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Mapping the role of Artificial Intelligence in real estate: A bibliometric and case study analysis

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Abstract

PURPOSE: *Accurately forecasting real estate prices presents a significant challenge due to the complex interplay of economic, social, and spatial variables. Artificial Intelligence (AI) offers a promising avenue to enhance predictive accuracy by integrating advanced analytical techniques. This study examines the role of AI in real estate pricing by identifying prevailing research trends and assessing its practical applications in cost reduction, process automation, and decision-making.* ***METHODOLOGY:*** *A two-pronged approach was employed, combining bibliometric analysis with insights from expert interviews. The bibliometric study mapped the evolution of AI-related research in real estate, highlighting key themes and methodological trends. The case study analysis provided complementary insights into how AI is applied in industry practice, particularly in streamlining construction processes, automating asset monitoring, and enhancing marketing strategies.* ***FINDINGS:*** *The study identifies a growing academic interest in AI-driven real estate research, particularly since 2018, with an increasing focus on machine learning, deep learning, and geospatial analysis. While scholarly research aligns with market needs in price forecasting and decision support, gaps remain in topics like operational efficiency and automation. Empirical evidence suggests that AI applications extend beyond price estimation, influencing profitability through process acceleration and cost optimization. However, international collaboration in the field remains low, limiting the scalability of AI-driven pricing models across different market contexts.* ***IMPLICATIONS:*** *The findings underscore AI's transformative impact on real estate by bridging research and industry applications. Theoretically, the study highlights the shift from management-oriented frameworks toward data-driven and algorithmic approaches. AI enhances price estimation by integrating diverse data sources and improving risk assessment. However, challenges persist, including data accessibility, algorithm interpretability, and the demand for specialized AI expertise. Addressing these issues could unlock further advancements in predictive modeling and real estate market efficiency.* ***ORIGINALITY AND VALUE:*** *This research provides a comprehensive perspective on AI's role in real estate pricing by integrating bibliometric analysis with case study insights. It extends existing knowledge by identifying key research gaps, emphasizing the need for interdisciplinary collaboration, and demonstrating AI's potential beyond price prediction to broader market dynamics and operational efficiencies.*

Keywords: *artificial intelligence, real estate, price prediction, hedonic pricing, bibliometric analysis, machine learning, deep learning, geospatial analysis, case study, real estate price prediction, predictive analytics in real estate, construction process automation, geospatial data analytics, AI-driven decision support systems, deep learning for property valuation, smart real estate technologies.*

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INTRODUCTION

In recent years, specific social, political, and financial stakeholders have pointed out the crucial relevance of Artificial Intelligence (AI) when setting the future course of the global economy within the changing world in terms of communications, human relations, environment, and mainly social structure of the entire population in present-day society. Today, the use of AI is massive in various human needs, and experts are evolving it in significant aspects such as early testing for decision-making business processes. Organizations have the option to apply AI in its entirety across all its strands, including Weak AI (WAI), Strong AI (SAI), machine learning (ML), Natural Language Processing (NLP), Random Forest (RF), or Artificial Neural Networks (ANN), among others.

Developers have mainly implemented most existing applications based on AI techniques for market analysis by extensively mining historical market data. Intending to make futuristic predictive analytics through machine learning, a subset of AI-related architectures, it creates models to predict market trends or business outcomes. Earlier consumption values have been habitually reflected from the actual requirements since some markets are being redefined from the data economy in unprecedented ways, thus allowing companies to access information about hyper-segmented audiences directly. Specifically, in the case of the real estate sector, this would involve taking historical data on discards from at least the last ten years into account. However, forecasting home prices through AI automation is challenging due to the many variables affecting this dynamic market.

Real estate price prediction challenges align with Hayek's (1945, 1988) argument on the dispersed nature of economic knowledge, where market participants possess localized insights that centralized models may struggle to capture. Traditional valuation approaches, such as hedonic pricing models (Can, 1992; Rosen, 1974), rely on high-quality data but face limitations in addressing market complexities (Álvarez de Linera Alperi et al., 2024). Moreover, economic shocks and regulatory effects (Gyourko & Molloy, 2015; Knoll et al., 2017) introduce further unpredictability. AI-driven methodologies, leveraging large datasets, offer a potential breakthrough by identifying patterns beyond human analytical capabilities (Rafiei & Adeli, 2015).

The paper concerns whether price training in the real estate sector can be predictable under normal market circumstances using AI techniques. Despite the increasing integration of AI into various industries, the specific role of AI in real estate pricing remains underexplored. Most existing studies focus on general market trends or individual AI applications. However, there is still a lack of comprehensive analysis of how AI-driven methodologies, particularly machine learning and automation, reshape price formation in real estate markets. This study aims to fill this gap by combining bibliometric analysis with expert insights to identify emerging research trends and real-world applications. Although previous literature in the research field is scarce, the study focused on bibliometric analysis to shed light on what has been happening in the real estate sector on an international level, particularly in those matters relating to housing problems in large cities. It is also about grouping research trends and unifying the key topics from earlier studies to classify them. In addition to previous findings, the most frequently used keywords can be identified from previous studies, thus establishing the basis for future research approaches. This study aims to analyze how AI technologies contribute to transforming real estate price prediction and market dynamics. Specifically, it seeks to identify key research trends, assess AI-driven innovations in pricing strategies, and explore their implications for entrepreneurship and management in the real estate sector.

In order to cope with this goal, the key question (Q) is how AI-based techniques are transforming real estate pricing and management. In addition to this issue, further research questions (RQs) have arisen as follows:

RQ1: What are the main AI-driven methodologies applied to real estate pricing?
RQ2: How has AI and real estate research evolved recently?
RQ3: What are the challenges and opportunities of AI in real estate pricing?

Throughout the present work, related answers are provided to motivate researchers to think for themselves about using AI techniques in predicting consumer behaviors, since the housing market is particularly sensitive to short-term supply shortfalls and house price shocks. It is interesting to note how investors seek strong profitability, which becomes more complicated as the economic deceleration is imposed in markets where supply is insufficient, especially for countries with inefficient domestic rental housing markets.

This paper has been divided into six parts. Firstly, after the abstract, the introduction shows how necessary studies on its research matter are, and they demand further approaches and willingness to improve the knowledge of the price formation in the housing market from the massive use of AI techniques. Secondly, the theoretical underpinnings describe the current knowledge about the matter studied through the analysis of findings from the most relevant works. Thirdly, the twofold methodology is presented. Fourthly and fifthly, the results from the bibliometric analysis and the case study research are summarized, respectively. Finally, the conclusions of the research paper are discussed, including the implications of this research, its limitations, and suggested avenues for further study.

THEORETICAL UNDERPINNINGS: IS PRICE PREDICTION A FATAL CONCEIT?

Is it possible to predict the prices of real estate properties? According to the conclusions of Nobel Laureate F. A. Hayek, in his seminal paper "The Use of Knowledge in Society" (1945), states that the knowledge necessary for efficient economic coordination is dispersed among individuals and cannot be centrally possessed or processed. In the context of real estate, the information needed to determine the appropriate prices for properties is decentralized and not fully accessible to any single entity or authority: market participants possess unique and localized knowledge about factors such as the condition of the property, neighborhood dynamics, future development plans, and individual preferences.

It could be argued that, while this knowledge is not available to everyone, there could be experts about certain geographic locations, such as real estate agents operating in a part of the city, a town, or a village. While experts can certainly allocate some specialized knowledge, it would still be a fatal conceit (also in the words of Hayek (1988)) to pretend to have absolute certainty of the setting of prices. Many factors influence real estate prices, including economic conditions, demographics, government policies, consumer preferences, and local supply and demand dynamics. Many of these factors are constantly changing and can be unpredictable. Additionally, individual preferences and perceptions play an important role in determining the value of a property, and these can vary widely between buyers.

