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.

J. Bronckers (✉)
FIBREE, Noordwijk, The Netherlands
e-mail: Jo.bronckers@fibree.org

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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.

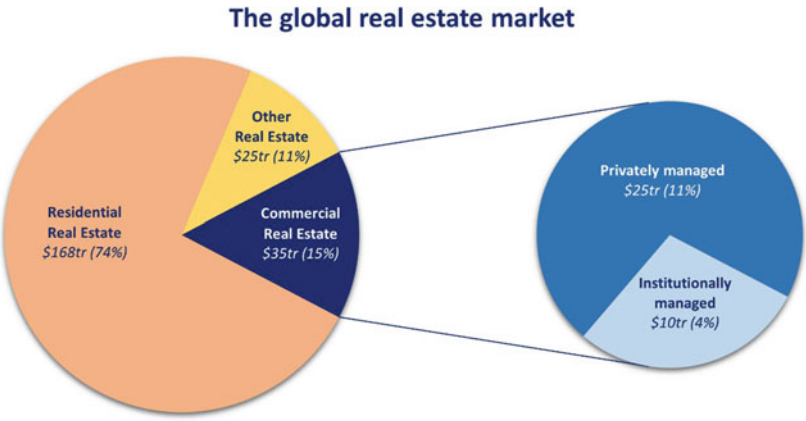

Fig. 1 Commercial Real Estate accounts for 15% of the global Real Estate market

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:

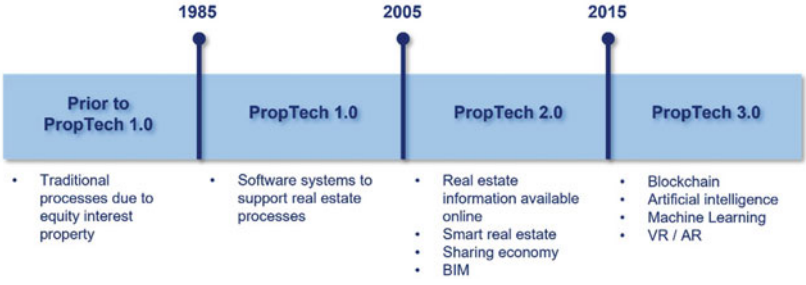

Fig. 2 Evolution of information technology in real estate towards PropTech 3.0 (Baum, A. 2017, personal adaptation)

