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Blockchain in real estate: Recent developments and empirical applications

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ABSTRACT

The real estate sector is often presented as an exemplary field that benefits from practical blockchain applications. The general hypothesis is that, in theory, blockchain could solve some significant challenges the real estate sector is facing, such as nontransparency, inefficiencies, fraud and corruption, high costs, and trust issues. However, the literature focuses on blockchain’s theoretical benefits, challenges, or concepts. This research aims to understand the recent developments in the blockchain literature, specifically in the real estate sector, and to understand the current real-world applications by collecting empirical evidence from blockchain studies. The systematic literature review identified 262 relevant documents, after which a thematic content analysis was performed. Conceptual blockchain literature was identified to propose blockchain benefits for the real estate sector in four categories: land administration, real estate transactions, tokenization, and real estate management. The thematic content analysis also identified 26 empirical applications, of which all except one were related to land administration. Although the conceptual and theoretical blockchain literature presents blockchain as a disruptive and transformative technology for the real estate sector, the empirical applications suggest that blockchain adoption materializes more in hybrid, smaller-scale settings, where blockchain is merely an add-on layer to existing systems. Overall, most of the conceptual blockchain benefits remain empirically unconfirmed. On the other hand, the empirical applications suggest that blockchain could, for example, increase efficiency, reduce time, and provide verifiability, transparency, and automation, even in smaller-scale, hybrid settings. In addition, the applications indicate that blockchain could, in some cases, help reduce fraud and increase security and trust compared with centralized digital solutions. Finally, the empirical insights emphasize the role of political will, regulatory framework, availability of reliable digital data, public-private partnerships, and educational aspects in blockchain applications.

1. Introduction

The real estate sector accounts for approximately 60% of the world’s wealth, totaling over USD 200 trillion (Savills, 2016), 36% of final energy demand in 2017, and nearly 40% of energy-related carbon dioxide emissions globally (International Energy Agency, United Nations Environment Programme, 2018). The real estate sector is defined here as property consisting of land and buildings, immovable property of this nature, an interest vested in this, an item of real property, and buildings or housing in general (Oxford English Dictionary, 2020). Despite its global economic, environmental, and societal significance, the real estate sector’s digital maturity is consistently evaluated as being low compared with many other industries (Calvino et al., 2018; Manyika et al., 2021), signaling a significant potential for increasing productivity through more widespread implementation of digitalization.

Blockchain is a decentralized transaction and data management technology developed first for the Bitcoin cryptocurrency in 2008 (Yli-Huumo et al., 2016). The definition of blockchain varies in the literature, and terminological confusion exists. Blockchain can be broadly described as a sequence of digital records or “blocks” linked using cryptography. Each block is verifiable and virtually unchangeable, distributed, and managed typically in a peer-to-peer network. The blockchain allows transactions to occur without an intermediary (Yli-Huumo et al., 2016), providing transparent, tamper-proof, and secure systems that can enable new innovative consumer and business solutions (Andoni et al., 2019). Blockchain also refers to the underpinning technology (Oxford English Dictionary, 2021).

In the current review, the definition of blockchain is not limited to the above definitions but is instead regarded in the broad scope. Thus, the present research regards distributed ledger technology and blockchain technology as synonym categories. To date, Bitcoin and other so-called cryptocurrencies have received most of the growing public

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attention. However, a growing amount of research has focused on blockchain applications within different fields. The real estate sector is one of the most significant focus areas in this domain and is often provided as an example of benefiting from practical blockchain applications.

Initially, in 1998, legal scholar and cryptographer Nick Szabo envisaged a secure and decentralized property title system (Szabo, 2021). A decade later, the pseudonymous ‘Satoshi Nakamoto’ introduced the blockchain concept (Nakamoto, 2008), solving the double-spending problem plaguing Szabo’s property title system. Since then, many different blockchain proposals for the real estate sector have been presented. The general hypothesis seems to be that blockchain could, in theory, solve some of the significant challenges the real estate sector faces, such as nontransparency, inefficiencies, fraud and corruption, high costs, and trust issues.

Many reviews have examined blockchain’s potential, benefits, and challenges within the real estate sector but have mainly concentrated on one area, such as land administration (Ekemode et al., 2019; Ferreira, 2021). Bennett et al. included blockchain in their systematic research synthesis of emerging data technologies in the global land administration sector and provided a detailed outlook of blockchain’s potential in land administration in 2019 (Bennett et al., 2019). However, Bennett et al. concluded that in 2019, it was simply too early to make broader claims about the potential impacts of blockchain on the sector.

Additionally, the real estate sector, especially land administration, is mentioned as one potential blockchain application in systematic literature reviews conducted from other perspectives, such as smart city and e-government (Khanna et al., 2021; Majeed et al., 2021), smart contracts (Alotaibi and Alshamrani, 2021; Xu et al., 2021), or blockchain general industrial applications (Sanka et al., 2021). However, compared with how often real estate is provided as an example of a potential blockchain application in the academic literature, systematic reviews providing an up-to-date and thorough understanding of the potential of blockchain for the whole real estate sector beyond land administration are lacking (Ferreira, 2021). With blockchain technology developing at such a rapid pace, research is being increasingly published, leaving previous works quickly out of date.

Moreover, most research on blockchain in the real estate sector has dealt with theoretical concepts instead of empirical settings. In fact, most research conducted on blockchain applications in general is on the conceptual level. The number of quantitative and qualitative business-related research studies is limited, and theory-driven empirical research is rare (Karamchandani et al., 2020; Ristius and Spohrer, 2017; Toufaily et al., 2021), which leaves the applicability of blockchain deficiency understood. The blockchain literature on the real estate sector is no exception. The current paper aims to help fill this research gap by bridging the empirical insights of real-world blockchain applications into the conceptual real estate sector perspectives, thus bringing the theoretical discussion to firmer grounds.

The current research aims to answer the following questions: How has the understanding of blockchain adoption benefits and challenges in the real estate sector developed in recent years? What are the empirical blockchain applications in the real estate sector? What are the empirical insights compared with the theoretical perspectives in the real estate sector?