In this complex landscape, companies operating in the real estate industry consider that transferring, operating, and managing knowledge plays a pivotal role in addressing uncertainties and fostering innovation. To that end, the use of AI can be an indispensable help. As highlighted in recent studies, the favorable impact of knowledge transfer on innovation underscores the importance of establishing robust systems to produce, manage, and share information effectively (Paredes-Chacín et al., 2024). Similarly, entrepreneurial agility, directly and indirectly, influences organizational performance (Haylemariam et al., 2024), which emerges as particularly relevant in dynamic environments like real estate markets. Furthermore, entrepreneurial alertness (Montiel-Campos, 2023) and agile leadership (Porkodi, 2024), characterized by digital innovation, trust, and competency, significantly improve operational outcomes, organizational growth, and team collaboration. Together, these insights highlight the critical role of adaptive strategies and innovative approaches in navigating dynamically multifaceted and ever-changing real estate markets.

Real estate prices are required by a variety of stakeholders, including real estate agents, appraisers, assessors, mortgage lenders, brokers, property developers, and investors and fund managers, among others (Pagourtzi et al., 2003), the valuation of the asset is "less a function of discounted present value than one of finding recently traded assets of comparable value" (Peterson & Flanagan, 2009). Since price is essential to many people, this information should be subject to an appropriate level of certainty. Mostly, this is because of (i) the high transaction costs that are specific from one region to another and between property types; (ii) the existence of greater information asymmetries than in the stock markets; and (iii) the high delays and longer time to complete a transaction when compared to the stock markets (Kabaivanov & Markovska, 2021). Among the stakeholders involved in the study of real estate prices are urban managers and policymakers, which means that the analysis is also linked to decision-making processes at the level of urban governance (Guarini et al., 2018; Guarini et al., 2024), helping to define the existing opportunities and barriers for urban development (Downs, 2005).

Among classic analysis models, hedonic pricing models stand out as one of the main tools for estimating and analyzing the impact of various attributes on price determination (Can, 1992; Rosen 1974). However, these models exhibit reliability levels that largely depend on the data quality used for training and analysis (Álvarez de Linera Alperi et al., 2024). Numerous studies examine the individualized impact of attributes such as green spaces (Chen et al., 2023), property views (Potrawa & Tetereva, 2022), or daylight exposure (Loro et al., 2024). Additionally, studies analyze the formation of prices in specific locations, such as Beijing (Duan et al., 2021), Turin (Loro et al., 2024), Seattle (Rodriguez-Serrano, 2025), or Xi'an (Luo et al., 2025), for both sales and rental markets. In price formation, the role of land prices is prominent (Knoll et al., 2017), both from a market perspective and as a result of regulatory effects (Gyourko & Molloy, 2015). These prices, primarily studied at

the city level, can be associated with the concept of "superstar cities" (Gyourko et al., 2013). In this context of difficulty in defining housing prices, the use of artificial intelligence becomes critically important, as it enables real-time responses to the needs of market agents by processing vast amounts of information, offering an unprecedented level of insight. Building on the traditional methods discussed by Pagourtzi et al. (2003) and incorporating machine learning tools, it is possible to advance toward a more accurate definition of housing prices through techniques such as neural networks (Peterson & Flanagan, 2009), support vector machines (Wang et al., 2013) or Random Forest models (Antipov & Pokryshevskaya, 2012), with combined approaches (Park & Kwon Bae, 2015) allowing for the validation of results. These tools are complemented by the growing importance of spatial modeling and cartography in developing pricing models and the increasing use of unstructured data such as photographs or reviews, as highlighted by Potrawa and Tetereva (2022).

Although the importance of the models themselves is significant, one of the most notable differences in the literature lies in the quantity and quality of data used. In general, machine learning models are applied again to highly localized settings, such as the case of and are also used for purposes beyond price definition. For instance, assessing methods based on Interpretable Machine Learning (IML) from decision-making that permits identifying associative relationships between related variables in greater resolution on the real state market (Lorenz et al., 2022) or even analyzing the characteristics of bare ownership (Guarini et al., 2025).

Despite the efforts made to predict real estate prices (e.g., Rafiei and Adeli, 2015), they appear to be challenging to expect in the short term because of the direct impact of economic events, changes in supply and demand, and speculative factors that can cause sudden and seemingly unpredictable fluctuations. Additionally, significant changes in the medium- and long-term complicate forecasting efforts. Some structural factors, such as demographic trends, changing government policies, and changing economic dynamics, add extra complexity, thus complicating the capabilities of traditional forecasting models. Accurately predicting the direction and extent of future changes in housing prices is difficult due to the dynamic interaction of these variables over time, underscoring the importance of sophisticated analytical methods and a deep understanding of the inherent complexities of this market. Given the complexities and limitations of traditional forecasting methods, the integration of AI emerges as a promising avenue to enhance price prediction accuracy. This raises the fundamental question that drives this research:

Q: How is AI transforming real estate pricing and management?

Addressing this question requires exploring the principal AI-driven methodologies applied to real estate pricing, analyzing recent research trends, and identifying key challenges and opportunities associated with AI adoption in real estate markets.

Nevertheless, artificial intelligence that uses vast amounts of data to extract patterns that may elude human analysts might overcome these shortcomings. Therefore, the following methodology will focus on this issue to shed light on AIs' ability to predict real estate prices effectively.

RESEARCH METHODOLOGY

The first research problem analyzed in this study is exploratory. For this reason, it is deemed that approaching literature and then completing the research with qualitative methodologies would be the most appropriate. For the sake of completeness, a two-fold research methodology is put into practice in this study. First, a bibliometric analysis was conducted using the Bibliometrix statistical package in the R program to process 3,000 articles from the Web of Science (WoS) and Scopus databases. Secondly, the motor themes and the thematic clusters obtained from the bibliometric analysis were used to design an interview protocol for its use in highly skilled and AI-knowledgeable entrepreneurs and managers of the real estate industry in Spain. Case study research tools such as interview transcription and codification allowed the authors to bridge the gap between scholars' knowledge siloed in academic publications and the hands-on vision of industry practitioners.

Bibliometric analyses have proven their validity in different settings, such as the link between business innovation, funding, and policy framework (Mallinguh & Zoltan, 2020) or social innovation (Silveira & Zilber, 2017), to cite only two. In this research, the search for bibliometric analysis covers specialized journals, conferences, and books until March 25, 2025. In addition, specific criteria have been applied to include works that address real estate price prediction using artificial intelligence techniques. Reviewed models include linear and logistic regressions, decision trees, random forests, neural networks, fuzzy models, support vector machines, or k-nearest neighbors in their application to the definition of hedonic prices.

To carry out the study, successive data downloads were performed based on the following criteria for WoS (equivalent to Scopus):

> TS=((real AND estate AND artificial AND intelligence) OR (real AND estate AND ai) OR (real AND estate AND smart) OR (real AND estate AND vector AND machine) OR (real AND estate AND random AND forest) OR (real AND estate AND fuzzy) OR (real AND estate AND neural AND network) OR (real AND estate AND decision AND tree) OR (real AND estate AND mass AND appraisal)).

The data downloaded from WoS generated 2,469 records, while the data from Scopus yielded 2,656 records. The merging of these datasets using the mergeDbSources command produced a combined database of 3,912 records, which was subsequently reduced to 3,908 after removing records dated before 1978 and discarding 1,217 duplicate entries. Once the combined database from WoS and Scopus was available, a vocabulary control process was carried out to standardize terms and enhance the clarity of the results. This involved generating a data frame containing all variants of the most frequently cited terms (e.g., "real-estates," "real estate market," "real estate prices," "house's prices," "real estate industries," "real estate investment," "real estate development") and replacing them in the merged dataset used for analysis. This process enabled a cleaner and more consistent output from the bibliometric analysis.

Subsequently, the information from the articles was analyzed with the R statistical program R (version 4.3.1), using the *bibliometrix* (version 4.1.4) package (Aria & Cuccurullo 2017). First, the data were analyzed globally. Then, the results were segmented according to the criteria of sources, authors, outstanding terms' presence, importance in literature, and evolution over time.

After obtaining the results of the bibliometric study, the second part of the research started. A multiple interview method was used to explore the results obtained through bibliometric analysis and refine the research with practitioners' responses. These methodologies allow for a better understanding of the phenomena concerning context (Ridder, 2017). The case study methodology of Eisenhardt (1989) has been followed, considering that the research question for this section was derived from the bibliometric analysis results. The cases analyzed are relevant and cross-cutting within the industry, involving participants from companies of different sizes and at various stages of the value chain in the real estate sector.