> 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

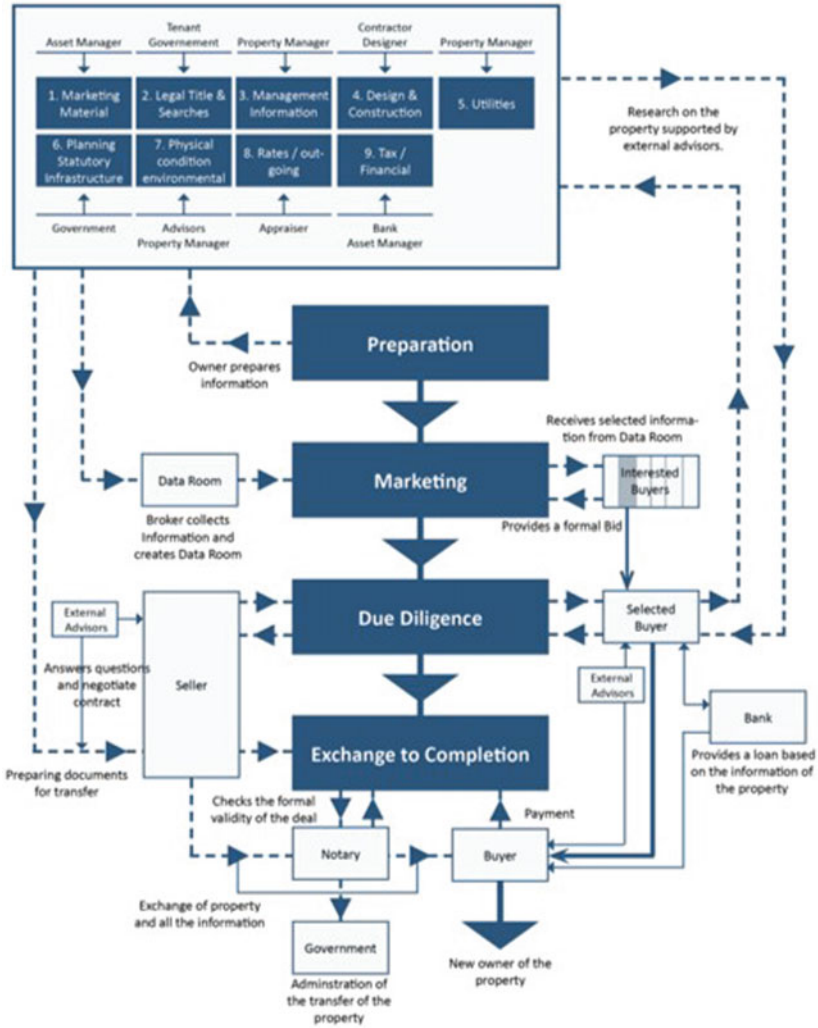

Fig. 4 Information exchange during the transfer process (*Source* Dijkstra [2017])

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

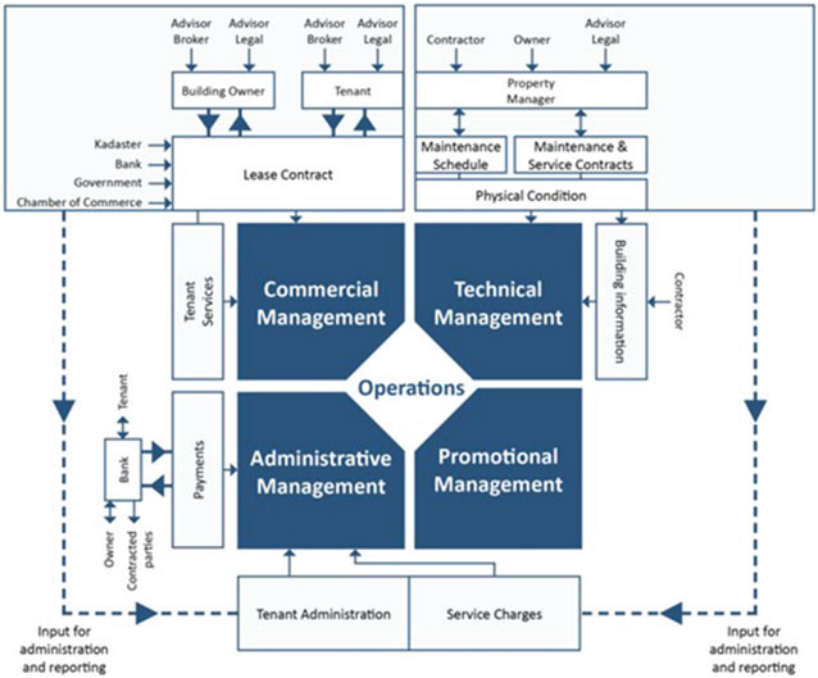

Fig. 6 Information exchange during the operation process (*Source* Dijkstra [2017])

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:

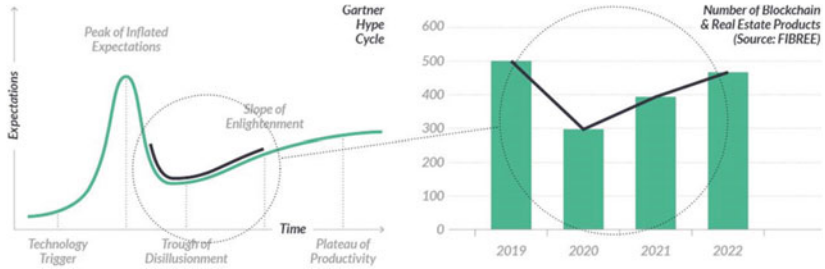

Fig. 7 The state of blockchain in real estate (*Source* FIBREE)

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.