The current review contributes to the general blockchain research and understanding of blockchain application within a highly significant global sector, that is, real estate, by reflecting on how conceptual blockchain real estate perspectives compare with the empirical insights. The research provides a state-of-the-art outlook on the most recent developments and blockchain’s likely impact on the sector. Because empirical blockchain research is generally scarce and the vast majority of exponentially increasing blockchain research continues to be conceptual and theoretical, bridging the theoretical perspectives to empirical insights is meaningful.

The current research follows a systematic three-step methodology. Altogether, 262 documents were identified and analyzed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (Liberati et al., 2009). A formalized thematic content analysis with the following characteristics was used: identifying themes in the text and assigning them descriptive codes that are later merged to form meaningful, more conceptual categories. The analysis compared the conceptual blockchain proposals and their benefits and challenges to the recent adoption themes (2020–) and real-world empirical applications.

The current paper is structured as follows: Section 2 describes the methodology and data. Section 3 first summarize the benefits and challenges the general blockchain literature suggests for the real estate sector to set a starting point for understanding the recent developments. Section 3.1 then analyzes the recent insights on blockchain adoption in the real estate sector from real estate-focused papers published from 2020 onwards. Finally, the results presented in Section 3.3 concentrate only on empirical applications in the real estate sector to provide concrete evidence and validate the conceptual benefits and challenges. Section 4 discusses the results and summarizes the entire work.
2. Methodology and data

This systematic review followed a three-step approach to understanding blockchain applications in the real estate sector, as Fig. 1 illustrates:

The first step began with a literature search in the following electronic databases: Scopus, Proquest, Web of Science, and Science Direct. The search terms (“blockchain OR “block chain” OR “distributed ledger” OR “DLT”) AND “real estate” were used. Only English peer-reviewed sources published after 2008 were included. The searches were run from June 9, 2020, to June 15, 2020, on December 31, 2020, and from November 5, 2021, to December 31, 2021. A limited updated literature search was conducted on Google Scholar in two rounds: the first round on August 20, 2020, which screened the first 36 results pages. The following rounds on November 6, 2021, and December 31, 2021, screened the first 10 results pages. On Google Scholar, articles directly referring to real estate in their title (e.g., property, housing, land) were included. The final studies contained primarily academic literature, but some reports, theses, and magazine articles were included because blockchain technology has also been developing rapidly outside academia. Including both perspectives ensures a broader state-of-the-art understanding of the technology’s applicability in the real estate sector.

The PRISMA flow chart in Fig. A1 in Appendix 1 summarizes the study selection process and is used to improve the reporting of this systematic review. The first phase of the study selection screened the articles’ records and excluded irrelevant document types, for example, indexes, tables of contents, and glossaries. The current research has focused on the real estate sector, excluding documents with construction, cryptocurrency, energy, supply chain, and pure Internet of Things (IoT) focus. The second phase assessed the eligibility of the documents by reading full-text documents. In this phase, the main reason for exclusion was that the document only mentioned blockchain or real estate but did not discuss them in the same context, which occurred for more than half of all excluded articles. The second most common reason for exclusion was that the document only mentioned real estate as a general blockchain application without concrete examples or justifications with almost 20% share. The assessment of the full-text documents resulted in the final literature of 262 documents categorized by their publishing year, publication type, and primary field of publication.

More than half of the documents were published after 2019 as Fig. 2 illustrates. The annual number of published papers presented an increasing trend. Most of the literature was journal articles (52.9%) and conference proceedings (21.1%). The remaining literature included book sections, reports, theses, and magazine articles, as illustrated in Fig. 3.

The document focus presented in Fig. 3 shows that conceptual papers and documents containing some descriptions of blockchain examples in the real estate sector contributed the most significant shares of the literature, closely followed by documents whose primary focus was on blockchain in the real estate sector. The primary field of each publication in Fig. 3 shows computer and information science publishing comprised most of the papers, with an almost 45% share of the literature. The real estate sector accounted for the second most popular field (16%), followed by business and management (7.3%). The publication fields highlight that the most recent focus of the research field has been technical. The principal authors’ locations included 58 countries altogether, implying that the research theme has received worldwide attention. Three of the most active countries were India, the US, and the UK.

The second step of the research process analyzed the data with thematic content analysis using QDAS software, ATLAS.ti version 8.4.4, to identify three themes: conceptual proposals, recent adoption themes from 2020 onwards, and empirical applications. The systematic qualitative review began without a coding framework in mind. For the conceptual proposals, the analysis started by studying the documents, marking all the sentences describing blockchain proposals in the real estate sector, and assigning preliminary codes to describe the usage. Then, the descriptive preliminary codes were grouped into more conceptual code categories. After identifying the blockchain proposals, descriptive codes were appointed for the benefits and challenges suggested for the identified blockchain real estate proposals. The descriptive codes were later conceptualized by merging codes with similar meanings together, as suggested by Friese (Friese, 2019), to allow meaningful analysis. A similar method of first assigning descriptive codes and later merging them into conceptual categories was conducted for the recent themes discussing blockchain adoption in the real estate sector.

Fig. 2. Publishing year of the documents and number of documents with empirical focus.

Fig. 3. Literature by publication types and primary publication fields.
sector from 2020 onwards and for the real-world empirical applications. The benefits and challenges of all three themes were identified and analyzed similarly.

As Fig. 1 illustrates, the number of documents analyzed in each thematic content analysis round varied. The third and final step continued the analysis by comparing the results of the different rounds of thematic content analysis to understand how the benefits and challenges conceptually proposed differed from the recent adoption themes and those assessed in the empirical applications. The queries, code grouping, network features, research memo features, and visual networks provided by ATLAS.ti helped answer the research questions in the analysis phase.

3. Results: blockchain in the real estate sector

The research showed that the conceptual and theoretical blockchain literature, which has continued to increase exponentially, has proposed blockchain benefits and challenges for the real estate sector in four broad categories—land administration, transactions, tokenization, and real estate management—which here are presented in the order of prevalence (see Table A in the supplementary material for an overview). The land administration category contains blockchain-based applications that specify a link to the land and title registration systems. The proposed blockchain applications in the land administration category mainly consist of technical concepts (Spielman, 2020; Soner et al., 2021; Ali et al., 2020; Thakur et al., 2020; Konashevych, 2020a; Mendi et al., 2020). The transaction category refers to commercial and residential real estate sales where the participants may be professional or retail investors or consumers. Tokenization refers to digitally representing real estate as blockchain-based tokens. The tokenization category also includes platforms for real estate tokenization and crowdfunding. The last category, real estate management, includes blockchain proposals for concepts such as rental platforms, real estate data storage solutions, and multiple listing services. All four categories are interrelated and overlapping, especially transaction and tokenization.

