166,464 pieces of LAND available in Sandbox. The size of each plot of land is 96 × 96 m. Since there will not be much land left to purchase on the open market, some investors are considering purchasing LAND tracts and holding them for potential capital gains.
- **Roblox** is a gaming platform that allows users to create their games and experiences. The company has over 40 million daily active users, and it is growing rapidly in popularity. These are just a few examples of the many businesses that are using the metaverse to reach a global audience. As the metaverse continues to grow, we can expect to see even more businesses adopt this technology to reach new customers and grow their businesses.

7 Reduce Costs

Each of the metaverse real estate platforms has its own currency to buy and land. Hence, the transactions in metaverse real estate are not like traditional banking transactions, in this way, investors are enjoying the cost-free transactions through different cryptocurrencies (Gadekallu et al., 2022).

The significance of this property lies in the fact that we are moving from sales within closed marketplaces to the possibilities offered by a marketplace that has an open and free economy. The ease with which

users can create and then trade NFTs around the world through the blockchain is impressive and can bring many changes to the real estate industry. Transferability allows NFTs to be sold at a higher price than the real thing:

- Digital property can be sold in minutes without the need for a broker.
- Registration is self-contained.
- The property needs no maintenance.

The real estate industry has historically been slow to embrace innovative technologies, but it holds immense potential for blockchain applications. Real estate's inherent characteristics, such as immobility and easy accessibility to third parties, make it an ideal candidate for leveraging blockchain-based solutions like collateralized claims. As the digital asset landscape continues to expand, we are witnessing a transformation of everyday activities and business processes into computer-readable formats. Money itself has largely become digital, with only a small fraction existing as physical cash. By incorporating blockchain technology, real estate transactions, exchanges, and sales can benefit from enhanced efficiency and reduced issues. Digitized platforms enabled by blockchain will pave the way for numerous advantages for key stakeholders. Faster transaction processing, reduced costs, and increased availability of data are among the primary benefits. Transparency in transactions is crucial for creating a healthy environment that instills trust among buyers, sellers, and real estate agents. Simultaneously, privacy protection measures ensure that sensitive information remains secure (Kiong, 2022).

The affordability of virtual real estate surpasses that of physical property, with costs ranging from a few hundred to several thousand dollars. Fractioning high-yield properties such as luxury apartments, villas, and hotels in the form of tokens will allow small and micro-investors to enter a market hitherto precluded to them while also providing additional benefits that ultimately open a new era in the real estate market.

Virtual real estate transactions offer a remarkable departure from traditional property transactions, which often entail lengthy processes spanning months. By leveraging Ethereum's blockchain technology, these transactions can now be completed swiftly, typically within minutes. The adoption of Ethereum enables buyers and owners of substantial real

estate assets to sidestep the exorbitant costs associated with intermediaries and overcome the time-consuming obstacles imposed by national and supranational regulations.

One notable advantage of virtual real estate lies in its exemption from state or federal tax laws (Friedberg & Arendt, 2022). Consequently, property owners are not obligated to pay capital gains taxes when selling their virtual assets. Furthermore, there exists no imposed limit on the number of properties an investor can acquire within the metaverse, as there are no governing regulations on land ownership in this digital realm.

The rise of virtual worlds presents a logical progression for major corporations to establish virtual stores within these immersive environments. Prominent brands like Domino's have already embraced this trend, offering the convenience of ordering pizza from their Metaverse Decentraland store, and having it delivered to customers' real-world addresses. Collaborations between companies such as Adidas and Karlie Kloss within Decentraland further exemplify the growing integration of virtual and real-world experiences. Attendees of these corporate-sponsored virtual gatherings were even rewarded with complimentary virtual Adidas shoes for their avatars.

The cost-effectiveness of virtual events has not gone unnoticed by businesses. They recognize that hosting virtual gatherings can yield substantial savings compared to their real-world counterparts. For instance, envision the possibilities if Nike were to create a breathtaking virtual shopping experience within the metaverse, eliminating the need for physical stores on every Main Street in America. Such a virtual store would offer unparalleled accessibility, allowing anyone, anywhere, at any time to engage in seamless shopping experiences.

8 Experiment with Innovative Designs and Structures

The rise of Web3 and the metaverse is bringing about a significant revolution in many industries, including real estate, design, and architecture. As technological breakthroughs open fresh and exciting opportunities for digital real estate, leasing, advertising, and undertakings within the metaverse, these disciplines are on the verge of a paradigm change. The metaverse provides an environment where architects can experiment with and redefine their designs in novel ways, pushing the limits of form and space. It offers architects a rare chance to display their ideas that have

not been put into action yet. Through an improved request for proposal (RFP) process, architects can now interact with a large audience in any country. As a result, it is anticipated that the value of digital assets in the metaverse would skyrocket, providing architects with new opportunities and recognition in this digital environment.

Ideas that began during the epidemic have evolved into the concept of the house, which transcends conventional architectural design and embodies the canonical essence of a work of art. In this context, the limitless nature of space becomes apparent, offering endless possibilities for architectural exploration and innovation. Like a virtual canvas, it is an empty place to be filled and bridged. A viewpoint change and the development of new abilities are required considering the advent of the metaverse. It includes several technological layers, such as 3D modeling, augmented reality cloud technologies, character design, NFTs, blockchain, geospatial mapping, and more. Consequently, the definition of "architecture" expands to encompass a broader range of specializations and talents.

When it comes to developing real estate in the metaverse, certain aspects are simpler compared to the physical world. There is no need to navigate planning and zoning regulations or address utility concerns. Nevertheless, the excitement of creating something from scratch remains intact. Unlike in the real world, where architects are almost always required to design stable structures that will not unexpectedly collapse, architectural plans are optional in the metaverse. For small structures or billboards, it may not be cost-effective to hire an architect. However, for projects that demand visual impact and warrant additional investment, a metaverse architect becomes a crucial asset. They can bring your vision to life efficiently, requiring minimal involvement from you, the client. Below are some of the prominent architects in the metaverse who have made significant contributions to the field (Fig. 4).

The sale of the House on Mars (SOLD MARCH 14TH, 2020 FOR 288.0 ETH ON SUPER RARE) marked the beginning of a new era that some scholars have called "hybrid reality" (Fig. 5).

This year, an internationally renowned architectural firm made headlines by unveiling its ambitious project to construct a metaverse of its own, known as the Liberland Metaverse. Embracing a libertarian ethos, this virtual city envisions a bustling hub replete with a grand city hall, captivating NFT galleries, diverse shops, modern office spaces, and an innovative startup incubator catering to the cryptocurrency industry.

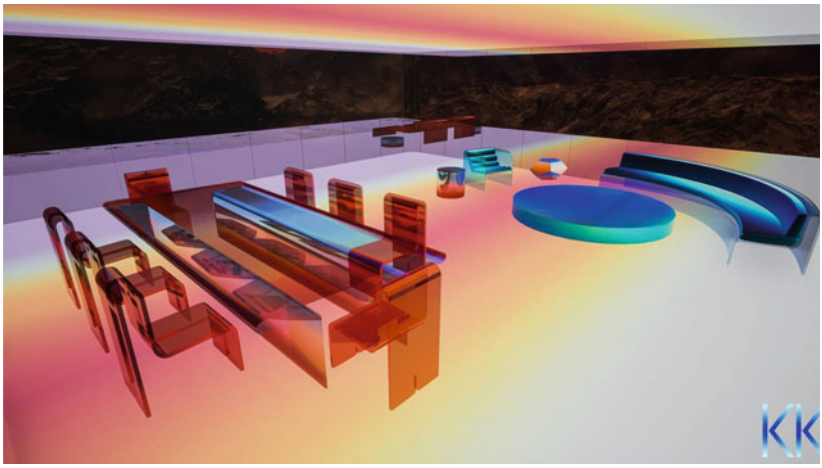

Fig. 4 Mars House by Krista Kim Studio Inc.

Fig. 5 Liberland metaverse (*Photo* Zaha Hadid Architects)

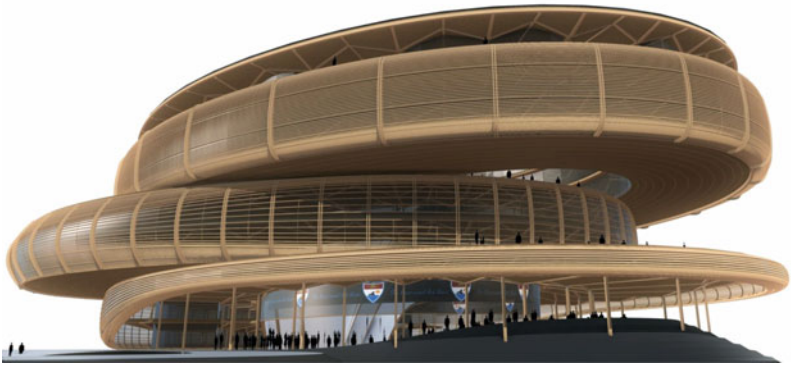

Fig. 6 Zaha Hadid Architects

Drawing inspiration from the distinctive design language pioneered by its esteemed founder, Zaha Hadid, the structures within the metaverse exhibit a harmonious blend of fluid curves and striking angles, embodying the firm's celebrated aesthetic (Fig. 6).

The architectural designs of Zaha Hadid Architects, known for their futuristic and undulating structures, are prominently featured in the construction projects within the Liberland Metaverse. These virtual spaces, accessible to all, serve as venues for social, cultural, and business activities, while the remaining land is leased or sold to developers and businesses. In this digital realm, the conventional rules of real-life architecture do not necessarily apply. Facilities deemed essential in physical buildings, such as kitchens or bathrooms, are not replicated in the Liberland Metaverse. Moreover, weather conditions are no longer a constraint, enabling outdoor spaces to be utilized in versatile ways. Nonetheless, like physical constructions, architects must prioritize the social functionality of the spaces, in addition to their aesthetics, recognizing the significance of space in facilitating social interactions.

Architectural pursuits within the metaverse have transcended niche interests and have been embraced by established firms. Liberated from the limitations of physics, material properties, and construction costs, the metaverse has unlocked a new realm of architectural expression. The profession engages with this expanding field of digital environments in numerous ways. One noteworthy example is "The Row," a

renowned members-only, master-planned virtual world real estate development. Artists who are currently shaping culture have designed a range of virtual buildings for The Row, which is situated in the Monaverse—a decentralized virtual world platform built on the Ethereum blockchain. Among these creations are a house converted from a giant statue by Daniel Arsham and a residence that changes color throughout the day. Such architectural masterpieces are rare finds on Earth.

"The Row" comprises 30 distinctive landmarks, each designed by a different artist. These landmarks are available for purchase as non-fungible tokens (NFTs). Buyers of NFTs obtain the right to deploy their landmarks on virtual world land within The Row District, subject to a fee. Recognizing the continued importance of physical spaces for companies, the firm strongly advocates for the synergy between virtual and physical environments. Consequently, architects, rather than graphic designers, should be entrusted with the task of designing these sites (Figs. 7 and 8).

Sygnum, a Swiss bank, officially launched its metaverse hub in Decentraland on September 27, 2022. The launch of Sygnum's metaverse hub is a significant milestone for the bank and the metaverse industry. It is the first time that a traditional financial institution has opened a branch in the metaverse, and it signals the growing importance of the metaverse as a financial and economic hub. There is ongoing and intense debate

Fig. 7 Ares, the Greek god of war, was turned into a house by Daniel Arsham

Fig. 8 Sygnum: the first Swiss bank to open a metaverse hub

surrounding the metaverse, with differing views on its potential impact. Some envision it as the future of architecture, while others see it as a speculative phenomenon driven primarily by monetization. The extent to which the metaverse will create new revenue streams for architects or fundamentally transform the architectural profession is still uncertain.

9 Challenges and Risks of Investing in Virtual Real Estate

Investing in virtual real estate carries inherent risks that investors need to be aware of. The unique nature of the metaverse has created an environment where scams can thrive. Although more corporations and individual investors are purchasing virtual land, it is high stakes endeavor suitable only for those with substantial financial resources and a willingness to take risks. Experts strongly advise retail investors against venturing into this realm, as the value of virtual land is contingent upon finding a willing buyer at a given price. If the price suddenly plummets, investors may lose their entire investment. Certain areas within the metaverse, such as the Fashion District in Genesis Plaza or WonderMine Crafting, are bustling with activity, while others resemble ghost towns. Experts caution retail investors to view the metaverse as a form of entertainment rather than

a viable investment asset. Furthermore, they emphasize the absence of regulation, noting that the metaverse is a technology and innovation that necessitates regulatory measures to protect investor interests. They argue for a collaborative effort involving tech companies and government entities to safeguard investors, rather than placing blame solely on technological advancements.

10 Platform Operators Control Virtual Real Property Rights

Traditional and virtual real estate differ significantly from one another, creating special dangers for investors. Virtual real estate only exists on a digital platform, as opposed to physical real estate, which can be immediately sensed through our senses. As a result, owners of virtual real property on a platform are left with no property rights and no remedy if the platform operator restricts an owner's access or deletes the platform entirely.

Platform operators have the freedom to draft terms of use as they see fit, and virtual real property owners must accept these terms without negotiation. Most metaverse platforms incorporate terms of use that shield the operator from liability and grant them broad discretion over virtual real property rights. For instance, Decentraland's terms of use state that the platform operator has no obligation to ensure the platform's longevity and may cease its operation in the future without any liability. Similarly, The Sandbox's terms allow the operator to block an owner's access to the platform and terminate their content creation and upload rights at any time, solely at the operator's discretion. Although a banned or restricted owner may still retain the title, their ownership rights are severely restricted (Jentzsch, 2016).

Consequently, platform operators exert more influence over virtual real property rights compared to government counterparts in the traditional real estate realm. This results in virtual real property owners inherently possessing fewer property rights. Moreover, the lack of substantial regulation grants platform operators' significant discretion with limited liability, thereby increasing the likelihood of potential misconduct. Unfortunately, this risk is unavoidable since there is no insurance industry for virtual real property, preventing owners from transferring the risk to another party.

11 DAOs Are Useful But Create More Complexity

A DAO, short for decentralized autonomous organization, is an innovative organizational structure enabled by blockchain technology. It is often likened to a crypto co-op, a "financial flash mob," or a "group chat with a bank account." In essence, DAOs are groups formed for a common purpose, such as investing in startups, managing stablecoins, or acquiring NFTs. According to ConsenSys, a blockchain organization, DAOs are governing bodies responsible for allocating resources to affiliated projects and ensuring their long-term success. As the concept of the Metaverse continues to evolve, DAOs are increasingly focusing on leveraging and investing in this virtual realm. With Goldman Sachs valuing the sector at $8 trillion, attention has turned to the potential for accessibility, usability, and monetization of these digital worlds (Jentzsch, 2016).

Prominent players in the Metaverse, including Adidas, Nike, Snoop Dogg, and JPMorgan, are acquiring digital land to connect with consumers in the realm of Web3. However, the prohibitive cost of entry remains a major barrier to widespread participation in the digital land rush. DAOs are actively seeking ways to create more equitable opportunities for investing in and utilizing these virtual worlds. By facilitating the sharing, renting, and investment in digital land within the Metaverse, DAOs have the potential to significantly assist in onboarding new participants to Web3, making engagement with digital land more accessible to all.

In their short lifespans, DAOs have experienced both explosive growth and catastrophic failures, espousing admirable ideals of equality on paper yet often falling woefully short when the rubber meets the road. At their best, DAOs represent an exciting alternative to traditional forms of human organization. At their worst, they are pyramid schemes. Certain DAOs achieve wide representation through collaborative decision-making, but others run the danger of replicating quasi-oligarchic patterns by centralizing governance tokens among a limited group of influential participants, such as venture capitalists and early insiders. The monetary value of membership tokens can also incentivize corruption from within, as in the case of MetaDAO, whose members were robbed of $3.2 million in a rug pull scam run by the group's founders. DAOs also suffer from a lack of accountability and transparency. In many DAOs, participants are allowed to be anonymous, which opens the door to potential abuses at high levels of power.

12 Security Concerns

The security issues surrounding the metaverse are of utmost importance and greatly impact the dynamics of this virtual space. While numerous enterprises are exploring the possibilities offered by the metaverse, it is essential to consider potential concerns that come along with it. The technologies powering metaverse platforms, namely Augmented Reality (AR) and Virtual Reality (VR), serve as the interface for this immersive experience. However, these technologies also bring forth significant risks in terms of security and privacy, which can extend into the metaverse environment (Nelson, 2009).

With the emergence of the metaverse as a novel concept, many individuals lack sufficient understanding of its intricacies. Exploiting this information gap, unscrupulous individuals are taking advantage of the situation by generating counterfeit links to popular metaverse platforms. Once these fraudulent links are activated, scammers gain unauthorized access to the user's virtual wallet, enabling them to initiate fund transfers using smart contracts. Regrettably, these transactions are exceedingly challenging to reverse, leaving the stolen cryptocurrency nearly irretrievable. Shockingly, cryptocurrency-related crimes amassed an astonishing $14 billion in 2021 alone. The profitability of these deceptive metaverse links has led to their wide availability for sale on the dark web (Wu et al., 2023).

13 SecurityRisks of Augmented Reality

Augmented Reality (AR) plays a crucial role in shaping the metaverse and offers exciting possibilities for data gathering. However, along with these advancements come potential security risks that can significantly impact user privacy. It is important to reflect on these risks and understand their implications for both the metaverse and AR technology.

The hacker compromise of AR gadgets is one of the crucial issues. In the event of such a breach, classified information and sensitive data may be made available, raising the possibility of their misuse or illegal access. Users' privacy should be protected at all costs, and steps must be taken to stop and correct any violations (Cifrino, 2014).

Additionally, AR businesses must put in place robust security to safeguard the user data they collect. It is crucial to protect user data and make sure that privacy laws are followed. This entails putting in place

strict security procedures, encryption methods, and safe storage options for the AR data they gather. AR firms may preserve user privacy and stop illegal access to user data by giving priority to safe storage solutions that use strong encryption methods. Another critical area that requires investigation is the sharing of AR data with outside parties. It is critical to comprehend the scope of user data sharing undertaken by AR companies and the objectives for which this sharing occurs (Roesner et al., 2014). To guarantee that users have control over their data and understand how it is being used, transparent policies and unambiguous permission methods should be in place.

These privacy risks within the metaverse, stemming from AR technology, raise concerns such as social engineering attacks, credential theft, and denial of service. AR companies must address these risks through robust security measures. By doing so, they can mitigate potential threats and protect user privacy, fostering a more secure and trustworthy metaverse experience (Wu et al., 2023).

14 Credentials

In recent months, a surge of phishing scams has targeted investors, specifically those who have purchased virtual property. These scams operate by luring individuals to click on seemingly legitimate links, often through emails, which redirect them to websites that closely resemble popular metaverse platforms such as Decentraland. Unfortunately, once the unsuspecting victim enters their login credentials, the hackers gain access to their personal information, allowing them to swiftly drain their digital wallets of funds and valuable NFTs. Tragically, by the time victims realize the theft, it is often too late to recover their assets due to the irreversible nature of blockchain transactions (Wu et al., 2023).

The decentralized nature of the metaverse poses additional challenges for those who fall victim to property theft. Without a central authority to turn to for assistance or to seek restitution, victims are left without recourse. The absence of regulatory oversight in this virtual realm creates an environment akin to a new frontier—both exhilarating and perilous—making it an ideal breeding ground for malicious scammers.

15 Smart Contracts

The execution and enforcement of contracts in the context of virtual real estate transactions is another crucial factor to consider. Smart contracts, which are self-executing contracts created using blockchain technology, are crucial in this area. By removing the need for middlemen, these smart contracts make it possible to facilitate virtual property sales, leases, and other transactions seamlessly (Levi & Lipton, 2018). But there are issues with contract creation, fulfillment, and enforcement in the metaverse, which cause legal uncertainty. It may be difficult to apply conventional contract law to digital transactions, especially when resolving disputes resulting from smart contracts. Such issues can call for the interpretation of complex codes and might fall under several different legal jurisdictions (Bouachir et al., 2022).

16 Copyright

In addition, virtual real estate includes digital possessions like' model homes, landscapes, and other artistic elements that might be protected by copyright, trademark, or other intellectual property laws. However, these assets virtual form creates issues with ownership, licensing, and infringement. It can be difficult to recognize and uphold intellectual property rights in the virtual world, for instance, because unauthorized reproduction or use of virtual assets may occur within the metaverse (Bouachir et al., 2022).

To counteract such fraudulent activities, investors in virtual real estate should implement two-step authorization as an additional layer of security for their virtual wallets. Several blockchain-based businesses are beginning to integrate features that enable the reporting of stolen cryptocurrencies. This reporting mechanism disables the reported cryptocurrency, preventing it from being bought or sold, thus discouraging phishing scams.

17 Speculations

The unpredictable trajectory of the metaverse is simultaneously its most thrilling and daunting aspect. It presents numerous possibilities, but investors face the risk of allocating funds to the wrong ventures and ending up empty-handed. In essence, it resembles a gamble at its current

stage. The gamble extends beyond acquiring virtual property; it also involves taking a chance on the specific metaverse platform chosen. Presently, there is not a single unified metaverse, but rather multiple platforms offering metaverse technologies. While many envision a future where the metaverse functions as a connected space, it remains fragmented, necessitating the selection of one or more platforms to invest in for land ownership. Should the platform housing one's metaverse real estate falter, the risk of losing it entirely becomes a reality (Hari Lal & MK, 2022).

The creation of legal frameworks and laws tries to manage the legal issues related to virtual real estate as the metaverse develops. Through the usage of virtual worlds, users from various nations can communicate and engage in the same virtual space. Given the differences in rules and regulations among jurisdictions, this raises concerns regarding the applicable legal framework governing virtual real estate transactions. Legal issues such as jurisdictional disputes, international legal complications, and conflicting laws may arise; these issues must be carefully considered and resolved inside the metaverse (Mackenzie, 2022).

Currently, determining which metaverse platforms will succeed or fail remains uncertain. Popular options like Decentraland or The Sandbox may appear cartoonish and pixelated, with vast expanses of empty, unused space. Critics argue that the real deception lies in convincing companies that purchasing land in such places represents a sound investment for the future, despite the limited time users spend there (Hari Lal & MK, 2022).

18 Lack of Regulation

For the metaverse to become a viable place to live and conduct business, it will require real-world controls to safeguard users against abuse, fraud, and loss. However, implementing global regulations is a time-consuming and challenging task. In the meantime, the metaverse creators must take proactive measures by establishing their code of conduct, referred to as meta code.

The metaverse is no longer confined to science fiction; therefore, it is essential to consider the potential threats it poses to individuals and businesses. To ensure the safety of users, regulators and architects of virtual spaces should work together without delay. Technological innovation often outpaces regulatory frameworks, resulting in a lack of supervision over the metaverse's operations at present (Rosenberg, 2022).

First, the currencies used in virtual worlds are unlike real money. They mostly consist of digital money or in-game money like Fortnite V-Bucks. There is no government-backed protection against loss or fraudulent activity, even though accounts or wallets can be used to store these assets.

Secondly, in contrast to the real world, the value of virtual goods bought and exchanged in the metaverse is less palpable. An NFT or virtual piece of real estate may seem valuable, but that value may not necessarily hold. Furthermore, there are not enough safeguards for consumers, such as return rights or other comparable provisions.

Currently, the metaverse is home to approximately 160 businesses, and many more are sure to follow. These independent operators might continue operating indefinitely without a regulatory framework. Furthermore, there may be few ways to stop an offshore investment organization from setting up shop in a region of the metaverse that is accessible to users from other virtual worlds, without worldwide control of the metaverse. The most likely consequence is that some virtual worlds will be governed by laws, perhaps pertaining to asset transferability or privacy. Fraud and financial gain could both be concerns in unregulated online environments.

19 Virtual Worlds with Real Financial Services

The metaverse relies on technologies such as blockchain and distributed ledger systems, which inherently minimize transaction risks and reduce the need for financial regulation. However, this conflicts with the core essence of the metaverse, which values anonymity and the ability to assume different identities in a virtual world. While anonymity is a key attraction for many users, it poses challenges for implementing regulations, as proving one's identity becomes less straightforward. Privacy concerns are prevalent among metaverse users, with 41% globally and 55% of U.S. internet users worrying about the tracking and misuse of personal data.

Strong ties between online and offline personalities and adherence to rules that guarantee financial safety are necessary for financial regulation in the metaverse to be effective. In the developing virtual reality world, important requirements like "know your customer" (KYC), tax regulations, risk management techniques, and comparable frameworks will find their place. As the metaverse becomes increasingly realistic, there will be a greater need for regulation. The emergence of asset classes within the

metaverse could eventually hold significant value, requiring robust supervisory and governance frameworks akin to those in the physical world. As more is at stake, there is a greater necessity for protection.

20 Law Recommendations

The metaverse, overseen by a 'Metarules Compliance Officer' within firms, should prioritize four essential elements. First, it must enforce Know Your Customer (KYC) requirements, ensuring that users verify their real-world identities. This includes implementing a robust process to register minors and minimize abusive behavior. Second, it should provide safe spaces for mental well-being and employ AI (Artificial Intelligence) tools to monitor addiction and post-traumatic stress disorder (PTSD). Third, users should have the ability to opt into specific levels of content and frequently confirm their comfort with it. Lastly, there should be a cross-industry database of bad actors and their real-world identities to maintain a secure environment.

Virtual assets like NFTs may be governed by conventional financial laws governing securities, banking, money transmission, and commodities in the metaverse. Some blockchain-based assets might meet the definition of "investment contracts" and as a result be subject to securities legislation. A complicated system of rules would need to be put in place for sales, trading, and other operations to comply with securities laws.

To effectively manage financial risks in the metaverse, well-defined processes are crucial. For instance, when independent stablecoins are transferred into or out of meta wallets, exchange fees should be transparently published. Additionally, significant loans or trades should require real-world collateral. It makes sense to contract out ID verification to a dependable third party and offer insurance against individual loss or third-party damage. Supporting these processes and enabling embedded finance, securitization, wealth creation, and taxes will need leveraging technologies from the real financial sector.

An industry body could introduce a quality stamp that signifies virtual worlds as self-regulating and adhering to prescribed standards, guaranteeing safety for visitors. Metaverse users would then have the choice to stick to approved areas or venture into clearly unregulated environments. In addition to external controls, self-regulation will be critical and can be achieved through enhanced transparency, credibility, and accountability,

backed by best-practice processes. Crises will inevitably occur, but collectively, governments, businesses, and consumers can learn from them. How we respond as a collective will shape the metaverse of the future, making it a complementary and enriching extension of our real lives.

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Asset Tokenization in Real Estate: Theoretical Perspectives and Empirical Approaches

Khalil Alnabulsi

1 Introduction

Real estate refers to land and any improvements on it, including buildings, natural resources, and other tangible assets. It is a significant sector of the economy that encompasses residential, commercial, industrial, and agricultural properties. Real estate is without a doubt one of the largest and most important sectors in the United States and around the world. Moreover, the total value of the world's real estate assets was predicted to be $326.5 trillion in 2020, significantly above the value of all equities, bonds, and currencies combined. The global worth of the real estate business is substantially lower, estimated to be $2.2–$3.3 trillion, but it still surpasses a wide range of other industries, including machinery, oil and gas production, fashion, and consumer electronics.

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Since the invention of Blockchain technology by Satoshi Nakamoto (2008), the media has propagated a plethora of stories with ambitious declarations of projects that were to disrupt numerous industries, including governance, bureaucracy, and public registries. One intriguing area of investigation is peer-to-peer deeds with land titles and other property rights. Fortunately, Blockchain technology (BCT) gained magnitude through the launch of the cryptocurrency, bitcoin is being expanded to many other business processes. Tokenization of assets is one such expansions, Asset tokenization is a rapidly growing area of blockchain technology that allows digital assets to be purchased, sold, and exchanged on the blockchain. With the dramatic rise of decentralized finance, we saw an increase in all forms of assets, including equities, money, debt, and real estate (Bamakan et al., 2022). Tokenization on blockchains has been a consistent trend since the beginning of 2018. A blockchain is essentially a shared and distributed ledger, and it might help the real estate market address a variety of difficulties. Transactions are processed in blocks, and the blocks are encrypted and cryptographically connected in a chain. Furthermore, the processing occurs within a network of nodes with a consumer design that is designed to decentralize authority.

Representing real assets as digital tokens allow issuers and holders of those tokens to achieve the benefit of cryptocurrency which refers to security, liquidity, and immutability to real-world assets (Sazandrishvili, 2020). The ability to "fractionalize ownership" of real assets is one advantage of tokenization. However, fractionalized ownership is comparable to a real estate investment trust (REIT). The primary distinction between REIT investment and fractionalized ownership is that REIT investing involves purchasing a security in the business that owns the investment property. While fractionalized ownership owes a portion of the tangible property itself. Property is first appraised and valued in real estate tokenization. It is then subdivided into smaller fractions or tokens that can be represented on a blockchain platform. These tokens can be sold to investors, allowing them to own a portion of the property without having to purchase the entire property. These tokens' ownership is recorded on the blockchain, giving transparency.

Investors have recognized real estate as a suitable market for tokenization via blockchain. This new type of investment eliminates a variety of problems associated with direct investments, from which investors can profit in addition to existing forms of indirect investments (Kreppmeier et al., 2022). The properties can be split into many single tokens, which

enable fractional ownership. Thus, retail investors have access to previously unattainable assets which helps them to diversify their portfolios. Therefore, Real estate tokens are the digital analog of owning real estate (Baum, 2020).