The interviewees were selected from companies operating within the same NACE category defined by the European Commission (L – Real Estate Activities). The sample included companies of various sizes (micro-enterprises, SMEs, and large firms) and professionals at different stages of their careers, including entrepreneurs, investors, department heads, and CEOs. This approach aimed at ensuring representation of the diverse circumstances and levels of exposure to AI within the real estate sector. A critical criterion for selecting participants was their direct involvement with or exposure to AI in their professional activities, significantly limiting the pool of suitable candidates. The three authors developed the interview guide collaboratively and validated it in June 2024 through consultation with another researcher in the field. This external feedback helped refine the questions and improve their alignment with the study's objectives, leading to minor adjustments in the interview protocol and facilitating a more effective capture of decision-making processes.

At this stage, the study adopts an inductive method based on cases that provide greater precision to the research, as suggested by Dubois and Gadde (2002), to investigate the adoption of AI in the real estate sector. Each interview has served as an individual case, allowing subsequent comparisons that reveal patterns and trends applicable to the industry. These data were collected through semi-structured interviews with selected industry experts who hold positions of responsibility in their companies and, therefore, require knowledge of and, in some cases, the use of AI to carry out their current tasks and make future decisions. Participation was voluntary, with complete freedom regarding their responses and their continuation in the interview. It was subject to authorization to record and anonymously publish the results, following confidentiality agreements (NDA) offered to all interviewees.

The interviews were conducted in June and July 2024, following a structured procedure based on the conclusions of the bibliometric study and the conceptual framework generated from the literature. Pilot tests were conducted to verify the validity and potential for knowledge generation of the questions and their alignment with the previously defined research questions. The interviews lasted between 25 and 45 minutes, as shown in Table 1. After being initially recorded by Author #1, they were transcribed and subsequently reviewed for accuracy by Authors #2 and #3. Text mining techniques were employed for the analysis, with the interviews being coded by Author #1 using Atlas.ti software (version 24.2.0). This tool, downloaded from https://atlasti.com/es, was selected for qualitative data analysis from research interviews. This AI-related software identifies the most relevant categories and patterns aligned with the study's objectives.

Table 1. Expert interviews general information

Expert	Company category [1]	NACE category [2]	Interview role	Experience in the industry	Duration and date of the interview
1	Micro	L	Founder - CEO	8 years	25 min (June 2024)
2	SME	L	Investor	20 years	40 min (June 2024)
3	Large-sized	L	Chief Operation Officer	25 years	36 min (June 2024)
4	SME	L	CEO	15 years	29 min (July 2024)

Note: [1] European Commission (2003); [2] NACE Rev.2 (European Commission, 2006).

RESULTS FROM THE BIBLIOMETRIC ANALYSIS

This section presents the results obtained in the analysis, starting from the general analysis of the documents and their authorship, to advance in the study associated with identifying the main tools and words that make up the evolution of the research concerning the definition of real estate prices.

First, the general structure of the documents was studied, showing that 2025 sources have been published on average at 1.93 documents per source, as indicated in Table 2. The average age of documents is 7.47 years, which should be contextualized given that documents have existed since 1978, i.e., over a period of 46 years. A total of 7,339 authors participated in the preparation of the papers, an average of 2.68 authors per document. In 1,028 cases, the authorship was the sole authorship, with a total of 863 people in this situation, which implies that in 38 cases, the authors published more than one article individually. In the case of the typology of the documents, 42.22% have been published as articles in different forms (general, book chapter, early access, research article, etc.), while 39.00% come from proceedings, conference papers, and conference reviews. There are 9.49% in the form of a dissertation/thesis and 4.07% in books, book chapters, and book reviews, 1.79% of reviews, leaving 3.43% in other formats. Finally, it should be noted that the study is mainly carried out by authors of the same nationality, with a rate of 7.7% of articles with international co-authorship.

Table 2. Summarized table of collected data for the study

Documents	3,908	Authors	7,339
Sources (Journals, Books, etc)	2,025	Authors of single-authored docs	1,028
Document Average Age	7.47	Single-authored docs	863
Average citations per doc	7.18	Co-Authors per Doc	2.68

Source: Own elaboration from *bibliometrix*.

Figure 1 shows the scientific output related to the topic of study over time. Scientific interest grew during the first decade of the 21st century, stabilizing between 2012 and 2016. From 2016 onward, a turning point was observed, with sustained growth continuing to the present. Over a period of eight years, scientific output increased more than five times.

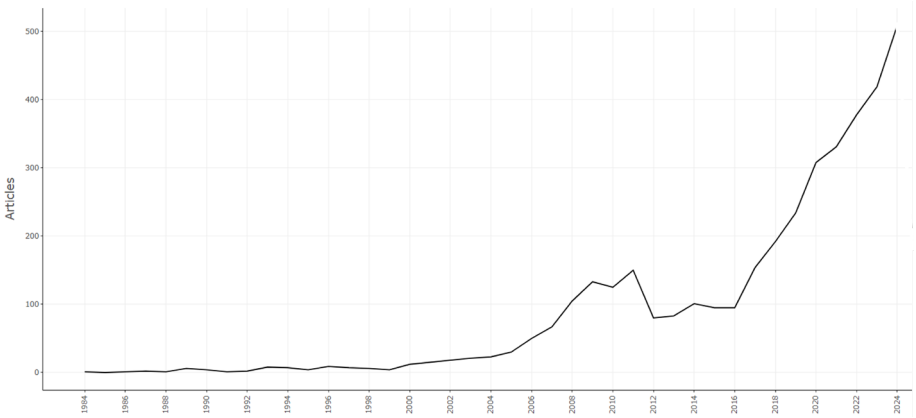

Figure 1. Evolution of the number of scientific publications included in the study from 1978 to 2025

Source: Own elaboration from *bibliometrix*.

These works are presented in different academic sources, among which the volume published in 'Lecture Notes in Networks and Systems' stands out, as shown in Figure 2. It is also observed that the concentration of sources is low, and a large majority of the published articles have no more than two publications. The importance of conferences among the available publications also stands out.

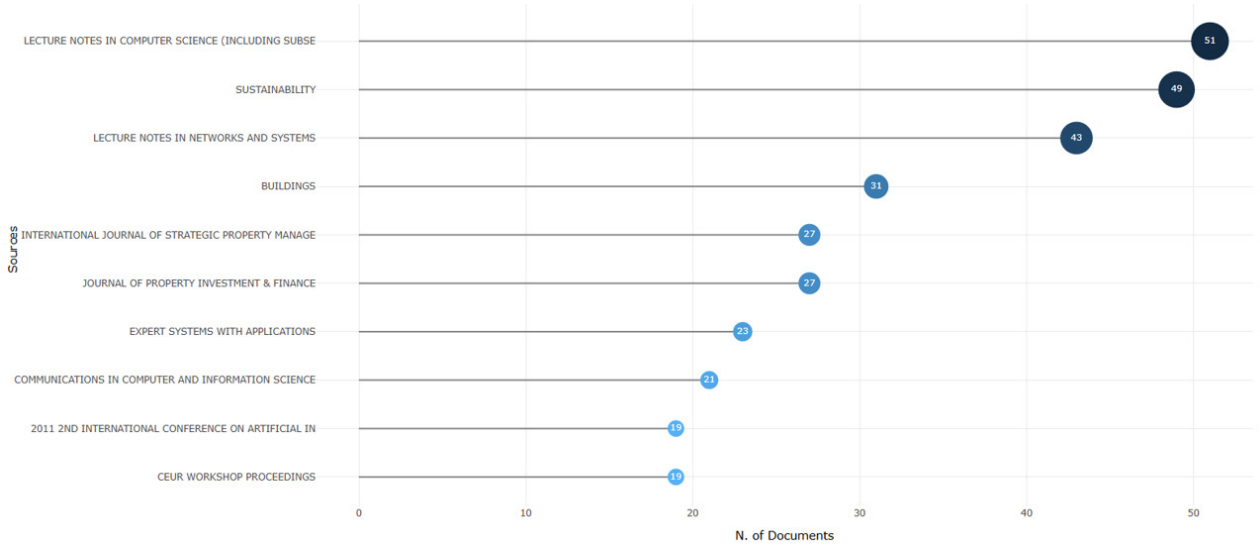

Figure 2. Main sources where contributions have been published.