The main benefits the blockchain literature has continued to conceptually and theoretically propose for the real estate sector in these four categories are increased trust and efficiency, reduced corruption and fraud, inclusion, and cost reduction. The literature simultaneously has continued to highlight certain blockchain adoption challenges: implementation complexities, legal uncertainties, and technical issues. Moreover, even from the beginning, the mostly conceptual and theoretical literature has shown that blockchain adoption would still require intermediation in the real estate sector, especially within the land administration category.

3.1. Real estate literature’s recent emphasis on blockchain adoption

Since 2020, the real estate literature has started to pay more attention to blockchain adoption. Interestingly, even if the general blockchain literature continues to propose concepts and benefits in the four broad categories described above, the real estate-focused blockchain literature concentrates primarily on land administration. Tokenization also receives some attention, but transactions and real estate management receive only limited attention. This finding implies that even if, theoretically, blockchain could be adopted in four categories in the real estate sector, the recent literature suggests that not all these categories are currently relevant.

The first recent emphasis of blockchain adoption within land administration is the hybrid approach, which refers to phased adoption, initially proposed in 2017 (Lemieux, 2017a, 2016) and 2018 (Graglia and Mellon, 2018). Bennett et al. described the current blockchain application in land administration with the concept of a ‘hybrid approach,’ referring to the combined use of conventional database technologies integrated with blockchain technology (Bennett et al., 2021). The hybrid approach focuses on specific land dealings, activities, and actors instead of whole-of-sector digital transformation designs and aims for minimal disruption to existing institutions and infrastructures. Whereas Sandberg regarded today’s land administration applications as “considerably more modest propositions to incorporate the blockchain system into the existing registration systems for control purposes, not to replace them” (Sandberg, 2021), Bennett et al. concluded that the hybrid approach appears to offer a way to overcome blockchain adoption challenges by minimizing disruption while maximizing the benefits powered by smart contracts (Bennett et al., 2021).

Nicolaou-Manias and Wu have recently concluded that incorporating blockchain into existing registries is a safer first step than replacing them (Nicolaou-Manias and Wu, 2021). Others have also considered replacing current land registries with blockchain-based land and title registries unrealistic (Nastri, 2021; Yapiçoglu and Leshinsky, 2020). In 2019, Allessie et al. examined blockchain applications for digital government and concluded that blockchain is always “just one layer of a more developed service” (Allessie et al., 2019).

Interestingly, the theoretical literature has even recently introduced blockchain as disruptive, revolutionary, or transformative for the real estate sector (Khanna et al., 2021; Ahmad et al., 2021; Hewa et al., 2020; Kim and Huh, 2020; Ullah and Al-Turjman, 2021; Chow and Tan, 2021). This finding suggests that the typical blockchain narrative is so strong that it has not kept up with current developments in the real estate sector. Rodima-Taylor proposed that the performance of blockchain in land administration should be viewed in the light of “imaginaries and metaphors surrounding empirical applications,” reminding us that blockchain is not the first technology to evoke powerful narratives about its advantages (Rodima-Taylor, 2021).

The recently highlighted hybrid approach has not been without criticism. One way to implement the hybrid approach is to store hashes of the original data on the blockchain and keep the original data off-chain. However, Konashevych noted that although the idea has even been piloted, hashing does not protect the data, only the hashes of the original data, leaving the centralized registry still vulnerable (Konashevych, 2021). If the original data were destroyed, it would be unrecoverable through the published hashes. Lemieux et al. warned that hybrid models could offer the worst from both the centralized and future decentralized worlds when considering the balance between information governance risks and new strategic business opportunities, proposing that information executives embrace decentralization as quickly as possible (Lemieux et al., 2020). Nevertheless, Lemieux et al. agreed that hybrid approaches may be prudent and remain the primary application mode for the foreseeable future, even with their limitations (Lemieux et al., 2020). García-Teruel questioned whether a small-scale, partial blockchain implementation in land administration could provide significant benefits for the conveying system (García-Teruel, 2020).

The hybrid approach, modest as it may be, does seem to help with complex blockchain implementation, which the theoretical blockchain literature has identified as the most significant blockchain challenge within land administration.

Legal issues were theoretically identified as the land administration’s second most significant blockchain challenge. Compared with fully decentralized solutions, the hybrid approach likely eases legal challenges with its minimal disruption to current systems. Even if the hybrid approach does not provide the decentralization benefits proposed by the theoretical blockchain literature, the most often theoretically proposed blockchain benefits of increased trust, efficiency, and fraud prevention may still be realized with the hybrid approach, depending on the implementation details.

The second recent emphasis on blockchain land administration studies has shown how the mere digitization of land records has benefited many developing countries but has highlighted the limitations and drawbacks of these centralized digitalization initiatives. One of the main limitations is that centralized digital registries are prone to fraud (Benbunan-Fich and Castellanos, 2018; Bennett et al., 2021). For example, Kshetri described how the digitalization process shifted power
and even increased corruption and fraud in the Bhoomi system in India because digitalization moved the management of the records from the villages to district-level offices, where the records were prone to corruption and fraud (Kshetri, 2021). Kshetri also reported cyberattacks on recently digitized centralized records in India, leading to approximately 3 million land property disputes in 2018 (Dinesh Kumar and Manaswin, 2021). The digital registry adopted in 2013 brought significant efficiency advantages in Kazakhstan but left the centralized system prone to fraud and technical failures (Akhmetbek and Spacek, 2021). In Georgia, building a digital land registry database did not fully solve the public trust crisis in government agencies because there were concerns of corruption and cyber threats toward the centralized database (Shang and Price, 2018). Even if the Swedish land registry was digitized in the 1970 s and has not suffered from similar trust issues, the land transaction process is inefficient and nontransparent (McMurren et al., 2021).