The following are the advantages of asset tokenization: First, worldwide investment access. With the prevalence of fractional ownership and access to markets without intermediaries, asset tokenization would make investments broadly accessible. Second, increased liquidity. It is significantly easier to trade digital tokens on a blockchain than traditional real estate. Third, without the use of banks or other intermediaries, tokens can be traded directly between buyers and sellers. Fourth, blockchain assets can change hands at the speed of thought, allowing for speedier transactions. The majority of blockchain may be accessible via a web browser, and transactions can be conducted in real time. Fifth, blockchain is one of the most transparent financial systems in the sense that every single transaction is recorded.

The tokenization of real estate in the narrow sense refers to the process of breaking up ownership of a real estate property into smaller, tradable units called tokens, which are then recorded on a blockchain. These tokens are represented as a share of ownership in the property. This allows investors to participate in real estate ownership and investment opportunities that were previously inaccessible due to high entry barriers, such as large minimum investment requirements or limited liquidity. Moreover, the concept of tokenization of real estate is relatively new, but it is gaining popularity due to its potential to democratize real estate investment and increase liquidity in the market.

The use of tokens makes it possible to convert the value of real estate objects into a more liquid form. Furthermore, in the case of tokens, they can be used as mortgages to increase the effectiveness of real estate ownership by employing idle economic resources. However, by linking tokens with actual assets, tokenization can assist to stabilize the crypto economy and reduce volatility in the digital currency market (Kalyuzhnova, 2018). Tokenization enables the customization of new investment and utility goods, as well as the creation of new opportunities in the real estate market by providing liquidity (Gupta et al., 2020; Latifi et al., 2019; Morrow & Zarrebini, 2019) by creating efficient secondary markets (Baum, 2020) through expanding the pool of potential investors and the global investment base (Smith et al., 2019). Blockchain technology enables the real estate to be tokenized, resulting in the formation of a

new trading instrument known as a security token (STO), making it easier and more viable to trade real estate (Podshivalov, 2022). In working with tokens, several ways of tokenization must be considered. Tokens issued for the future right to buy or lease a property are known as "Utility" tokens (a valuable token that grants the opportunity to purchase a company's product). Utility tokens offer the right to receive rights to assets (such as real estate) or services (such as rent). There are concerns about transferring the property title to the token's owner. In countries that employ the Torrens title system, obtaining actual rights to real estate requires passing the registration procedure for making changes to the register. Real estate tokenization will improve the economy since real estate values are more stable than exchange-traded assets, resulting in less fluctuating token values. Furthermore, the simple exchange of real estate tokens will raise the economy's capitalization.

2 The Regulatory Framework of Real Estate Tokenization

Blockchain-based real estate crowdfunding systems envision a situation in which consumers can index their periodic small investments to the value of a property they want to buy and/or sell. The regulatory framework for asset tokenization varies from country to country and depends on the specific type of asset being tokenized. However, some general principles could apply to most jurisdictions as the following:

- Securities regulation: In most jurisdictions, asset tokens are treated as securities and are subject to securities regulation. This means that issues of asset tokens must comply with securities laws, including registration, disclosure, and reporting requirements.
- Anti-Money Laundering (AML) and Know-Your-Customer (KYC) compliance: Asset tokenization platforms are required to comply with AML and KYC regulations to prevent money laundering and other illegal activities.
- Smart Contract Security and Legal Enforceability: The smart contracts used to issue and manage asset tokens must be audited to ensure that they are secure and function as intended. Real estate tokenization relies on the use of smart contracts to facilitate transactions. However, there may be concerns about the security and

reliability of smart contracts, as well as the legal enforceability of their terms and conditions.

- Fractional Ownership Regulations: Tokenizing real estate assets enables fractional ownership, allowing multiple investors to own a portion of a property. However, local regulations may have specific provisions regarding fractional ownership, including limitations on the number of owners, transfer restrictions, and disclosure requirements.
- Property Ownership Laws: Real estate tokenization involves transferring ownership rights to digital tokens. However, property ownership laws and regulations vary across jurisdictions, and there may be restrictions or requirements that affect the transfer of ownership through tokenization.
- Consumer protection: Asset tokenization platforms must provide adequate disclosure to investors, and investors must have a clear understanding of the risks associated with investing in asset tokens.
- Taxation: The taxation of asset tokens varies depending on the jurisdiction. In some countries, asset tokens are treated as property, while in others, they are subject to capital gain tax.
- Jurisdictional compliance: The regulatory framework for asset tokenization may vary from country to country, and issues must comply with the laws and regulations of each jurisdiction in which they operate.

In the context of legal and governance aspects, Garcia-Teruel and Simón-Moreno (2021) comparison of different legal systems within the EU. The findings show that tokenization would have varied legal status in five countries, even with less controlled limited property rights. In the same vein, Wang (2021) pointed out that the conflicting regulatory regimes that prevent the international exchange of security tokens may undermine the benefits of tokenization. Regarding the Italian experience in real estate crowdfunding platforms, Creta and Tenca (2021) identified the main challenges in Italy's current regulatory framework. Chow and Tan (2022) revealed that legislative and legal uncertainties are the key barriers to tokenized security in the Asia–Pacific (APAC) region. The intermediate structure of real estate tokenization such as special purpose vehicles (SPVs) is still regarded as a preferred option for tokenization instead of tokenization real estate ownership (Baum, 2020).

Overall, the regulatory framework of asset tokenization includes securities regulations, AML and KYC regulations, and tax laws. These regulations aim to protect investors, ensure market integrity, and promote financial stability. As the asset tokenization industry continues to evolve, it is likely that new regulations will be introduced to address emerging risks and challenges. In the United States, for example, the tokenization of real estate is regulated by the Securities and Exchange Commission (SEC). The SEC requires that tokens be registered as securities if they meet the definition of security under the Securities Act of 1933. This means that the tokens must be registered with the SEC, and investors must be provided with detailed disclosures about the investment, including information about the issuer, the asset underlying the token, and the risks associated with the investment.

In Europe, the tokenization of real estate is regulated by the European Securities and Markets Authority (ESMA). ESMA oversees the regulation of the securities market across the European Union (EU) and requires that tokens be registered as securities if they meet the definition of a security under the Markets in Financial Instruments Directive (MiFID II). This means that the tokens must be registered with the relevant national securities regulator, and investors must be provided with detailed disclosures about the investment. Additionally, the tokenization of real estate may also be subject to other regulations, such as anti-money laundering (AML) and know-your-customer (KYC) regulations. AML and KYC regulations are designed to prevent money laundering and terrorist financing by requiring financial institutions to identify and verify the identity of the customers. It is important to note that the legal barriers and regulations surrounding real estate tokenization are evolving rapidly, and they may vary significantly depending on the jurisdiction. Therefore, it is crucial to seek legal advice from professionals familiar with the specific laws and regulations of the relevant jurisdiction before engaging in real estate tokenization.

As shown in Fig. 1, the legal design of blockchain-based real estate crowdfunding. Firstly, investors must identify and select a real estate project in which they want to buy. The evaluation process takes place and is incorporated into the price on the crowdfunding platform. After completing the KYC, the investor buys real estate tokens on the platform.

Real estate investment tokenization faces legal obstacles, regulatory ambiguity, and terminological disparities in blockchain-based property transactions (Sazandrishvili, 2020). In most jurisdictions, directly

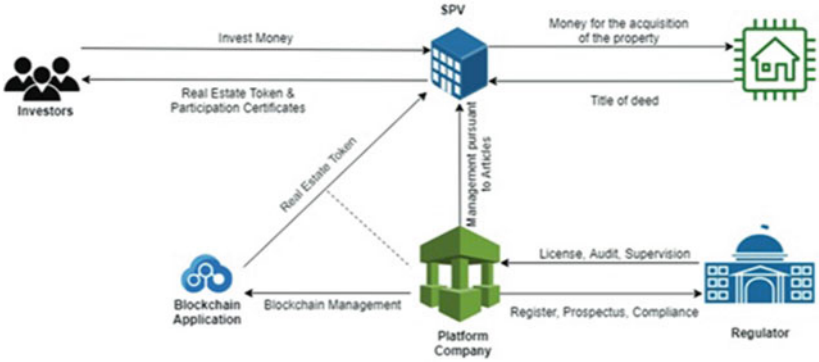

Fig. 1 The legal design of blockchain-based real estate crowdfunding (*Source* Adapted from Avci and Erzurmlu [2023])

tokenizing real estate is not possible, necessitating an intermediate structure such as an SPV. However, from a regulatory standpoint, token classification is critical. As a result, enterprises engaging in certain security token activities must obtain the necessary permits and adhere to the rules and regulations (Gupta et al., 2020). Real estate is a wide and expensive business, making it difficult for new investors to participate in large-scale projects. Multiple investors can own a portion of a property through tokenization, making real estate contributions more accessible to a wider audience. Furthermore, tokenization simplifies automatic earnings distribution among stakeholders, addresses property-related rights like inheritance, and improves liquidity for real estate businesses. Moreover, Tokens of the ERC777 standard could represent the ownership of the real estate, which can be purchased by an investor and traded on secondary exchanges via smart contracts (Serrano, 2022).

The real estate tokenization market has pioneered their way of new business which attracts new investors to be interested in. The following are examples of these businesses:

- Reental: A Spanish firm that accepts real estate investments as low as 100 euros. It has approximately 7200 users and has tokenized 25 characteristics through fractionalization.
- Propy: A platform that enables clients to buy and sell real estate using cryptocurrencies, NFTs, and standard payment methods. This

platform functions as a real estate transaction market with lower market entrance barriers. Propy's developers use smart contracts to automate the transactions of all assets on the platform.
- Estate Protocol: A platform built on the Ethereum blockchain that offers an NFT marker backed by real estate assets and allows for the investment and fractionalization of all of its assets.
- Domoblock: A European company focused on real estate based on the Ethereum blockchain, in Domoblock, investors can participate with invest in tokenized assets starting at 200 euros.
- RealT: An American planform that facilitates real estate investment by representing property ownership with a digital token on the Ethereum blockchain.

3 A Brief Look at the Relevant Literature on Real Estate Tokenization

Real estate has been identified by investors, project developers, and market participants. This new form of investment solves a range of problems that might arise from direct investment from which investors can benefit in addition to the existing forms of indirect investment. The properties can be split into different tokens. A real estate token is like a closed-end fund, involving one property, not a portfolio such as an open-end fund or REITs. However, in the case of REITs, investors do not own the properties and cannot influence the decision to invest in a particular property (Kreppmeier et al., 2022).

The literature on real estate tokens is mostly comprised of a theoretical nature regarding the general characteristics (Gupta et al., 2020; Markheim & Berentsen, 2021). In their study, they represent descriptive data based on a sample for real estate tokens in the USA and Switzerland. Notwithstanding, the advantages of digital tokens, they pointed toward challenges such as regulatory uncertainties and long transaction times. While the concept of asset tokenization is relatively new, there have been some empirical studies and research conducted on this topic. Here is a brief overview of the empirical literature on asset tokenization:

- Liquidity and market efficiency: Several studies have explored the impact of asset tokenization on liquidity and market efficiency. They found that tokenization can enhance liquidity by enabling fractional

ownership and facilitating secondary trading. It also has the potential to reduce transaction costs and increase market depth, leading to improved market efficiency.

- Real estate tokenization: Real estate tokenization has gained significant attention. Research has examined the benefits and challenges of tokenizing real estate assets. Empirical evidence suggests that tokenization can unlock liquidity in traditionally illiquid real estate markets, attract new investors, and provide diversification opportunities. However, challenges related to regulatory compliance, valuation, and investor protection still need to be addressed.
- Startups and Initial Coin Offerings (ICOs): Many studies have focused on the tokenization of startup equity through ICOs. These studies have explored the impact of tokenization on fundraising, investor behavior, and market dynamics. They found that tokenization can lower entry barriers for investors, provide more efficient fundraising mechanisms, and create new investment opportunities. However, ICOs also face some challenges related to regulatory compliance. Investor protection, and fraudulent activities.
- Tokenization and Financial Inclusion: Some researchers have examined the potential of asset tokenization to promote financial inclusion, particularly in developing countries. By enhancing fractional ownership.
- Reducing investment barriers, tokenization can allow individuals with limited resources to participate in previously inaccessible markets. Empirical evidence in this is still limited but suggests the potential benefits of asset tokenization in promoting financial inclusion.

Tokenization provides blockchain benefits for real estate investors. The relevant literature proposed tokenization for both direct and indirect real estate investment options. Tokenization first real estate investment benefits are inclusion and efficiency, as well as liquidity and cost reduction. According to Chow and Tan (2022), the growing number of cryptocurrencies and non-fungible tokens (NFT) will expand the number of investors who can invest in real estate tokens. Furthermore, Baum (2020) noted that investor interest for security tokens for single real estate assets appears to be restricted in the past and now. Swinkels (2023) examined the role of financial and economic consequences of tokenizing 58 residential rental properties in the US. The results suggested that tokenization

leads to dispersed ownership of properties of modest value. Moreover, investors in real estate tokens diversify their portfolios well. Hence, real estate tokens seem to be related to real estate prices.

Blockchain and smart contracts are the foundations of tokenization (Colliers, 2020). Moreover, the blockchain facilitates the tokenization of real estate through fractionalization. On one hand, tokens are digitally represented as physical assets (Liu et al., 2020). On the other hand, smart contract simplifies real estate transactions. According to the recent blockchain adoption literature in real estate, more empirical research is needed (Bennett et al., 2021; Konashevych, 2020; Rodima-Taylor, 2021). Saari et al. (2022) provide a timely systematic literature review on blockchain's theoretical perspective on the real estate sector. They demonstrated that the majority of the existing literature concentrated on blockchain applications in land administration, followed by property transactions, real estate investment, leasing and renting, and real estate administration. Karamitsos et al. (2018) presented the blockchain and smart contracts for the real estate sector, they noticed that in the real estate sector, some benefits will enhance real estate development such as meeting certain requirements to improve the efficiency of the current process. In the real estate sector, different transactions involved different parties such as landlords and financial institutions. However, blockchain technology can separate transactions between various parties. According to Fisch et al. (2022) Initial coin offerings (ICOs) are used to capitalize on the tokenization approach of expressing fractional ownership in an asset with a blockchain-based token. Furthermore, they give an empirical comparison of ICOs, venture money, and REITs. The combination of the results from two empirical studies demonstrated the importance of various categories when raising funds through ICOs.

Investing in traditional real estate raised some concerns and problems that investors refuse to invest in, in the table below some examples (Table 1):

Zhou et al. (2021) provided an example of real estate tokenization by using Ethereum. Hence, making it secure. Moreover, they proposed a common platform where the asset owners can be connected to the investors as well as the investors have to register on the platform. For each user registered on the platform have to verify both KYC and AML. Once it is done, the user will have access to the service of the platform. The findings of their work suggest that the tokenization of assets offers

Table 1 Concerns that investors refuse to invest in traditional real estate

Reasons	*Source*
Real estate transactions are complex and lengthy processes. Involves verification of lawyers, agents, and financial institutions	Liu et al. (2020)
Real estate transaction costs are high. Comprising; legal, brokerage, and banking fees	Liu et al. (2020)
Real estate market data are fragmented and lack transparency	Wouda and Opdenakker (2019)
Strict regulations such as extremely high barriers	Veuger (2018)

many benefits such as liquidity, faster and cheaper transactions, and accessibility. In China, Yang and Wang (2020) analyzed the status of real estate transactions based on blockchain technology. The results demonstrated that through the Hyperledger Fabric platform, the sellers can directly release information about the real estate sale, and that information is obtained from the registration department which ensures the accuracy and transparency of the information.

4 Concluding Remarks

The development of disruption, Blockchain, and real estate in the coming years is not only an obvious feature of a specific era but also its social impact and user behavior. This also applies to how this real estate transition can be best recorded, guided, and used in society on an international, national, and regional scale. Disruptive organizations respond to environmental viability and so define competitive strength. This affects both the current and future value of real estate. The advantages of Blockchain applications in real estate operations include more effective and efficient transactions, more transparency, a stronger platform for investment, and the establishment of new mortgage markets. All of this will lead to increased trust in key components of an economy, such as land and real estate, as well as a transition from the "Internet of things" to an "economy of things."

Tokenization is the process of creating a digital share of ownership that can be sold and possibly opens an asset to a larger universe of investors. Blockchain enables the simple and safe purchase and sale of illiquid assets such as real estate. Crowdfunding, as a fundraising technique, enables

small investors to have access to dependable markets, including tokenized assets. The combination of these three ideas might have a substantial impact on the real estate market. Nonetheless, some legal and market hurdles would persist. Most solutions to legal concerns entail issuing a participation certificate for each real estate token. Changes in value conceptions have an impact on real estate evaluation and perception. The perspective of changing real estate users and owners influences the property's Management must be inventive, value-driven, and adaptable. Disruption orientation should be interpreted as evidence that the real estate sector is capable of innovating and concentrating its assets. Irrational behavior has inflated the financial and real estate markets. The fear of "eating or being eaten" governs people's actions. Individuals and institutions must continually manage financial and thus real estate markets since they are fundamentally unstable.

The proposed legal structure preserves the anticipated benefits of blockchain tokenization of real estate assets, such as transactional data transparency, while mitigating market-related challenges such as asset heterogeneity, providing investors with direct access to primary and secondary markets or increasing asset liquidity, improving informational efficiency while lowering entry barriers, and the absence of bankruptcy-remote entities. Furthermore, it may ease certain difficulties associated with operational efficiencies, such as the need to create a distinct SPV for each asset tokenization. As a result, the organization's costs and expenses are reduced. Surprisingly, the majority of the literature concentrated on blockchain in land administration. Overall, the blockchain potential in the real estate sector appears to be overlooked when compared to all of the alternatives outlined in the literature for addressing real estate sector challenges. Only the land administration sub-sector has some genuine solutions in place, thus blockchain potential in traditional real estate is just beginning to emerge. Limited empirical research has focused on the development of blockchain technology applications in real estate. Therefore, it is interesting to do a more-in-depth review of how the development of blockchain technology could improve the current transaction process. In addition to interdisciplinary research on blockchain applications in real estate, such as political, economic, environmental, legal, and behavioral aspects. Overall, prominent research in exploring blockchain's potential to provide insight into climate and environmental issues will enhance and enhance the extent of the literature.

In conclusion, asset tokenization has emerged as an innovative and transformative approach to real estate investment and ownership. Recent developments in technology and regulatory frameworks have paved the way for the tokenization of real estate assets, enabling investors to access fractional ownership and liquidity in real estate markets that were previously unavailable. Empirical studies have shown that tokenization can provide benefits to investors, such as increased accessibility, transparency, and liquidity. However, there are still challenges to be addressed, including regulatory compliance, cybersecurity risks, and potential market volatility. Moving forward, real estate industry stakeholders need to continue to explore the potential of asset tokenization, while also addressing these challenges and ensuring that this innovative investment approach is properly regulated and secure. With the right infrastructure and regulatory framework in place, asset tokenization has the potential to revolutionize real estate investment and provide a more accessible and inclusive approach to asset ownership. Several directions for future research on asset tokenization and mainly on real estate tokenization seem beneficial.

Real estate tokenization is an emerging area that combines real estate assets with blockchain technology, enabling the fractional ownership and trading of real estate through digital tokens. As this field continues to evolve, several potential future research directions can contribute to a deeper understanding and advancement of real estate tokenization. First, Research can focus on the legal and regulatory aspects of real estate tokenization, including securities laws, property rights, governance structures, and investor protection. Exploring the challenges and opportunities in different jurisdictions can help policymakers develop appropriate frameworks that facilitate the adoption of real estate tokenization while ensuring compliance and mitigating risks. Secondly, investigate the impact of tokenization on real estate markets and liquidity. Research can analyze the effects of increased liquidity, improved price discovery, and accessibility to a wider range of investors. Understanding how tokenization influences market dynamics, including supply and demand dynamics, pricing mechanisms, and transaction volumes, can provide valuable insights for market participants and regulators. Moreover, explore methodologies for valuing tokenized real estate assets. Lastly, Research can investigate the development of robust valuation models and pricing mechanisms for real estate tokens, considering factors such as property

location, income generation potential, asset quality, and market sentiment. Developing accurate valuation techniques can enhance transparency and trust in tokenized real estate markets. Study the applicability of real estate tokenization across different asset classes, such as residential properties, commercial buildings, industrial facilities, or undeveloped land. By pursuing research in these areas, scholars, practitioners, and policymakers can contribute to the development of a robust framework for real estate tokenization, address challenges, and realize the potential benefits of this revolutionary technology in the real estate market.

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Distribution of PropTech Benefits to Stakeholders of Real Estate Market

Ali Murad Syed

1 Introduction

The mortality levels are declining, and life expectancy levels are increasing in the world. The latest predictions by the United Nations indicate that the world's population might increase to around 8.5 billion in 2030 and 9.7 billion in 2050.[1] The distribution of population in various continents has also changed over the last few decades. This accelerated increase in population puts unprecedented challenges to all the countries especially environmental, societal, and economic challenges. These challenges occurring due to the increasing population can be responded to by looking at future demographic trends and making strategic plans based on that information. Countries should prepare to meet the growing number of population and they need to invest in human capital by providing adequate housing, healthcare, and education facilities to all ages.

[1] https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf.

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Real estate purchases are expensive, not an easy decision to buy/sell and not traded as frequently as financial assets in the financial markets. Because of these unique features, most individuals feel the need for some advice from a professional and it ultimately increases the transaction costs. Information is the key input into the due diligence phase of any real estate transaction. If the value added by the professionals (intermediaries) is simply a source of information, their intermediary position is at risk and there is a possibility that buyers and sellers foster new ways to contact each other. Information and communication technology (ICT) may provide a means to make this possible. Developments in information and communications technology (ICT) have revolutionized almost every aspect of modern humanity including the real estate industry. Baum (2017) highlighted that this change has been facilitated in no small way by three activities: information provision, transaction, and effective control. The real estate industry also enjoyed the presence of ICT and the accelerated growth of digitization in real estate operations has led to the development of a real estate domain denoted as PropTech. The term "PropTech" can be defined as the use of modern technologies in the field of real estate industry. The increasing importance of digital transformations in the financial industry is now becoming also popular in the real estate industry which has a potential to transform the way the traditional real estate transactions take place. Bittini et al. (2022) argued that the real estate industry can no longer shut itself off from fundamental technological innovations although it is somehow slow to adopt this change. Due to the COVID-19, various players of the real estate industry were forced to experience new services and products by use of technology called PropTech. Investors' requirements have grown during the pandemic, which indicates the vital impact that technology has made in the real estate industry over the last 2–3 years.

Economic sociologists consider various markets more as socially constructed phenomena instead of only fragile, technical, and natural free-floating entities. The more a stakeholder in a real estate industry able to broaden and obscure the network of entities the greater asymmetry it can create between itself and other agencies (Callon, 1998). In his theory of social construction of markets, Callon (1998) argued that an organized market cannot be reduced to a simple system of trade and transaction. As per author it is a process in which agents design and produce goods and enter competition to attain a demand. Weidenfeld, Williams, and Butler

(2010) discussed the importance of explicit-to-explicit knowledge transfers, and integrated ideas that could be copied. This transfer of knowledge resulted in new products or process innovations by the receivers. Considering the work of Callon (1998) and Weidenfeld et al. (2010) the inclusion of technology into the real estate market is easily understood. The real estate market has seven specific characteristics impacting the economic or physical nature and is prone to change or, not known as an industry that promptly accepts change. Bittini et al. (2022) insisted that the real estate industry can no longer close itself off from technological innovations despite its characteristics of being slow to embrace change.

Crowston and Wigand (1999) discussed the features of real estate industry and described it as an information-intensive and information-driven industry having high value, presence of intermediaries and also witnessing changes in information technology (IT).

PropTech is a part of digital transformation in the real estate industry, and it focuses on two aspects including the technology and mentality changes of the people. Berman, Schallmo, and Williams (2022) discussed that the Israeli real estate industry has been slow in implementing contemporary digital technologies. The authors argued that digital start-ups can shape the real estate industry and solve its challenges while fundamentally transforming its traditional business models.

PropTech proved to be the leading catalyst to the business culture transformation and processes in the real estate industry. For instance, solutions like internal mapping, property transaction management, facilitation in leasing process, valuation analytics, data analytics, and smart buildings can ease the digital transformation of the sector, etc. PropTech has saved time and money for millions of developers and property managers worldwide.

2 Advantages of PropTech to Various Stakeholders

There are several PropTech benefits to various stakeholders in the real estate industry. Various stakeholders are using PropTech for different purposes and the benefits also vary from stakeholder to stakeholder. An important advantage of Proptech is the increase in liquidity and the reduction of transaction costs. This benefit of PropTech is more advantageous to the buyer side in the real estate industry and they can go through

more number of buying options which were not there before the introduction of technology in the real estate industry. Fu (2022) discussed that the introduction of PropTech improved the liquidity by increasing supply, lowering transaction costs, and making more accessibility in the property transaction process of the Swedish real estate industry.

The rental sector of the real estate market also got several benefits from the introduction of PropTech. The interaction between the landlords and the perspective tenants has increased due to Proptech and both parties of the rental sector can use various channels of communication, and this facilitated their relation which ultimately increases the transparency in the rental transactions. The landlord and tenant relation was in favor of landlords before the introduction of Proptech, but this relation has equally balanced after the introduction of PropTech. Wood, Phelps, Economy, and Space (2018) argued that rental propTech platforms (RPPs) are going to change the landlords and tenants relationship and the role of RPPs will be similar to mediators of these relationships, claiming transparency, and efficiency. Gillespie and society (2010) discussed that digital platforms transmit social bias, and these platforms are more than utilities which facilitate the landlord and prospective tenant interaction while showing themselves as neutral. The authors mentioned that various features in these digital platforms are responsible for this inequality of data. Wainwright, Economy, and Space (2023) discussed the landlord and tenant power relations in the UK private rental sector are changing whereas historically, the power balance has favored landlords. The argument of historical power balance toward landlords is also argued by Fields, Rogers, and society (2021); Porter et al. (2019). The PropTech can also help designate individual rooms much faster and in a more flexible way for the landlords. This allows the more efficient use of space capacities in the rental market. We also see contemporary trends in the real estate market. Companies are moving away from traditional office space and into a more disintegrated common space which is facilitated using PropTech.

Another important benefit of PropTech is the effective use of data in the real estate market. Data collected through PropTech can be applied to many aspects of the real estate market, from property valuations to transaction processing. In fact, it is already transforming many aspects of the real estate industry. The data can be used to assess various demographic factors, preferences of various market participants, their risk levels, their bias toward a particular sub-sector, any specific trend in the market,

etc. Various stakeholders of the real estate industry can use the effective use of this data to generate more profit and to best organize it and apply it to improve their business. This use of PropTech is more beneficial for the seller side to make business and marketing strategies accordingly. The use of data is also beneficial to the landlords in the rental sector for targeted promotion of their projects to perspective tenants. Fourcade and Healy (2017) described that modern forms of information processing are "*the most recent installment in the continuing development of the control revolution*". The author argued that information dragnets produce data which is huge and is analyzed to sort and slot people into categories of preference, riskiness, or similar features to define new strategies of profit-making. The digital platforms can be described as a new shape of these information dragnets. Another benefit of PropTech is the use of real estate data for risk mitigation and predictive analysis. This benefit will help all the stakeholders including the buyers, sellers, and agents to forecast the future direction of real estate market with comparatively higher level of certainty which was not possible before ProPTech. Putatunda (2019) used advanced machine learning and artificial intelligence techniques and predicted the housing prices by considering input features of the Indian real estate industry which will help the buying side of any real estate transaction.

But other is one downside of this real estate data use. PropTech platforms are powerful, and these platforms save and make use of private data, like information about leaseholders of an apartment building. It's important for such tools to be safe against incursions by bad players. The data collected through PropTech can also be influenced to reshape the preferences of the market participants. The participants using these platforms have to ensure that data is collected responsibly, and customers' privacy is maintained. Many legal issues will be specific to the technology and the use of data.

The introduction of PropTech in the real estate industry is also helping the economy as a number of start-up projects and companies are entering into the market which will add value to the economy. Start-up projects and start-up companies are the most important in this PropTech concept and their numbers have grown significantly in many countries over the last few years. Big data and data analytics allow more innovation in the real estate market. This is also the primary reason there have been increased investments in the Proptech companies for the past few years in several countries.

PropTech communities are being created in many countries which are described as a collection of real estate professionals, technology experts, entrepreneurs, and community representatives which are united in a network. In these communities' real estate professionals, technologists, entrepreneurs, and city builders have come together to learn from one another. Being a part of these communities various stakeholders can easily keep up to date with what's happening within the PropTech industry, and within the Proptech Collective. Siniak, Kauko, Shavrov, and Marina (2020) discussed that almost 50 countries have created PropTech national communities, which are united in a single network and these communities arrange international symposiums, seminars, and workshops that influence the generation of new projects.

Another big advantage of PropTech is the facilitation of property acquisition and management process for the investors of the real estate industry. This benefit is more important for the international investors in any real estate market. The use of PropTech facilitates the property acquisition process and the legalities involved in the process and also creates transparency in the process. Mills and Gotsill (2020) concluded that in the Japanese real estate industry there is a need of PropTech that could facilitate the property acquisition process and management for these non-Japanese investors. System dynamics of real estate industry could be improved by the addition of Proptech which makes the real estate market transparent. This is one of the major benefits of PropTech and will eventually increase the focus of international real estate investors. International investors have major concerns about the transparency of real estate and PropTech can solve this problem. This will lead to higher growth of the real estate market in terms of volume of transactions and market capitalization.