Source: Own elaboration from *bibliometrix*.

Figure 3 shows the production of the top 10 authors over the last years between 2002 and the first quarter of 2025. It can be observed how the publications are widely distributed among many authors and how there is a significant link to the subject over long periods. The most prolific authors in terms of the number of publications are Trawinski B., Lasota T., and Liu Y., with 47, 46, and 42 documents, respectively. A strong collaborative pattern between Trawinski and Lasota started in 2007, with Telec joining this collaboration from 2009 onward. An initial peak in the activity of the most prominent authors is evident between 2008 and 2011, followed by a renewed surge from 2019 to the present. This trend aligns with what was observed in Figure 1 regarding the overall publication volume in the field.

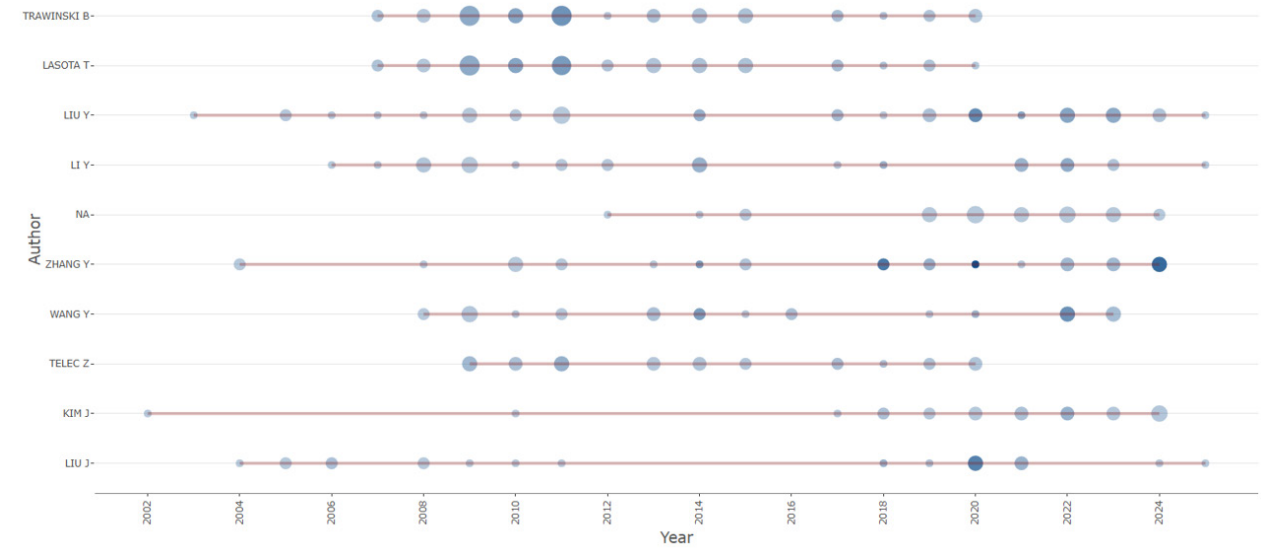

Figure 3. Publications of representative authors over time

Source: Own elaboration from *bibliometrix*.

Figure 4 shows that most of the articles are presented as papers written by researchers of the same nationality, with international collaboration being reduced to an average of around 7.7% for most countries. Regarding the number of contributions, in absolute terms, it is worth noting that Chinese authors have consistently been the main contributors to the field. Following China, the role of the United States, India, Korea, and Italy stands out, as these countries rank among the top five with significantly higher publication output than others. In contrast to the volume of publications, the United States stands out in terms of cited documents, with nearly twice as many citations as China and almost six times more than Korea, the third most cited country.

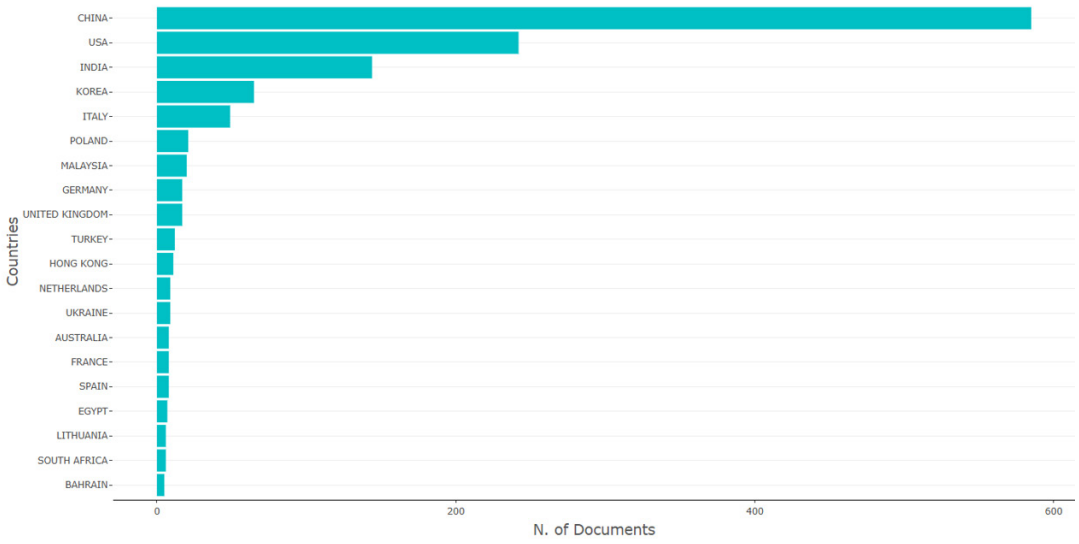

Figure 4. Location of corresponding authors by country

Source: Own elaboration from *bibliometrix*.

Figure 5 shows the geographical distribution of all the corresponding authors of the documents under study. The highest concentration of authors in the field is found in China, with 855 individuals representing 26.4% of the total authors. They are followed by the United States (416), India (298), and Italy (154), while the role of authors from South Korea (72) appears more limited. The top ten publishing countries account for 68.9% of the total, which rises to 88.88% when considering the top 30 countries. This indicates a high concentration of publications in Asia and the Americas, whereas in Europe, there is a broader participation from various countries. Within Europe, Italy stands out as the most representative country, both in terms of the number of documents and the number of authors involved.

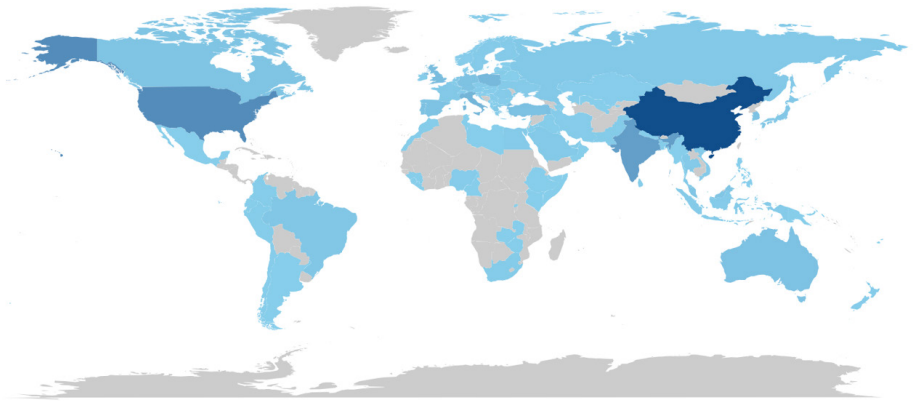

Figure 5. Distribution of publications by country

Source: Own elaboration from *bibliometrix*.