Konashevych noted that even if many countries have used electronic cadastral systems for years, they still rely heavily on paper transactions (Konashevych, 2020b). Even if blockchain cannot resolve how to bring citizens and properties into the formal land registry system initially—a primary land administration challenge identified already in the theoretical blockchain literature (Vos et al., 2017; Kalyuzhnova, 2018; Anand et al., 2017)—this recent highlight on blockchain versus digitalized centralized registries is meaningful, especially for emerging economies.

The third recent emphasis in land administration adoption literature has started paying increased attention to the institutional and organizational aspects of blockchain adoption that significantly impact implementation. Blockchain should not be viewed as producing uniform results in all markets and societies but rather as part of a “distributed calculative agency shaped by local histories, geographies, policies, and regulations” (Rodima-Taylor, 2021). Others have also recently highlighted the local and country-specific context that should be included in blockchain application analysis (Ferreira, 2021; Adam and Favezkas, 2021; Ashurst and Tempesta, 2021; von Wangenheim, 2020). Such a detailed analysis of the complexities of land tenure issues has recently been examined, for example, in Ghana (Mintah et al., 2021). Lemieux et al. suggested paying attention to each solution’s physical and logical architecture because different configurations provide different outcomes (Lemieux et al., 2020). Kshetri emphasized how different groups interpret various technological systems differently (Kshetri, 2021). The theoretical and conceptual literature has identified complex implementation requiring collaboration with many stakeholders as the main blockchain challenge within land administration (Graglia and Mellon, 2018; Vos et al., 2017).

The fourth recent land administration adoption emphasis has encouraged attention beyond the firm level to the whole-sector-wide broader ecosystem (Bennett et al., 2021; Lemieux et al., 2020; Yuthas, 2021). For example, Prosukovska described how seemingly minor changes in the value chains could eventually disrupt the existing transactional routines if the Swedish blockchain land administration pilot succeeds in moving into production; she detailed how brokers and other organizations, whose market share the Swedish blockchain system could potentially be reduced, launched a new platform called Tambur in 2018, only months before live testing of the blockchain application. The consortium made the workflow more efficient with traditional technology while preserving the status quo. Because only brokers can interact with the banks on the platform, the platform solidified the brokers’ role in the Swedish real estate transactions (Prosukovska, 2021).

The recent blockchain literature on real estate transactions has highlighted how implementing blockchain concepts to reduce information asymmetries in real estate transactions would require updated policies or reward mechanisms for the parties to share information. Not all parties would likely benefit from the reduced information asymmetries (Hoksbergen et al., 2021). Some parties’ resistance to reducing information asymmetries is likely a blockchain adoption barrier in real estate transactions.

The recent literature has also shed light on blockchain implementation barriers within the real estate sector. Ullah et al. investigated barriers to digitalization in general in the Australian real estate sector, concluding that blockchain adoption barriers are complex (Ullah et al., 2021). Whereas the previous literature has often highlighted the difficulties of creating smart contracts, recently, the interpretation of smart contract language (processing language, computer code) to natural language has received more attention. For example, both Nasti and García-Teruel et al. illustrated how the knowability of the smart contract’s content and contractual rule binding the individual might become an issue unless natural language is used, for example, in the metadata of the smart contract (Garcia-Teruel and Simón-Moreno, 2021; Nasti, 2021).

The first blockchain adoption emphasis for real estate tokenization is the legal and governance aspects. Garcia-Teruel et al.’s comparison of different legal systems identified differences in asset-backed tokens’ validity, even within the EU (Garcia-Teruel and Simón-Moreno, 2021); they showed that tokenization in five countries would have different legal standings, even with generally less regulated limited property rights. Hence, the following question emerges: If the legal viability varies greatly between countries within the EU, how far are we with genuine, global cross-border transactions (Garcia-Teruel and Simón-Moreno, 2021)? Similarly, Wang noted that the conflicting regulatory regimes that prevent the free and international exchange of security tokens may undermine the advantages of tokenization (Wang, 2020). Currently, it is unclear how the token economy can achieve global alignment. Creta and Tenca provided another example of the importance of regulatory certainty for blockchain applications (Creta and Tenca, 2021); their interviews with real estate crowdfunding platform operators in Italy identified that the main challenge is Italy’s current regulatory framework, which did not include explicit token-focused regulations. Some respondents even said that they were working with companies in other countries where regulation was already in force (Creta and Tenca, 2021). The respondents to the Asia Securities Industry and Financial Markets Association survey also highlighted regulatory and legal uncertainty as the main challenge to tokenized security (Chow and Tan, 2021). Simultaneously, the recent literature has provided some examples of countries that have started to clarify their regulatory framework (Chow and Tan, 2021).

The second blockchain adoption emphasis for real estate tokenization was the intermediate structures, such as special purpose vehicles (SPVs) or funds, which are still regarded as preferable options for tokenization rather than directly tokenizing real estate ownership (Garcia-Teruel and Simón-Moreno, 2021; Baum, 2021). The intermediate structure seems to be in line with the “hybrid approach” discussion related to blockchain land administration. Interestingly, Chow and Tan highlighted how the currently available real estate investment trusts (REITs) have solved some of the issues that tokenization aims to tackle. Nevertheless, REITs have limitations and inefficiencies (Chow and Tan, 2021). To support this case, Baum described how the limited “pragmatic execution possibilities” of property investment strategies explain the considerable difference in the actual allocation of real estate in institutional investors’ portfolios in 2019 (around 10%) compared with the allocation suggested by modern portfolio theory (as much as 30–60%) (Baum, 2021). Interestingly, it is relatively easy to see similarities in this discussion to how digitization has already solved some, but not all, land administration challenges. The real estate tokenization literature’s third adoption emphasis was the demand for the products. On the one hand, Chow and Tan believed that the COVID-19 pandemic accelerated the adoption of digital services for consumers, businesses, and even the government, especially in the Asia-Pacific region, contributing to the demand for financial products using apps (Chow and Tan, 2021). Additionally, they argued that the growing number of cryptocurrency and nonfungible tokens (NFT) will also increase the number of investors able, ready, and willing to invest in real estate tokens. They also
regarded the increasing trend in central bank digital currencies as a promising development that could lower administrative and transaction costs in post-tokenization processes (Chow and Tan, 2021).