PropTech can increase the competition in the real estate market which will affect the buyer side in the real estate transactions. Another benefit is the increase in market competition because of Proptech. Before the introduction of Proptech, the buyers had limited options of buying and the market makers took advantage of it to control the prices in the absence of pure market competition. Through Proptech the buyers can achieve more returns from the real estate market as buying and selling is done based on touch market competition. Fu (2022) mentioned that more and more competitors are entering the Swedish PropTech market, which will bring more competition and more cooperation at the same time.

The ultimate benefit of PropTech is the increase in the overall value of properties. All the above-mentioned benefits can improve the overall value of real estate properties for the sellers, and in turn, this will lead to higher rental returns for the landlords. Buildings with Proptech are associated with quality and are deemed more valuable than buildings that don't use Proptech. For the buyers, the value of the properties may be seen as a drawback but they also get a number of benefits like transparency, increased market competition, facilitation in the acquisition process, reduction in transaction costs, etc.

There are a number of benefits to developers along with some drawbacks of PropTech. Acemoglu and Restrepo (2018) discussed the negative impact of PropTech on wages in the sectors where technological penetration is increasing. The authors also discussed the other side of the issue that new technologies create innovative products and new tasks that could increase the demand for labor.

Another big advantage of using PropTech lies in achieving a sustainable environment. By adopting propTech solutions such as smart building sensors, stakeholders can achieve their ESG environment, social and governance goals and benefit from higher-quality buildings and low energy consumption which can be viewed as an added value.

Property marketing companies are taking advantage of PropTech in several ways. 3-D tour or digital floor plan are gaining importance in the buyers before taking a buying decision. Property marketing companies are taking advantage of edgy web design that excites the customers, on-brand content creation that engages them, and B2B digital marketing campaigns that cut through the noise.

The construction industry is considered an integral part of the real estate industry. Numerous technologies have been developed to make things easier and more streamlined in the construction industry. PropTech has shown its ability time and time again to help people from all walks of the real estate industry to optimize all aspects of property management. With the use of technology, developers, architects, engineers, contractors, and other stakeholders in a construction project can lead to better coordination. Another benefit is the all-encompassing cost efficiency. PropTech also benefits the developers in the real estate industry. Developers are designing and constructing buildings that are operated by tech platforms and enable the operation and management of these real estate assets much easier. These tech platforms examine various building characteristics, analyze the building characteristic data, and generate insights to

optimize the building's environment and operations. PropTech is also reshaping architectural companies. It is a difficult decision for any architectural firm to decide whether they should demolish or renovate old structures or which material they should use for a particular project or the reduction of carbon emissions. The use of Proptech has changed the traditional thinking toward these and many other traditional queries of this industry. With the use of virtual reality (VR) and augmented reality (AR), project teams can collaborate more effectively, identify potential problems rarely, and ensure that everyone involved in the construction process has a shared understanding of what the final product will look like. With AR, we can see property as it would look in real life, with all the furniture and fittings in place. And with VR, we can walk through a property and get a feel for the space before you make any decisions.

In the real estate market, for years, paper checks and clunky online processes have been utilized to collect earnest money deposits, pay commissions and referrals, and collect deposit checks. Digital payments, alternative investment platforms, and access to market data form key elements of FinTech innovations and are relevant for real estate. By moving onto these digital platforms, companies are focusing on improving and systemizing the way money changes hands within a real estate company's transaction lifecycle and operations. This effectively removes the disparate and cumbersome systems utilized to transmit money. They also help to reduce transaction costs. Also, more transparency and enhanced promotion brings more benefits to the players of the market.

One potential drawback of using PropTech is the loss of some level of clientele relationship. Depending on technology alone for all compliance issues can lead to loss of personal relationships with the clients. To ensure full compliance, regular checking of the processes and protocols for efficient working is needed. Cybersecurity is also a rapidly increasing risk center for PropTech platforms. Cybersecurity has become vital for all companies that manage large amounts of customer data, and the risks of a breach can impact both the customers and the business, with possible consequences from the regulators for not protecting personal data.

We have discussed a number of pros and cons of PropTech, and we can say that the advantages of PropTech far outweigh its disadvantages.

3 Final Discussion

Due to the COVID-19, various players of the real estate industry were forced to experience new services and products by use of technology called PropTech. Using technology and digital transformation, both sides in real estate transactions are witnessing boosting confidence in adapting to new technology. All those factors formed a strong footing for the PropTech industry to continue advancing in the post-pandemic stage. It is also expected to have more and more competitors entering the digitalized real estate market which will ultimately bring higher competition and more collaboration at the same time.

In this paper we have discussed several benefits of PropTech to various stakeholders of the real estate industry and have shown that every stakeholder is benefiting from the use of PropTech but the level of benefit also varies among the stakeholders. We have also shown that the pros of PropTech are far greater than the cons and that is the real driving force for this growth. Real estate players are integrating technology deep into their activities from the beginning. Soon it will become a mindset—a given that no real estate project can be planned, leased, managed, purchased, or sold without the involvement of tech. PropTech has a promising future and has already started to shape the real estate for tomorrow. PropTech has great potential in the real estate industry, but at the same time it needs a clear regulatory framework that replaces unethical practices with practical and innovative technology-powered solutions.

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Fragmented Data Landscape and Data Asymmetries in the Real Estate Industry

Hamad Hazeem and Ebrahim AlBurshaid

1 Introduction

The real estate industry, renowned for its complexity and vast amounts of information, faces a significant challenge: fragmented data. Understanding fragmented data in the real estate industry is crucial for unlocking its potential and addressing its inherent challenges. Fragmented data refers to the scattered and disjointed nature of the information within the industry, hindering efficient decision-making and impeding transactions. This chapter explores the impact of fragmented data on real estate transactions and sheds light on the challenges and inefficiencies it causes.

One of the primary consequences of fragmented data is the presence of data asymmetries, where certain stakeholders possess more information than others. These asymmetries create an imbalance of power, leading to suboptimal outcomes and a lack of transparency in real estate transactions. It is essential to delve into the implications and consequences of

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data asymmetries to develop strategies that can mitigate their effects and promote fairness.

To address fragmented data, the real estate industry is witnessing data standardization and centralization trends. The need for a more unified and consistent data framework is driving efforts to establish industry-wide standards and central repositories. These trends aim to bridge the gap between various sources of information, enabling stakeholders to access accurate and comprehensive data.

Leveraging technology is instrumental in overcoming data fragmentation in real estate. Artificial Intelligence (AI) and Machine Learning (ML) are revolutionizing data analysis in the industry. These advanced technologies can process vast amounts of data, extract valuable insights, and automate repetitive tasks, ultimately streamlining real estate processes and improving decision-making.

Another promising solution to fragmented data is blockchain technology. Blockchain offers a decentralized and immutable ledger to securely store and verify real estate data. By eliminating intermediaries and enhancing trust, blockchain has the potential to revolutionize the industry's data infrastructure and alleviate many of the challenges posed by fragmented data.

Several successful applications of blockchain in real estate have emerged, ranging from property transactions to property management and crowdfunding. These real-world examples demonstrate the transformative power of blockchain in addressing data fragmentation and improving efficiency, transparency, and security in the real estate industry.

Looking to the future, the integration of fragmented data holds immense potential for transforming the real estate landscape. By realizing the vision of unified data, the industry can unlock new opportunities, improve decision-making, and create a more transparent and efficient ecosystem. Additionally, artificial intelligence, machine learning, and blockchain technologies will continue to play pivotal roles in shaping the future of real estate data integration.

2 Understanding Fragmented Data and Data Asymmetric in the Real Estate Industry

Understanding fragmented data and data asymmetry is crucial in the real estate industry. Fragmented data refers to the dispersed and heterogeneous nature of information available within the sector. Various sources,

including property listings, transaction records, market reports, and demographic data, generate real estate data. However, this data is often scattered across different platforms, making it difficult to access and analyze comprehensively.

Moreover, data asymmetry further compounds the challenge. Information imbalances exist between buyers, sellers, and intermediaries in the real estate industry. For example, sellers may know more about a property's condition or history than buyers. Similarly, real estate agents may have access to exclusive market insights that are not readily available to the general public. These information asymmetries can lead to inefficiencies and hinder fair transactions.

2.1 The Fragmentation of Data in the Real Estate Industry: The Impact and Challenges

The fragmentation of data in the real estate industry leads to a host of problems. For example, it can be difficult for buyers and sellers to access accurate and up-to-date market information due to the lack of centralized data sources. Additionally, agents and brokers may find it challenging to keep track of their client's transactions, as data is dispersed across multiple systems and platforms (Market, 2020). Furthermore, due to the challenges posed by fragmented data, service providers such as appraisers, attorneys, inspectors, lenders, and insurers are limited in their ability to provide timely and reliable services. Fragmented data also increases the risk of errors or inconsistencies within real estate transactions. When key information is missing or unavailable from disparate sources, there is an increased likelihood of costly delays or complications.

The impact of fragmented data on real estate transactions cannot be overstated. When a homebuyer, for instance, embarks on the journey of purchasing a property, the presence of fragmented data can significantly impede the process. Picture a scenario where incomplete property records, inconsistent valuations, and discrepancies in ownership information emerge at various transaction stages. These fragmented data elements act as barriers that hinder the buyer's ability to make well-informed decisions. Table 1 shows the element of fragmented data.

The consequences become increasingly apparent as the buyer tries to navigate through the sea of fragmented data. Uncertainty becomes a prevailing theme, making it challenging for the buyer to clearly understand the property's history, condition, and any potential risks associated

Table 1 Fragmented data with examples

Fragmented Data Element	*Examples*
Property Information	Inconsistent property addresses, incomplete legal descriptions, inconsistent zoning information
Ownership Records	Fragmented ownership records, discrepancies in title documents, outdated ownership information
Financial Data	Incomplete or inconsistent property values, rental/lease agreements, inconsistent income/expense records
Market Data	Incomplete or inconsistent data on comparable sales, rental rates, vacancy rates, market trends
Legal and Regulatory Information	Fragmented zoning regulations, incomplete compliance records, inconsistent building codes
Transaction History	Fragmented sales history, incomplete transaction details, inconsistent lease history
Documentation and Contracts	Incomplete lease agreements, inconsistent purchase contracts, missing legal documents
Property Management Data	Inconsistent maintenance records, incomplete tenant information, inconsistent rental payment history
Data Formats and Standards	Lack of standardized data structures, different file formats, incompatible data systems

with it. The lack of comprehensive and reliable data causes frustration and introduces a level of risk that could have been mitigated with a more cohesive and complete dataset (Starr et al., 2021).

Furthermore, the presence of fragmented data in real estate transactions leads to delays and additional costs. The buyer may find themselves caught in a cycle of back-and-forth communication with various parties involved, such as real estate agents, lenders, and title companies, attempting to gather and reconcile disparate pieces of information. These time-consuming efforts can result in missed opportunities, extended timelines, and financial implications for the buyer.

In addition to the buyer's experience, the impact of fragmented data extends to other stakeholders involved in the transaction, such as sellers and real estate professionals. Inaccurate or inconsistent data can lead to misaligned expectations, disputes, and potential legal issues. The lack of

trust and transparency stemming from fragmented data can erode the confidence of all parties involved, potentially hindering future transactions and damaging professional relationships.

To address the impact of fragmented data on real estate transactions, industry players recognize the urgent need for solutions that enhance data integrity, accessibility, and standardization. This involves embracing technologies that can streamline data management processes, facilitate data sharing and collaboration, and provide a unified platform for real estate professionals to access reliable and up-to-date information.

By addressing the challenges posed by fragmented data, the real estate industry can foster greater transparency, efficiency, and trust in transactions. The ability to access comprehensive and accurate data at every stage of the transaction empowers buyers, sellers, and professionals alike to make informed decisions, minimize risks, and optimize outcomes.

Data fragmentation poses significant challenges and inefficiencies in the real estate industry. When data is scattered across various sources, systems, and formats, obtaining a comprehensive and accurate view of the market becomes difficult. This fragmentation can lead to inconsistencies, redundancies, and inaccuracies in real estate data, hindering decision-making processes and creating inefficiencies throughout the industry.

One of the primary challenges of data fragmentation is the lack of data consistency and comparability. Different organizations and stakeholders may use different data formats, definitions, and measurement standards, making it challenging to analyze and compare data across different properties or locations. This inconsistency makes it difficult for market participants to identify trends, assess market conditions, and make informed investment decisions.

Data fragmentation also introduces information asymmetries among industry participants. When data is not standardized and centralized, certain parties may have access to more information or possess proprietary data that others do not. This can lead to unequal bargaining power, reduced market transparency, and potentially unfair outcomes in real estate transactions. Inefficient processes, such as manual data entry and reconciliation, further exacerbate these challenges, resulting in delays, errors, and increased costs. Table 2 lists some of the fragmented data challenges with examples.

One trend to overcome the fragmented data landscape in real estate is adopting data standardization and centralization efforts, such as using common data standards and platforms for sharing data. This can help

Table 2 Fragmented data challenges

Fragmented Data Challenge	*Examples*
Incomplete Data	Missing property details, incomplete ownership records, incomplete financial information
Inconsistent Data	Conflicting property addresses, inconsistent property valuations, conflicting transaction history
Duplicated Data	Duplicate property listings, duplicated ownership records, redundant financial data
Data Silos	Data stored in separate systems, lack of data integration between platforms
Data Incompatibility	Incompatible data formats, data systems that cannot communicate with each other
Limited Data Access	Restricted access to crucial data, limited availability of public records
Data Security and Privacy	Concerns regarding data breaches, unauthorized access to sensitive information
Data Verification	Difficulty in verifying the accuracy and authenticity of data, lack of data validation processes
Data Governance	Inadequate data governance policies, lack of standardized data management practices

streamline data access and analysis and improve real estate transactions' overall efficiency and transparency. Other trends include the use of artificial intelligence and machine learning to analyze and interpret large volumes of real estate data and the development of blockchain technology to create secure, decentralized real estate data registries. Blockchain and artificial intelligence (AI) technologies can be used to create more efficient data management systems that better organize and centralize data across stakeholders. Additionally, standardized reporting systems and an increased focus on data security can help ensure that all relevant parties have access to accurate and up-to-date information. By leveraging these technologies, the real estate industry may be able to overcome the challenges posed by its fragmented data landscape and create a smoother, more efficient transaction process for all involved.

Example: A homebuyer is in the process of purchasing a property and encounters fragmented data throughout the transaction. Incomplete property records, inconsistent valuations, and discrepancies in ownership information hinder the buyer's decision-making. The fragmented data creates uncertainty, delays, and additional costs in the transaction, impacting the buyer's overall experience and potentially affecting the final outcome.

2.2 Data Asymmetries: Implications and Consequences in Real Estate

The use of digital systems and technologies to reduce the effects of data asymmetries in the real estate industry is becoming increasingly popular. For example, AI-driven platforms can analyze large amounts of market data to identify trends and forecast outcomes accurately. Similarly, blockchain technology can help streamline transactions by creating immutable records that are accessible across multiple stakeholders. By leveraging such technologies, buyers and sellers can be better informed when it comes to making real estate decisions, while service providers can ensure that their services remain timely and accurate. Ultimately, a more data-driven approach to real estate could lead to greater transparency, fairer negotiations, and more successful transactions overall.

Overcoming data asymmetries in the real estate industry globally requires a multi-faceted approach. Some strategies that can help include:

1. **Increased Transparency**: Encouraging more transparent disclosure of information related to real estate transactions can help to level the playing field and reduce information imbalances between parties.
2. **Improved Access to Data**: Making real estate data more accessible to all parties involved in a transaction can help to ensure that everyone has access to the same information and can make more informed decisions.
3. **Standardization of Data**: Establishing common standards for real estate data can help to ensure that data is consistent and comparable across different markets and regions.
4. **Education and Training**: Providing education and training to buyers, sellers, and other stakeholders on the real estate transaction process can help ensure that everyone is better informed and can navigate the process more effectively.
5. **Use of Technology**: Leveraging technology, such as artificial intelligence and machine learning, can help to automate data analysis and interpretation and reduce the potential for human bias and errors. Additionally, blockchain technology can help create secure, decentralized data registries that can be accessed by all parties involved in a transaction.

In the real estate industry, data asymmetries play a crucial role in shaping market dynamics and influencing the outcomes of transactions. Data asymmetry refers to the uneven distribution of information among different stakeholders, where certain parties possess more information or proprietary data compared to others. This disparity in access to information can lead to significant implications and consequences for all participants involved in real estate transactions.

One of the key implications of data asymmetries is the imbalance of power among market participants. When one party has access to more comprehensive and accurate data, they gain a significant advantage in negotiations and decision-making processes. For example, a property seller who possesses detailed information about the property's condition, history, or market trends may be able to command a higher price or negotiate more favorable terms, while the buyer may be at a disadvantage due to limited access to such critical information.

Data asymmetries can also contribute to reduce market transparency. When relevant information is not readily available or is selectively disclosed, it becomes challenging for buyers, sellers, and investors to obtain a holistic understanding of the market conditions. This lack of transparency can erode trust and confidence in the real estate industry, making it more difficult for participants to make informed decisions.

The consequences of data asymmetries in real estate transactions can be far-reaching. For buyers, inadequate access to information may result in misinformed investment decisions, potential financial risks, or unforeseen challenges after the purchase. Sellers, on the other hand, may benefit from information asymmetry by maximizing their profits or concealing property flaws. This can lead to dissatisfaction, disputes, and legal issues, negatively impacting the overall reputation of the industry.

Moreover, data asymmetries can perpetuate existing inequalities within the real estate market. For instance, large institutional investors or experienced industry players may have better access to data and resources, enabling them to exploit market inefficiencies and gain a competitive edge over individual buyers or small-scale investors. This can further widen the wealth gap and limit opportunities for aspiring participants to enter or thrive in the real estate industry.

Addressing data asymmetries is crucial for fostering a fair and efficient real estate market. One approach is to promote enhanced data transparency and accessibility. By implementing standardized data protocols,

centralizing information sources, and ensuring equal access for all stakeholders, the industry can mitigate the adverse effects of data asymmetry. This includes providing comprehensive property information, market data, and transaction history to enable informed decision-making and level the playing field for all participants.

Emerging technologies such as artificial intelligence (AI) and blockchain can also contribute to reducing data asymmetries. AI-powered analytics can process vast amounts of data and provide valuable insights to all market participants, enabling them to make data-driven decisions. With its decentralized and transparent nature, blockchain technology can facilitate secure and immutable storage of property records, ensuring that information is accessible and verifiable by all relevant parties.

The difference between the two concepts which are fragmented data and data asymmetry, can be summarized in the Table 3.

In summary, data asymmetries in the real estate industry have significant implications and consequences for market participants. Unequal access to information can create power imbalances, hinder transparency, and perpetuate inequalities within the market. Addressing these asymmetries through enhanced data transparency, standardized protocols, and emerging technologies is crucial for building a fair, efficient, and inclusive real estate industry. Empowering all stakeholders with equal access

Table 3 Fragmented data and data asymmetry

Data Fragmentation	*Data Asymmetry*
Refers to the situation where data is scattered or divided into multiple sources, systems, or formats	Refers to an imbalance or unequal distribution of information among stakeholders
Arises from the lack of data integration and standardization	Arises from differences in access to information, knowledge, or expertise
Can lead to difficulties in aggregating, analyzing, and utilizing data effectively	Can result in power imbalances, unfair advantages, or disadvantaged positions for certain stakeholders
Focuses on the organization and structure of data	Focuses on the distribution and accessibility of information among stakeholders
Examples: Incomplete property records, inconsistent data formats, duplicated data, and data silos	Examples: Information asymmetry between buyers and sellers, unequal access to market data, and disparities in financial knowledge

to information can foster trust, enhance market efficiency, and promote equal opportunities for all participants.

Example: In a real estate market, sellers possess more information about their properties compared to potential buyers. Sellers may selectively disclose certain information or present it in a biased manner, leading to data asymmetries. Buyers lacking complete and accurate information may make suboptimal decisions or be at a disadvantage during negotiations. Addressing data asymmetries is crucial for creating a fair and transparent real estate market.

3 Trends in Data Standardization and Centralization for Real Estate

Trends in Data Standardization and Centralization for Real Estate are shaping the way data is managed and exchanged within the industry. With the increasing complexity and volume of real estate data, there is a growing recognition of the need for standardized data formats, common data standards, and centralized data sources. These trends aim to improve data accessibility, interoperability, and overall efficiency in the real estate sector.

Trends in Data Standardization and Centralization for Real Estate involve the adoption of practices and technologies aimed at standardizing and centralizing data within the real estate industry. These trends address the challenges posed by fragmented data, which can hinder data exchange, interoperability, and efficient decision-making processes. Here are some key aspects of these trends:

1. **Harmonizing Data Formats**: One of the trends is the movement toward harmonizing data formats in the real estate industry. This involves establishing common data structures, definitions, and schemas that enable consistent representation and interpretation of real estate data. By standardizing data formats, stakeholders can ensure compatibility and seamless integration of data across different platforms and systems.
2. **Establishing Common Data Standards**: Another important trend is developing and adopting common data standards in real estate. These standards define the rules and guidelines for collecting, organizing, and sharing real estate data. They cover various aspects,

including property attributes, transaction information, legal documentation, and market data. Common data standards promote industry consistency, accuracy, and transparency, facilitating easier data exchange and analysis.

3. **Centralizing Data Sources**: Data centralization is a trend that involves consolidating data sources in a centralized repository or platform. This approach aims to overcome the challenges of fragmented data, where information is scattered across various databases, systems, and organizations. By centralizing data sources, stakeholders can access a comprehensive and up-to-date dataset, reducing the need for manual data collection and enabling more efficient analysis and decision-making.
4. **Improving Data Accessibility and Interoperability**: The focus on data standardization and centralization trends aims to enhance data accessibility and interoperability within the real estate industry. By adopting common data formats and centralized data sources, stakeholders can easily share and exchange information, regardless of the systems or platforms they use. This promotes collaboration, streamlines workflows, and facilitates seamless data integration across different stages of real estate transactions and processes.

Overall, the trends in data standardization and centralization for real estate are driven by the recognition of the importance of high-quality, consistent, and easily accessible data. These trends aim to overcome the challenges posed by fragmented data, improve data transparency and accuracy, and enable more efficient and informed decision-making processes in the real estate industry.

Example: A real estate association recognizes the negative impact of fragmented data on its members' operations. They initiate a collaborative effort to establish a centralized data repository that consolidates information from multiple sources. The association bridges the gap created by fragmented data through data-sharing agreements and technological integration, enabling stakeholders to access comprehensive and reliable data for their real estate activities.

Overcoming the implications and challenges of fragmented data in the real estate sector requires a strategic approach and the implementation of various factors. Here are some key factors that can help address fragmented data in the real estate industry:

1. **Data Standardization**: Establishing common data standards and formats is crucial to ensuring consistency and compatibility across different platforms and systems. Stakeholders can overcome data fragmentation by standardizing data elements, definitions, and structures and enabling seamless data exchange and integration.
2. **Centralized Data Repositories**: Centralizing data sources into a single repository or platform provides a unified hub for storing, accessing, and managing real estate data. This centralization eliminates the need to navigate through multiple databases and systems, streamlines data retrieval processes, and reduces the risk of incomplete or inconsistent information.
3. **Data Governance Framework**: Implementing a robust data governance framework helps organizations define clear data ownership, data quality standards, and data management processes. This framework ensures that data is accurately captured, maintained, and shared, mitigating the challenges posed by fragmented and unreliable data.
4. **Interoperability and Integration**: Promoting interoperability between different real estate systems and platforms enables seamless data exchange and integration. APIs (Application Programming Interfaces) and data integration tools play a crucial role in facilitating the flow of data between different systems, minimizing data fragmentation, and improving data accessibility.
5. **Industry Collaboration**: Collaborating with industry stakeholders, including real estate agents, brokers, property developers, and government bodies, is essential to address fragmented data challenges collectively. By establishing industry-wide initiatives, organizations can work together to develop common data standards, share best practices, and promote data integration.
6. **Data Quality Control**: Implementing robust data quality control measures helps ensure that data is accurate, complete, and reliable. This includes conducting regular data audits, validating data sources, and implementing data cleansing and validation processes to minimize errors and inconsistencies in the data.
7. **Data Security and Privacy**: Safeguarding real estate data is crucial to maintain trust and protect sensitive information. Implementing robust security measures, such as encryption, access controls, and data anonymization techniques, helps ensure data security and compliance with privacy regulations.

By considering these factors and adopting a holistic approach, the real estate industry can overcome the implications and challenges of fragmented data. This will lead to enhanced data integrity, improved decision-making processes, and a more efficient and transparent real estate ecosystem.

Example: Realizing the need for data standardization, industry organizations collaborate to develop a common data schema and format that allows for seamless data exchange among different real estate platforms. By adopting a standardized approach, stakeholders can easily integrate their systems, share data, and derive valuable insights, ultimately improving operational efficiency and decision-making processes.

4 Leveraging Technology to Overcome Data Fragmentation in Real Estate in the Real Estate Industry

In today's digital age, data plays a pivotal role in the real estate industry. However, the presence of fragmented data poses significant challenges for market participants. In this chapter, we will explore the role of technology in overcoming data fragmentation in the real estate sector. We will delve into advanced tools, platforms, and data management systems that can be leveraged to integrate and streamline fragmented data sources. By embracing technology-driven solutions, the industry can unlock the potential of data and achieve a more efficient, transparent, and data-driven real estate ecosystem.

4.1 Technology Solutions for Data Integration

Technology solutions for data integration refer to various tools, platforms, and systems that enable the consolidation and harmonization of fragmented data from multiple sources. These solutions are designed to streamline the integration process, improve data quality, and enhance data accessibility and interoperability. Here are some examples of technology solutions for data integration:

1. **Data Integration Platforms**: These platforms provide a centralized hub where data from different sources can be aggregated, transformed, and synchronized. They offer features such as data

mapping, data cleansing, and data validation, allowing for the seamless integration of diverse datasets. Data integration platforms enable organizations to create a unified view of data, reducing redundancies and inconsistencies (Meschini et al., 2022).

2. **Extract, Transform, Load (ETL) Tools**: ETL tools are widely used in data integration processes. They facilitate the extraction of data from various sources, transform it into a standardized format, and load it into a target system (Vassiliadis, 2009). ETL tools automate the data integration process, enabling efficient and reliable data movement across different platforms and databases.
3. **Application Programming Interfaces (APIs)**: APIs allow systems and applications to communicate and share data with each other. By leveraging APIs, organizations can establish seamless connections between different software solutions, enabling the exchange of data in real time. APIs provide a structured, standardized way to integrate data from multiple sources, enhancing data connectivity and interoperability.
4. **Data Virtualization**: Data virtualization is a technology that allows organizations to access and integrate data from various sources without physically moving or replicating the data. It provides a virtual layer that abstracts the complexities of data sources, enabling users to query and retrieve data as if it were stored in a single location. Data virtualization improves data agility, as it eliminates the need for extensive data replication and synchronization.
5. **Master Data Management (MDM) Systems**: MDM systems focus on creating and managing a central repository of master data, which includes core business entities such as customers, products, and properties in the context of real estate. These systems ensure data consistency, accuracy, and governance across different applications and databases (Kuznetsov et al., 2022). MDM systems play a crucial role in data integration by providing a reliable and authoritative source of data for integration purposes.
6. **Cloud-Based Integration Platforms**: Cloud-based integration platforms offer a scalable and flexible solution for data integration. These platforms leverage cloud infrastructure to provide robust integration capabilities, allowing organizations to connect and integrate data from various sources located on-premises or in the cloud (Jin et al., 2018). Cloud-based integration platforms offer enhanced agility, scalability, and cost-effectiveness for data integration initiatives.

By utilizing these technology solutions, organizations can overcome the challenges of data fragmentation and achieve a unified and comprehensive view of data in the real estate industry. These solutions streamline data integration processes, improve data quality, and enable stakeholders to make informed decisions based on accurate and accessible data.

4.2 Artificial Intelligence and Machine Learning in Data Integration

Artificial Intelligence (AI) and Machine Learning (ML) are two powerful technologies that can greatly enhance data integration processes. They offer innovative approaches to automate and optimize various aspects of data integration, improving efficiency, accuracy, and scalability (Conway, 2018). Here's an overview of how AI and ML are utilized in data integration:

1. **Data Mapping and Transformation**: AI and ML algorithms can automatically analyze and understand the structure and semantics of data from different sources. They can learn from existing mappings and transformations to suggest or generate new mappings, reducing the manual effort required in the data integration process. AI and ML techniques can handle complex data formats, identify relationships, and resolve data conflicts or inconsistencies, such as generating new mappings based on existing mappings and patterns between different datasets.
2. **Entity Resolution and Data Deduplication**: When integrating data from multiple sources, it is common to encounter duplicate or redundant records. AI and ML algorithms can be employed to perform entity resolution, which involves identifying and linking similar entities across different datasets. By using advanced similarity matching techniques, these algorithms can detect duplicates, merge records, and create a unified view of entities, enhance data quality, and eliminate redundancies (Li et al., 2020).
3. **Data Cleansing and Quality Improvement**: AI and ML techniques can assist in data cleansing and quality improvement by automatically detecting and correcting errors, inconsistencies, and outliers in the integrated dataset. These algorithms can learn from historical data patterns and apply intelligent data cleansing rules to enhance the accuracy and completeness of the integrated data.