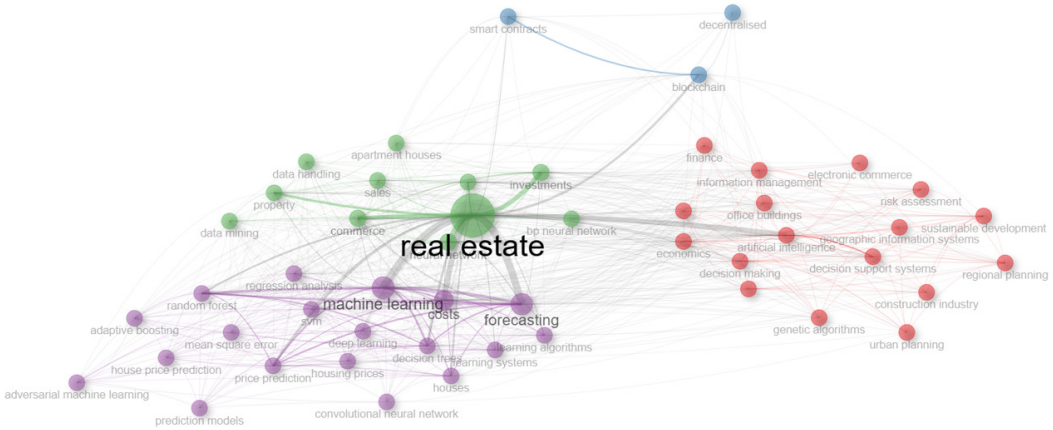

Figure 6. Representation of the co-occurrence network on the main terms analyzed

Source: Own elaboration from *bibliometrix*.

Enriched keywords were used to generate the co-occurrence map (Figure 6), with method parameters set to automatic layout and Walktrap as the clustering algorithm. A total of 50 nodes were positioned. Under these parameters, a total of four clusters were formed. In first place appears the term *Real Estate*, highlighted in green as the thematic core of the study. This cluster is dominated by traditional real estate market terms centered on concepts such as sales, housing, and investments. Below it, the purple cluster stands out, associated with using predictive models and machine learning, encompassing mainly technical concepts such as *machine learning*, *random forest*, and *forecasting*. The third cluster, shown in red, presents an interdisciplinary approach, including such issues as *urban planning*, *decision-making*, and *sustainability*, combined with technological terms like *artificial intelligence*, which serves as the core of the research. Finally, the blue cluster is related to emerging technologies such as *blockchain* and *smart contracts* in the real estate sector.

Figure 7 shows the strategic diagram, which presents research topics based on their relevance in the field (centrality) and their level of development (density). In the upper right quadrant are the Motor Themes, which lead the research line by combining a high level of relevance and development. This includes topics such as artificial intelligence, decision-making, and risk management. In contrast, the lower left quadrant contains themes that are either emerging or in decline. Here we find emerging technologies such as blockchain, smart contracts, and decentralization, along with broader terms that are only partially represented in the field, such as investments, smart cities, and sustainability. Finally, in the lower right quadrant are the Basic Themes, which include the real estate sector, neural networks, and commerce, foundational topics that are central but less internally developed.

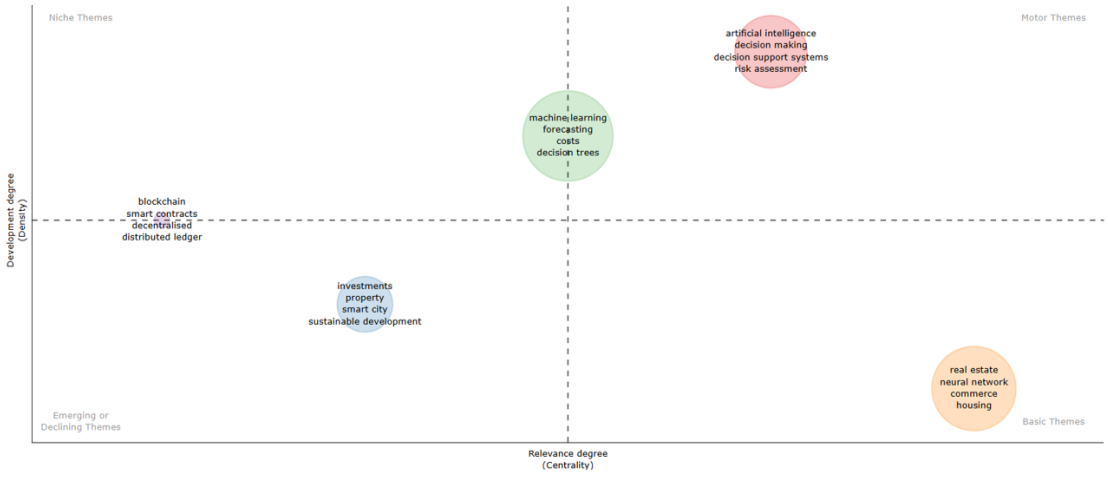

Figure 7. Overview of the density and relevance of the key terms from related papers

Source: Own elaboration from *bibliometrix*.

Figure 8 shows the change in key issues over time, including the historical density of each term's appearances. The results show a significant increase in interest in recent years and highlight what was previously noted regarding the growth from 2008 to 2012, followed by a decline in interest for many of the studied terms. The frequency peaks are found between 2023 and 2024, with continuity observed into the first quarter of 2025. Among the top five cases, three terms stand out for their extensive temporal development: "real estate," "neural network," and "artificial intelligence." "Machine learning" has also shown steady growth since the early 21st century, while "blockchain" emerged prominently starting in 2018. Emerging terms such as "random forest," "deep learning," "smart contracts," and "smart cities" are also evident, along with the consolidation of technical terms like "decision trees" and "support vector machines". However, these have not experienced the same surge in recent years as others.

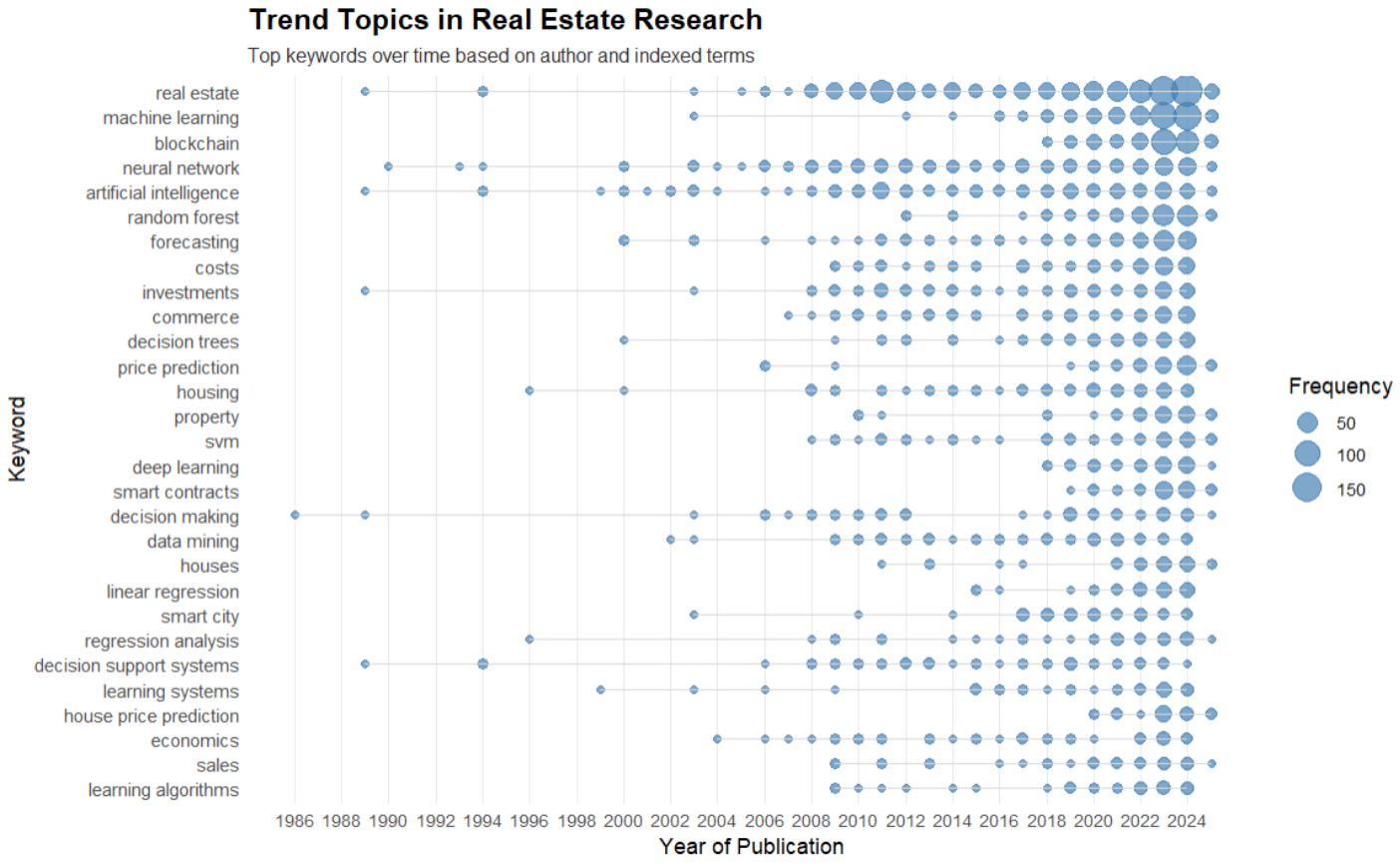

Figure 8. Temporal representation of the preponderant terms in the analyzed works

Source: Own elaboration from *bibliometrix*.