On the other hand, Baum continued to question the investor demand for security tokens for single real estate assets, stating the evidence for such both through history and the current period seems sketchy (Baum, 2021, 2020a). In addition, market participants would need to be comfortable with blockchain to invest in single-asset real estate tokens. Nevertheless, the literature has provided some examples of single-asset tokenization around the world. The critical factor limiting the growth of real estate security tokens is the lack of a centralized marketplace to facilitate the trading of tokens (Chow and Tan, 2021). Currently, real estate security tokens are restricted to only being traded on the platform where they are listed. If the platform lacks market depth and a higher enough number of trading participants, liquidity can become an issue (Chow and Tan, 2021).

Overall, the recent blockchain adoption literature for real estate has concluded that more empirical observations are required (Bennett et al., 2021; Konashhevych, 2020b). Rodima-Taylor noted that because the current blockchain application is diverse and disorganized, empirical insights are of “paramount importance” (Rodima-Taylor, 2021). Similarly, Adam and Fazekas called for experimentation, development, and rigorous testing of innovative cases (Adam and Fazekas, 2021). If blockchain adds value on top of digitalization, the digital processes could be altered and moved to blockchain applications (Adam and Fazekas, 2021).

3.2. Empirical insights

The current research identified 26 empirical applications discussed in the blockchain for real estate sector literature until 31 December 2021. Table B in the Supplementary Materials lists all the identified applications by category. In addition to these applications, the literature has mentioned some other examples of blockchain land administration initiatives and real estate tokenization platforms (see, e.g., a list of tokenizations in Baum, 2021). However, these were excluded from the practical application overview unless more detailed information was provided. Interestingly, all the detailed empirical applications concerned blockchain land administration or tokenization; no detailed applications were described for real estate management or transactions. Because most of the empirical applications had a link to land and title registries, they were categorized under land administration. Table B in the Supplementary Materials shows the empirically estimated main blockchain benefits and practical adoption challenges for each application if empirical evaluations were available.

Five land administration applications were in use, for example, in Afghanistan, Estonia, Georgia, India (Andhra Pradesh), and the United Arab Emirates (Dubai), whereas in most others, no progress beyond pilots or tests has been reported. At least three land administration applications, for example, Honduras, Ukraine, and the US (Cook County, Illinois), have been reported as discontinued. Most of the applications have been developed in public–private partnerships, where a governmental actor or local official has partnered with one or multiple private sector parties, most typically blockchain technology providers.

Most land administration empirical applications fall into Bennett et al.’s hybrid solutions category, where blockchain has been implemented as “a somewhat independent technology layer while not disrupting the existing technology arrangements” (Bennett et al., 2021). Generally, the empirical applications strongly show how Bennett et al.’s and Allessie et al.’s 2019 statements (Allessie et al., 2019) still hold true: blockchain has neither been transformative nor even disruptive for the public sector and land registries, contrary to how blockchain was initially portrayed. Blockchain has often been complementary or only partially substitutes for existing online public services. These empirical findings seem to validate the hybrid approach. Similarly, most tokenization applications detailed in the literature have concerned single assets, and most used a hybrid structure (e.g., a REIT or SPV).

However, the literature did not include enough technical details to provide a uniform description of all the applications. For example, the literature has been lacking details on how the United Arab Emirates (Dubai) used blockchain in its rental process. In Estonia, the e-Land registry has shortened the transaction process from three months to eight days (e-estonia.com, 2022). However, this shortening was not attributed to the use of blockchain, even if the government of Estonia has reportedly been using KSI Blockchain to secure its critical data, including property registry (Nicolau-Manias and Wu, 2021). Another noteworthy point about these identified blockchain applications within land administration is that most applications were for a specific function linked to land registry registries rather than full-scale land administration processes, supporting Bennett et al.’s recent views (Bennett et al., 2021). Finally, empirical evaluations existed for 12 of 26 applications identified in the blockchain for the real estate sector.

This section provides an overview of how the empirically assessed benefits and challenges of blockchain application in the real estate sector compare to the theoretically proposed ones. To keep the discussion relatively focused, the analysis covers the empirical insights as a whole instead of an application-by-application or category analysis.

Because only a few of the empirically assessed blockchain applications were in use, little can be concluded about the theoretical blockchain benefits in the real estate sector, and the outcomes of blockchain applications have been somewhat unclear (Konashhevych, 2021; Lazzushivil, 2019).

The main theoretical blockchain benefit for the real estate sector was increased trust, which many of the empirical applications (e.g., Georgian) aimed at (Allessie et al., 2019; Rodima-Taylor, 2021; Lamiex et al., 2020; Lazzushivil, 2019). The empirical insights have proposed that blockchain would increase trust mainly through verifiability (Bennett et al., 2021; Giderdzishvili et al., 2018; Kshetri, 2021; Chang and Wang, 2021; Kempe, 2017 Mar) but would, in some of the applications, bring new trust issues, for example, related to data (Lamiex, 2017b), as already proposed theoretically. Trust was also difficult to empirically verify (Lamiex, 2017a). The second most often mentioned theoretical blockchain benefit for the real estate sector has been efficiency. The empirical findings indicated that blockchain application could indeed increase efficiency in the real estate sector (Alketbi et al., 2020; Allessie et al., 2019; Bennett et al., 2021; Shang and Price, 2018; Kempe, 2017 Mar), reduce time (Akhmetbek and Spacek, 2021; Rodima-Taylor, 2021; Kempe, 2017; Alketbi et al., 2020; Allessie et al., 2019), provide automation (Akhmetbek and Spacek, 2021; Alketbi et al., 2020; Bennett et al., 2021; Chang and Wang, 2021; Kempe, 2017 Mar), and simplify current processes (Akhmetbek and Spacek, 2021; Allessie et al., 2019; Bennett et al., 2021). The empirical studies also suggested that blockchain in real estate could increase verifiability (Kshetri, 2021; Shang and Price, 2018; Giderdzishvili et al., 2018; Kempe, 2017; Chang and Wang, 2021) and transparency (Alketbi et al., 2020; Allessie et al., 2019; Bennett et al., 2021; Lazzushivil, 2019; Chang and Wang, 2021; Kempe, 2017 Mar). The other empirically estimated blockchain benefit in the real estate sector was fraud and corruption prevention (Alketbi et al., 2020; Allessie et al., 2019; Bennett et al., 2021; Kshetri, 2021; Kempe, 2017 Mar; McBurne et al., 2021), showing the theoretical benefit. Fraud reduction in empirical applications has mainly been achieved through publicity (Alketbi et al., 2020; Bennett et al., 2021; Kempe, 2017 Mar).