4. **Schema Matching and Integration**: AI and ML algorithms can analyze the schema and structure of data sources to identify potential matches and mappings between different datasets. They can learn from historical integration mappings and schema patterns to provide suggestions or automate the mapping and integration process. This reduces the time and effort required to manually define mappings and ensures more accurate and consistent data integration.

By leveraging AI and ML in data integration, organizations can streamline and accelerate the process, reduce manual effort and errors, improve data quality and consistency, and enable more effective decision-making based on integrated and reliable data. These technologies play a critical role in overcoming the complexities and challenges of data integration in modern data-driven environments.

4.3 Blockchain Technology: A Solution to Fragmented Data in Real Estate and Data Asymmetries

Fragmented data in real estate refers to the dispersed and disjointed nature of information across various platforms, databases, and entities involved in property transactions. This fragmentation leads to inefficiencies, errors, and a lack of trust among participants. Data asymmetries, on the other hand, refer to the unequal distribution of information among different stakeholders, which can create power imbalances and hinder fair and transparent transactions.

Blockchain technology offers several key advantages that can address these challenges:

1. **Data Integrity**: Blockchain provides a tamper-proof and transparent ledger where data records are stored in a decentralized manner (Bharambe et al., 2023). Each transaction or data entry is cryptographically linked to previous entries, creating an unchangeable chain of information. This ensures the integrity and immutability of real estate data, reducing the risk of fraudulent activities, data manipulation, and disputes.
2. **Transparency and Trust**: With blockchain, all participants have access to the same set of verified data, eliminating the need for intermediaries and reducing information asymmetries. Transactions

and changes to property records are recorded on the blockchain, allowing for real-time visibility and transparency. This enhances trust among stakeholders and reduces the reliance on third-party intermediaries.

3. **Smart Contracts**: Blockchain technology enables the use of smart contracts, which are self-executing agreements with predefined conditions and automated actions. Smart contracts can streamline real estate transactions by automating processes such as property transfers, escrow payments, and title transfers (Mohanta & Jena, 2018). This eliminates the need for manual paperwork, reduces the risk of errors, and increases the speed and efficiency of transactions.
4. **Tokenization of Assets**: Blockchain facilitates the tokenization of real estate assets, representing ownership or investment interests as digital tokens on the blockchain. This allows for fractional ownership, increased liquidity, and easier transferability of real estate assets. Tokenization opens up new avenues for crowdfunding, real estate investment trusts (REITs), and secondary markets, making real estate investments more accessible and inclusive (Smith & Vora, 2019).
5. **Enhanced Data Security**: Blockchain technology employs advanced cryptographic algorithms to secure data and transactions. With its decentralized nature, blockchain eliminates single points of failure and reduces the vulnerability to cyber-attacks. This enhances the overall security of real estate data and protects sensitive information, such as personal details, financial records, and property ownership records.
6. **Immutable Data Storage**: Blockchain is a decentralized and distributed ledger that records transactions in a secure and immutable manner. Data stored on the blockchain cannot be altered or tampered with, providing high data integrity. In the context of data integration, blockchain can be used to store and verify integrated data, ensuring its immutability and authenticity.
7. **Consensus Mechanisms**: Blockchain relies on consensus mechanisms, such as Proof of Work (PoW) or Proof of Stake (PoS), to validate and agree on the state of the ledger. This consensus ensures that all participants in the network have a shared and consistent view of the data. By leveraging consensus mechanisms, blockchain can facilitate data interoperability by enabling different parties to access and trust a single, unified source of data.

8. **Data Provenance and Auditing**: Blockchain provides a transparent and auditable record of data transactions and changes. Each transaction is timestamped, linked to previous transactions, and stored across multiple nodes in the network. This allows for a comprehensive data provenance trail, making tracking the origin, ownership, and changes made to the data easier. Blockchain-based data provenance enhances data integrity and enables auditing capabilities in the data integration process.

The disadvantages of utilizing Blockchain in Real Estate Transactions can be found in the Table 4.

It's important to consider these advantages and disadvantages when evaluating the implementation of blockchain in real estate transactions.

Table 4 Disadvantage of utilizing Blockchain in Real Estate

Disadvantage	*Explanation*
Scalability	Blockchain technology currently faces scalability challenges, limiting its ability to handle a high volume of transactions simultaneously
Adoption Challenges	Widespread adoption of blockchain in the real estate industry may face resistance and require significant coordination among stakeholders
Regulatory and Legal Considerations	The legal and regulatory frameworks surrounding blockchain in real estate transactions are still evolving, presenting challenges and uncertainties
Technical Complexity	Implementing and integrating blockchain technology into existing systems may require specialized expertise and investment in infrastructure
Privacy Concerns	The transparent nature of blockchain may raise privacy concerns regarding sensitive information
Energy Consumption	Blockchain technology, particularly in public networks, can consume a significant amount of energy, posing environmental concerns
Education and Awareness	The successful adoption of blockchain requires education and awareness among professionals to understand its potential benefits and limitations

The real estate industry can overcome data integrity and interoperability challenges by leveraging blockchain technology. Blockchain provides a secure, transparent, and decentralized infrastructure that ensures the integrity of integrated data, facilitates data interoperability, and enables trusted and efficient data exchanges among different stakeholders.

Example: A real estate brokerage firm adopts a cloud-based data management system that enables seamless integration of fragmented data from multiple listing services, property databases, and transaction platforms. The technology provides data cleansing, normalization, and integration functionalities, resulting in a centralized and consistent data repository. By leveraging technology, the firm minimizes data fragmentation, enhances data accuracy, and improves operational efficiency.

Examples of blockchain applications in the real estate industry include:

- **Property Title Management**: Blockchain can provide a secure and transparent platform for recording and verifying property titles. This eliminates the need for manual title searches and reduces the risk of fraudulent title transfers.
- **Land Registry Systems**: Blockchain-based land registries can improve the efficiency and accuracy of land record management. By digitizing land records on the blockchain, stakeholders can access verified and up-to-date information, reducing the chances of disputes and improving land governance.
- **Real Estate Crowdfunding**: Blockchain enables the tokenization of real estate assets, allowing fractional ownership and crowdfunding of properties. This opens up opportunities for smaller investors to participate in real estate projects and enhances liquidity in the market.
- **Identity Verification**: Blockchain can be used for secure identity verification, streamlining the KYC (Know Your Customer) process in real estate transactions. This enhances due diligence and reduces the risk of identity theft and fraud.

Blockchain technology has the potential to revolutionize the real estate industry by addressing the challenges of fragmented data and data asymmetries. By leveraging blockchain, stakeholders can achieve greater transparency and efficiency.

Example: A consortium of real estate companies collaborates to develop a blockchain-based platform for property transactions. By leveraging blockchain technology, the platform ensures that property information, ownership records, and transaction details are stored in a secure and transparent manner. This eliminates the problem of fragmented data by providing a single, trusted source of information accessible to all stakeholders, including buyers, sellers, and regulators.

5 Closing the Information Gap: Strategies for Minimizing Data Fragmentation and Data Asymmetries

Closing the information gap is vital for minimizing data fragmentation and data asymmetries in various industries, including real estate. Several strategies can be implemented to address these challenges and promote a more transparent and efficient marketplace.

Firstly, establishing data-sharing platforms and standardized data formats can help minimize data fragmentation. Creating centralized databases that aggregate information from different sources allows stakeholders to access comprehensive data in one location. Additionally, adopting standardized data formats ensures compatibility and ease of integration across various systems, reducing the fragmentation of information. Secondly, leveraging technology and data analytics tools can facilitate data integration and analysis. Advanced technologies such as artificial intelligence and machine learning can process and analyze vast amounts of data, providing valuable insights and patterns. Real estate professionals can utilize these tools to consolidate fragmented data, uncover hidden trends, and gain a holistic understanding of the market. Furthermore, promoting data transparency and open access is crucial for minimizing data asymmetries. Implementing regulations and industry standards that require the disclosure of relevant property information helps level the playing field for all parties involved. Real estate agents and intermediaries should strive to provide accurate and up-to-date information to potential buyers, ensuring fair and informed decision-making. Moreover, increasing data literacy among industry professionals and consumers is essential. Stakeholders can navigate through fragmented data more effectively by enhancing their understanding of data analysis and interpretation. This includes providing training and educational resources to real estate agents, enabling them to

leverage data-driven insights and communicate transparently with clients. Lastly, collaboration among stakeholders is key to closing the information gap. Real estate companies, industry associations, and government entities can collaborate to consolidate data and promote transparency by fostering partnerships and data-sharing agreements. Sharing best practices and collaborating on data standards will contribute to a more unified and accessible data ecosystem.

5.1 Empowering Stakeholders Through Accessible and Consistent Real Estate Data

In the digital era, access to reliable and timely data is crucial for stakeholders in the real estate industry to make informed decisions and effectively navigate the market. The title "Empowering Stakeholders through Accessible and Consistent Real Estate Data" emphasizes the importance of providing stakeholders with accessible and consistent data to enhance their decision-making capabilities. In this section, we delve into the strategies and technologies that empower stakeholders by ensuring they have the necessary tools and information at their disposal.

1. **Centralized Data Platforms**: Implementing centralized data platforms allows stakeholders, such as buyers, sellers, agents, and investors, to access a comprehensive repository of real estate data. These platforms serve as a one-stop hub where users can retrieve property listings, market trends, historical data, and other relevant information. By aggregating data from various sources and presenting it in a user-friendly manner, these platforms enable stakeholders to analyze market conditions and make data-driven decisions.
2. **Open Data Initiatives**: Open data initiatives aim to make real estate data publicly available and easily accessible to a wide range of stakeholders. Governments, municipalities, and real estate organizations can release datasets on property transactions, zoning regulations, property valuations, and other relevant information. By promoting open data policies, stakeholders gain access to comprehensive and up-to-date data that fosters transparency, innovation, and informed decision-making.
3. **Data Standardization**: Standardizing real estate data formats and terminology is crucial for ensuring consistency and comparability

across the industry. By establishing common data standards, stakeholders can easily exchange and integrate data from different sources. This promotes interoperability and enhances the quality and reliability of the information available to stakeholders, reducing confusion and facilitating efficient data analysis.

4. **Real-Time Data Updates**: Providing real-time data updates ensures that stakeholders have access to the most current and accurate information. Technologies such as application programming interfaces (APIs) and data feeds enable stakeholders to receive real-time updates on property listings, market trends, and other relevant data. This empowers stakeholders to make timely decisions based on the latest information, giving them a competitive edge in the market.
5. **Data Visualization and Analytics Tools**: Utilizing data visualization and analytics tools enables stakeholders to derive meaningful insights from complex real estate data. These tools present data in visually appealing and interactive formats, making it easier for stakeholders to understand market trends, property performance, and investment opportunities. These tools enhance their decision-making capabilities by empowering stakeholders to explore and analyze data intuitively.
6. **Mobile Applications**: Mobile applications tailored for the real estate industry provide stakeholders with on-the-go access to data and tools. These applications allow users to search for properties, view property details, access market insights, and even communicate with agents or brokers. By harnessing the power of mobile technology, stakeholders can access and utilize real estate data anytime and anywhere, empowering them to make informed decisions on the move.
7. **Data Privacy and Security Measures**: Ensuring the privacy and security of real estate data is crucial to building trust among stakeholders. Implementing robust data protection measures, including encryption, access controls, and secure storage, helps safeguard sensitive information. Stakeholders can confidently engage with accessible data platforms knowing that their data is protected, enhancing their willingness to participate and contribute to the real estate market.

By empowering stakeholders through accessible and consistent real estate data, the industry can foster transparency, innovation, and efficiency. Providing stakeholders with the necessary tools and information allows them to confidently make well-informed decisions, seize opportunities, and navigate the real estate landscape. Ultimately, empowering stakeholders through data accessibility strengthens the overall integrity and effectiveness of the real estate market.

Example: A government regulatory body mandates all real estate agencies to adhere to standardized data formats and reporting requirements when submitting property information. By enforcing data standardization, the regulatory body ensures that all market participants have equal access to accurate and consistent data. This approach helps eliminate unfair advantages or disadvantages and promotes fair competition in the real estate industry.

5.2 Blockchain Case Studies and Real-World Examples

Several real-world examples demonstrate the successful implementation of blockchain in the real estate industry:

- **Propy**: Propy is a blockchain-based platform that enables cross-border real estate transactions. It uses smart contracts to automate the purchase process, record ownership on the blockchain, and facilitate secure and transparent transactions. Propy has completed multiple real estate deals, including the first blockchain-based property transfer in the United States (Mohanta & Jena, 2018).
- **Ubitquity**: Ubitquity is a blockchain-based platform that offers secure title recording and management solutions. It enables the recording of property titles on the blockchain, providing an immutable and transparent record of ownership. Ubitquity has partnered with governments and title companies to streamline title transfer processes and reduce fraud (Spielman, 2016).
- **BitRent**: BitRent is a blockchain-based platform that focuses on real estate development and investment. It allows investors to participate in real estate projects through tokenization, enabling fractional ownership and liquidity (Business et al., 2019). Blockchain ensures transparency, security, and accurate distribution of profits among stakeholders.

- **Deedcoin**: Deedcoin uses blockchain technology to revolutionize the real estate commission structure. It allows buyers and sellers to connect directly with real estate agents, eliminating the need for traditional brokerage intermediaries (Kibet et al., 2019). By utilizing smart contracts and decentralized networks, Deedcoin reduces costs and increases transparency in real estate transactions.
- **ChromaWay**: ChromaWay is a blockchain company that has implemented blockchain solutions for land registry systems. For example, they partnered with the Swedish Land Registry to develop a blockchain-based platform for registering and managing property transactions. This system improves the efficiency of property transfers and enhances transparency and trust in the land registration process (Yu et al., 2020).
- **Harbor**: a blockchain platform that offers tokenization solutions for real estate assets, allowing property owners to tokenize their properties and offer investment opportunities to a broader range of investors. This enables fractional ownership and simplifies the process of buying, selling, and trading real estate assets.
- **Sweden's Lantmäteriet**: the national land registry authority, has piloted a blockchain project to digitize and store property records. By digitizing land titles on the blockchain, they have significantly reduced the fragmentation and inefficiencies associated with paper-based records, enabling seamless access and verification of property data (Mcmurren et al., 2018).

Therefore, blockchain technology offers promising solutions to address the real estate industry's fragmented data landscape and information asymmetries. Through applications such as blockchain-based transactions, property management, smart contracts, and crowdfunding, real estate transactions can become more efficient, transparent, and secure. With continued innovation and adoption, blockchain has the potential to reshape the future of real estate.

6 Summary

Fragmented data landscape and data asymmetries are related challenges in the real estate industry but are distinct. A fragmented data landscape refers to the lack of standardization and centralization of data across the various stakeholders involved in real estate transactions, including buyers, sellers,

agents, brokers, and other service providers. This can make it difficult to access and analyze data and can lead to inefficiencies, inconsistencies, and errors in real estate transactions. At the same time, data asymmetries refer to situations where one party in a real estate transaction has more or better information than the other party. For example, a seller may have access to more detailed information about a property's history and condition than a buyer, or a real estate agent may have more market data and insights than a client. These information imbalances can create challenges for the less informed party in negotiating the transaction and may lead to unfair or unfavorable outcomes.

The solution to the problem of the fragmented data landscape and data asymmetries in the real estate industry involves several strategies. First, data integration and standardization play a vital role in consolidating fragmented data from various sources. Stakeholders can access comprehensive and consistent information in a centralized repository by implementing data-sharing platforms and standardized data formats. Second, the adoption of advanced technologies such as artificial intelligence and machine learning helps process and analyze large volumes of data, uncovering valuable insights and patterns. This enables a more holistic view of the real estate market and minimizes data asymmetries. Transparency and disclosure practices are also essential in reducing data asymmetries. Real estate agents and intermediaries should provide accurate and up-to-date information to potential buyers, promoting a level playing field. Collaboration among industry stakeholders and the establishment of common data standards and frameworks further contribute to reducing fragmentation and enhancing transparency. Additionally, increasing data literacy among real estate professionals and consumers through training and educational resources enables more effective navigation of fragmented data. Lastly, the implementation of blockchain technology can address data fragmentation by creating a decentralized and immutable ledger for real estate transactions. This promotes secure and transparent data sharing, reducing information gaps and enhancing trust among participants. By implementing these solutions, the real estate industry can mitigate the challenges of fragmented data and data asymmetries, fostering a more transparent and efficient marketplace.

By acknowledging and delving into these intricate challenges, we set the foundation for exploring their profound impact on real estate transactions. Understanding the detrimental effects of fragmented data and data asymmetries can motivate stakeholders to address these issues proactively.

By striving for greater standardization, centralization, and accessibility of data, the industry can improve operational efficiency, reduce errors, and facilitate smoother transactions. Moreover, promoting transparency and equal access to information can level the playing field, fostering fairer outcomes and greater trust among all parties involved in real estate dealings. Through these efforts, the real estate industry can pave the way for more streamlined, efficient, and equitable processes that benefit everyone involved.

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Digital Building Logbook—The Mother Use Case for Blockchain in Real Estate

Jo Bronckers

A question I have often been asked over the past few years is: What is now an example of a good use case for blockchain in the real estate industry? Asking the question, experience has taught me, immediately prompts a counter-question to its author, namely: To what extent are you familiar with the uses of blockchain technology in real estate processes? Unfortunately, it then quickly becomes apparent that the level of knowledge varies widely between us and, as a result, this knowledge gap affects the imagination of the value that blockchain technology can add to information exchange in real estate processes. This common situation is the reason for me to approach this chapter as an exploratory study, in which I will substantiate why I believe a Digital Building Logbook is the mother-use case for blockchain in real estate. I will provide a reasoned answer to this from my own practical experience, supplemented by scientific and applied research.

In this chapter, I will successively address and answer the following questions:

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1. What is a Digital Building Logbook (DBL)?
2. How does blockchain add significant value to a DBL?
3. Why is DBL the Mother Use Case for Blockchain in Real Estate?

1 Context: A Car Maintenance Book Versus a DBL

Suppose you want to buy a used car and have a choice of two identical vehicles. Vehicle A has a perfectly kept service book, showing exactly at what mileage what maintenance was carried out and that this was always done by the relevant brand dealer with all invoices also attached as further specification. Vehicle B also has a service booklet, but it documents sporadic life-cycle events, carried out without further specification by various unknown garages and only occasionally provided with an odometer reading. Which of the two vehicles are you willing to pay more for? (Image 1).

This example illustrates the value of keeping proper records of an investment property. Strange that we seem to have forgotten this when it comes to real estate, even though real estate often involves much larger investments.

Thirty years ago, when digitisation of the real estate sector was still in its infancy, building owners stored all relevant documentation about their buildings in binders that were stored together in a steel cupboard. Anytime the landlord needed something from his property, he would go to this steel cupboard and have all the relevant information quickly to hand on paper.

With the digitisation of the property industry over the past decades, a lot of paper-based information has been converted into digital information and stored in a variety of software systems. Digitisation enabled building owners to outsource non-core business activities, thus creating new business opportunities for suppliers who could further specialise in specific aspects of property management. As a result, property owners in fact pay to have third parties store information about their buildings in a structured way, but in proprietary databases of third parties. Lease contracts and financial management information were housed in property management platforms. Design drawings, maintenance plans and changes to a building ended up in architects' BIM systems or

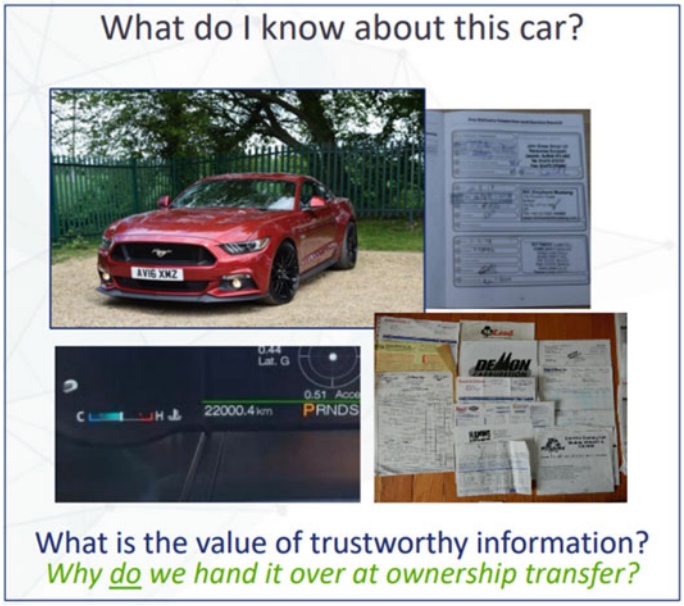

Image 1 Car performance and maintenance documentation (*Source* www.recheck.io)

in municipal zoning databases. Construction and maintenance companies recorded their supply-chain information in their own ERP systems. Property situations were increasingly digitised in cadastral registrations. Operational building information was collected in Building management systems (BMS). And so on (Image 2).

Where once all essential information could be found in that one steel cabinet, now the owner has to tap into various third-party systems, platforms and databases to complete the puzzle again. Indeed, often the owner has to pay again when he wants to receive his own information back or make it available to other third parties to work with it. Increasingly, property owners long for a return to the days when they had all the relevant information available in their steel cabinet at the time one needed it. A DBL may well provide the solution in this regard.

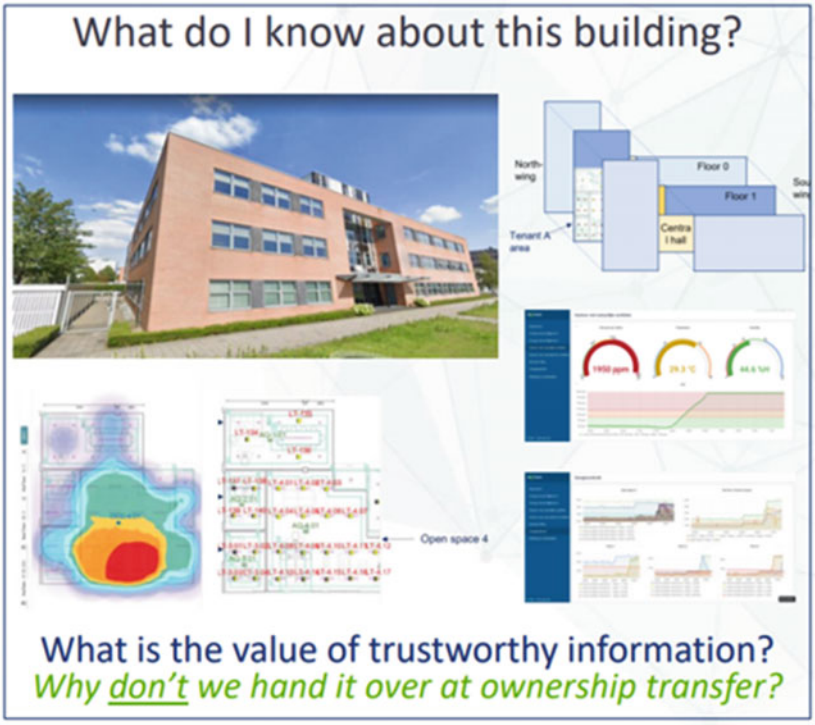

Image 2 Building performance documentation (*Source* www.recheck.io)

Finally, it is surprising to note that the moment a car is sold, it is common and results in a higher price when all known historical information gets transferred with it to the new owner. In contrast, when buildings are transferred from one owner to another we accept that much of the collected information does not go with it and as a result it gets lost during the life cycle of the building. Even for the new owner, this often means starting again from scratch to pull together relevant information on the building's history, maintenance, and performance. It obviously does not yet affect the market price of the building. But how long will it remain like this?

2 What Is a DBL?

To properly answer the question of what a DBL is, I will divide it into several sub-questions that will be answered successively in this section. To start with, we will make a comparison with a digital twin to answer the question to what extent a DBL is different from existing software systems used to manage buildings. Then, once it is clear in which a DBL is different from those existing systems, the question is asked who the key users of a DBL are and for what purpose. Finally, the question can then be asked what costs are involved in realising a DBL for a building and to what extent these costs can be recovered. So, the last question is about the revenue model of a DBL.

In fact, a DBL is an example of a digital twin of a particular building. Digital twins in the built environment range from basic to complex and are categorised into five types as shown below (Image 3):

Digital twins need not attempt to mirror everything about the original system. What is essential is the need to develop digital twins that are fit for purpose, while the level of fidelity will vary depending on the primary use cases.

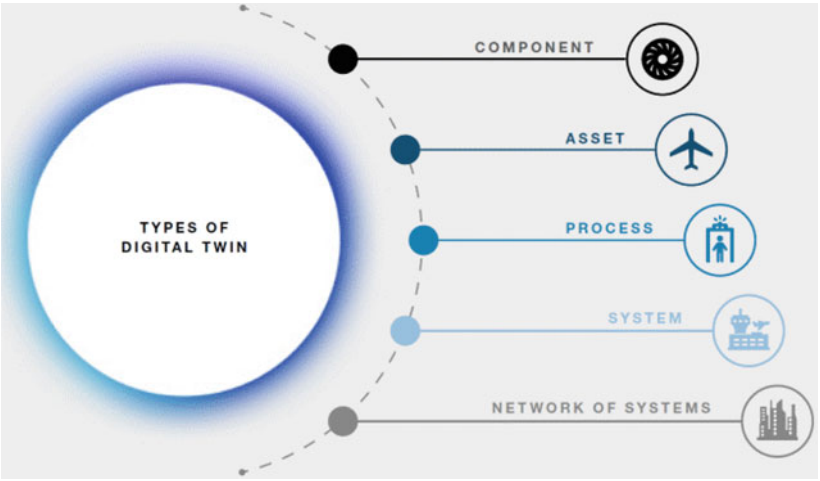

Image 3 Types of digital twins (*Source* theconstructor.org)

2.1 *Wherein Does a DBL Differ from Existing Data- and Software Systems?*

In general, a digital twin is a virtual/digital replica of physical objects such as devices, processes, or systems that help companies make model-driven decisions. The purpose of a digital twin is to perform cost-effective simulations. These examples are time-consuming and costly to simulate without a digital twin, which is why data scientists and IT professionals use real-time data to develop digital models that mimic real-world assets in the digital space. The digital twin technology uses IoT sensors, log files, and other relevant information to collect real-world data for the accurate modelling of assets. Market research by MarketsandMarkets (MarketsandMarkets, 2020) forecasts an explosive growth of the market for digital twins in all industries worldwide. The Digital Twin Market was valued at USD 3.1 billion in 2020 and is expected to reach USD 48.2 billion by 2026, at a CAGR of 58% from 2020 to 2026. According to this research automotive and transportation is the largest industry sector for digital twinning and the market for system digital twin accounts for the largest market share. For example, in the automotive and transportation industry, Tesla Motors is using a digital twin solution for every car it manufactures for better performance and business improvement. Gartner (2022) even predicts in February 2022 that the market will develop four times faster: 'The digital twin market will cross the chasm in 2026 to reach $183 billion in revenue by 2031, with composite digital twins presenting the largest opportunity.' The big question remains to what extent this also applies to market developments for digital twins in the built environment?

Digital twins are relatively new in the architecture, engineering, construction, and operation (AECO) industry, and therefore several ambiguities exist in terms of the concept, applications, and integration of digital twins with existing technologies used in the industry. Many people compare a DBL with BIM, but strictly that is not correct. A DBL is far more comprehensive than a BIM representation of the building in question. In other words: BIM-data can be part of a DBL, where a DBL can't be part of a BIM. In their research 'Digital Twins in Built Environments' (Shahzad et al., 2022), Muhammad Shahzad of the Foundation Property Management in Abu Dhabi, describe the main differences. They describe 17 characteristics that, according to their research, are present in DBLs but absent in BIM, ranging from real-time representation of operational data to enhanced site logistics.

Besides BIM, there are often more software and data platforms in use for managing a building as an asset or the operational activities inside a building. Think of property management systems for managing contractual obligations between building owners, tenants, and suppliers. Think also of a Building management system with operational performance data from installations in the building (Image 4).

Collecting data from different sources has several challenges. First, the data must be able to be brought into the DBL. Is the data machine readable? Different data exchange standards and data protocols are used in the market. Think of LoRaWAN (https://lora-alliance.org/about-lorawan/), Modbus (https://modbus.org/), BACnet (https://bacnet.org/), M-Bus (https://m-bus.com/), MQTT (https://mqtt.org/), and many more. A DBL is thus ideally compatible with the most common data standards.

