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The present and future of the digital transformation of real estate: A systematic review of smart real estate

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Abstract

The contribution of the real estate industry to the global and regional economy is remarkable, yet in today's evolving digital technology and digital economy, the digital transformation of the real estate industry is lagging behind other industries. This is, on the one hand, due to the solidified processes and systems linked to the upstream and downstream real estate industries, and, on the other hand, due to the fact that digital technology disrupts traditional ways of doing business, making the industry full of uncertainty. The digital transformation of the real estate industry is a broad and emerging concept. Various related research fields are concerned with the penetration and application of different innovative technologies to the industry. This study provides a systematic review focusing on the field of smart real estate using the bibliometric analysis approach under the guidance of PRISMA. The bibliometric analyses were performed in RStudio by utilizing 22 scientific documents indexed in Scopus and Web of Science that were published from 2012 to 2022. The findings suggest that: (i) smart real estate research is still a new but rapidly emerging field; (ii) only limited academic institutions from a few countries, such as the University of New South Wales in Australia, have shown significant contributions; (iii) the research exhibits specific collaborative network characteristics, leading to a high concentration of authors and citations; and (iv) data-driven topics such as "machine learning," "information management," "data analytics" and "big data" indicate a high degree of research density and centrality.

Keywords: smart real estate, digital transformation, digital economy, innovative technology, data-driven, property technology (PropTech), systematic review, bibliometric analysis, PRISMA, RStudio

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Introduction

Digital technologies are driving worldwide innovation and disruption across numerous industries. However, the real estate industry has been slow to embrace technology, and this trend may take some time to catch on [1]. The real estate industry is thought to be difficult to innovate in due to the presence of hard barriers in solidified processes and systems [2], and digital technologies also present disruption to the old way of doing business and necessitate significant changes by organizations to compete in the new environment [3]. Smartness is always an indicator for innovative digital technology, and the real estate industry is empowered with such smartness through the applications of several technologies, including virtual and augmented realities (VR and AR), big data, robotics, 3D scanning drones, clouds, software as a service (SaaS), wearable technologies [1], digital twin, and CyberGIS [4]. The real estate industry plays a pivotal role in economic development at both global and regional level; therefore, it is imminent to promote the digital transformation of the real estate industry and conform to the transformation of Industry 4.0 [5] and Marketing 4.0 [6].

The purpose of this study is to systematically review the extant literature on smart real estate associated with a bibliometric analysis, to investigate current theoretical developments in the literature, and to provide future guidance for both academic scholars and industry practitioners. In line with the purpose, this study develops a novel approach to the design science research methodology of business informatics by introducing the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [7].

This study is organized as follows: the first section introduces the research background and purpose of the study; followed by the materials and method section, which illustrates the PRISMA flowchart of identification and selection of scientific documents used for bibliometric analysis; the third section provides in-depth insights through the aspects of (i) the development trend of the research field; (ii) the performance of countries and institutions; (iii) trends in authorship and collaborations; and (iv) the analysis of keyword co-occurrences and thematic evolution. Finally, the conclusions and limitations of the study are shown.

1. Materials and method

A systematic review is a review that uses specific, systematic approaches to collect and synthesize the findings of studies that address a clearly defined research

purpose [8]. This study employed the PRISMA approach (hereafter referred to as the PRISMA 2020 statement), one of the most frequently consulted approaches for mixed quantitative and qualitative systematic reviews [7]. Unlike previous established design science research of purpose-oriented study, such as Archer's six-step design science research of programming, data collection and analysis, synthesis of objectives and analysis results, development, prototyping, and documentation [9, 10], the PRISMA approach contains a 27-item checklist with detailed explanations of each item considered essential for reporting in systematic reviews, which make such an approach distinctive and enable researchers to provide a transparent, complete, and accurate process while exploring the state of knowledge in a chosen research field and identifying future research priorities [7].