On the other hand, the electronic ID systems blockchain systems require might open new avenues for fraud, a concern raised, for example, in the Estonian context (Sullivan and Burger, 2017). Overall, blockchain applications might help reduce some types of fraud, but leave doors open for others (Lamiex, 2017a, 2016; Kempe, 2017). Overall, the empirical insights have supported that blockchain could indeed increase security, at some level (Konashhevych, 2021; Kshetri, 2021), for users (Kempe, 2017), especially for data (Allessie et al., 2019; Akhmetbek and Spacek, 2021; Lazzushivil, 2019).
Because most of the blockchain applications assessed empirically were hybrid applications where blockchain was added on top, the government’s role in land administration processes might increase, as estimated, for example, in the Swedish application (Rodima-Taylor, 2021). Overall, the governments retained a central role in land administration blockchain applications (Akhmetbek and Spacek, 2021; Allessie et al., 2019; Bennett et al., 2021; Kshetri, 2021; Lazuashvili et al., 2019; Lemieux et al., 2020; Rodima-Taylor, 2021), confirming the theory that blockchain has not been disintermediating the real estate sector. The empirical insights proved that removing the governmental role has not been the target of many applications (Rodima-Taylor, 2021; Akhmetbek and Spacek, 2021; Kempe, 2017).

The Indian application in Andhra Pradesh has shown how decentralizing the land registries to the village level helped fight corruption compared with the previous centralized digital solution that allowed the large- and middle-scale farmers to take advantage of the centralized systems at the expense of small farmers (Kshetri, 2021); hence, in some cases, blockchain could provide added benefits of fraud prevention, trust, and security compared with centralized digital solutions. Even if the blockchain system used in Andhra Pradesh was permissioned and the number of nodes limited, blockchain guaranteed that the nodes (agencies) could not tamper with the records without other nodes noticing, acting as balances and checks to each other (Kshetri, 2021). However, the other empirical assessments did not contain further comparisons to centralized digital solutions, so concluding with the current literature would be implausible. Only Kempe argued that the Swedish application could not be accomplished without blockchain (Kempe, 2017).

Blockchain’s ability to reduce costs received mixed assessments in the empirical studies. Blockchain could help reduce some costs (e.g., costs for the citizens in Kazakhstan (Akhmetbek and Spacek, 2021) and Andhra Pradesh, India (Kshetri, 2021), the process automation costs for service providers in the Dubai application, and transaction costs in the Swedish application (Allessie et al., 2019; McMurren et al., 2021; Kempe, 2017) but may increase others. For example, in the Swedish application, hybrid solutions might increase operation costs because blockchain costs just come on top of the current structures. Similarly, in the Georgian application, where the hybrid approach used Bitcoin on top of current systems, the process was even more expensive than a centralized solution (Lazuashvili et al., 2019). None of the empirical studies contained implementation cost assessments. Kshetri described how using a local blockchain company helped decrease implementation costs in the Andhra Pradesh, India application (Kshetri, 2021). Overall, blockchain implementation and operation costs, especially in the current hybrid settings, need more empirical research to draw conclusions on blockchain’s economic viability within the real estate sector.

The empirical applications shed more light on the challenges of blockchain applications, suggesting some blockchain application enablers, if not even drivers. The empirical findings supported the theory that blockchain implementation in the real estate sector has required governmental support and political will to increase transparency and reduce fraud. In most cases, blockchain land administration applications were conducted in public–private partnerships. The government’s support and will to increase transparency was regarded as a critical driver, for example, in the Georgian and Indian applications (Benbunan-Fich and Castellanos, 2018; Kshetri, 2021). The empirical assessments also highlighted the importance of the autonomy of the governmental actor (Akhmetbek and Spacek, 2021). Blockchain applications in the Indian Andhra Pradesh application, political rivalry was identified as an implementation challenge, because of which the project failed to gain broad support (Kshetri, 2021). The importance of political will was also evident in the Honduran application, which was discontinued for political reasons and a lack of governmental support (Lemieux et al., 2020; Benbunan-Fich and Castellanos, 2018).

Interestingly, when the implementing parties’ interests were aligned, they seemed willing to openly discuss their blockchain land administration initiatives in public during the pilot and even benefit from such publicity (Benbunan-Fich and Castellanos, 2018). This publicity and public–private partnership have been most evident in the Swedish application, where the publicity for both the government and private companies has been significant (Kempe, 2017). In the discontinued Honduran application, the government never made public comments (Benbunan-Fich and Castellanos, 2018). Governmental or local blockchain strategies also demonstrated indirect governmental support.

In addition to governmental support, the empirical applications also stressed the educational aspects mentioned but that have not received that much attention in the theoretical challenges. It would seem that overall, other blockchain initiatives, general experience, or familiarity with blockchains or cryptocurrencies in the region have helped pave the path toward blockchain real estate adoption. This pro-blockchain environment was most often noted in the Georgian (Benbunan-Fich and Castellanos, 2018; Rodima-Taylor, 2021; Eder, 2019) and Kazakhstan (Akhmetbek and Spacek, 2021) applications. In addition to pre-existing familiarity with blockchains, the empirical assessments proposed that educating the public about blockchain benefits may also be an implementation driver. In the Indian Andhra Pradesh implementation, the officials visited villages to address concerns, educate landowners, and explain blockchain benefits (Kshetri, 2021). The Georgian application also reported similar educational activities for the population (Shang and Price, 2018). Educational matters might also become implementation challenges, here in line with the theory. For example, a lack of local blockchain expertise was identified as a scaling challenge in the Indian application (Kshetri, 2021). In the Canadian application, failed change management was evaluated as one of the constraints explaining why a more traditional approach was chosen instead of the piloted blockchain system. Educational aspects were not always blockchain related; the high illiteracy rates of the Andhra Pradesh population seemed to limit the full blockchain benefits (Kshetri, 2021).