To be able to convert the available data into useful information that can then be combined with other useful information, it is important to know exactly what the data refers to, for which in data management terminology identifiers and ontologies are used. Worldwide, there are many different methods used to identify a building or its components. Some use a cadastral registration number of the building, others use street name and house number, others have their own project number or utility connection number, and so on. Not every identifier relates to the same scale level, making it difficult to compare

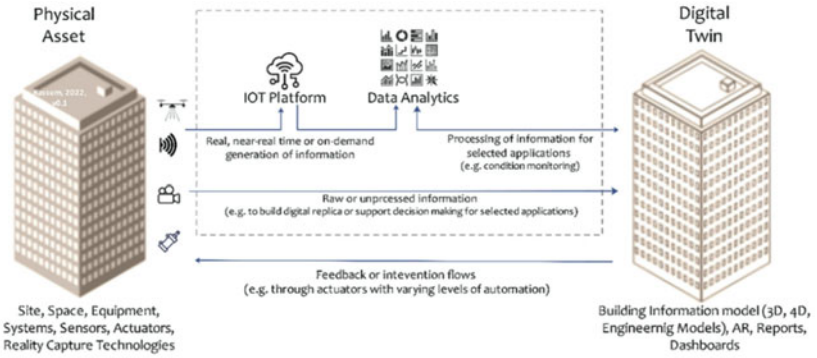

Image 4 A DBL collects data from various sources and aggregates them in one digital twin, the DBL of the building in question (*Source* Shahzad et al.)

information coming from different sources. Within one and the same country, dozens of formats are soon used interchangeably and, internationally, there are thousands of different methods. And when exchanging data between different countries this complexity grows exponentially. Universal applicable uniform identifiers and ontologies for enhanced machine-enabled interpretation of data from so many different sources can be of great value. Different ontologies are available to help structure data about buildings. Examples include SAREF4BLDG (https://saref.etsi.org/saref4bldg/v1.1.2/), Brickschema (https://brickschema.org/ontology/), Haystack (https://project-haystack.org/doc/docHaystack/Ontology), Google Digital Buildings (https://google.github.io/digitalbuildings/ontology/), and more. Not all data sources are already providing these more advanced data structuring solutions, although there is a wide consensus that this could be of great value for the entire sector.

The need for data and information arises throughout the life cycle, but there is especially high demand for certain types of information like operational performance (energy performance certificate/actual energy consumption, or greenhouse gas emissions), information for disclosures (detailed results of a sustainability assessment, energy label), material inventory (type, quantity, quality of materials installed, risks for health and environment), and Evidence on various topics (systematic commissioning, maintenance, repairs, resistance to natural hazards, satisfaction of users).

Building and construction of life-cycle activities that typically give rise to the demand for data. Traditionally, regarding information demand, there are certain important moments in the life cycle of a building. Some of these moments occur only once or a few times like design and realisation, purchase/investment, insurance, sale/divesting, and demolition. Others are more frequent like letting, valuation, repair/renovation, reporting, or maintenance. In the current market, the data needed too often are still not available, not accessible, or not usable or reliable due to inadequate data processing at earlier stages in the life cycle.

Muhammad Shahzad et al. (2022) conclude in their research paper: 'The challenges facing the implementation of digital twins are related to the availability of technology and the complexity of technological systems constituting digital twins; lack of common data standards and tools, data security, and ownership; workforce upskilling; and the necessity for systemic cultural change.'

Another recent study conducted by Gómez-Gil, M., et al. and published in the *Journal of Building Engineering* (2023) comes to similar conclusions, when examining the challenges of applying a DBL in Spain or Italy. In their study, they examined the effect of data quality at the input side of a DBL to the data quality at the output side. This paper analyses the sources that currently exist in Spain and Italy, focusing respectively on Aragon and Lombardy region, and addressing their interoperability possibilities and the indicators collected (Image 5).

However much relevant DBL data is available in existing digital sources (40% in Spain, 35% in Italy), there is a big lack of interoperability of data.

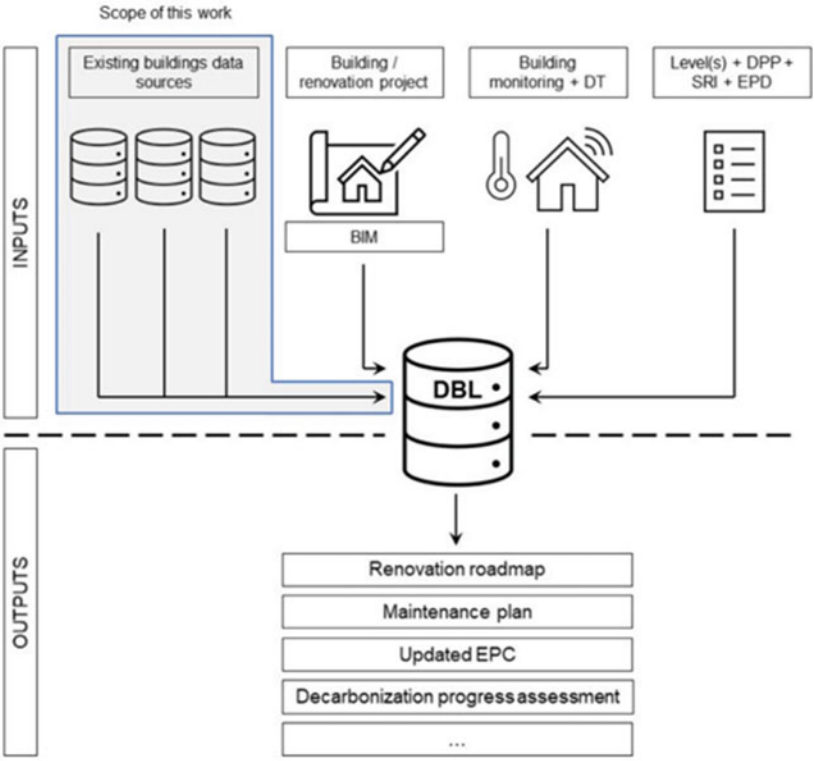

Image 5 Proposal of inputs and outputs of the Digital Building Logbook (DBL) as gateway by Gómez-Gil, M., et al. (https://thisismagma.com/)

However, some of the data sources are interoperable in both countries, and important sources like the cadastres of Spain and Italy are not at all providing interoperable data. Crucial data sources (are not yet available) regardless of the fact that open data is encouraged in both countries. The study gives general guidelines for the implementation of a DBL at a European scale:

- Data collection should be made better accessible and structured in a more uniform way with better transparency on data quality. With a demand for many new data, this is of growing importance.
- Future-proof interoperability features are needed to avoid the burdens of API-management with a fast-growing number of sources delivering an exponentially growing amount of data.
- A token-based authentication system is highly recommended with uniform identifiers and ontologies making data better machine-readable.

In solving many of these challenges, blockchain can be of tremendous help, as will be discussed later in this chapter. Before we dive into that, the different key users and their purposes of using a DBL will be described in the next section.

2.2 Who Are the Key Users of a DBL?

In the previous section, it became clear that a DBL integrates information coming from other software platforms that process and generate specific information regarding the building. The architect, builder, and maintenance contractor will often work in BIM, or in their own system. The property manager will use his property management system, the government uses its system to manage building information, and the facility manager uses another system. With so many different systems already in use, what does a DBL add? To get a better understanding, it is important to know who the different stakeholders are that might be users of a DBL in the built environment.

The built environment has many different stakeholders operating at different stages of the building life cycle. In her research, Hazal Şimşek (2022) identifies 5 top use cases for digital twins in the real estate industry. When closer examining these use cases it becomes obvious there

are many different users expected to experience benefits from a DBL. The most important stakeholders regarding the use of a DBL are described below:

- Building owners: private and public entities acting as individual or institutional stakeholders. Their role can be widely different. Think of owner-occupier, landlord, housing company, REIT, asset- or property manager, seller, buyer, and many more.
- Tenants and users of the building: users of the building, who interact with all available equipment and information to fulfil their basic need for an optimised safe, comfortable, efficient, and affordable housing of their daily activities.
- Government agencies in their role as legislators and regulators: local governments, national governments, and statistical offices.
- Real estate developers: initiative takers managing the different stakeholders involved in the planning and realisation phase.
- Service providers during design and construction: designers, engineers, consultants.
- Construction service providers: contractors, builders, craftsmen, and finishers.
- Real estate services providers: real estate brokers, property managers, facility managers.
- Service providers during operation: facility managers, cleaning and maintenance service providers, utility companies, or emergency services.
- Assessors and consultants: sustainability assessors, compliance managers, LCA specialists, and sustainability certifiers.

This wide diversity of users shows once more that uniformity of standards to enhance data interoperability and improved data security for sharing data in a trusted way are of major importance to reduce management, operating, and maintenance costs. When data is considered to be of strategic value at the initial stage, well-structured data infrastructure can bring many benefits to the different stakeholders along the building's life cycle. Maintenance and utilities account for approximately 27% of the operating expenses of a real estate firm. A DBL can help real estate companies cut operating costs by up to 35%, while improving living standards and fostering sustainability (Şimşek, 2022).

In their white paper on digital twins (2022), RICS adds some additional important future purposes on sustainability performance disclosure and ESG-data collection as an additional realm where a DBL can have significant advantages for real estate managers: '*Digital twins are expected to develop as a critical tool in all phases of the asset life cycle. Environmental, social and governance requirements are increasingly challenging to fulfil without a whole-of-life view of a construction project and the resulting asset.*'

Sustainability performance is a fast-growing topic in de real estate industry. Constructors, Banks, Developers, and Investors need to deliver more and more proof of how their buildings contribute to the goals of the Paris Climate Agreement, or at least data that show that a building does not significantly harm the environment. It means that entirely new datasets and sources need to be sourced. Most of the data about the sustainability performance of a building will be needed to be disclosed on an annual basis. As long as commercial real estate data remains siloed and disparate without a common language to standardise information collection and sharing, the challenge of aggregating and processing a fast-growing amount of data in an efficient way is rapidly becoming a serious business issue. Currently, real estate and property managers are spending a lot of their time to aggregate this information manually from all those different databases, platforms, and systems with all their different identifiers and formats. And next year this administrative burden will return, and after another year it returns, and again and again. A smart strategic investment in a DBL could well make much of this annual workload a thing of the past for building owners for good. And they are rapidly realising that!

In their survey conducted in Q3 2021 (2022), RICS received input from almost 200 real estate and construction professionals. When asked to select the top three current uses or possible future uses of digital twins in the design and construction phase, 54.4% of the respondents selected 'Facilitating data sharing to deliver performance efficiencies for all stakeholders' as their top choice (see Images 5 and 6).

Thinking about this in more detail, the question of who is responsible for bringing up to standard and continuously maintaining the desired data quality in such a multi-stakeholder and multi-purpose landscape quickly arises, as well as how access to a DBL's de and authorisations to edit or verify data should be arranged. Ideally, one would expect that the data

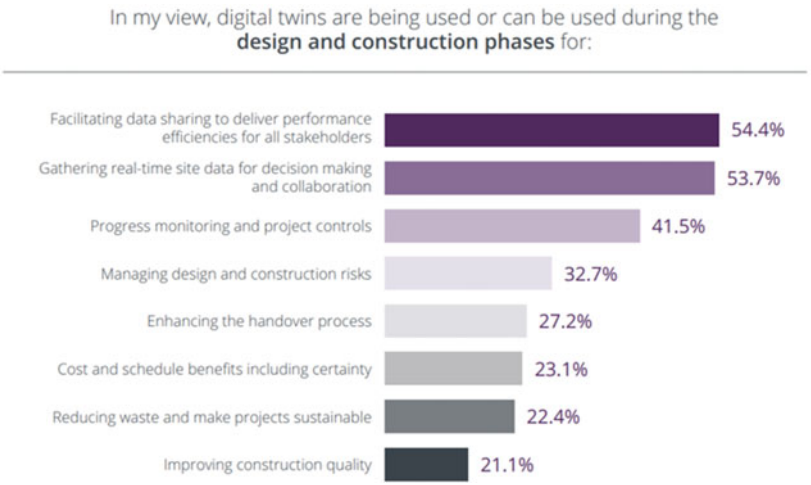

Image 6 Current use of digital twins (*Source* RICS UK-survey Q3 2021)

belonging to the property in question should be owned by the property owner. And that this property owner should also be responsible for maintaining data quality and managing access rights and editing authorisations. In today's fragmented data landscape, data resides in external sources and is often owned by the external software party. They often see having data as an additional revenue model and thus try to keep ownership of the data with them in their siloes, rather than transferring it back to the building owner. This is due to the increasing displeasure of the building owner. Once building owners are offered a better alternative that can put them back in charge of all their relevant building data, they are likely to welcome it with open arms.

3 How Does Blockchain Add Significant Value to a DBL?

Before diving into how blockchain technology can add value to a DBL, let's first shine a light on how a DBL at all adds value to the building construction and management industry.

3.1 The Added Value of a DBL

In a podcast about digital twins, broadcasted on 3 October 2022, McKinsey-partner Kimberly Borden talks about the value digital twins can add to business processes (McKinsey & Company, 2022). Although she commits that the topic is still in its infancy in many industries, she literally says: 'There is a tremendous amount of value a digital twin can bring. One of the biggest areas of value is reducing time to market, development time. It allows for rapid iterations and optimizations of product designs far faster than physically testing every single prototype. Further, it often results in tremendous improvements in product quality, as you can imagine. These can be through the manufacturing process, meaning that after you simulate the product in manufacturing, it'll allow you to see where there are flaws in the design and adjust that. Further, in service you can see how the design may not be functioning appropriately, and therefore you can redesign it in real time. Finally, increases in revenue of as much as 10% are seen by developing customer twins that allow customers to fully interact and immerse themselves within the product. Daimler, for example, has done that very nicely to allow customers to test-drive the vehicle ahead of ever getting in a car.'

When projecting these values to the AECO industry of buildings, one doesn't need a lot of imagination on how the same values can get unlocked.

These added values are not only seen from a business perspective but also the governments see the potential added value of DBL's. In Europe, for example, a DBL is being seen as one of the key contributors to realising the desired disclosure and supervision on the ecological footprint of the built environment. The European Commission (EC) is committed to achieving climate neutrality by 2050 and has set ambitious targets to reduce greenhouse emissions (GHG) by at least 55% before 2030. The Energy Performance of Buildings Directive (EPBD) is an important part of the EC's plans to reach these goals, as existing buildings in Europe currently account for 40% of energy consumption and 36% of all GHG emissions in the EU. Through building renovation, not only can the eco-footprint be reduced, but new jobs can be created, depopulation of urban centres can be addressed, excessive rents in cities can be reduced, and historic buildings can be preserved. This effort can also boost economic growth in the region.

Besides the EBPD, the European legal framework is developing rapidly, which will have a major impact beyond Europe. New European directives such as CSRD (https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en) and SFDR (https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en) demand increasing transparency and disclosure from investors, but also from users of buildings regarding the sustainability contribution of their investments in the built environment. As a result, an information chain is set in motion that will also force the suppliers of relevant parties, even if they are located outside Europe, to provide more data on the sustainability character of the products and services they supply (Image 7).

To complete this section on the added value of a DBL, I went in search of financial parameters. Although there is still little experience in the application of DBLs, there have been some interesting explorations in this area. For instance, in an internet publication on the Consulting Engineer Survivor (Lengthorn, 2020), Paul Lengthorn Chartered Engineer, MBA, BEng, member of the Institute of Asset Management (IAM), and independent practicing Consulting Engineer calculates a Return-on-Investment period of DBLs for 7 different building types, ranging from a prime office building through a hospital to a distribution centre. Based on

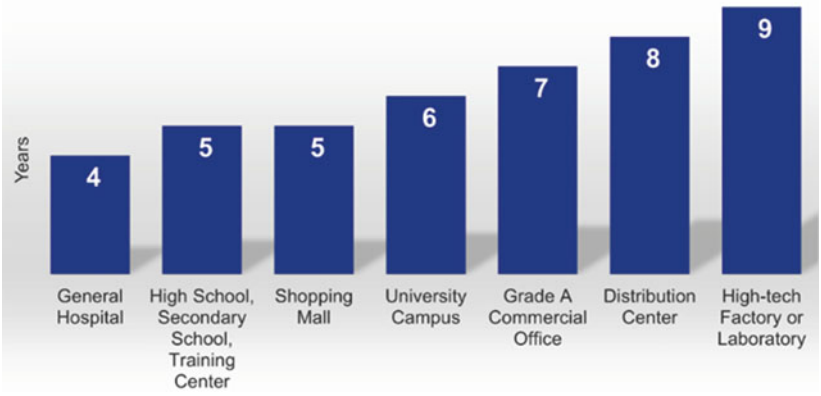

Image 7 Payback period of DBL investments for different building types (*Source* P. Lengthorn)

current spending on consulting and property management improvements, he calculates what the budget is for a DBL. He then sets this against the cost of implementation to arrive at an ROI indication per. Based on his assumptions, he arrives at a payback period for DBL investments of between 4 (general hospital) and 9 years (high-tech factory or lab). As an outsider, it is difficult to validate the assumptions and outcomes of these ROI calculations. Thus, for follow-up research, it is highly recommended to make and compare more of these types of calculations to get a better sense and broader consensus on the profitability of investing in DBLs. However, one thing can already be stated: once the market starts using DBLs more, it is highly plausible that marginal costs will fall rapidly. After all, with an easily scalable digital model, the R&D costs that preceded its development can be shared across a rapidly growing group of users. Knowing that around 5 years are relatively short periods for a building life cycle, the payback periods described by Lengthorn (2020) thus offer an attractive prospect for relatively rapid and widespread market adoption of DBLs in the coming YEARS, provided the main obstacles can be resolved.

3.2 The Added Value of Blockchain to a DBL

To a certain extent many of the current challenges described in this article can be countered with application of advanced technologies, like blockchain. Using the general guidelines for the implementation of a DBL at a European scale, described earlier (Gómez-Gil et al., 2023), we can peel off the current data challenges and identify how blockchain technology can add value for each criterion. By using findings from our own research conducted at FIBREE this section describes how this will work. Let's first have a look at the examples from our own practice that we will be referring to later on.

3.3 FIBREE's Unique Object Identification Methodology at the Core of Blockchain-Based Value Add

With respect to solving data-interoperability challenges, FIBREE conducted a fundamental research project in 2019 together with a 360-degree representation of market players in de real estate and construction industry that was supported by the Dutch government. Convinced that blockchain could make a lot more sense in the real estate industry if data

interoperability could be brought to a higher level first and observing that the many existing initiatives were not applying a truly industry-wide approach, was the driver to start this endeavour. The main research question was if and how a uniform identification methodology could be introduced to enhance data operability between all public and private sources that are often using different identifiers for (parts of) the same building. Via desk research many examples elsewhere in the world were deeply investigated, concluding that an identification layer with a content-independent open-source methodology would be of great added value to the industry. Also concluding that such a methodology was at that moment nowhere available. Based on these findings, FIBREE developed a so-called Unique Object Identifier (UOI) methodology (FIBREE, 2020). The result is an open source and universal applicable identification-methodology intended to provide a uniform identification linking code and ontology to data coming from different sources. Exactly like a bar-code or QR-code, the UOI methodology is open and available to be used by anyone who intends to improve data interoperability of real estate data. It respects all existing identifiers and can easily be added as a connector code to other databases, also dramatically reducing the need for costly API-management at later stages (Image 8).

This UOI solution addresses one of the most fundamental challenges to achieving a DBL, namely the standardisation of the properties' identification parameters.

The ever-increasing amount of digital data—both the number of accessible sources and the collected data history cause this increase—creates a growing data management problem. In the current situation, many data

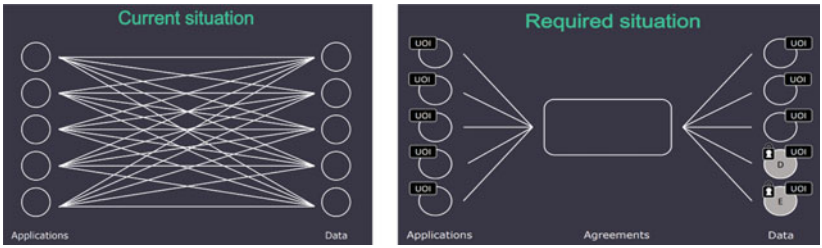

Image 8 Unique Object Identifier (UOI) by FIBREE for enhanced data interoperability

are exchanged between different databases or software systems with so-called Application Programming Interfaces (API). However, as soon as one of the databases or software systems is replaced or a new one is added, the whole API landscape needs to be checked and updates need to be made to restore interoperability. Furthermore, it will be essential that all connected applications and sources can exchange data in an automated way. To create such an automated ecosystem for data, a sophisticated data-infrastructure layer can be extremely valuable. Information not only needs to be findable in each of the connected sources, it should also be made accessible, interoperable, and reusable by other applications. At the core of such an ecosystem, the combination of universal applicable unique object identifiers (UOI) together with a common ontology for semantic interpretation by machines plays an important role. It enables keeping data in so-called 'single sources of truth' on various levels of detail from different systems uniform interoperable, comparable with other data, and reusable.

It won't be rocket science to understand a UOI needs to be able to identify parts of a building in more than the two-dimensions we know from land title registrations or addresses. In addition, another extremely important real estate-specific challenge is to keep data together throughout the entire life cycle of a building. A building often has a very long lifespan in which far-reaching changes in the information structure can regularly take place. Think, for example, of splitting or merging objects. This often results in a break in the historical information chain of the object in question. It is precisely these life-cycle events that were considered when developing the UOI, and information can now be kept together digitally in a relatively simple manner using the UOI system as a four-dimensional identification methodology applicable to any built structure in the world.

The core of the UOI system consists of a meronomy of identifiers that can help structure the various spatial scales in which data occurs in data sources and software systems. By means of properties and ontologies, machine readability is unified and by means of so-called blockchain hashes, the various sub-UOIs in the relevant building meronomy are linked to the parent UOI. Or, in the case of life-cycle events, the set of UOIs belonging to the old situation is linked with a blockchain hash to a new set of UOIs representing the new situation. In this way, the UOI has become a simple and universally applicable 128-bit code—similar to a QR code—that can be added to any database and software system as a

universal linking code as an additional field. The growing complexity of API management can thus, in theory, if everyone decides to join in, be reduced to a very manageable and manageable situation in which only one API remains. After all, both from every data source and every receiving application, only the API to the universal UOI linking code is needed.

The main added value of this blockchain-based UOI methodology for DBLs is that data is made interoperable and can be easily aggregated from different scales and sources in a central place, e.g. a DBL. Also, the UOI methodology ensures that, despite life-cycle events, a historical data set can be created and combined there to generate in-depth analyses and insights about the building in question. By equating the Mother-UOI with the official title registry of the physical building, the UOI methodology facilitates the creation of a DBL as a real digital twin of the object in question.

3.4 Other Blockchain Value Add

At FIBREE we see a growing number of our corporate members focussing on the development of DBL-solutions by embedding blockchain technology.

Magma (https://thisismagma.com/), a supplier of such blockchain-based DBL solutions, offers Platform as a Service that allows you to experience a one-of-a-kind four-dimensional digital twin (3D Space + Time Model) of your building. This digital twin features the ability to record all the contractual and architectural documentation validated by the building's stakeholders. So obviously the dimension of time plays an important role in DBLs.

Another supplier of blockchain-based DBL-solutions, ReCheck (https://recheck.io/), mentions structuring and interoperability of data as an important value of a blockchain-based DBL, so increased transparency and reliability of data can be used to be shared with stakeholders for multiple purposes or for easing disclosure and reporting on property performances. Because ReCheck was also involved as a tech-partner in various UOI-pilots, it is no coincidence that their DBL solution is compatible to the UOI methodology.

Both Magma and ReCheck mention the validation of data that trigger contractual clauses, and preservation of data with the building along its lifecycle as important values a blockchain-based DBL creates. Both are capitalising on the potential of blockchain technology to solve for specific

privacy-sensitive data, aggregating the data to achieve GDPR compliance while maintaining data trust from the source. Last but not least, cyber security gets a lot of attention. Both are using tokenised data-access and -share features to enable the data owner to allow controlled data exchange with key stakeholders. With hashes to the blockchain, the authenticity of data entries and output can be easily verified by anyone who needs to know it.

When the specific blockchain applications applied by these two examples are compared with the general guidelines for DBLs as described by Gómez-Gil, M., et al. (2023), it is noticeable that, combined with the UOI methodology, all formulated guidelines and challenges are completely addressed.

New relevant datasets and software systems or sensors can now be aggregated in a structured way and added to the central DBL database of the concerned building. Data exchange can be fully GDPR-compliant between any public or privately hosted database. Using the UOI methodology, the data-gathering process takes place in a homogeneous manner. The combination of UOI with access and editing authorisations is guaranteed by the software providers. Standardisation of the properties' identification parameters is made possible. And with token-based authentication systems verified access and permissions can be granted by the DBL-owner in a customised way to all third parties. Solving issues related to data-privacy and data-ownership is also part of the blockchain-based DBL solutions.

In fact, the practical examples mentioned above make it clear that blockchain technology can bridge the gap towards wider adoption of value-added DBLs. However, just because the last hurdle has been cleared at the technology level does not mean that the market will immediately embrace it and adopt it widely. Perhaps the biggest problem for adoption is much more the lack of know-how and the general unfamiliarity that exists in the construction and real estate market with the strategic value that data can have and how technology can already enable the industry to quickly exploit this strategic value. In other words, expressed in Everett-Rogers' terminology appropriate to the theory of diffusion of innovations (2003): the challenge will be the leap from being a new, little-known, and exploratory product, to mass adoption and well-known status.

From a scientific and societal point of view, it is highly recommended to embrace the pioneers in this field and set up different small and larger pilot projects together with them, continue to conduct ongoing

scientific research around these pilot projects, and thus convince market players and governments, on the basis of well-founded and proven good working solutions, of the added value that UOI- and blockchain-based DBL-solutions offer in the time to come.

4 Why Is DBL the Mother Use Case for Blockchain in Real Estate?

Property is the world's biggest asset class, with a lack of digitisation to date—this bricks-and-mortar industry still stubbornly relies on Excel and emails. This creates both a problem and an opportunity.

Building a real estate property takes a lot of planning and coordination between stakeholders, after all, a building is often meant to perform its function for many decades in a particular environment. It involves large investments with long durations. But every investment object also has to be sold one day. This means that even at the design & construction stage, careful thought must be given to possible life-cycle events in operation or even at the end of a building's life cycle and how to deal with them. Managing real estate therefore means being able to look far ahead and assess both short-term and long-term risks to anticipate them in time. In managing real estate risks, having trustworthy data and up-to-date information and transparency is key. The image demonstrates how in the hierarchic real estate management system a large amount of data sourced 'at the floor' of a property will be aggregated from operational, up to tactical and strategic decision-making levels. What the image clearly shows is that the higher the management level is, the lower the amount of data is, while the reliability-necessity and required data quality of information increases (Image 9).

It also becomes obvious that there are many different data-sources and stakeholders involved in the hierarchical real estate process, who all do something with the data, but above all can do their work more efficiently the moment they have access to high-quality data always supporting their processes. Think about architects, municipalities, construction companies, subcontractors, investors, banks, appraisers, maintenance engineers, demolition companies, and so on. Each contributes to their own processes to enrich the information available about the building.

A research paper Proptech 3.0: The future of real estate (Baum, 2017) devotes an entire chapter to the value blockchain can bring to the real estate market. The report states the following about the value

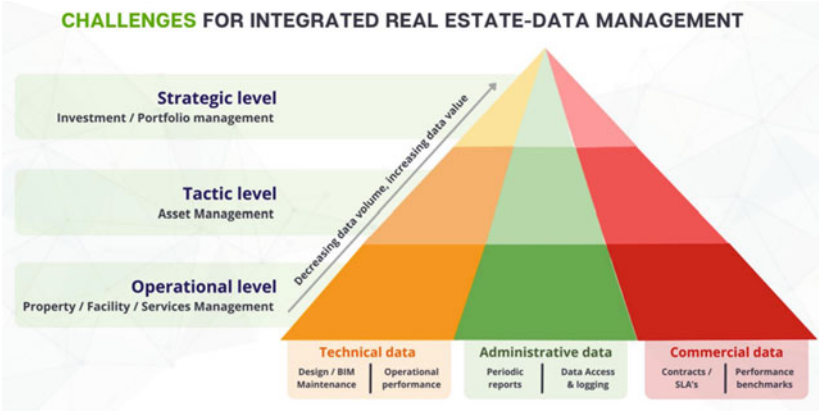

Image 9 Challenges for integrated real estate data-management (*Source* ReCheck.io)

of Blockchain technology has the potential to revolutionise the real estate industry. It can create trust-based interactions that will replace centralised institutions and enable peer-to-peer collaboration. Data quality is improved by blockchain protocols, and its international scope allows for international data-exchange standards to be created. Disintermediation, fraud prevention, digital currency, smart contracts, faster transactions, and lower costs are all potential benefits that blockchain could bring to the real estate market. Despite these advantages, security and fraud prevention remain serious issues that must be addressed (Image 10).