The word cloud illustrated in Figure 9 highlights the importance of the main elements associated with real estate. Terms such as costs, investments, forecasting, price prediction, commerce, decision-making, and property can be observed. However, the most prominent aspect of these terms is their association with the application of technology and artificial intelligence, as evidenced by the appearance of machine learning, neural networks, blockchain, artificial intelligence, and random forest.

Figure 9. Word cloud from those related papers from 1988 to 2023

Source: Own elaboration from *bibliometrix*.

The main articles, ordered from highest to lowest according to the number of citations, appear in Table 3. It can be seen how all of them show a similar citation range, from 365 for the first to 172 for the tenth. All the listed articles were published before 2018, with the top five appearing before 2010. It can be observed that 6 out of the 10 articles are related to real estate valuation, both in terms of market prices (Pagourtzi et al., 2003; Peterson & Flanagan, 2009; Antipov & Pokryshevskaya, 2012; Park & Kwon Bae, 2015; Rafiei & Adeli, 2016), as well as income and cost levels within the construction process (Rafiei & Adeli, 2018). Some articles use housing variables to analyze urban aspects, such as smart growth (Downs, 2005), gentrification (Quastel, 2009), and service quality (Tseng, 2009). Lastly, the study by Bourassa et al. (2003) combines housing price prediction with urban segmentation factors.

Table 3. Summary of most cited articles concerning the study

Artícle	Autores	Journal	Year	Cites
A causal and effect decision making model of service quality expectation using grey-fuzzy DEMATEL approach	Tseng, M.-L.	Expert Systems with Applications	2009	365
Smart growth: Why we discuss it more than we do it	Downs, A.	Journal of the American Planning Association	2005	299
Real estate appraisal: A review of valuation methods	Pagourtzi, E.; Assimakopoulos, V.; Hatzichristos, T.; French, N.	Journal of Property Investment & Finance	2003	296
Political ecologies of gentrification	Quastel, N.	Urban Geography	2009	276
Do housing submarkets really matter?	Bourassa, S.C.; Hoesli, M.; Peng, V.S.	Journal of Housing Economics	2003	274
Using machine learning algorithms for housing price prediction: The case of Fairfax County, Virginia housing data	Park, B.; Kwon Bae, J.	Expert Systems with Applications	2015	272
A novel machine learning model for estimation of sale prices of real estate units	Rafiei, M.H.; Adeli, H.	Journal of Construction Engineering and Management	2016	227
Novel Machine-Learning Model for Estimating Construction Costs Considering Economic Variables and Indexes	Rafiei, M.H.; Adeli, H.	Journal of Construction Engineering and Management	2018	201
Mass appraisal of residential apartments: An application of Random forest for valuation and a CART-based approach for model diagnostics	Antipov, E.A.; Pokryshevskaya, E.B.	Expert Systems with Applications	2012	184
Neural network hedonic pricing models in mass real estate appraisal	Peterson, S.; Flanagan, A.B.	Journal of Real Estate Research	2009	172

Source: Own compilation based on WoS.

The bibliometric analysis shows that technology use in the real estate sector, emphasizing asset valuation, is a topic of growing interest in academic literature. This interest experienced an initial surge around the 2007 financial crisis, later stabilizing in the mid-2010s, but has seen a renewed boom over the past seven years with the advancement of artificial intelligence. Among the results obtained, serving as a foundation for the next phase of this study in the form of case analysis, three major thematic clusters emerge: traditional real estate concepts, the application of technology to real estate assets, and the broader connection with urban planning, industry, and decision-making processes. The analysis also highlights the increasing research focus on concepts such as artificial intelligence, decision-making, risk assessment, and the recent interest in disruptive technologies like blockchain and smart contracts. Together, these elements have enabled the development of the following case study phase through expert interviews.

FINDINGS FROM THE CASE STUDY

As discussed in the Methodology section, the present research is based on a twofold strategy. After settling the academic knowledge from the field through a bibliometric analysis, practitioners' insights have been sought using in-depth interviews with five experts in the Spanish real estate industry. The interview protocol was created with thematic dimensions obtained from the bibliometric analysis. To facilitate comparison with the results of the bibliometric analysis, the insights from the interviews have been grouped into three sections. First, the direct impacts on real estate price prediction are addressed, with the analysis divided into two aspects: the first based on the process and tools of predictive analysis, and the second stemming from the importance attributed to geospatial information by the interviewees. This section concludes with an analysis of the real estate market linked to investment, profitability, and risk.

The case study analysis reveals different action lines beyond those observed in the bibliometric analysis, enriching the main research lines. There is significant interest in various topics that have a cross-sectional impact on the real estate business. These interests include using algorithms, the current and future valuation of assets, geospatial analysis, information capture and acquisition, comprehensive investment management, risk limitation, and generative AI. Despite this interest, the current use of AI varies considerably among companies; in some cases, AI serves as a complementary activity with the potential to add value to the core business, while in others, it has assumed a central role across different business areas. This role spans from enabling new capabilities offered by the tool to improving employees' ability to perform tasks more efficiently and with greater quality.

AI and housing price prediction

Predictive analysis process

The definition of housing prices emerges as a transversal element in the responses obtained; however, it takes on different nuances depending on the business profile of the cases analyzed. A more supply-oriented approach is observed in developer and construction companies, while the perspective shifts towards demand in companies focused on the real estate sector. In the first case, there is interest in valuing large housing portfolios and reducing the manual work involved; in the second, factors such as purchasing power or credit capacity stand out, closely linked to the creditworthiness of everyone. In combining both perspectives, elements related to geospatial data usage emerge, along with the ability to access both public and private information and cross-referencing these data points to obtain a more complete picture.

In this area, there is consensus on the importance of pre-analysis processes, which include data quality, cleaning, and preparation; these preparatory steps are considered more valuable than the tools used. Among the tools associated with higher precision are neural networks and random forests. The ability to efficiently process large volumes of data is unique in all cases. AI is highlighted for its ability to act intertemporally in price prediction, providing additional capabilities compared to traditional methods. Furthermore, AI use improves valuations even in areas where direct comparisons are unavailable. Regarding predictive capacity, there is an expectation that we will offer real-time valuations along with the ability to anticipate market changes. This allows AI to deliver more consistent predictions throughout the market for various properties, locations, or socioeconomic conditions, as highlighted by interviewee #2.

"AI shifts the paradigm: from analyzing a single opportunity to simultaneously evaluating 26 million properties and selecting the optimal one, fundamentally transforming the process of price determination."

In terms of achieving comprehensive asset information, as illustrated by interviewee # 4, "*even calculating how housing prices vary by proximity in meters to a bus stop*", a key challenge in price definition is identifying unique characteristics of each property that are difficult to computerize. These characteristics enable valuation experts with extensive knowledge of neighborhoods and properties to have unique market information for making these price estimates. Statements such as "*The real estate agent [...] is not going to disappear, but rather [...] they will be the ones to rely on these tools to gain more, more capability*" (Interviewee #3) highlight both the quantity and quality of valuations and clients managed.