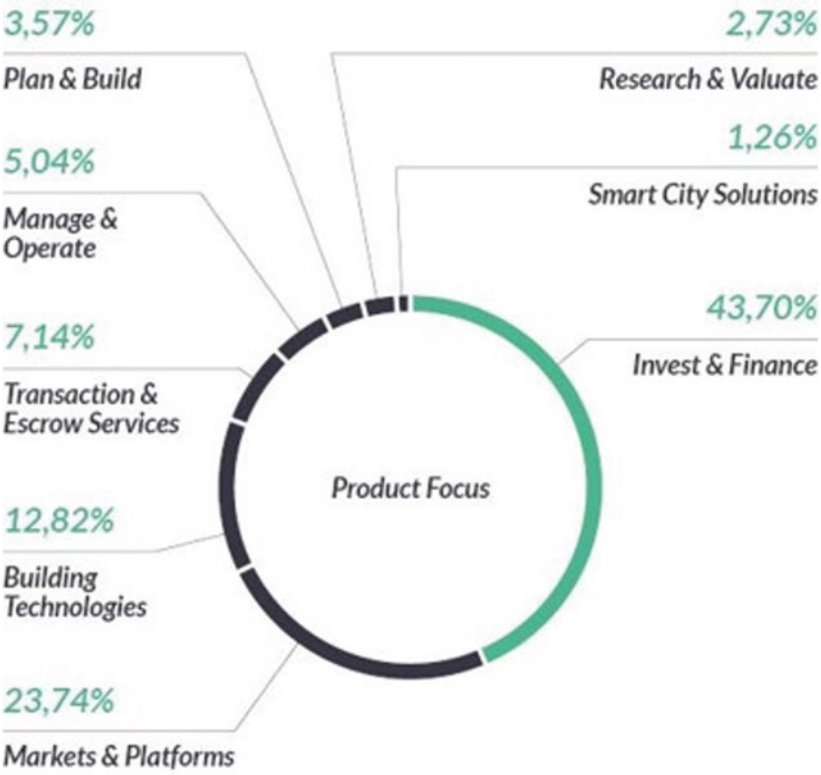

Fig. 8 The distribution of product categories in the total database of 2022 (*Source* FIBREE [2022])

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

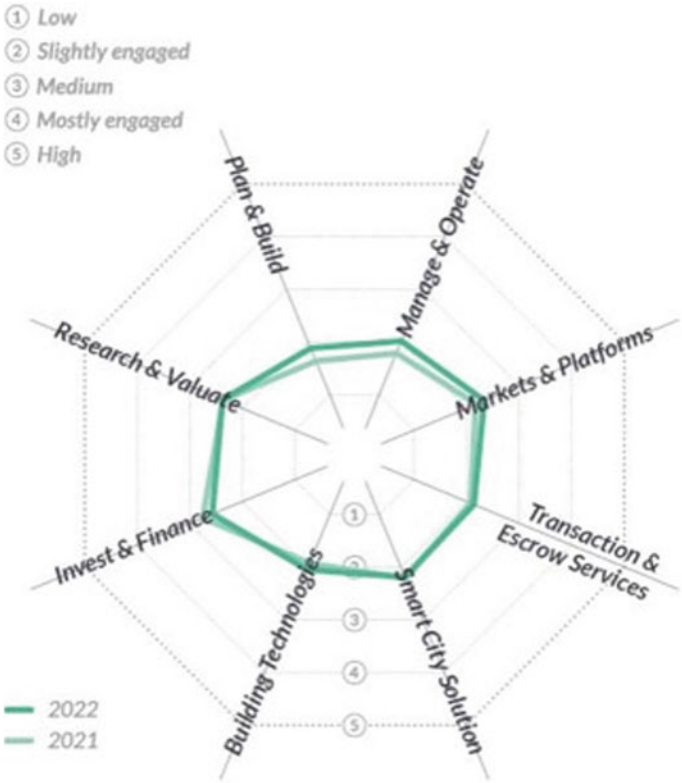

Fig. 9 Level of market engagement for blockchain-based real estate products (*Source* FIBREE [2022])

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).

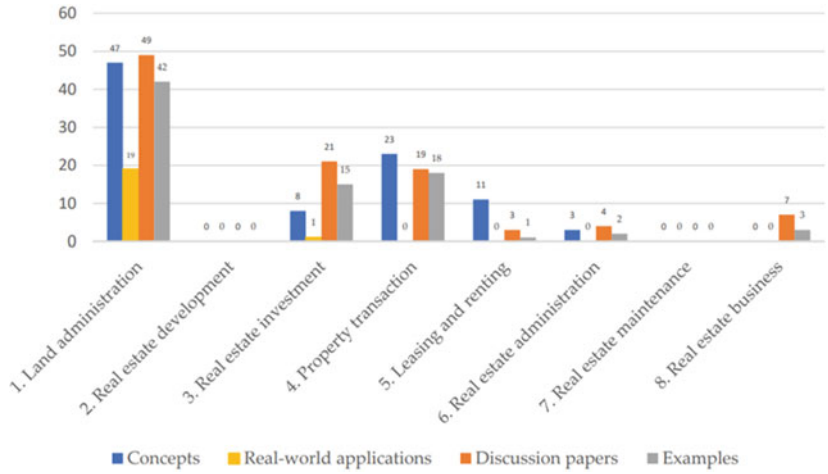

Fig. 10 Document classification by real estate subsectors and paper types by Saari, A. et al. (2022a, 2022b)

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

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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

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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

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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

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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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