With a fast-growing amount of digitally available data about a building—besides a fast-growing number of digital data sources, also coming from ever more historical data—the challenge to work efficiently with all these data is growing exponentially. The traditional way of working in which data is often still verified manually is becoming increasingly complex and expensive. Here a DBL, and more particular a blockchain-based DBL, can become the core of a way more efficiency and data-driven real estate and construction industry. For example, like already mentioned before, operating expenses of a real estate firm can be cut by up to 35%, while improving living standards and fostering sustainability (Şimşek, 2022). In the same digits, it may be expected this will also work for all the other roles in the real estate and construction industry chain

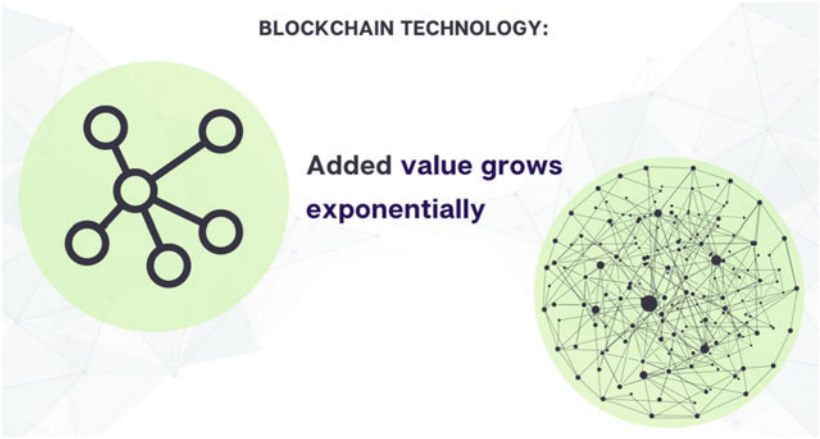

Image 10 The added value of blockchain technology (*Source* ReCheck.io)

once the challenges of a DBL can be solved, for example by applying blockchain technology. Architects, owners, (sub)contractors, and all the other roles involved can then more efficiently collaborate and share and update their reliable data about the building how it is designed, how it is permitted, how it is built, being used and maintained, being retrofitted, or being disassembled at the end of a usage phase. When a DBL can hold the most relevant data about a building in one single place along its entire life cycle and when this information can easily be transferred to successive owners of the building, at the same moment the legal ownership of the physical asset is being transferred at a notary's office, a DBL for every building can be considered as the 'golden thread' of information. Blockchain can add exponentially growing value in that perspective because data can be certified with a hash to a blockchain at the moment they are sourced or being processed. This way the DBL will be created as a 'single source of truth' that benefits all.

4.1 Why the Mother Use Case?

Besides DBLs, there are many more applications in commercial real estate where blockchain technology can add value (see Chapter 4), such as tokenised investing and financing, land title registrations, automation of

transactions and building maintenance, and more. What all these applications have in common is that in the core, risk management plays an important role. And to manage these risks right, having the right information in a trustworthy way available is at the core of adding a lot of value to existing processes with DBLs. Every real estate token investor wants to understand the risks of his investment, no matter how fragmented his investment in a property will be. A blockchain-based digital building logbook can easily provide access to all token holders but also revoke it when the token is being sold. A DBL can make an important contribution to make token providers comply with their duty of care to retail investors. By law, consumers investing in real estate must be adequately informed by the real estate token provider about the characteristics and risks of their investment, the so-called legal duty of care.

But there are more reasons why DBL can be considered the mother-use case for blockchain in real estate. Some of the blockchain applications for real estate still face significant regulatory burdens. These burdens will very likely cause significant delays in wide market adoption. Creating a DBL is hardly hampered by complicating laws and regulations, so adoption can start instantly and does not rely on getting legal approval first. It is only the handling of privacy-sensitive information that affects a DBL, but when the information gathering is with a UOI only connected to different parts of a building and not at all to a certain person, this will remove many data privacy burdens. For the remaining GDPR compliance blockchain technology in combination with UOI can be valuable in anchoring trust in data from the source, while taking the data itself to a higher level of aggregation from a privacy sensitivity perspective. A DBL won't be able to remove all regulatory hurdles for real estate token providers, but it can be of great value to achieve data compliance.

4.2 What Is the Industry Then Waiting For?

The commercial real estate sector will have to recognise and embrace the strategic value of high data quality for this to happen. However, that would mean a fundamental cultural shift in this industry, which is one of the least digitised of all industries. Such a transition will not happen automatically, the 'coalition of the willing' will experience resistance from fewer change-makers, so it will take its time and demands considerable patience.

Demonstrating the undisputed benefits that DBLs deliver to its pioneers and then educating real estate professionals with these learnings and the know-how can provide significant acceleration in this regard. If the industry manages to become more open to the adoption of digitisation and cutting-edge technologies like blockchain technology more specifically, I am convinced that a DBL may well become the mother-use case for blockchain in real estate. So, the question for me is not if, but mainly when the market will be open to this.

The near future will tell us.

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Land Title Solutions Across The World With Blockchain: A Review

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1 Introduction

Land titles establish ownership or rights to a property or land (Ali, 2016; Essougong, 2019; Njoh, 2018) and are used to transfer ownership or grant land use rights. They typically include information about the owner, land location, size, boundaries (Ehwi, 2016; Gollapalli, 2020), and encumbrances or rights (Latorre, 2015). Land titles are registered through government agencies like land registries or title offices (Benbunan-Fich, 2018; Konashevych, 2021; Murtazashvili, 2016).

Registering land titles is vital for the economy, landowners, citizens and investors. It establishes property rights, encourages land investment and increases access to credit (Gao, 2021; Green, 2019; Kan, 2021; Newman, 2015). Thus, land title registration can positively affect

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economic activity, land use and productivity (Newman, 2015). It is also crucial to landowners as it provides a legal framework to protect against fraudulent claims, boundary disputes and other issues that may arise due to unclear land ownership (di Ciccio et al., 2019; Gollapalli, 2020; Karrupusamy et al., 2019; Nandi, 2020). A formal land title can facilitate access to credit, land transfer, future planning (Green, 2019; Karrupusamy et al., 2019; Menon, 2017) and ensure equitable land distribution and access for citizens, particularly for marginalized communities (Bhateja et al., 2021; Nasarre-Aznar, 2018). Moreover, investors benefit from increased investor confidence which leads to economic growth (Kubitza, 2018; McCarthy, 2018; Newman, 2015; Saull, 2020).

Although land title administration is vital for the economy, landowners, citizens and investors, it suffers numerous challenges globally. Acquiring and managing land titles can be inefficient and complicated in many countries as shown in various studies (Alam, 2022; Gupta, 2019; Nandi, 2020; Njoh, 2018; Saari, 2022; Wouda, 2019). For example, in Cameroon, the land title administration process involves at least six institutional bodies and numerous members and committees (Nandi, 2020; Njoh, 2018). Inefficient data quality and unstructured, non-digital and non-standardized data exacerbate the problems of land title administration (Wouda, 2019). Furthermore, the cumbersome and lengthy land title administration process involves multiple government bodies and different types of documentation, making it more challenging to manage (Alam, 2022). Abdulai (2006) and Saull (2020) document that land registration can also be costly and time-consuming (e.g. in the United Kingdom). These inefficiencies in land title administration can be attributed to the paper-based systems used to manage land titles, which are challenging to access and maintain and are vulnerable to natural and human disasters (Benbunan-Fich, 2018).

Additionally, Abdulai (2006) reports that land conflicts exist globally, with conflict rates of 15% in the Philippines and 10% in Honduras. Incomplete documentation leads to disputes over land ownership among many landowners worldwide (Mintah, 2020; Murtazashvili, 2016; Yapicioglu, 2020). In the United States[1] and Australia (Arruñada, 2018), land registration faces challenges such as fraud, public record errors and property boundary disputes which lead to conflicts over ownership and title. In

[1] Retrieved from https://www.alta.org/media/pdf/CH01.pdf (accessed on 25.02.2023).

Kenya, many people need formal titles to their land, making it difficult to access credit, sell or transfer property and resolve disputes over ownership (Wily, 2018). Moreover, historical injustices such as colonialism and land grabs have also contributed to ongoing disputes over land ownership and usage (Chiaravalloti, 2017; Gupta, 2020; Kan, 2021).

Differing land ownership laws pose another issue since these vary significantly between countries and regions, being influenced by history, culture, geography and politics, making it challenging to establish a uniform legal framework (Arruñada, 2018; di Ciccio et al., 2019; McCarthy, 2018). In some countries, the legal framework for land titles is fragmented and inconsistent due to various government bodies initiating laws independently and rarely collaborating (Essougong, 2019; McCarthy, 2018). According to Latorre (2015), certain nations have chosen to omit impoverished individuals and their belongings from the legal system governing land titles. This exclusion has resulted in instability, disputes and a lack of confidence in land registrations, particularly when multiple owners are given rights to the same land. In China, on the other hand, the state owns land titles while individuals and businesses can acquire long-term leases for land use. However, the government has faced allegations of employing eminent domain to seize land without providing adequate compensation and this has sparked protests and social unrest (Gao, 2021; Kan, 2021). These examples signify the prevalence of diverse land ownership laws that disrupt both the stability and control of land ownership matters.

Worst still, the prevalence of corruption and bribery hinders the procurement of clear and secure land titles in some countries. For instance, governmental officials may demand bribes or engage in fraudulent practices to alter land titles which lead to legal challenges (Alam, 2022; Ehwi, 2016; Gollapalli, 2020; Singh, 2020). Njoh (2018) defines bribery as an illegal payment to process land title registration and legal titling fees. In the Southern continent of America, such as Brazil, land titles are registered with the government but corruption and disputes over indigenous land rights typically plague the system. As a result, many people require formal titles to their land, making it difficult to access credit, sell or transfer property and resolve disputes over ownership (Chiaravalloti, 2017; Fetzer & Marden, 2017).

Finally, the advent of the COVID-19 pandemic which had negatively impacted global economies due to lockdowns and movement restrictions (Jagun et al., 2022) had intensified the challenges in completing

registration procedures for land titles which required additional workforce—showing that such a calamity can adversely affect the real estate industry, land and properties (Balemi et al., 2021; Jiang, 2021).

In this connection, the use of various technologies have shown to improve land title registration, management efficiency and accuracy, while reducing fraud and disputes over ownership, as well as increasing transparency and accountability (Gupta, 2019; Zulkifli et al., 2015), ultimately promoting economic development and social stability (Abdulai, 2006). For instance, some countries are adopting digital land registries that use computerized systems to manage land titles and related information which improves accuracy, accessibility and transparency and minimizes paperwork and processing times (Mintah, 2020; Rodima-Taylor, 2021). In addition, the Geographic Information System (GIS) is also being deployed as a technology to map and analyze land data, such as property boundaries, zoning regulations and land use patterns to improve land planning and management (Gao, 2021). Mobile applications are yet another technique to access land titles and related information such as land boundaries, land use regulations and ownership history. These are especially useful in areas with limited access to physical documents (Suganthe, 2021).

Of particular interest here, however, is the blockchain ledger system. Blockchain can safely record and verify transactions with blocks, nodes, consensus protocol, cryptography, smart contract and distributed ledgers. It offers a decentralized system (Benbunan-Fich, 2018; Dutta, 2020; S. Wang, 2018) to decrease fraud and disputes in land ownership while enhancing the transparency and security of land titles (Ali, 2019; di Ciccio et al., 2019; Monrat et al., 2019). Its application is seen across industries such as finance, healthcare (Deloitte, 2018) and logistics since it can provide a reliable and transparent way of recording and verifying transactions (Dutta, 2020; Kouhizadeh et al., 2021; Monrat et al., 2019). Xie et al. (2019) define the distributed ledger as a "decentralised database maintained by several nodes over a peer-to-peer network"—making it resistant to hacking and fraud (Karrupusamy et al., 2019; Monrat et al., 2019).

The usefulness of blockchain in this topic thus motivates the formulation of the following four research questions to determine how blockchain technology fills land title challenges and issues: (1) How does blockchain resolve land title issues worldwide? (2) How does blockchain manage land title elements worldwide? (3) How does blockchain achieve land title

benefits worldwide? (4) How are blockchain technology challenges dealt with and what are the proposed solutions?

The results of this study have several practical contributions for regulators—namely, maintaining transparency and accountability in land title administration, reducing the incidence of fraudulent activities, strengthening the verification, documentation and record-keeping processes and enhancing security and trust among landowners. The findings will also clarify for investors on the importance of blockchain in land title registration as it can prevent fraudulent activities, reduce the time and cost involved in land title administration, simplifies land ownership verification and improves access to finance.

2 Literature Review

Section 2 of the study examines the literature on land titles and blockchain. Section 2.1 covers the main components of land titles, such as land title's elements, benefits and significance of land titles, regulations and investment, and the pandemic's impact on the land titles. Section 2.2 discusses the concepts, features, benefits and challenges of blockchain technology, while Sect. 2.3 explores its applications in land titles globally.

2.1 Land Titles

2.1.1 Elements

Land titles have seven essential elements. These include identifying the land's location, boundaries, size, identity number, land type, price and other distinguishing details (Ehwi, 2016; Gollapalli, 2020). Ownership information (Gollapalli, 2020) such as previous, current and co-owners, is the second element. The third element is liens and encumbrances such as outstanding mortgages or other claims that could affect ownership or value (Krupa, 2019). The fourth element includes restrictions and easements (Abdulai, 2006; Saari, 2022; Zulkifli et al., 2015) which cover legal limitations on land use and any rights of the way other parties may have. The fifth element constitutes transfer history (Pongnumkul, 2020) which includes all previous ownership transfers and relevant information. The sixth element is the legal description of the land (Kan, 2021; Wily, 2018) which meets the jurisdiction's requirements, while the seventh element involves the signature and seal of the owner, relevant parties and the issuing authority (Latorre, 2015).

2.1.2 *Benefits and Significance*

A Land title offers three main benefits for landowners: proof of ownership (Abdulai, 2006; Murtazashvili, 2016), protection against fraud (Essougong, 2019; McCarthy, 2018) and access to credit and financing facilities (Green, 2019; Menon, 2017; Probst, 2020). Land title registration protects against fraudulent sales and transfers of property, as well as enhances the land's value by giving buyers or investors' confidence in the land's clear and legal ownership history (Green, 2019; Lai, 2017). Additionally, landowners with land titles can use their land as collateral for loans and other financial services which is an essential requirement for investing and developing land.

2.1.3 *Regulation and Investments*

Land title regulation encompasses laws, policies and procedures (Abubakari, 2018; McCarthy, 2018) that govern land ownership and transfer, ensuring transparent, secure and reliable land ownership. Properly regulated land titles are essential for safe real estate investment (Abdulai, 2006; Menon, 2017; Newman, 2015) as unregulated land titles can lead to disputes and title defects. Land title regulation assures investors that land titles are legitimate and secure (Abdulai, 2006; McCarthy, 2018; Murtazashvili, 2016) and prevents fraud and illegal activities (Krishnapriya, 2020) such as selling land without ownership. It also promotes transparency and accountability in land ownership by ensuring correct documentation of land transactions and ownership history, thus protecting the interests of all parties involved (Wily, 2018; Zulkifli et al., 2015).

2.1.4 *Implications of Pandemics on Land Titles*

The COVID-19 pandemic has had complex and varied implications on land titles, affecting landowners and investors. It has caused delays in processing land title applications since government offices and land registries have temporarily shut down or were short-staffed (Jagun et al., 2022). The calamity had also disrupted land transactions (Zeng & Yi, 2022) with many people losing jobs or experiencing reduced income (Balemi et al., 2021) and needing assistance to buy or sell properties. The changes in land values had additionally impacted the value of land used as collateral for loans and this influenced land titles (Balemi et al., 2021). Scammers and fraudsters on the other hand leverage the situation by exploiting the vulnerabilities in the property market (Y. Zhang et al.,

2022). Governments worldwide responded by introducing measures to mitigate the impact of COVID-19 on their economies which involved changes to the legal and regulatory frameworks such as temporary moratoriums on eviction or foreclosure proceedings which otherwise may have affected the rights of property owners and lenders.

2.2 Blockchain Technology

2.2.1 Concepts

A block is a digital record of transactions added to the blockchain. Each block contains a unique code (a hash), identifying it, as well as the previous block in the chain (Karrupusamy et al., 2019; Krishnapriya, 2020; Li et al., 2020; R. Zhang, 2019). According to R. Zhang (2019), the hash value represents a block cryptographic image and serves as a cryptographic linkage to the previous block in the blockchain. Once a block is added to the blockchain, it cannot be altered or deleted (Cole, 2019; Makhdoom, 2019; Y. Wang, 2019a). The nodes are individual computers or servers in the blockchain network (Lemieux, 2016). Each node has a copy of the entire blockchain ledger (a collection of blocks) and validates transactions (Monrat et al., 2019; R. Zhang, 2019).

Blockchain technology uses a consensus protocol to add transactions inside the blocks. It is a set of rules that governs how transactions are validated and added to the blockchain (di Ciccio et al., 2019; R. Zhang, 2019). The most common consensus protocol is called Proof-of-Work (PoW) which requires nodes to solve complex mathematical equations to validate transactions by miners (Salah, 2019).

Miners are peers who use their computational power skills to mine for blocks in the blockchain. Their nodes need to solve a computational puzzle and then publish the block. The miner who solves the puzzle first will win and obtain the opportunity to create a new block. Incentives will be given to miners upon successfully creating a new block. Typically, miners use a consensus protocol to publish and validate the transactions (Monrat et al., 2019; Zheng, 2018).

Cryptography is the science of encrypting and decrypting information. Blockchain technology uses cryptography to secure transactions and prevent fraud (Feng et al., 2019). It provides a “trustless network” mechanism to avoid intermediaries (Ali, 2019), by encrypting a transaction using a private key, and only the intended recipient can decrypt it using their public key.

Furthermore, blockchain uses smart contracts based on Ethereum (Li et al., 2020). S. Wang (2019) defines smart contracts as "the computer protocols that digitally facilitate, verify and enforce the contracts made between two or more parties on blockchain". Smart contracts are self-executing contracts with the terms of an agreement between buyer and seller being directly written into lines of code. They allow for the automated and secure execution of complex business transactions without intermediaries (Li et al., 2020; Xie et al., 2019; Zheng, 2018).

2.2.2 Features

Blockchain technology is known for its key features that enhance security, transparency and decentralization, making it potentially transformative for various industries. With the evolution of blockchain technology, innovative use cases and applications are expected to emerge. Due to its decentralized nature, blockchain is less vulnerable to fraud and other cybersecurity threats (Ali, 2019; McGhin, 2019). Furthermore, the transparency of all transactions allows for enhanced accountability and a decreased likelihood of corruption, as stated by Wang (2019b). The technology is well-suited for applications where security and data privacy are paramount (Dutta, 2020; R. Zhang, 2019), including financial transactions and healthcare records. Additionally, using cryptographic algorithms ensures high security (Salah, 2019) and once a transaction is added to the blockchain it becomes immutable (Ali, 2019; Kouhizadeh et al., 2021). Due to its ability to ensure data integrity, blockchain is highly suitable for various applications, including real estate transactions, supply chain management and safeguarding intellectual property rights.

2.2.3 Benefits

Blockchain technology offers substantial advantages and holds the potential to catalyze revolutionary shifts in diverse industries. Among its primary merits is the capacity to minimize expenses by eliminating intermediaries and reducing transaction durations, as affirmed by Casino (2019), Xie et al. (2019) and Zheng (2020). Since blockchain technology streamlines processes, removing intermediaries such as banks or brokers and, ultimately, fee reductions are made possible. This is particularly beneficial in finance, where fees may be high.

Furthermore, blockchain technology helps to improve efficiency by automating processes and reducing the time required for manual tasks (Dutta, 2020; Kouhizadeh et al., 2021; Pongnumkul, 2020; Y. Wang,

2019a). This contributes to reducing errors and improving productivity, particularly when concerning supply chain management and real estate industries.

2.2.4 Challenges

While blockchain technology has the potential to bring about significant benefits, its challenges must be addressed to enable its widespread adoption. Three main problems are discussed here. One of the biggest challenges facing blockchain technology is scalability (Makhdoom, 2019; Monrat et al., 2019; Sengupta, 2020; Xie et al., 2019; Zheng, 2018). As the number of transactions on the blockchain increases, the network can become congested. This decelerates transaction time and increases fees, making it difficult for blockchain to compete with traditional centralized systems pertaining to speed and scalability.

Interoperability shapes a second challenge (Ali, 2019; Casino, 2019; McGhin, 2019; Monrat et al., 2019). Interoperability is critical for widespread blockchain technology adoption as it allows seamless integration between different systems. However, there are currently many blockchain platforms, each with its protocols and standards. Therefore, transferring data or assets between different blockchains is problematic. Each blockchain platform typically has unique protocols, consensus mechanisms and data structures. This diversity in blockchain technologies makes establishing direct communication and transferring assets between blockchains difficult. Furthermore, regulating this diversity is another challenge (Dutta, 2020; Gürkaynak, 2018; Saari, 2022).

In conclusion, the validation of transactions and the upkeep of the network in blockchain technology necessitate substantial computational resources (Dutta, 2020; Li et al., 2020; Panarello, 2018; Salah, 2019). Consequently, blockchain can consume considerable energy, especially when employing proof-of-work (PoW) consensus algorithms. The high energy consumption of blockchain technology has led to serious concerns about its environmental impact and sustainability issues (Cole, 2019; Y. Wang, 2019b).

2.3 Blockchain Applications in Land Title

2.3.1 Ghana

Ghana is one of the countries that has implemented blockchain technology in its land title registration system (Ehwi, 2016). One of the major

challenges it faced was the need for more trust among stakeholders in the land administration sector (Ameyaw & de Vries, 2020). The country has been struggling with land title issues such as fraud, double sales and lack of transparency (di Ciccio et al., 2019; Mintah, 2020; Rodima-Taylor, 2021). According to Eder (2019), 80% of all land registries in Ghana are undocumented, making it easier for expropriation and fraud. The implementation of blockchain technology in the land title registration system addresses such a challenge.

Thus, in 2019 Ghanaian government launched a pilot project to test the use of blockchain technology for land title registration. The project, conducted in two regions of the country, involved collaborations with stakeholders in the land administration sector: the Land Title and Registration Division; the Ministry of Lands and Natural Resources and the Ghana Revenue Authority. The project involved the creation of a blockchain-based land registry designed to store land title information in a tamper-proof manner (Eder, 2019; Rodima-Taylor, 2021). Bitland (Ghanaian FinTech Company) used blockchain to register official title deeds, aiming to gain people's trust in the new technology. The company believed that upon registration of land titles in this system, landowners will be able to apply for loans and mortgages from the local banks[2] (Ehwi, 2016).

2.3.2 Afghanistan

In Afghanistan, where most people have suffered from corruption and violence[3] and survive on $1.1 daily[4] (Forbes, 2020), the COVID-19 pandemic has further impacted negatively, increasing poverty levels from 54 to 70%. To make things worse, according to the United Nations (UN), more than 80% of properties in Afghanistan are not registered or

[2] Retrievedfrom https://www.bakermckenzie.com/-/media/files/insight/publications/2019/02/report_Blockchainandcryptocurrencyreg_feb2019.pdf (accessed on 28.02.2023).

[3] Retrieved from https://www.ledgerinsights.com/riskstream-trials-Blockchain-death-notifications-for-life-insurance/ (accessed on 02.03.2023).

[4] Retrieved from www.forbes.com/sites/lukefitzpatrick/2020/12/02/the-united-nations-golandregistry-blockchain-initiative-takes-on-a-challenging-first-assignment-in_afghanistan/?sh=1a23f4bd6bee (accessed on 02.03.2023).

do not have a title or formal ownership document.[5] In 2019, the UN-Habitat and UN Office of Information and Communication Technology established a project called "goLandRegistry" to create a land registry to enable access to secure land rights in Afghanistan. The UN collaborated with private entities to develop blockchain applications to manage land titles to accomplish this project. It aimed to register, document, secure and verify land title information (Katuu, 2022). On registration of land, the landowners receive an occupancy certificate and according to Konashevych (2021), blockchain-based applications have issued approximately one million occupancy certificates in Afghanistan.

2.3.3 Georgia

In 2016, the Georgian government embarked on a project to digitalize its land registry through blockchain technology to create a secure and tamper-proof system for tracking property transactions. The project aimed to solve corruption and land dispossession in the country's real estate market which had been a long issue (Rodima-Taylor, 2021).

The Georgian National Agency of Public Registry developed the blockchain-based land registry system with BitFury Group, a blockchain technology company. The system was built using private blockchain technology which differs from public blockchain systems like the Bitcoin and Ethereum (Benbunan-Fich, 2018; Rodima-Taylor, 2021). Firstly, the implementation of this system has brought numerous advantages to Georgia. In 2016, the World Bank recognized Georgia's property registration process as the most efficient among 189 countries (Benbunan-Fich, 2018; Rodima-Taylor, 2021). However, it is noteworthy that Transparency International's Corruption Perception Index ranked Georgia poorly in 2003 (Benbunan-Fich, 2018). Secondly, by 2018 1.5 million Georgian land titles had been issued on blockchain (Rodima-Taylor, 2021). Thirdly, the implementation of blockchain in land titles has improved transparency and rebuilt trust in the land registry process (Benbunan-Fich, 2018).

2.3.4 Sweden

According to Eder (2019), by 2016 Sweden "was already the world's most developed land registry, facilitating digital signatures, personalized

[5] Retrieved from https://cointelegraph.com/news/un-Blockchain-tool-aims-to-improve-land-registry-in-afghanistan-s-cities (accessed on 02.03.2023).

verifications, digital contracts to mitigate the risk of incorrect registries and increased trust between actors". It begun implementing and experiencing blockchain in land titles in 2016 (Kalyuzhnova, 2018), whereby implementation aimed to keep land titles public, open, transparent and secure (Rodima-Taylor, 2021).

A partnership was forged between the Swedish Land Registry, blockchain start-up, ChromaWay and telecommunications provider, Telia Company (Konashevych, 2021; Rodima-Taylor, 2021) pertaining to blockchain implementation in land titles. The implementation saved Swedish taxpayers over USD 106 million per year by automating the processes, eliminating paperwork, reducing the involvement of intermediaries and mitigating risk (Nasarre-Aznar, 2018; Rodima-Taylor, 2021). It also eliminated the need for agents to verify purchasing documents (Rodima-Taylor, 2021), allowing the buyer to connect with banks for loans and collateral in real-time (Rodima-Taylor, 2021).

The application of blockchain in land title registration systems in the aforementioned countries confirms its value. Protected land rights, reduced poverty and improved efficiency, transparency and security in the land registry were just some of the benefits of deploying this technology. The influence of blockchain has paved the way to beat numerous land title-related challenges and lead the path to superior land administration.

3 Methodology

This study reviews current literature on how blockchain technology can solve land title issues and handle management and registration challenges. It first clarifies the main concepts of land titles and an in-depth background of the main challenges in land registration and management worldwide. Next, it highlights how blockchain resolves various land title issues worldwide.

Published articles between 2015 and 2023 were extracted from the Scopus Database using important keywords, namely, "Blockchain", "Land Title", "Land Title and Blockchain", "Property and Blockchain" and "Land and Blockchain". A total number of 1173 records (articles) were found. These records were grouped into 6 categories: blockchain (technology), land titles (or land), land titles and blockchain (together), real estate and blockchain, property and blockchain and land and blockchain. Using the Mendeley software (version 2.84.0), 166 duplicated records were removed. In addition, records with no metadata (missing authors

or years), those that were not downloadable and those that did not discuss blockchain in the land title, property or real estate were removed. This process resulted in a total of 138 selected records for the study. All selected records were then uploaded to the NVivo software (version 1.7.1) for data coding, text searching and managing the data files.

4 Results and Discussions

The previous studies included in this research showed the importance of blockchain and its most significant concepts, features and benefits in managing land titles. Despite the few countries that have applied the Blockchain to land title and the challenges facing Blockchain technology, there are successful and continuous experiences of experimenting with the use of Blockchain in the land title administration context, not to mention the tangible benefits so far from this technology in those countries which implemented Blockchain in land title. In the following paragraphs, we discuss how Blockchain technology can solve land property problems in different countries.

4.1 Blockchain: Resolving Land Title Issues

Blockchain technology has garnered considerable attention as a potential remedy for the inefficiencies and complexities associated with land title management. This study's findings reveal that blockchain can revolutionize land title transactions, reducing costs, enhancing accessibility and improving data security. The ultimate goal is to develop a highly usable and efficient land registration process.

Furthermore, this research explains how blockchain technology can help curb fraud and other ownership problems which can possibly arise. In addition, it also explains how it can manage legal consistencies in the process of managing land titles with full transparency. Moreover, this research also explains how standardized smart contracts can be used for automation purposes in order to increase the efficiency of land title registration processes. Additionally, this research also explains how blockchain technology can be used to eradicate corruption and bribery. The transparency offered by blockchain and its decentralized process enhances the reliability and trustworthiness of the land title registration process in eliminating or reducing these two problems. This research also highlights the ability of blockchain technology in managing land title registrations

during pandemic periods such as COVID-19. The digital characteristics of this technology enable land title registrations to be conducted safely without the risk of virus infections.

Moreover, the transparency and accessibility of blockchain technology also facilitate easier monitoring and regulation of land title transactions by authorities. Ultimately, blockchain technology ensures the continuity of land title transactions during pandemics by minimizing the need for physical interactions and paperwork.

4.2 Blockchain: Managing Land Title Elements

An efficient and decentralized method for managing land title elements is made available by employing blockchain technology. It includes the provision of a decentralized ledger for recording and verifying ownership information, establishing tamper-proof records of ownership transfers, monitoring liens and encumbrances and ensuring adherence to legal prerequisites. Implementing blockchain in land title management improves efficiency, enhances security and increases accuracy, thereby mitigating the risks associated with fraud and errors. Further exploration and implementation of blockchain technology can revolutionize land title management systems, improving transparency and trust among stakeholders involved in land transactions.

4.3 Blockchain: Achieving Land Title Benefits

The research emphasizes the advantages of integrating blockchain technology into land title administration. By enabling an unchangeable and distributed ledger of land title transactions, blockchain establishes a transparent and secure system for transferring ownership rights. Smart contracts ensure authorized and secure transfers, while the decentralized nature of blockchain enhances transparency and security. These benefits align with several key objectives, including achieving proof of ownership and transparency, preventing fraud, increasing value in land title management and facilitating access to financing and enhanced liquidity.