Geospatial improvements

Geospatial analysis becomes a fundamental element for the interviewees since the real estate sector is entirely linked to location. On the one hand, every property characteristic is influenced by its location, with the asset value highly dependent on it; on the other hand, significant regulations and usage limitations are associated with each space that affect potential business and personal decisions. Digital tools for this type of analysis have evolved significantly in recent years, from the initial work with GIS to integrating modern Big Data platforms that combine technologies such as satellite imagery and the development of digital twins.

"In the real estate sector, everything revolves around georeferenced data [...] because physical location is crucial for any analysis." Interviewee #4

Regarding asset valuation, geospatial analysis allows cross-referencing of socioeconomic information, such as the risk of non-payment, as indicated by interviewee #1 *"what we are trying to propose is the ability to predict the creditworthiness of tenants entering the system"* or property occupation. Here, the ability of AI to handle geolocated data and execute large-scale evaluations of residential units across a region stands out, moving from individual cases to large-scale analysis. In this context, geospatial analysis links characteristics that facilitate urban development and foster innovation in cities, identifying factors that drive greater activity and dynamism and enabling the establishment of a "genome" of cities, achievable only through geospatial analysis. This process provides strategic value by predicting aspects such as urban flows or city socioeconomic patterns.

In general, the value of AI in using geolocated data is evident. This analysis increases the importance of elements such as proximity to services, accessibility to housing, and characteristics of the urban environment. Its potential applications include optimizing land use and, as a result, urban development, done from both public and private perspectives. In the latter case, it allows developers to maximize efficiency and effectiveness. For example, it can reduce the time needed to make decisions on the acquisition of buildable plots by automatically analyzing many possible combinations to present the "*two or three best options*," enabling one to "*make decisions about the purchase of a plot even before buying it, with far more information than we have today.*" (Interviewee #3). Additionally, AI's ability to evaluate multiple architectural combinations allows work that traditionally takes months to be completed in a matter of hours. This capability enables, among other objectives, the maximization of buildability according to urban regulations, optimizing the number of housing units and land use. Similarly, it can provide early cost estimates for renovations based on factors such as photographs, generating an assessment linked to the price in a comprehensive valuation of both elements.

A third point addressed in the case study is the relationship between AI and informed investment and risk management patterns within the real estate market. The main findings point toward a common goal: achieving safer investments and optimizing time and resources. These objectives are achieved by mitigating financial risks and conducting preventive investment analysis, which improves the precision of feasibility studies. Using artificial intelligence (AI), risk assessment incorporates specific factors derived from cross-referencing socioeconomic data, geolocation, and occupancy of properties, while also integrating macroeconomic elements that provide a comprehensive view of the risks and expected returns for each asset.

Real estate market: Investment and costs

The study reveals specific patterns based on business areas. In the case of real estate leasing, it highlights the importance of socioeconomic analysis to increase investment security by identifying tenant behavior patterns and classifying their credit quality and likelihood of default. This type of analysis is especially useful in highly regulated markets where tenants have greater protection, thus providing greater certainty for property owners.

Regarding construction and rehabilitation projects, the study identifies the value of AI in urban rehabilitation and problem detection in buildings from both socioeconomic and energy-related perspectives. It also highlights AI's ability to analyze land buildability and assess investment feasibility according to regulatory and market conditions. This technology simulates many combinations in seconds, identifying the most profitable designs before closing a purchase. In this way, AI interrelates these key points (asset valuation, geolocation, and risk) to improve the analysis of the risk-return relationship of different investments.

The expected effects of using AI are increased operational efficiency derived from process automation. This encompasses different aspects, including internal company tasks and external activities in customer relations. Internal advantages include the previously mentioned creation of simulations and the selection of optimal investment options, along with additional capabilities such as drafting and reviewing legal documents and developing technical skills to assess the need for building interventions. One example is the ability to detect issues such as dampness or cracks in properties and, based on these, estimate associated repair costs. This allows budget calculations without the need to visit the properties, thereby streamlining the decision-making process. Similarly, new capabilities have emerged for inspecting construction sites via drones, which, thanks to AI tools, can autonomously measure and document hard-to-reach elements, such as air conditioning ducts.

"With AI, we can determine the optimal architectural fit to maximize allowable buildability under the law, performing 100,000 combinations per second within hours." Interviewee #3

In terms of external advantages, these include communication tasks and customer interaction activities. In the area of communication, AI accelerates content creation by generating document drafts tailored to the company's communication preferences, which increases the efficiency of the communication team, as shown in "*the result is that instead of facing a blank page […] what you do is move on to supervising what the AI has created*" (Interviewee #3). Additionally, the use of chatbots is considered a capability already established, though constantly evolving through AI intervention. This enhances customer interaction in sales and post-sales processes, a skill believed to improve customer experience while reducing costs.

It is important to note the expected application of AI in other emerging technological fields, such as collaborative robots (COBOTS). Here, AI could improve workplace safety and health, resulting in a reduced risk of injury to employees and improved working conditions. This improvement is particularly impactful in the construction sector, given the physically demanding nature of many tasks.

Finally, it is worth highlighting the barriers and challenges the respondents identified, including personal and process-related aspects. Personal limitations stem from the difficulty of finding professionals with dual skills that combine specific technical knowledge with advanced technological competencies, which can delay the adoption of these technologies. In terms of process challenges, the complexity of sourcing information is noted. In this regard, on the one hand, there is a need to develop robust and highly automated algorithms; on the other, the reliance on private information sources is considered a barrier, contrasting with the availability of open data, which varies widely across countries.

The interviews provide insights into using terms overlooked in the bibliometric analysis, such as "real-time" and the application of knowledge to unique elements, with "unique" referring to those that lack comparable data for estimation purposes. Another key point emphasized by the interviewees is the importance of geospatial analysis, a concept that connects socioeconomic or regulatory variables. Geolocation is also used from a strategic urban planning perspective, with the idea of a "city genome" linked to artificial intelligence, elements associated with the red node seen in Table 7. As is typical in business activities, the interviewees also value applying AI solutions to profitability and investment risk concepts. In summary, the interviews offer a practical view of the research, indicating that the results of AI applications are focused on business and urban planning issues, that is, the interests of stakeholders within the real estate market.

DISCUSSION

This study provides a detailed exploration of how AI is reshaping real estate pricing and explores other possible AI applications. To that end, bibliometric analysis has been combined with insights from case studies. The present research highlights several important contributions to the field by analyzing scientific publications and market trends.

First, the bibliometric analysis reveals a marked increase in academic interest, with a notable increase in contributions since 2018. Despite this growth, the field remains localized, with international collaboration below 10%. This underscores the opportunity to advance global research that can bridge local and national studies to uncover universal pricing patterns. The geographic concentration of contributions, particularly in China, the USA, India, and Italy, also indicates international interest and development disparities.

Second, the study identifies a clear alignment between academic concerns and market needs. Real estate investment, decision-making, cost reduction, and price forecasting dominate research and case study findings. However, certain market priorities, such as operational efficiency and process automation, are underrepresented in the literature, probably due to the challenges in consolidating dispersed and proprietary business data for academic purposes.

Third, the study traced a shift in academic focus from management-oriented concepts such as "decision support systems" and "risk assessment" to technological approaches that involve machine learning, blockchain, and smart contracts. This evolution mirrors market trends, where innovation tools have become secondary to integrating multiple AI functionalities to solve complex real-world problems.

Lastly, the study highlights the ability of AI to transform business processes, from reducing construction timelines to automating asset monitoring and optimizing marketing strategies. These capabilities directly translate into cost savings and improved profitability, influencing real estate prices and market dynamics. Integrating geospatial data, socioeconomic factors, and advanced algorithms positions AI as a powerful tool to improve accuracy and efficiency in real estate valuation.

The responses obtained during the case study are not equivalently represented or adequately represented in the bibliometric analysis. Consequently, AI functionalities associated with cost reduction in business operations emerge as analysis tools and solutions that accelerate the construction process, thus reducing the timelines for real estate promotion. This could have significant implications for price setting: On the one hand, in business, time equates to costs; on the other, this acceleration could lead to greater profitability, potentially impacting land prices. Another notable aspect of cost reduction in the market is the role of AI in marketing and sales activities, particularly in content generation for communication and customer management. Although not prominently featured in the bibliometric results, these areas may significantly affect company costs and, consequently, real estate prices and associated returns. Alongside cost reduction, automation possibilities also emerge. In this case, emphasis has been placed on operations related to monitoring the condition of rental assets through artificial intelligence models. These models, which understand market dynamics, such as demand fluctuations, and individual factors, such as the risk of default, facilitate business decision-making.