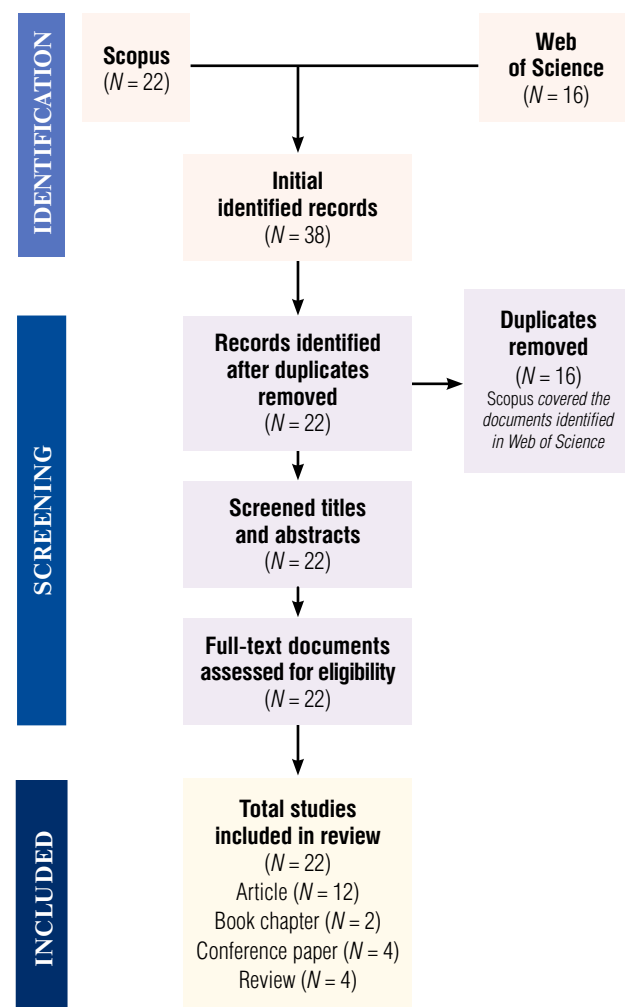


Fig. 1. PRISMA flowchart for scientific documents identification and selection.

On the first stage of scientific document identification, the two main scientific bibliographic databases [11], Web of Science (WoS) and Scopus, were selected for bibliographic data retrieval. The search query “smart real estate” was entered into the topic search in Web of Science and “TITLE-ABS-KEY” in Scopus. In order to ensure data synchronization, data retrieval was done for both databases on the same day, January 9, 2023. Differing from some similar systematic studies (e.g., [12]), the search was not limited by the Web of Sciences core bibliographic collections (e.g., the Social Sciences Citation Index (SSCI)) and no time constraints were set, which were operated similarly in Scopus, and the language of the documents was limited to English for both databases. A total of 38 initially identified scientific records of smart-real estate relevant studies were obtained, of which 22 were included in Scopus and 16 in the Web of Sciences. Both bibliographic metadata were imported into RStudio during the second stage of document screening in order to detect duplicate records and merge the two biblio-

metric datasets using the *bibliometrix* package in RStudio. *Bibliometrix* is the most widely used R package for bibliometric studies [13], which are increasingly referenced in scientific publications. Following the five-step bibliometric dataset merging with duplicates using the *bibliometrix* package (see *Table 1*), 16 duplicates were identified and found to be covered by the Scopus databases, after which 22 records of scientific documents were confirmed eligible for systematic analysis through the screening of titles and abstracts for each.

On the third stage, 22 scientific documents were included for further analysis in the systematic review, including 12 journal articles, 2 book chapters, 4 conference papers, and 4 reviews. Adhering to the purpose of this study, the comprehensive bibliometric analysis was performed in the Biblioshiny app of the *bibliometrix* package in RStudio, which provides a web interface for the *bibliometrix* package that is used to analyze the bibliographic data in a visualized graphical format and provide insights into the conceptual themes [11].

Table 1.