4.4 Blockchain: Dealing with the Challenges

Various methods exist to address the blockchain scalability challenge. These include Segregated Witness (Xie et al., 2019), which separates

signature data from transaction data. Secondly, Lightning Network (Gürkaynak, 2018; Wust, 2018; Xie et al., 2019), a second-layer solution enabling off-chain transactions. Thirdly, Sharding (Ali, 2019; Xie et al., 2019) splits the blockchain into smaller parts. Fourthly, Proof-of-Stake (PoS) is a consensus algorithm that replaces PoW (Ali, 2019; Makhdoom, 2019; Monrat et al., 2019). Fifthly, Sidechains (Ali, 2019; Panarello, 2018; Yapicioglu, 2020) are separate blockchains linked to the main blockchain. Sixthly, State Channels (Köpke et al., 2019; S. Wang, 2019), another second-layer solution that enables direct transactions between parties, and seventhly, Plasma (Makhdoom, 2019; Panarello, 2018; S. Wang, 2019), which connects smaller blockchains to the main blockchain to process more transactions.

The interoperability challenge poses a significant obstacle for blockchain technology, referring to the ability of different blockchain networks to communicate and interact. Several approaches have been proposed to address this challenge. Atomic swaps enable direct peer-to-peer trades between blockchain networks within a centralized exchange. The Interledger Protocol (ILP) is an open protocol suite that facilitates transactions across blockchain networks. Platforms like Polkadot and Cosmos utilize relay chains and parachains or a hub-and-spoke architecture to connect diverse blockchain networks.

Maintaining the integrity and security of a blockchain network requires substantial computational resources, which increase with the addition of nodes and transactions. To tackle this challenge, various solutions have been proposed. These include employing more efficient algorithms, reducing transaction data size, implementing new consensus mechanisms and utilizing off-chain solutions such as sidechains, state channels or sharing. These approaches aim to enhance the efficiency and scalability of the blockchain network while minimizing the computational power needed. Another alternative is transitioning to a different consensus mechanism, such as PoS, which can reduce the computational requirements for network maintenance.

5 Conclusion

Our investigation into the most relevant and recent literature encompassing land title administration issues and the deployment of blockchain technology in resolving this topic clarifies that such a technology has the

potential to revolutionize land title administration processes. The findings reveal that a few shortcomings within the blockchain technology, its benefits prove far more important, offering land title administration processes the potential for enhanced efficiency and resolution to problems of transparency and security in recording and verifying land. In particular, blockchain enables land titles to be accurately recorded, easily traced and securely transferred. It ensures that land titles are immutable, reducing the likelihood of fraud and disputes over land ownership. Furthermore, blockchain eliminates intermediaries and streamlines processes, saving time and reducing costs for all parties involved. By providing a secure and transparent platform, this technology can enhance the trust and transparency of land title systems, thereby facilitating and growing investment in the real estate sector.

In conclusion, blockchain technology can help enhance efficiency, transparency and security in the land title registration process.

5.1 Practical Contribution

Generally, blockchain technology provides a lot of benefits to land title registrations. It enhances transparency, accountability, consistency, efficiency and security of this whole process. Finally, it can facilitate cross-border land transactions, reducing transaction time and cost and smoothing business across borders.

Our findings will also contribute toward land property investors since blockchain technology can encourage such investments by providing secure and efficient land title administration. Firstly, it creates a tamper-proof and secure land registry by storing land titles in a decentralized and immutable ledger, preventing fraudulent activities like double-spending and ownership disputes. Secondly, it streamlines land registration, transfer and verification processes, making it easier for investors to acquire and transfer land titles and reducing the risk of errors and corruption. Thirdly, it increases transparency in land title administration by providing a public ledger that records all transactions related to land titles, allowing investors to verify the ownership and history of a piece of land before investing in it. Finally, it improves access to finance by providing a transparent and auditable record of land ownership, making it easier for landowners to use their land as collateral for loans and increasing investment in land property.

5.2 *Limitations and Future Research*

This study has a few limitations. First, it only reviewed articles extracted from one database, i.e. the Scopus database. Second, in addition to the limited focus on four selected use cases with blockchain implementation in land titles, the present work has also excluded the failed cases of implementing such technology in the topic.

Hence, for more insight and progress on the topic, research on implementing blockchain for land titles should also cover aspects of the legal and regulatory environment, technical infrastructure, governance and security requirements and cost and benefit assessments. Some future work may also be required to investigate the factors influencing the adoption and acceptance of blockchain-based land title systems from the perspectives of various stakeholders.

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Tokenized Real Estate Investments

Ploypailin Kijkasiwat

As can be seen in the growing amount of real estate tokenization across the globe, there are still differences in terms of the number of successful cases in developing and developed countries. It is therefore important to learn what the differences are. Correspondingly, this chapter examines the current situation of the real estate business which has been tokenized in Thailand as a developing country. It shows the processes and related entities which must be involved. By way of comparison, the chapter demonstrates the situation in the United States of America (USA) as a developed country. Law and regulations underpinning the tokenization between two countries are considered in order to see the connection with the development of active secondary markets.

Illiquidity is characteristic of the real estate market. Through tokenization, a greater number of investors would be able to participate in the market and construct diversified portfolios with modest capital investments. Real Estate tokenization is the process of buying and selling digital tokens for investment which will be mobilized for the development of a

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project. Tokenization has the potential to reduce costs and process time, increase operational efficiency, improve transparency, and facilitate a series of innovative investments. Tokenization also supports regulatory compliance, information security rules, privacy laws, and investor reporting. New services include asset tokenization, or tokenized ownership, as the security for high-value goods that broadens the investor base, increases liquidity, and decreases resell risks where parties trade and settle directly within minutes at low cost (Serrano, 2023).

This chapter considers the case study of real estate tokenization in Thailand and compares the demand for real estate tokenization in Thailand with the USA. This comparison provides insights into the differences in tokenization in developing and developed countries. There are other pertinent aspects to consider in such a comparison. Although blockchain technology is generally applied to manage real estate tokenization, the success of tokenization depends on the presence and quality of laws and regulatory support, involvement as well as the perceived value for relevant stakeholders which could be different between developed and developing countries. Differences will include processes to deal with the risks of transacting, fraudulent trading activity (Dutta, 2020; Zheng & Sandner, 2022) as well as the demands of real estate tokenization.

Real estate tokenization has grown in significance in Thailand where there is an increasing amount of real estate. With support from the Securities and Exchange Commission (SEC) through setting up an asset tokenization system and issuing laws and regulations, real estate builders as well as founders are using this method for raising funds and making a project grow. Issuing digital tokens to invest in real estate (real estate-backed ICO) can be done in three ways: firstly, direct property purchasing; secondly, purchasing 75% of the shares of the company holding that property; and thirdly, investing in leasehold rights in immovable properties. The real estate must be developed and fully evaluated by approved appraisers. The investment cannot be worth less than 80% of the project value or less than 500 million Thai Baht. The income or benefits from that real estate will be shared among digital token holders. It is stated that a real estate-backed ICO is similar to a real estate investment trust (REITs) (Baum, 2020), but a real estate-backed ICO is more flexible. Investing in real estate-backed tokens can provide returns to token holders in various forms such as profit in cash and the right to stay in an immovable property. In order to have a mechanism to protect investors, a real estate-backed ICO requires issuers to offer digital tokens and work

with trustees appointed by SEC. The trustee is responsible for the performance of the digital token issuer and undertaking duties to maintain the rights of token holders (Baum, 2020).

Table 1 presents comparative information regarding digital assets and ICO laws and regulations in Thailand and the USA.

The USA developed regulations that are part of the current laws used in the American stock exchange which allow people to trade digital currency. In Thailand, an emergency decree on digital asset businesses, B.E. 2561, was promulgated in 2018. This Act aims to protect investors from fraud as well as facilitate fundraising activities for businesses and related entities. Any real estate project cannot issue digital tokens directly, and transactions must be processed through an intermediary called the ICO Portal. This process has the advantage of allowing investors to invest in real estate with less capital. For real estate builders or owners, they can raise funds in a new way, and avoid the risk of insolvency associated with debt-based contracts (Hassan et al., 2021; Kashi & Mohamad, 2017). As real estate tokenization adopts a blockchain management system, the token can be easily traced and has enhanced investment security (Chow & Tan, 2022; Starr et al., 2021).

In Thailand, tokenized funding first started in 2021, when the government gave priority to this type of fundraising by assigning the SEC to monitor the stakeholders and related entities. Under the Notification of the Ministry of Finance regarding licensing of digital asset businesses B.E. 2561 and The Notification of the Securities and Exchange Commission No. 19/2561 Re: Rules, Conditions, and Procedures for Undertaking Digital Asset Businesses, currently there are seven ICO portals in Thailand. These portals are Longroot, T-BOX, XSPRING Digital, BiTherb, Kubix, Fraction, and Token X. To support real estate transactions, ICO portals provide services and support systems for real estate tokenization. The services include screening real estate builders and owners, evaluating business plans, checking source codes of smart contracts and white paper, examining and analyzing potential investors, examining the ability of the investor to take risks, due diligence process, and SEC case submission and approval, the offer process, and post-offer monitoring. To be in the ICO portal, the company has to be established under Thai law, and the registered capital not be less than five million baht. ICO portals must have a professional system and adequate staff to process any steps of real estate tokenization. Table 2 shows the current ICO portal in Thailand.

Table 1 Information regarding digital asset and ICO laws and regulations in different countries

Country	*Innitial laws and regulations*	*Digital asset sold*	*Related laws for digital asset exchange*	*Different phases of token development*	*Related agency*
United States of America	U.S. Federal securities laws	Cryptocurrency, Digital tokens	Securities Act of 1933, Securities Act of 1934	Howey test	The US Securities and Exchange Commission (SEC) Financial Crimes Enforcement Network (FinCEN) The US Commodity Futures Trading Commission (CFTC) US Commodity Futures Trading Commission: CFTC
Thailand	Emergency Decree on Digital Asset Businesses B.E. 2561 (2018)	Cryptocurrency, Token digital (utility token, investment token)	Anti-Money Laundering Act	Pre-ICO phase (regulation relating to ICO-portal, white paper, source code) Post-ICO phase (regulation relating to cold walletsmart contract)	Securities and Exchange Commission (SEC) Ministry of Finance

Source Self-developed

Table 2 ICO Portal

Name	*Website*	*Platform Benefits*
Longroot	https://www.longroot.co.th/	
T-BOX	https://www.tbox.net	• Own equity in premium real estate assets • Receive dividend earnings in cash to your bank account
XSPRING Digital	https://www.xspringdigital.com/	• Partners with Fireblocks to provide institutional grade custody for wallet • Consolidated Services • Great Price with High Liquidity
BiTherb	https://www.bitherb.net	• Highest quality ICO Portal (fairness, accuracy, transparency, sustainability, scalability)
Kubix	https://www.kubix.co	• Provide a private wallet or non-custodial wallet
Fraction	https://www.fraction.co	• Easy and simple • Removing barriers • Diversified • Greater control • Secure and transparent
Token X	https://www.tokenx.finance	• Enterprise Grade Blockchain Network. Secured, Fast and Cost-efficient

Source https://www.sec.or.th/

For liquidity, currently, there are nine digital asset exchanges in Thailand which are certified shown in Table 3. They are BITKUB, Satang Pro, ERX, Zipmex, Upbit, Z.comEX, INVX, TDX, and T-BOX. The digital asset exchanges allow every entity to participate and engage in transactions legally. Real estate investors can trade and get financial advice from digital assets brokers who are approved by the SEC. Table 4 presents digital asset brokers in Thailand.

While Australia, the Asian countries of South Korea, and Singapore successfully launched real estate tokens via platforms like BrickX, KASA, ADDX, and Minterest, respectively (Chow & Tan, 2022), there are at present only two successful tokenized funding sessions in Thailand. The total value is more than 2665.2 million baht. According to the SEC's report (data as of July 2022), 30 companies have requested

Table 3 Digital asset exchange

Name	*Website*	*Cryptocurrency*	*Digital token*	*Strengths*
BITKUB	bitkub.com	✓	✓	• 24/7 support • Referer receives a commission, referee gets cash back • Strong security • Fast and scalable • Multi-device friendly
Satang Pro	satang.pro	✓	✓	• Available 24/7 • News and updates • Community discussion • Help build the future of technology
ERX	erx.io		✓	• Aggregated liquidity of brokers and dealers • User-friendly interfaces • Advanced trading feature • Call center and chat service
Zipmex	zipmex.com/th	✓	✓	• Best price, lowest fee • Support both Android and iOS
Upbit	th.upbit.com	✓	✓	• World-class blockchain technology • Regulatory expertise • Operational know-how • FinTech Expert with the Proven Record

(continued)

Table 3 (continued)

Name	*Website*	*Cryptocurrency*	*Digital token*	*Strengths*
Z.comEX	ex.z.com	✓	✓	• Brokerage services provider • Highest security • Highest liquidity • World standard prices
INVX	innovestx.co.th	✓	✓	• Intelligent Portfolios • Quick approval via a mobile application • Efficient asset management • Knowledgebase
TDX			✓	• Extensive experience and credibility • Digital token trading ecosystem • Trading easily accessible • IOS and Android support
T-BOX	tbox.net		✓ (not started yet)	• Own a piece of premium real estate assets • Receive dividend earnings in cash bank • Quick to Invest • Invest Easily and Safely

Source https://www.sec.or.th/

Table 4 Digital asset broker

Name	*Website*	*Cryptocurrency*	*Digital token*	*Fee*
Coins TH	coins.co.th			• Coins.co.th doesn't charge any fees for cryptocurrency conversion • 1% processing fee applied on direct purchase of asset only
Bitazza	bitazza.com	✓	✓	• No charge deposit fees for Crypto • For every withdrawal, a transaction fee will be charged for moving cryptocurrency out of their account. Withdrawal rates are determined by the blockchain network and can fluctuate without prior notice due to factors such as network congestion
KULAP	kulap.io	✓	✓	• Both trading and withdrawal fees are not applicable
Upbit	th.upbit.com	✓	✓	• If you use Lightning Transfer that can be used when withdrawing between Upbit accounts, the Withdrawal Fee is free • Withdrawal fees will be charged per transaction • No Deposit fees
Z.comEX	ex.z.com	✓	✓	• 0.15% Trading Fee
Zipmex	zipmex.com/th	✓	✓	• 0.1% trading fees
XSPRING Digital	xspringdigital.com	✓	✓	• No fee for trading

(continued)

Table 4 (continued)

Name	*Website*	*Cryptocurrency*	*Digital token*	*Fee*
INVX	innovestx.co.th	✓	✓	• On trading day, if the customer's actual fee is less than 50 baht on that day, the system will charge a minimum fee of 50 baht + VAT 7% immediately on the trading day • If the customer's actual fee is higher than 50 baht on that day, the system will charge the actual fee
KTX	krungthaixspring.com	✓ (not started yet)	✓ (not started yet)	

Source https://www.sec.or.th/digitalasset#list

ICO fundraising, which is in progress. Before the process of ICO, it is necessary to consult with SEC staff. The first project to be successfully tokenized was SiriHub which issued a real-estate-backed ICO with a fundraising value of 2.4 billion baht. Anyone who buys a Siri Hub Token will receive a return on the rent earned from the Siri Campus building and can also trade the token on the secondary market. That token offering was worth 2400 million baht. The offering price of 10 baht for 1 token meant that there were 240 million tokens in total, and the entire 2400 million baht sold out in a short time. Buyers of Siri Hub Tokens will earn quarterly returns on the rental performance of the Siri Campus Building, which has signed a 12-year lease. For the next 10 years, the return will be increased by 4–8%, and returns guaranteed for four years (Bangkokbiznews, 2023). While the second project is not related to real estate tokenization, where the tokenization involves entertainment, the initiative helps to make investors and business founders realize the possibility of raising funds through issuing the asset-backed tokens. Figure 1 demonstrates the process of real estate-backend ICO in Thailand. Figure 2 presents how the first case of real estate tokenization in Thailand is done.

In 2023, Condo-Backed Tokens were issued by the cooperation of Real Estate Exponential Company Limited and Token X (ICO Portal was

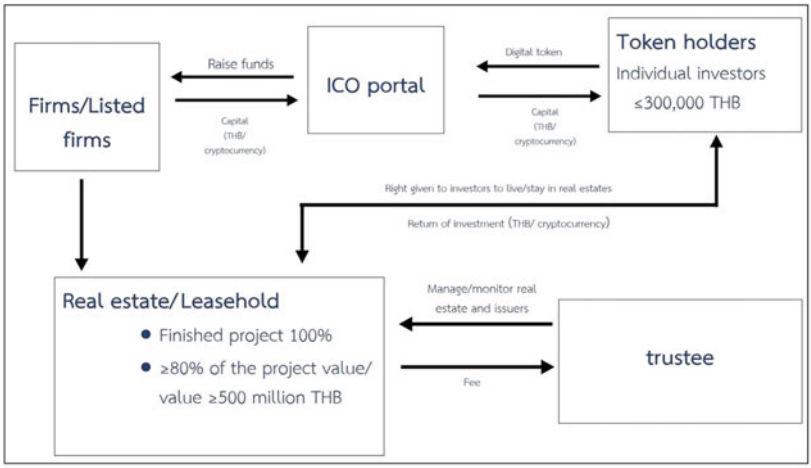

Fig. 1 Process of real estate-backend ICO in Thailand (*Source* https://www.sec.or.th/)

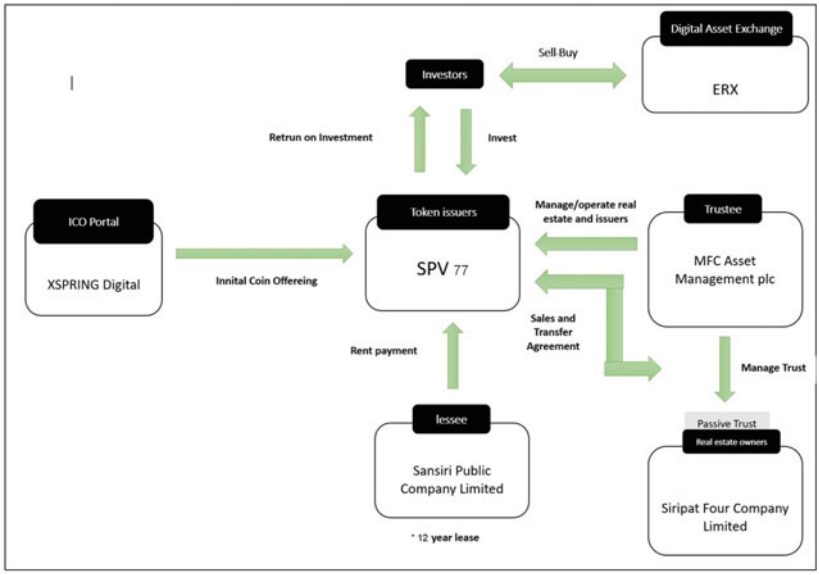

Fig. 2 Sirihub (*Source* https://spv77.digital/about/spv-77/)

approved by SEC). This will be the second project of real estate tokenization in Thailand. The project gives the opportunity to investors to invest in three good quality condo projects, namely Park Origin Phrom Phong (138 units), Park Origin Phayathai (123 units), and Park Origin Thonglor (100 units), and these are located in a prime location in the central business district (CBD). Investors can invest in this real estate via "RealX Investment Token". One token is equivalent to investing in 1 square inch of real condo area, and worth 182 baht. The life of the project is 10 years from the start date of the project. The guaranteed return for the first 5 years is at 4%, 4.25%, 4.50%, 4.75%, and 5% per year, respectively. These returns are derived from the income from the unit rental of the project in all three condos. From the sixth to the tenth year, token holders will receive the quarterly return from gradual sales of all three condo projects from net rentals (Thai PR, 2023). The units which are not rented will be sold out at the current market price at that time.

In 2022, condominium market showed signs of recovery from COVID-19 pandemic when everyone started to return to normal life, and people again looked for the convenience of living in the city. In 2021, the condo market was negative −30% compared to the previous year. In 2022, it had expanded by 10–15%, but the overall picture is still negative compared to the pre-COVID era. A positive recovery should be seen in 2023 when the group of customers who buy condos is individuals who are low-middle income people (Real Estate Information Center, 2023). Figure 3 shows the process of issuing condo-based tokens.

In USA, Token fundraisers must comply with the Securities Act. Additionally, there are also securities and stock market regulatory laws in each state. With different characteristics, companies, entrepreneurs, and token investors. Any trading must also comply with the relevant laws in each area. For example, real estate issuers must register with the SEC, and tokens can only be offered to accredited investors. Token trading must be processed through brokerage firms or broker–dealer authorized by the SEC. The financial industry regulatory authority is responsible for self-organization and advising on financial regulations in the financial industry, trading on the stock exchange, and alternative trading systems approved by the SEC (Sattasakdasiri, 2023).

The scale of tokenization is still limited when compared with the USA. During 2021–2022, in Thailand, only two projects successfully raised funds worth $76.1 million. The project named SanSiri Hub successfully raised funds valued at US$ 68.6 million. The situation is very different

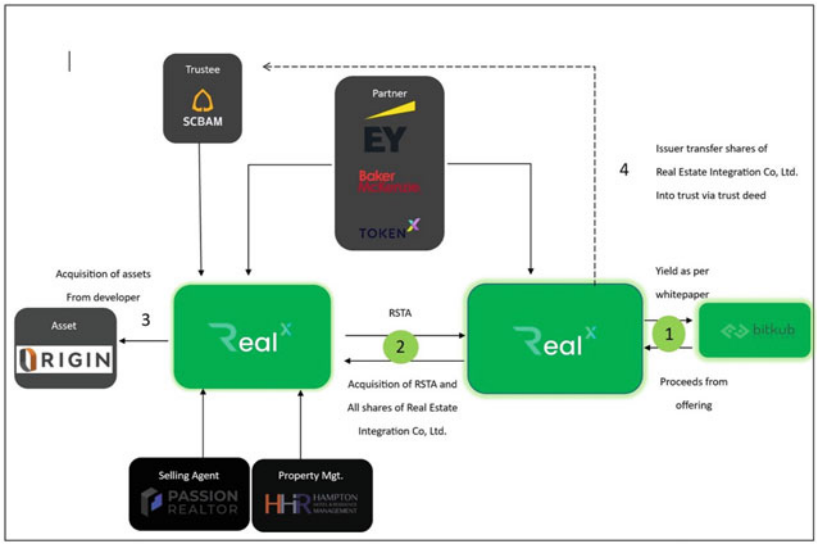

Fig. 3 The process of issuing condo-based token (*Source* https://www.terrabkk.com/)

from what happened in the USA. In 2020, there were 96 projects that had successfully raised funds to the value of $1456 million which is the fourth-highest rank in the world. In the USA, from October 2019 to February 2021, a real estate tokenization firm (RealT) tokenized 58 properties with 52 tokenized properties in Detroit (MI) and 6 in Chicago (IL), Rochester (NY), Deerfield Beach (FL), Cleveland (OH), Akron (OH), and Dearborn Heights (MI) (Swinkels, 2023). In the USA, property ownership and financial products legally require the "whitelisting" of participants prior to trading (Swinkels, 2023). In Thailand, the token issuers must obtain approval from the SEC. Token issuers must submit a registration statement and follow the process created by the SEC. Digital tokens are sold through an authorized digital token offering platform (ICO Portal) licensed by the SEC. In the USA, token fundraiser must comply with the Securities Act and Securities and Exchange Regulations Laws which is different for each State. Additionally, the issuer has to offer digital tokens only to accredited investors. Token trading can be done through

brokerage firms or brokers authorized by the US Securities and Exchange Commission (Sattasakdasiri, 2023).

It is undeniable that in both developing and developed countries, there are some issues regarding real estate tokenization. Many critics argue that selling price of real estate tokens can be overpriced in relation to the reality (Liu & Wang, 2019; Momtaz, 2020). Real estate investors may bid indiscriminately for both underpriced and overpriced IPOs, leaving them with full allocations in overpriced offerings and limited allocations in underpriced IPOs (Peltomäki, 2022; Rock, 1986). However, supporters of real estate tokenization argue that because of the guaranteed return, real estate tokenization is still better than investing in real estate. The argument is that tokenization is a better option because buyers do not have a responsibility to pay for additional costs relating to the real estate such as room decorations, electrical appliances, maintenance, common areas, insurance premiums, and facilities management fees (Serrano, 2022). Additionally, buyers do not need to pay for ownership transfer and mortgage fees. Therefore, proponents of tokenization argue that investing in real estate-backed tokens is still better. To tokenize single real estate assets, it is necessary to understand the comfort level with blockchain which underpins tokenization, and how this can be embedded into each step of tokenization following the law and regulation of each country.

In conclusion, this letter provides a short letter snapshotting about tokenization of real estate business in Thailand in terms of process, law and regulation, and entities' governance of the tokenized processes. Furthermore, the chapter demonstrates the comparison between Thailand as a developing country and the USA as a developed country regarding the number of successful cases of real estate tokenization. It states laws and regulations underneath the processes. The current figure gives the idea of how hard or easy real estate tokenization is in both developing and developed countries. As the number of success cases is quite different between Thailand and the USA, the paper raises issues for involved entities in the real estate business in Thailand and other developing countries to explore how to increase the number of successful real estate tokenization by learning from what happened in the USA.

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International (Lack of) Harmonization in Legislation for Blockchain Application in Cross-Border Real Estate Processes

Tuti Haryati Jasimin

1 Introduction

The revolutionary technology of blockchain has the potential to have a significant impact on all facets of government and business as well as the general economy. New marketplaces, value chains, and business models are produced by disruptive innovations, which eventually replace pre-existing ones. As the benefits of this system become more fully understood, blockchain technology is increasingly being used in real estate transactions. Blockchain offers a secure, decentralized, shared, and immutable digital ledger that accelerates the process of recording of entire transactions across peer-to-peer networks (Zīle & Strazdiņa, 2018). The real estate sector might undergo a revolution as a result of this.

Furthermore, blockchain technology also allows tracking a transparent information sharing with a business network. Accordingly, it has the potential to drastically reduce real estate transaction costs, eliminate investment barriers, and increase real estate's liquidity (Baum, 2022).

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There are several reasons why the present real estate transactions system is slow, but the validation procedure is by far the biggest one due to the documents that manually validated during this procedure (Hoxha & Sadiku, 2019). Eventually, blockchain applications might speed up and simplify the purchasing and selling processes of real estate. Additionally, the usage of smart contracts might automate a number of real estate transaction-related duties, including title checks and escrow services. Blockchain also offers a more secure means to track property ownership, which is another benefit of the blockchain application in real estate. Traditional methods of registering property ownership are frequently susceptible to fraud and mistakes. Blockchain provides a secure means to store this data. This might lessen cases of fraud and real estate fraud (Franks, 2020).

Technology is said to evolve continuously, and regulation is said to generally lag behind. Consequently, there are important legal difficulties that need to be resolved even though using blockchain technology to safely transfer real estate assets globally and generate capital across borders is an intriguing area and has the potential to drastically transform real estate transactions in the future. The technology is not yet fully regulated globally, which raises concerns about its potential use in the real estate industry worldwide (Garcia-Teruel, 2020). Blockchain is now going through an invention and experimentation phase. In order to precisely anticipate the legal and regulatory concerns, it would be advisable to wait for more time. But given the enormous potential of these applications, it is expected that blockchain technology would provide particular challenges for regulators. For the real estate cross-border transaction, there is also currently a lack of legal harmonization worldwide. It has created a global regulatory issue, and despite ongoing technical advancement, it is still difficult for regulation to keep up with change (Flink, 2021).

Accordingly, there are still many legal issues that need to be resolved, despite encouraging improvements in areas like tokenization and international guidelines for commercial disputes. This article presents a valuable legislation overview for blockchain applications in cross-border real estate process. This article also discusses some of the legal issues raised by some of the potential opportunity's uses of blockchain technology, with an emphasis on the challenges presented by smart contracts for the utilization of contract law and the likely impact of blockchain on the real estate market.

2 Potential Opportunities and Use Cases of Blockchain Application in Real Estate

Figure 1 shows the published articles on the blockchain use cases in real estate worldwide between the years 2016 and 2023 by various authors such as Saari et al. (2022), Humdullah et al. (2021), Kathy and Yuchen (2021), Nijland and Veuger (2019), Yang and Wang (2020), Anetta and Sabine (2020), Sadkov et al. (2020), Veugar (2017), and many more authors. By analysing the different opportunities from the authors, it could be summarized that the possibilities of blockchain application in real estate are divided into four major categories as illustrated in Fig. 2 namely digital record-keeping of real estate assets, smart contract, payment system, and transparent market. While the real estate blockchain use cases including property management, payment and leasing, loan and mortgage securitization, real estate funds, land registries, property development and construction, urban planning, identity of investor and tenant, project financing, and finally real-time accounting.

An essential indicator of a country's economic health is the real estate market. Housing starts, home prices, and current sales of homes are carefully watched indicators that can provide information about the state of an area's or nation's economy. One simply needs to reflect on the global financial crisis of 2008, which was brought on by the bursting of the worldwide housing bubble, to understand the sector's significance to the world economy. Accordingly, the real estate sector needs to increase transparency, get rid of bad sales tactics, tighten up mortgage regulations, control risky derivative trading on secondary markets, and promote better real estate investment strategies if it hopes to avoid another potentially disastrous property bubble burst.