The results obtained from both the bibliometric analysis and the case study align with the existing literature, highlighting the importance of data management and various machine-learning solutions for housing price analysis. Academic research findings are linked to specific locations and rely on databases focused on fields of study relating to that matter. Similarly, the responses from professionals reflect a dependency on data quality and emphasize the importance of its preprocessing before analysis. Efficient data management is critical for achieving reliable results and avoiding issues such as incorporating bias into analytical models.

The findings also converge on the availability of tools that enable a higher level of insight into decision-making, which fosters greater professionalization of the sector through access to high-quality information regarding property value and expected returns. This generates significant opportunities in the market, and it is particularly relevant to note the potential emergence of competitive barriers based on data ownership, access to technology, and the availability of the talent required to harness the power of AI in the real estate sector.

In summary, AI has great potential to improve the accuracy of real estate price estimates. This benefit results in more precise measurements and has broader implications, particularly regarding time: AI enables real-time responses and improves medium- and long-term forecasting. The analysis shows that the approach adopted to study this issue is based on the investment concept, with a strong focus on profitability and risk. Consequently, fundamental concepts such as housing or home are relegated from both business and academic perspectives.

CONCLUSIONS

The results obtained address the research questions formulated in the introduction. Firstly, they show how artificial intelligence has become a critical element in both academic research and real-world practice within the real estate sector, with a rapid increase in scholarly publications since 2018. This evolution is supported by various innovative tools and methodologies, including machine learning algorithms, among which random forest and support vector machines stand

out, and deep learning models, such as artificial neural networks. In this context, the interviews highlighted the importance of using combined methods and properly preparing databases to achieve accurate results. They also emphasized the significance of geospatial information as a key component for AI applications. Current challenges include technical aspects, such as the characterization of each property based on its unique features, which complicates modeling, as well as human resource limitations, particularly the difficulty in meeting the demand for professionals with expertise in applying AI within the sector.

The present study provides researchers with a roadmap for future studies into AI-driven innovations in real estate. Bibliographic analysis reveals significant gaps in global collaboration and operational applications, suggesting interdisciplinary and international research opportunities. Studies focusing on areas of underexplored, operational efficiency, automation, and marketing strategies could enrich academic discourse and provide actionable insights. Furthermore, the evolution of analytical objectives and technological concepts suggests a need to adapt research methodologies to reflect emerging tools and paradigms continuously. Researchers can better capture the nuances of AI's impact on real estate by integrating qualitative and quantitative approaches.

For practitioners and industry professionals, the findings highlight practical applications of AI for cost reduction, risk management, and process optimization. The ability of AI to accelerate construction timelines, improve marketing strategies, and improve decision-making processes offers tangible benefits to real estate firms. The study also underscores the importance of data quality: well-managed and cleaned datasets are critical to the effectiveness of AI models, particularly random forest and neural network algorithms. Furthermore, the need for skilled professionals becomes evident as AI adoption grows. Companies should invest in training programs to equip their workforce with the technical skills and knowledge necessary to harness the full potential of AI.

Policymakers can leverage insights from this study to create a supportive ecosystem for adopting AI in real estate. Policies that promote open data standards encourage international collaboration, and fostering innovation could accelerate the development and deployment of AI solutions. AI-driven analysis could also inform housing policies, urban planning, and interventions to ensure affordability and equitable access to housing. Finally, fostering education in the STEM domain, particularly on AI-related topics (both at university and vocational levels), can be of the greatest importance shortly.

Despite the academic contributions, this study has limitations that pave the way for future research. First, it is necessary to broaden the geographical scope of this study. The case study focuses on Spain, which could limit the applicability of its findings to other contexts. Expanding the scope to include diverse geographic regions could offer comparative insights into global and local real estate markets. Second, the bibliometric study captures only the first stages of a growing literature stream. Most likely, the many publications of the next few years will be able to enrich the results of bibliometric analysis. Third, the study highlights low levels of international collaboration in this field. Facilitating cross-border research could improve understanding of global housing trends and the role of AI in different cultural and economic contexts. Fourth and last, given the rapid pace of technological change, the study findings can quickly become outdated. Longitudinal studies that track AI developments over time could provide more dynamic insights into its evolving applications.

This study focused on using AI-related techniques in defining property indicators and exploring other possible applications in the real estate market, such as autonomous decision-making in setting prices. Through bibliometric analysis, emerging trends in price prediction can be detected, including the application of deep learning algorithms, the integration of geospatial data, and the consideration of socioeconomic factors. Understanding these trends allows us to anticipate future directions for research and development in this field of knowledge.

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Appendix

Summary of preliminary questions surveyed to respondents on questionnaires.

1) Context
   a. Could you tell us about your company/institution's role within the real estate business?
   b. Have you used AI-related tools in your work in the real estate sector?
   c. Are these tools associated with uses of deep learning, geospatial data applications, or do they integrate socioeconomic factors of the properties?
   d. What impact has the use of these tools had within your company? What impact has it had on your clients?
2) Implementation
   a. Which areas of the business initially benefited from the implementation of AI tools?
   b. What challenges did the company face during the initial implementation?
   c. What types of data are used to train AI models in the company?
3) Technical Issues and Algorithms
   a. What types of AI algorithms are used in the company?
   b. How long does it take to train a typical AI model used by your company?
   c. What platforms or technological tools do you use to implement and maintain deep learning models?
   d. How does the company handle the integration of these models into existing systems?
   e. How does the company update socioeconomic data with prior existing information?
4) Benefits and Drawbacks
   a. What have been the main advantages for the company in using AI?
   b. And the main drawbacks or challenges?
   c. Have you observed an increase/decrease in the accuracy of real estate valuations thanks to deep learning? If so, can you quantify these changes?
   d. How has deep learning improved the customer experience (e.g., in terms of property search, recommendations, etc.)?
   e. Have there been any changes in the company's operational efficiency?
5) Business Impact and Key Indicators
   a. What were the increases/decreases in gross sales (V/%) since the implementation of deep learning?
   b. How has deep learning affected the company's margins (V/%)?
   c. Has the company's ability to predict real estate market trends improved? In what way?
   d. What impact has it had on response times to customer inquiries?
   e. Are there any other Key Performance Indicators (KPIs) that evaluate the effectiveness of deep learning in your company?
6) Governance and Ethical Considerations
   a. Have you encountered any issues related to biases in data or deep learning models? If so, how did you address them?
   b. What measures are taken to ensure the transparency and interpretability of the models used?
7) Future Expectations for Business Development

a. What are the company's future plans in relation to deep learning?
b. What new areas of the business do you expect to explore with the help of deep learning?
c. How does the company plan to stay current with rapid advancements in deep learning technologies?

8) Non-use of AI variant
a. What are the reasons for not adopting AI in your company?
b. Have any obstacles been identified (excessive cost, distrust of the AI provider, difficulty in maintaining confidentiality of key information, or others)?
c. What challenges does the company face in its development without the use of AI? Are the company's competitive advantages at risk?

Biographical notes

Alejandro Segura de la Cal is an Assistant Professor in Economics and Management at the Universidad Politécnica de Madrid (UPM), specializing in the real estate sector. His research focuses on economic geography, land use dynamics, and the analysis of real estate markets through business simulation models. He has participated in national and international research projects and regularly collaborates with industry partners to bridge the gap between academic research and market practices. He is co-author of several publications focused on housing markets, urban economics, and strategic business modeling.

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Author contributions statement

Alejandro Segura de la Cal: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Resources, Data Curation, Writing, Project Administration. **Antonio Martínez Raya**: Conceptualization, Methodology, Validation, Review & Editing, Supervision, Project Administration. **Gustavo Morales-Alonso**: Conceptualization, Methodology, Validation, Investigation, Resources, Review & Editing, Supervision, Project Administration.

Conflicts of interest

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