The empirical findings confirmed that implementation was also empirically an application challenge. The implementation challenges were related to the availability of reliable digitized data. If such data existed, the empirical applications considered an implementation enabler, as highlighted in the Georgian application (Benbunan-Fich and Castellanos, 2018; Lazuashvili et al., 2019; Shang and Price, 2018; Eder, 2019). Similarly, if there was a lack of data overall, implementation was very challenging. Suppose the existing data were not trustworthy, entering new data rather than transferring the untrustworthy data to the blockchain was suggested to be a better option (Benbunan-Fich and Castellanos, 2018). This was the case in Honduras. The other implementation challenges were mostly related to complexities and scaling, which would require significant further work (Akhmetbek and Spacek, 2021; Bennett et al., 2021; Kempe, 2017 Mar; McMurren et al., 2021).

The empirical insights also supported the theory that, currently, regulatory uncertainty is a barrier and blockchain applications require legal changes. The importance of regulation has been most evident in the Swedish application. Despite the technological readiness, the application could not move to production because electronic signatures were not yet valid in real estate transactions in Sweden (Bennett et al., 2021; Rodima-Taylor, 2021; Kempe, 2017 Mar; McMurren et al., 2021). Also, in the tokenization context, Chang and Wang suggested that “The ICO Guidelines,” published by the Swiss authorities in February 2018, have contributed to “the choice of tokenization location (Chang and Wang, 2021), signaling that regulatory certainty affects blockchain adoption within the real estate sector.

Technical blockchain challenges have often been theoretically discussed, and some have been assessed in empirical settings, such as long-term data preservation and public–private key management (Lemieux, 2017a, 2016). However, the empirical applications highlighted the central role of smart contracts in blockchain applications in the real estate sector (Allessie et al., 2019; Bennett et al., 2021; Chang and Wang,
In tokenization, smart contracts might become exponentially more valuable if the size of the portfolio and the number of investors were to increase (Chang and Wang, 2021). Another empirically acknowledged technical enabler was the existing digital identity solution (Kshetri, 2021; Lazauashvili et al., 2019; Sullivan and Burger, 2017).

The only empirically assessed tokenization, the BrickMark application, has interesting similarities to the typical land administration applications: the hybrid approach (in tokenization: an intermediate structure instead of the real estate asset tokenized directly) and small-scale application (in tokenization: single asset). Even if tokenization theoretically can provide fractionalization and financial inclusion to retail investors, the BrickMark tokens have been offered only to accredited institutional investors, with only a handful holding the tokens (Chang and Wang, 2021). The same limitation has been true for most other tokenization applications described in the literature, indicating that tokenization was also adopted so that it would cause minimum disruption. Thus, the grand promises of tokenization have currently been left unconfirmed. However, BrickMark was reportedly planning to make BrickMark tokens available to retail investors through an EU-regulated security token offering. Overall, one tokenization application did not confirm the demand for single-asset real estate tokens. Thus, Baum’s concerns (Baum, 2021, 2020b) have remained unanswered.

The empirical applications proposed that the less disruption there is to current systems, the easier the blockchain implementation would be, supporting the theory that the hybrid approach can be a relevant implementation mode. This suggestion is, of course, intuitively easy to understand, but again, it rests in stark contrast to how blockchain has often been portrayed, even in the recent literature. The empirical applications showed that resistance may occur in many ways. In Kazakhstan’s application, widespread service distribution among banks was limited because the banks would need to adhere to cryptographic protection and information security requirements (Akmetbek and Sapek, 2021). The subtle power shifts that blockchain applications bring have also received empirical attention, for example, in the Swedish application (Rodima-Taylor, 2021). The failure to align interests between the parties has been empirically acknowledged as an implementation barrier (Benbunan-Fich and Castellanos, 2018; Lemieux et al., 2020). Similarly, the more the users can rely on existing interfaces (e.g., websites) to access the systems and do not need to know anything about blockchain, as in the Georgian (Shang and Price, 2018) and Indian (Kshetri, 2021) applications, the less resistance there has tended to be (Allessie et al., 2019).

In line with the small-scale, hybrid approach discussion, the empirical conclusions proposed that even though the full benefits of blockchain adoption have not been realized (Lemieux et al., 2020; Kshetri, 2021; Lazauashvili et al., 2019), blockchain has potential in the real estate sector (Akmetbek and Sapek, 2021; Bennett et al., 2021). The empirical conclusions also highlighted how blockchain alone cannot solve the primary land administration challenges (Rodima-Taylor, 2021) but instead requires institutional infrastructure (Shang and Price, Dec 28, 2018) and broader sociotechnical arrangements (Bennett et al., 2021). Many empirical studies have highlighted that the current applications had plans to further develop the system, for example, Georgia, Sweden, and BrickMark tokenization (Shang and Price, 2018; Goderdzishvili et al., 2018; Lazauashvili et al., 2019; Kempe, 2017; Allessie et al., 2019).

4. Discussion & conclusions

The current research has provided a comprehensive, state-of-the-art assessment of blockchain potential and applications in the real estate sector by bridging theoretical perspectives with empirical insights. It contributes to general blockchain research by clearly distinguishing between theoretical and empirically assessed blockchain benefits and challenges. Blockchain real estate proposals have emerged in four categories: land administration, real estate transactions, tokenization, and real estate management, but recent developments have focused primarily on land administration and tokenization. Twenty-six empirical applications were identified, and all of them, except one, were related to the land administration category. Thus, empirical insights could only be provided for theoretical benefits in the land administration category. On the other hand, this was also suggested by the literature review because land administration was also the most discussed theoretical real estate category for blockchain.