The good news is that blockchain in real estate can assist the industry in overcoming these obstacles and developing fresh growth prospects. Table 1 highlights the real estate blockchain-based use cases to address the abovementioned issues in the real estate industry.

2.1 Digital Record Keeping

Improper record-keeping, which is essential for quick business procedures, is another significant issue in the real estate industry. With blockchain application, each entity receives a unique digital identity that cannot be imitated or taken. It results in more open record-keeping for

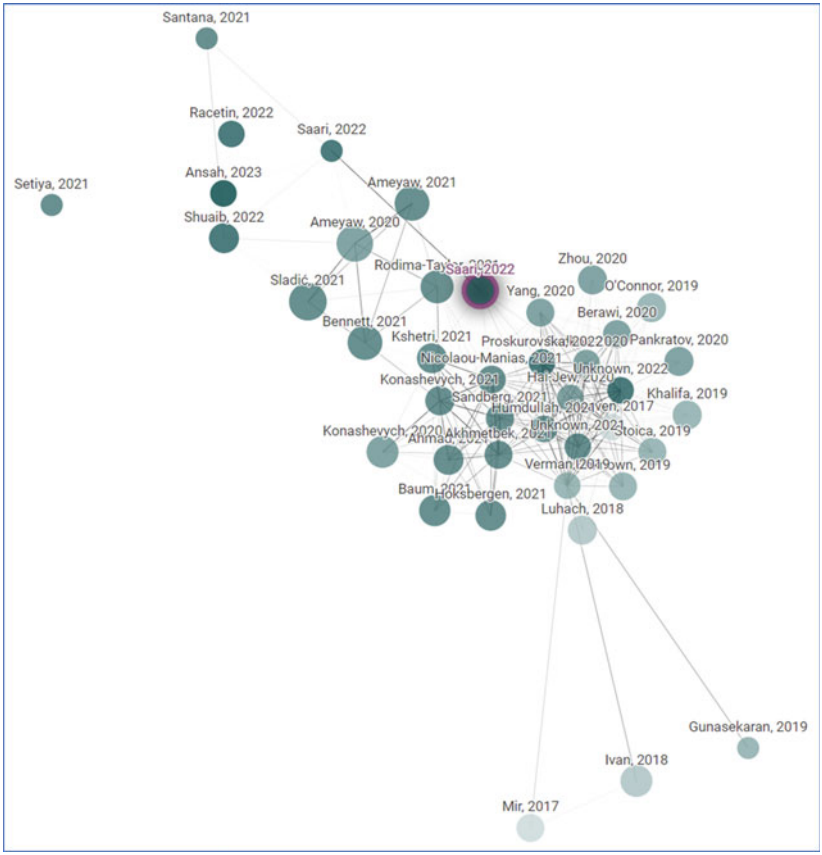

Fig. 1 Academic published articles on the blockchain use cases in the real estate industry worldwide between the years 2016 and 2023 (*Source* Own illustration)

all real estate documentation such as loans, liens, and property titles. Blockchain is a record-keeping technology that makes it possible to keep a growing number of records in a digital ledger. Individual blocks containing transactional data make up the ledger. Each block in the chain is irrevocably connected to the block before by cryptography, which is used to bind these blocks together (Till et al., 2017). When individuals talk about "a blockchain," they frequently mean the whole history of transactions that are kept in that specific record-keeping system. The

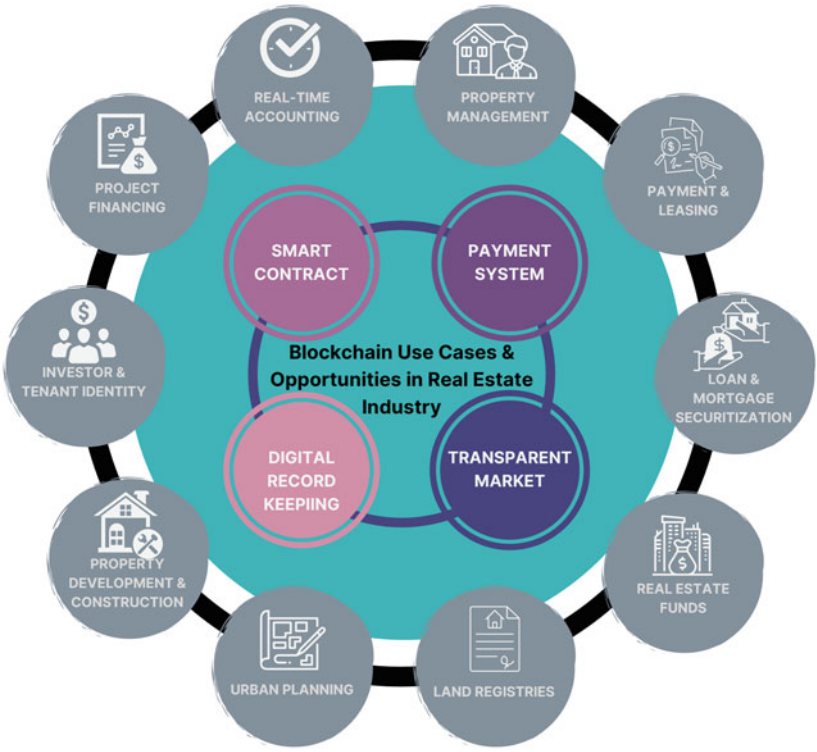

Fig. 2 Blockchain use cases and opportunities in the real estate industry (*Source* Own illustration)

blockchain ledger is a reliable record of activities and transactions since it may be added to but not modified.

Real estate properties can have their entire lifecycle digitalized and transferred on a blockchain (Götz et al., 2020). This is referred to the registration of various asset types that could be done by blockchain technology. In the US, there are chances for the title of property recording in a blockchain for Davidson Country (Spielman, 2016). While in the Netherlands, the advanced digital system called Kadaster is already in the market. Leveraging blockchain for record-keeping can be helpful in any situation where it might be beneficial to have evidence that data has not

Table 1 Use cases of Blockchain-based in real estate

Real Estate Blockchain use cases	*Details*
Real Estate Fund	Tokenization can assist with overseeing ownership rights, keeping track of past transactions, and understanding the state of assets, insurance, and property transfers. Additionally, it may aid in increasing the assets' liquidity
Project Financing	More investors will be attracted by transaction transparency, traceability, and security. Improved ROI and investor experiences will increase investor confidence
Property Management	Data sharing, rent collecting, payments, record keeping, property appraisal, and considerably upholding due diligence are all made easier by blockchain technology. It decreases the system's cost, time, and effectiveness
Land and Property Registries	Paper documents are prone to theft, loss, mishandling, and damage. Throughout the procedure, expensive legal arrangements are required. With its immutable ledger, blockchain offers a convenient primary source of truth for maintaining land registry records
Urban Planning	A comprehensive and trustworthy land record can help with improved urban planning. Blockchain-based solutions are required for smart cities to build sustainable urban environments
Property Development and Construction	By offering traceable and accountable procurement, streamlining the management of projects, and updating project status, blockchain in real estate can enhance the system. Another element will involve using smart contracts to make payments and agreements
Investor and Tenant Identity	Blockchain-based solutions will guarantee that new tenants and investors have been thoroughly validated. The risk of financial fraud will be decreased by background and identity checks

(continued)

Table 1 (continued)

Real Estate Blockchain use cases	*Details*
Payment and Leasing	By eliminating the necessity for manual reconciliation, Distribute Ledger will streamline all procedures, from collecting cash for construction to receiving payments from tenants or sales
Real Time Accounting	Investors and asset owners gain from automated and nearly instantaneous accounting when property ownership and financial flows are recorded on-chain. Future annual financial statement preparation will have the option of real-time audits for the balance sheet, cash flow statement, and statement of income. This makes it possible to make numerous advancements in investor relations, regulatory supervision, and compliance

Source Own Illustration

been altered or tampered with. Accordingly, blockchain technology can ensure the data integrity through the hash value, which means that there is evidence that the data has not been manipulated (Burgwinkel, 2016).

2.2 Smart Contract

Among the most successful blockchain developments are self-executing contract commonly known as smart contracts, which have enormous advantages for the banking and finance industries. Smart contract is a computer programme called contains codes that enable the automation of particular procedures. A straightforward cryptocurrency purchase is an illustration of it. If the buyer has enough money in their wallet, the smart contract will determine this (Garcia-Teruel, 2020). If so, the cryptocurrency transfer will happen. ChromaWay is an example of a blockchain real estate company using this technology in collaboration with Telia, a major Swedish telecoms firm. They want to digitize mortgages and sales contracts without any restrictions. Blockchain security mechanisms can unequivocally authenticate these papers once the necessary technology is in place (Horiachko, 2022).

A cryptographer and a legal expert, Szabo (1996) recognized the decentralized ledger's potential for smart contracts or self-executing contracts as early as 1994. He gave an early definition of a smart contract as:

> […] many kinds of contractual clauses (such as collateral, bonding, delineation of property rights, etc.) can be embedded in the hardware and software we deal with, in such a way as to make breach of contract expensive (if desired, sometimes prohibitively so) for the breacher.

He further asserted that smart contracts would facilitate the achievement of the four fundamental contract goals of observability, verifiability, privity, and enforceability. The real estate industry, which must manage a large transactions amount, could potentially gradually benefit from this technology. Blockchain technology offers a new method for tracking payments and exchanging money, but it also has the ability to make contracts smarter. Reducing the need for people to process and verify agreements is the aim of smart contracts (Martijn, 2017).

When buying or selling a home, the buyer and seller can now transact digitally instead of completing practically infinite paperwork. There is more security and transparency in the transaction than was previously achievable. Virtually no human interaction is necessary during the automated transactions. Everything created on the blockchain is self-executing once it is put into use (Horiachko, 2022). The parties engaged expend less time and effort, and there is also less expense and no possibility of fraud.

For a wide range of situations, the blockchain cryptographic ledger may log events and produce digital identities. Mortgage payments, escrow transfers, or deed transfers are a few examples of when this kind of ledger might be used. The digital contract would immediately transfer deed ownership as soon as the required funds and terms were met. Another option to consider is a digital lease that automatically deducts rent and service fees from an account with no human mistake and a complete audit record (Almond, 2016).

Smart contracts allow for the construction of more sophisticated transactions (such as the repayment of debts), and because they operate via a blockchain system, they are secure, trustworthy, and implemented without the involvement of a third party. Users can now build smart contracts using the Solidity programming language thanks to Ethereum,

but other blockchain protocols like NXT (public blockchain) and Corda (private blockchain) are now supporting this feature. Therefore, stakeholders would be able to continually verify the debtor's solvency through public databases, generate scheduled payments associated with the electricity and water suppliers contracts, and pay any necessary taxes, all while recording the contract, if several smart contracts were linked together for instance, with the government's administrative institutions.

2.3 Payment System

Current financing and payment methods for property transactions are sluggish, expensive, and opaque because of the considerable documentation needed and the involvement of numerous intermediaries. These problems become more obvious when a property is mortgage-financed and when cross-border transactions are necessary. The current mortgage approval procedure for residential properties takes an average of 30–60 days to complete. The length of time it takes to get accepted for commercial real estate, which is more difficult to go through compared to residential real estate, can be much longer, frequently taking over 90 days. Blockchain technology could be used to streamline and make this process more transparent. Validation of digital identities for properties, for instance, would enable a reduction in the amount of time needed for loan documentation and due diligence, speeding up the approval of mortgages.

Blockchain technology might be used by the lender and borrower to perform an unchangeable smart contract-based loan document that is completely available to all parties engaged in the legal process. Based on a survey by Moody's Investor Service, the US mortgage loan business may save up to 20% annually on costs by using blockchain technology, which translates to $1.7B in yearly savings (CBInsight, 2019).

Blockchain currencies, unlike the Dollar or the Euro, are entirely software from the beginning rather than being paper that is later represented by software. Software's capacity to be programmed gives it power. The cryptocurrencies can be programmed to escrow and distribute themselves, which is their main strength while humans and banks are required for fiat (non-crypto) currency (Lifthrasir, 2016).

The landlord typically requests a security deposit if somebody rents an apartment or a commercial space to cover any potential property damage. The money must remain in an exclusive escrow account and cannot be

used by the landlord. After the expiry terms of lease, the tenant must depend on the landlord's consideration to repay the security deposit. Both landlord and tenant establish a multi-signature transaction rather than paying into the landlord's bank account. Each party—the landlord, the tenant, and the arbitrator, a third, impartial party—receives a private key. Two of the three parties will need to utilize their secret keys in order to use the security deposit. Crypto-escrow is used to keep the money secure throughout the lease. The landlord uses his private key to issue the Bitcoin deposit at the end of the lease if the tenant didn't damage the property. The landlord would provide the arbitrator with proof that the renter caused damage to the property. The tenant shall have the right to reply. The arbitrator will use her private key to transfer the deposit to the victor after hearing from both sides.

2.4 Transparent Market

The lack of transparency among real estate players, which fosters corruption, fraud, money laundering, and limits business expansion, is one of the main issues in the real estate industry. Among the benefits of blockchain in real estate is shared secure databases (Horiachko, 2022). The distributed ledger and its immutable record of transactions are available to all network users. The distributed and shared nature of the ledger has various ramifications, including the fact that any network user can view transactions. Additionally, because the outcomes of the system can be trusted, there is no need to have faith in the other parties when using the distributed, shared ledger. Through unique mathematical operations and coding, this provides security and dependability.

All transactions are only recorded in blockchain once with this shared ledger, preventing the repetition of effort present in conventional corporate networks. Once a transaction has been added to the shared ledger, no participant is permitted to alter or interfere with it. A new transaction needs to be performed to undo an error in a transaction record before both transactions are displayed. Real estate buyers and sellers can readily access the databases, which contain all the information required for a transaction. All transaction records for leasing, buying, and selling become well known which could avoid the estate agents from moving other people especially involving the multiple listing services.

The blockchain might then be used to track the property's entire transaction history. As a result, when this technology is accepted by the market,

the necessity for middlemen or due diligence will vanish. This transparent market with blockchain-enable database significantly could reduce the risk of fraudulent with only the related real estate stakeholders such as buyers, sellers, and other service providers can always access information quickly and reliably, with the ability to make a modification or add necessary information. As a result, blockchain enables the development of a platform for all parties that enables automated, tokenized, speedier, and more secure communication as well as access to highly valuable real-time information.

Blockchain utilizes a permanent ledger system for the duration of the network. As a result, all information about the building's history or the property is recorded, available, and transparent to all prospective investors and buyers. The application of blockchain technology in real estate investing can be advantageous to all parties involved. Additionally, greater market transparency would make it simpler for regulators and associated businesses to understand the risks associated with real estate (Martijn, 2017).

3 Blockchain Applications in Real Estate Transactions

The ownership of various types of assets can be tracked and transferred using blockchain technology. Digital assets like NFTs, a representation of ownership of digital artwork and videos, are currently quite popular with this. Blockchain might, however, also be utilized to handle the ownership of physical assets, such as the deed to real estate and vehicles. The blockchain would be used by both parties to a transaction to first confirm who has the property and who has the funding before the sale could be finalized and recorded. With this method, they could transfer the property deed without having to manually submit documents to amend the county's official records; instead, the blockchain would be instantly updated.

For several decades, the real estate industry had been run using a meticulously outdated system that necessitated a never-ending list of middlemen and was very expensive for buyers, sellers, and investors to complete their real estate transactions (Jacob, 2022). Real estate transaction is not only expensive, it is also lengthy especially involving the due diligence process that engages with the high costs. This is due to the intervention of the middleman such as the estate agent, government database, and many more (Martijn, 2017) throughout the real estate transaction

process. The existence of these middlemen because they possess information that is either inaccessible to the general public or due to the necessary skills and authorizations are not present (Lifthrasir, 2016). When conducting due diligence, it may be possible to save a great deal of time and money provided all information is readily available and revised immediately whenever an event occurs. Hence, blockchain technology has opened up new possibilities for real estate transactions. The purchase and sale of real estate can be streamlined and made safer with the use of blockchain technology. This entails being able to trace a property's ownership history for buyers. It implies being able to offer more transparency on the sale process for sellers. Blockchain technology also can improve the quality of data, analysis, and decisions by acting as the connecting thread across the different technological systems and stakeholders associated with a real estate transaction (Deloitte, 2016).

Contrarily, many real estate deals feature conditional terms, take a while to complete, and demand a secure transfer. As a result, it is claimed that the use of blockchain technology can facilitate transactions more effectively because of some of its features that may enable quicker and more secure real estate transactions. To contribute to the entire procedure and complete transactions, a wallet is necessary. A wallet is a programme that enables you to store and exchange digital currency, similar to a bank account. A specific cryptographic method and an exclusive pair of independent but connected keys are used to secure the wallet. There are both public and private keys. Because of this, whenever an inquiry for a transaction is submitted using a wallet's private key, a person generates a digital signature that blockchains computers can use to confirm the transaction's origin and authenticity.

Blockchains can be public or private. Anybody can participate in a public blockchain, which means they can read, write, or verify the information stored on the blockchain. Notably, because no single entity controls the nodes, it is exceedingly impossible to change transactions that have been recorded in a public blockchain. In contrast, a private blockchain is managed by a company or group. It has the power to go back and change the blockchain, and it is the only one that can select who gets admitted to the system. With the exception of being distributed over numerous nodes to improve security, this private blockchain procedure is more comparable to an internal data storage system.

The most important thing to know about (public) blockchains is that the transactions take place in a peer-to-peer network. Furthermore, it has

no financial institutions or other third parties are required while the transaction is cryptographically proofed rather than relying upon a central authority. Besides that, the (public) blockchain required the trust that is placed in the network rather than a centralized authority. According to Mougayar (2016), a blockchain is a way to legally validate transactions without the use of intermediaries, a network for exchanging goods and services between parties or peers, and a database that keeps track of distributed ledgers in the open.

A new block is added to the network of data blocks with each transaction. Hashes are the fundamental building blocks of blockchains because they safeguard the data storage of the blockchain and create a fingerprint that verifies the accuracy of the data (Beck et al., 2018). The hash applies an algorithm to the file to create a data fingerprint that will not change if the file is left unchanged. It encodes the precise content of the original file and, if that information has to be confirmed again, creates a hash of that data. A consensus protocol is described as a proof-of-stake protocol. The timestamped nature of the hashes proves that the material was available at that time. According to the protocol, the network's computers, referred to as nodes, must verify the presence of a new transaction before it can be added to the database by comparing a new hash to those that already exist (Swan, 2015).

Blockchain's primary innovation is the decentralization of the system that comes about as a result of removing middlemen from transactions. Blockchain enables the centralization and removal of middlemen from every type of transaction between parties with Internet access worldwide. While in conventional transaction models, the central authority is responsible for verifying transactions, arbitrating conflicts, and doing other tasks including maintaining central ledgers. If a system's central authority is undermined, such as through hacking or manipulation, intruders have the ability to cause enormous damage (Swan, 2015). Because it eliminates the need for a central repository of records and replaces it with copies of the records distributed to all blockchain participants, the distributed ledger, or decentralized blockchain model, is viewed as being superior to conventional transaction models (Flink, 2021).

According to Tran (2018), real estate transactions may be impacted by blockchain technology and smart contracts in three different ways. Firstly, it establishes a transparent multiple listing service so that parties can view available properties in accordance with their own needs. In exchange for the platform's cryptocurrency, users submit their property listings onto a

multiple-listing service blockchain, giving both parties access to the data on the multiple-listing service. This would enable the process of searching for buyers, sellers, lessors, and lessees to be customized and streamlined. Inspections and property visits follow.

Secondly, by automating investigations, prior transactions, and searches for encumbrances on the property, blockchain, and smart contracts enable the establishment of smart identities that may drive the effectiveness and accuracy of due diligence. A digital identification unifies the data of the parties involved in a transaction on the blockchain. Digital identification data may contain statistics on vacant properties, buyer or renter profiles, finance and entity status, or indicators of performance. With the creation of a past history of the parties and the property, a valuable online record of the parties and the property is established, substantially facilitating the due diligence process. Agreements are confirmed by the accounting records and the parties once satisfied. With smart contracts, the parameters of the deal are written into the blockchain and used to start making payments for agreed-upon advances, security deposits, and earnest money while also formally documenting the transaction. Finally, the smart contract also could monitor cash flow and start automated payments. For automatic payments to real estate owners, property managers, and other interested parties as well as for near real-time reconciliation, smart contracts might utilize payment, rent, or cryptocurrency. As digital identities of people, places, and businesses are registered throughout the transaction, real-time data is accessible.

In summary, with the use of blockchain technology, real estate transactions may be completed more rapidly and with less paper. This is because blockchain technology makes it possible to transfer assets digitally, doing away with the necessity for contractual agreements or other physical documents. The capability to complete the entire real estate transaction process electronically can save a tonne of time. The fact that blockchain is extremely secure is another advantage. A decentralized ledger keeps track of every transaction, which cannot be altered or tempered. This provides buyers and sellers with the assurance that their transaction is secure.

3.1 Understanding Blockchain and Cryptocurrency

A wide range of sectors could be simultaneously disrupted and created by blockchain technology and cryptocurrency. Numerous big businesses, like Microsoft, along with millions of other vendors throughout the world,

are beginning to use blockchain technology and accept different cryptocurrencies in their transactions. Cryptocurrency is a particular type of digital currency and become a medium of exchange such as US Dollar. It is utilized to send and receive transactions over the internet using cryptographic techniques and their protocol to verify the fund transfer and to ensure the legitimacy of a transaction source and funds cannot be stolen (Wetzel, 2018). Cryptocurrency runs on a decentralized computer network without a need for central clearing authority. Cryptocurrency that has no physical form and transfers over the internet are allegedly "encrypted and permanently recorded on a digital ledger" that is impenetrable to other parties (Anello & Lee, 2017).

While there are many different cryptocurrencies, including Litecoin, Dogecoin, Etherium, Ripple, and others, bitcoin currently holds the largest market share and is the most widely used one (Simanta, 2018). It was able to capture users' interest because of its capacity to maintain user unanimity, but it really took off because of its transparency. Since then, Bitcoin has grown significantly, and by 2013, investors began to invest heavily in Bitcoin-related startups. Bitcoins can be traded for conventional money, goods, or services. Users can electronically transfer bitcoins via a computer, a mobile device, or a web application with the aid of wallet software. The development of the Ethereum platform in 2015 made it possible for blockchain to function with loans and connections. It was built on a smart contract mechanism, which ensured the execution of a transaction between the two parties. Ethereum's capacity to provide a quicker, safer, and more efficient environment led to the technology's widespread adoption.

Blockchain technology, the public ledger system that powers cryptocurrencies, has the power to upend a wide range of transactions in addition to the conventional payment systems. In most cases, a network of computers will be used to replicate a spreadsheet hundreds of times, which will then be updated constantly (Simanta, 2018). Although they are not only used in digital currency, they are also most known for their critical role in cryptocurrency systems that keep a secure and decentralized record of transactions. All the transaction records are stored digitally including stocks, bonds, and other financial assets which require miners to validate the keys and update the blockchain to reflect the transactions (Huges & Middlebrook, 2015).

The capacity of blockchain technology and cryptocurrencies to connect producers, customers, service providers, and end users will eventually

streamline the supply chain by excluding middlemen from the transaction. Increasing efficiency and lowering costs are immediate advantages. By 2025, some predict that about 10% of data on the world's gross domestic product (GDP) would be accommodated on blockchain (Tran, 2018). This expansion has prompted a wider acceptance of cryptocurrencies as a means of funding investments and transactions, leading to the emergence of new cryptocurrency exchanges where users may trade and move funds between cryptocurrencies and fiat money (Anello & Lee, 2017).

The emergence of blockchain technology and cryptocurrencies led to new uses for distributed ledger technology, particularly the smart contract (Firas et al., 2017). Smart contracts are seen as reliable and automated methods of recording calculations, just as blockchains are seen as reliable storage devices. Smart contracts have been defined as contracts in which code has taken the role of legalese. They are actually agreements that are primarily automated and written in computer code.

4 Cross-Border Transactions Challenges from a Legal Perspective

The use of blockchain technology in cross-border real estate transactions to safely sell real estate assets and generate capital is a promising strategy, but it requires legislation to be harmonized. The implications of smart contracts and the blockchain on domestic and international real estate transactions necessitate legislation in order to fully realize the potential of the technology (Garcia-Teruel, 2020). Although it is doubtful that all real estate transactions will be automated over the next ten years, blockchain technology has the potential to speed cross-border payments and improve the efficiency of leasing agreements, particularly for short-term leases or for buildings with a high number of renters (Tran, 2018). Cross-border real estate transactions are usually time-consuming and involve extra difficulties. Foreign exchange fees and the use of several intermediaries in a cross-border transaction generally lengthen the payment lead time and raise transaction expenses. It is significant to remember that blockchain technology still remains in its infancy and that real estate presents unique difficulties for its complete implementation. A significant challenge for the adoption of any new technology, blockchain-based platforms included, is navigating intricate regional legislation throughout the globe. Hence, many businesses are delaying the use of blockchain technology due to regulatory barriers. Nevertheless, there is some movement here.

The implementation of blockchain applications in cross-border real estate transactions faces some legal challenges (Mehdi, 2020). It ranges from ensuring an actual cross-border property acquisition among citizens from various member states to problems with cross-border agreements (Garcia-Teruel, 2020). Blockchain technology combined with smart contracts may improve the speed and security of these transactions, but it also presents challenges and limitations due to the dependence on the different countries' regulation (CBInsight, 2019). For instance, due to the rigidity of the relevant laws and the added administrative burden they place on the sale and transfer of tokens, a number of blockchain-based investments in real estate platforms are unable to allow participation from investors outside of the United States. Therefore, despite the loss of a sizable pool of potential investors, it is simpler for these platforms to simply exclude American participation. Additionally, not all jurisdictions and nations accept smart contracts as legally binding, which puts parties who are unaware of this in serious danger. This is especially true for transactions involving significant financial commitments, such as real estate and titles.

The issue is whether blockchain is at present adequately equipped to present the responsibilities of related organizations, for instance, real estate agents, legal professional, and land registries in ensuring a secure real estate transaction. The particular potential blockchain applications in the real estate industry include verifying transactions and examining other encumbrances. This technology must overcome a number of obstacles before it can be compared to the existing real estate conveyancing systems in terms of dependability, legality, and security on a global basis. So, in order to take full advantage of the use of blockchain and smart contract provisions with respect to both domestic and international real estate transactions, regulations are necessary.

Law and regulations that apply across borders will also be impacted. Blockchain typically operates without regard to international boundaries. Laws tend to be national. It can be difficult for legislators to create legal regulations that can effectively support digital assets and blockchain-based transactions within a single jurisdiction, and it can be even more difficult to make those regulations function across borders (Sanit, 2022). This process is hampered by inconsistent national regulations, which also act as a brake on the growth of the global crypto financial markets.

Given the deficiency of existing legislation enacted explicitly for the purposes of regulating blockchain technology-enabled applications in

general and virtual currency in particular, it may be premature to attempt any rigid categorization of the regulatory approaches adopted by different jurisdictions based on the civil and common law systems dichotomy. It is noteworthy that several nations have taken a prohibitionary regulatory approach by forbidding virtual currencies completely, including Bangladesh, Bolivia, China, Ecuador, Morocco, and Nepal. In this case, the specific circumstances surrounding China's prohibition of virtual currencies. Regarding the regulatory strategies used by countries that have included blockchain technology under their purview, those strategies take into account the fact that those nations have significant political and economic clout and whose regulatory practices inexorably affect the remaining countries of the world. Besides that, it also considers that the strategies are at the cutting-edge of the regulation of this technology, or have developed creative applications for the technology.

5 Conclusion

Blockchain technology offers a universal property buying and selling system with understandable tools to global buyers and sellers. All sales transactions will be able to be automated, and smart contracts will instantaneously verify their legality. Commercial real estate smart contracts make it possible to streamline every sale and instantly verify their legality. Any transactions that occur via the blockchain are performed almost instantaneously, regardless of the time of day or if it is the weekend. Blockchain technology for real estate, therefore, offers a global method for selling property and lessens the restrictions brought on by local issues.

While adopting blockchain technology could help with a number of issues in the real estate sector, there are always difficulties when switching to a new technology that is still in its infancy stage. A significant challenge for the adoption of any new technology, blockchain-based platforms included, is navigating intricate regional legislation throughout the globe. Among the legal challenges in implementing blockchain technology in cross-border real estate transactions including the need to address traditional intermediaries, the need to distinguish between types of transactions and countries and the challenges posed by the use of cryptographic keys. Still, not all jurisdictions and legal frameworks have adopted blockchain. Despite the fact that some real estate apps now incorporate blockchain technology, some users are still cautious of it because it has not yet received legal approval. Expect the blockchain to become a legitimate

industry standard once it is more generally recognized and understood. Due to different societal norms and financial investment market factors in different regulatory jurisdictions around the world, there is no universal strategy for the regulation of blockchain technology-enabled applications in general and virtual currencies in particular.

The adoption of blockchain in real estate is expected to take 10–15 years. The industry will undergo a thorough transformation that will benefit all parties involved once the pieces start to fall into place more quickly, but it is coming. In addition, there are still a lot of untapped potential uses for blockchain in conjunction with AI, ML, big data, and IoT technologies that may make it possible to provide solutions to numerous issues facing the real estate sector at the moment. It may be a little strange right now to think about real estate transactions on the blockchain. They do, however, have a plethora of real-world uses in security, data access convenience, and several other areas stated before. As a result, in the upcoming years, expect this technology to fundamentally alter the real estate market and other industries.

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