Interestingly, no empirical applications within the second most popular real estate transaction category were identified. This finding might signal that the grand theoretical promise of disintermediated, peer-to-peer real estate transactions has remained a distant dream. Most likely, the transaction applications would need to be built on top of the functioning blockchain land administration applications, potentially through tokenization. Even if the literature contained some single examples of, for example, houses purchased with cryptocurrencies, this development track for real estate transactions seems very unlikely given the high volatility of cryptocurrencies.

Some land administration applications included a shared workflow for the transaction process, such as the Swedish application. This linkage allowed for some inferences on the potential blockchain benefits for real estate transactions. For instance, the Swedish pilot would suggest that the theoretical benefits of transaction efficiency and transaction cost reduction could be achieved. However, the Swedish application has heavily stressed the importance of governmental support, reinforcing that blockchain real estate transactions would be unlikely to materialize without linkage to current land administration systems.

The literature included some descriptions of tokenization applications, and one application was also studied in empirical settings. Even if inclusion was the most often proposed theoretical real estate tokenization benefit, it has not yet materialized in the current applications to a large extent. The described real-world real estate tokens have currently only been available to limited groups and primarily used within intermediate structures. The contemporary cryptocurrency and nonfungible token (NFT) publicity may lower the general public’s threshold to purchase real estate security tokens, especially among younger tech-savvy generations. Nevertheless, few conclusions can be made based on the current cryptocurrency and NFT hype because its long-term viability contains many uncertainties.

Similarly, it is impossible to make large-scale, long-term conclusions on current real estate tokenization applications. If the current single tokenization initiatives or platforms were to scale, it would be crucial that secondary trading platforms are developed.

Although even the most recent blockchain literature has often presented blockchain as disruptive or transformative for the real estate sector, the empirical applications implied that blockchain adoption in the sector materialized more in hybrid, smaller-scale settings, where blockchain was merely an add-on layer—as proposed already in 2019 (Bennett et al., 2019; Allessie et al., 2019) and aligned with the recent discussion, as highlighted in Section 3.2.

The empirical applications proposed that blockchain could, for example, increase efficiency, reduce time and provide verifiability, transparency, and automation, even in smaller-scale, hybrid settings. The empirical insights also indicated that blockchain could, in some cases, help reduce fraud and increase security and trust compared with centralized digital solutions. Another interesting observation was that most of the empirical cases were in transitioning and developing countries, which may imply that the real estate sector in developed countries has been locked into existing technologies (i.e., high path dependency). However, more research should be conducted on whether current centralized digital solutions could be enhanced with other, more traditional technologies to make the current systems more efficient, secure, and fraud-preventative to ensure whether blockchain would be the only option, as claimed in the context of some of the applications.

The empirical insights highlighted how institutional changes and
process redesigning should complement blockchain application: technology alone cannot solve the current real estate sector issues. The role of political will, regulatory framework, availability of reliable digital data, public–private partnerships, and educational aspects in blockchain applications have all been emphasized. Overall, the recent literature’s call for a more detailed country- and context-specific analysis of blockchain applications was relevant. The empirical applications confirmed that country-specific institutional, environmental, and organizational factors can shape the benefits, challenges, barriers, and enablers of blockchain applications.

The current applications were primarily in the early stages, pilots, or small-scale production. Scaling and gaining widespread distribution of these current blockchain applications in the real estate sector would require significant further work and aligning interests with new stakeholders, which could be very demanding. The recent literature has started paying more attention to the resistance that will need to be overcome for scaling applications. Overall, even if recent applications did not seem to disrupt the real estate sector, it might be too early to draw conclusions for the future. Were the applications to succeed in battling resistance, getting buy-in from new participants, and scaling the solutions, the effects may be disruptive for some actors, such as real estate agents in the Swedish application.

Further works should continue assessing blockchain adoption enablers and barriers, power shifts, the role of policy and regulation, and ways to align interests on the system’s level because the enablers and challenges may change as the applications proceed to further stages. Generally, more research should assess the sector-level impacts of the applications that have moved into production. For practitioners considering or applying blockchain in the real estate sector, conducting thorough impact assessments would be advisable to help identify possible resistance.

The current study’s main limitation is that it does not allow an easy comparison of the research results directly to blockchain’s benefits and challenges, as identified in other blockchain research, because the current research did not use an existing framework when identifying the benefits and challenges. Being limited to papers found through academic databases and Google Scholar, the present study lacks the most recent industry developments. The academic literature has struggled to keep up with blockchain technology’s development pace. Also, not all real-world applications end up being examined and published in the literature. Additionally, the real estate management category could be underrepresented in this research because it was not possible to include smart city and IoT blockchain literature, which would likely include links to the real estate management category. However, other blockchain research has discussed the smart city and IoT themes. Another limitation is that the present study adopted a general and encompassing definition for

![Fig. A1. PRISMA flow diagram summarizing the literature retrieval process.](image-url)
blockchain without analyzing the effects of different blockchains, for example, permissioned or permissionless blockchains. Finally, using a literature review as the methodology in assessing empirical blockchain applications limits the findings to what has been published thus far and does not allow for direct comparisons of the empirical applications.

Future studies have several options. The economic viability of blockchain applications within the real estate sector is still very difficult to estimate because the empirical insights so far have provided very little data. Blockchain systems are very complex and contain many stakeholders. The financial standing of other players may decrease, while others may increase; costs within a company somewhere could increase and decrease elsewhere. What are the “public” economic benefits of land administration blockchain applications? What types of economic viability studies should be concluded, and which systems should they be compared with? Against which parameters should they be compared? Moreover, because blockchain is a foundational technology, the long-term potential of blockchain in the real estate sector cannot be concluded based on the current applications. Hence, continued multifield research on real estate blockchain applications is required.

CRediT authorship contribution statement

Anniina Saari: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft preparation, Writing – reviewing and editing.
Jussi Vimpari: Conceptualization, Writing – reviewing and editing.
Seppo Junnila: Conceptualization, Writing – reviewing and editing.

Declaration of Competing Interest

None

Data availability

Data will be made available on request.

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Appendix A

See Fig. A1 in appendix section.

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2022.106334.

References

Kalynova N., 2018. Transformation of the real estate market on the basis of use of the blockchain technologies: opportunities and problems. MATEC Web of Conferences. EDP Sciences,, Ierusalim, Russia, p. 06004.