**Five-step bibliometric dataset merging
with duplicates using the R package “bibliometrix”**

Step 1: Download and install package “bibliometrix” in RStudio

```
>install.packages (“bibliometrix”)
```

Step 2: Run the “bibliometrix” and “xlsx” package in RStudio

```
>library (bibliometrix)
>library (xlsx)
```

Step 3: Import and convert bibliographic files

```
>wos_data <- convert2df (“wos.txt”, dbsource = “wos”, format = “plaintext”)
#Import and convert the Web of Science dataset “wos.txt” and name the converted dataset as “wos_data”
>scopus_data <- convert2df (“scopus.bib”, dbsource = “scopus”, format = “bibtex”)
#Import and convert Scopus dataset “scopus.bib” and name the converted dataset as “scopus_data”
```

Step 4: Merge the WoS and Scopus database and remove the duplicated data

```
>merged_data <-mergeDbSources (wos_data, scopus_data, remove.duplicated = T)
#Merge the converted datasets and name the merged dataset as “merged_data”
#Duplicates with a count of 16 are automatically removed from the merged dataset
```

Step 5: Export the merged database to “xlsx” file and write the file name as “merged database”

```
>write.xlsx (merged_data, “merged database.xlsx”)
#Export the “xlsx” file and name it “merged database.xlsx”
```

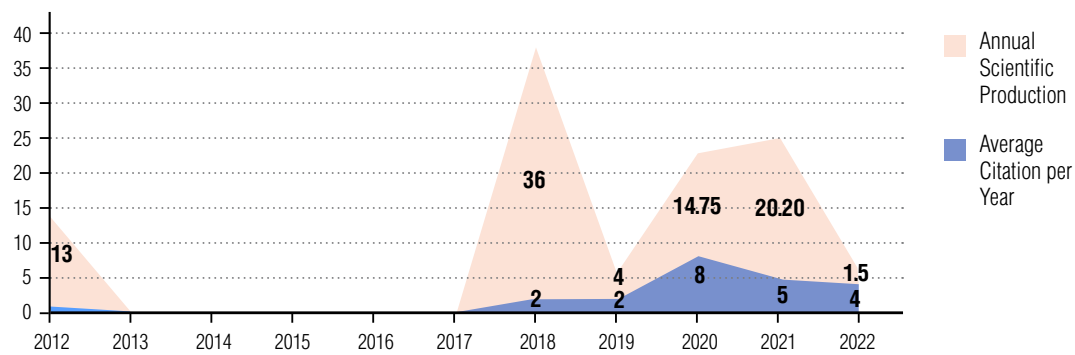


Fig. 2. Annual scientific production and average citations per year.

2. Results and discussion

2.1. Trend of development

Figure 2 shows the trend of research in the field of smart real estate. It is observed that the first research in this field appeared in 2012, followed by a gap in the five years from 2013 to 2017. Since 2018, the research in this field shows a gradual increase in the trend, reaching its peak in 2020, and a slow decrease from 2020 to 2022. Scientific documents published in 2018 received the most average citations per year (36), followed by documents published in 2020 and 2021, which received 14.75 and 20.2 average citations per year, respectively. As shown in Table 2, the bibliographic metadata consists of 22 scientific documents contributed by 50 researchers, with an average of 3.05 co-authors per document and an international co-authorship rate of 31.82%, including 12 journal articles, 2 book chapters, 4 conference papers, and 4 review articles. From 2012 to 2022, the annual growth rate was 14.87%, and the average number of citations per document reached 14.45 times.

2.2. Most contributing countries, institutions and authors

2.2.1. Most productive countries and institutions

A systematic review at the country or institutional level indicates the degree of internationalization of a specific research field [14]. A scientific publication from a country when at least one author is affiliated with an institution located in that country [15], and the individual collaboration in the research field adds up to an observable change in the structure of science [14].

A total of 14 countries have made their contributions in the research field of “smart real estate,” of which 6 countries have produced two or more scientific docu-

Table 2.

Descriptive bibliographic metadata

Description	Results
Main information	
Timespan	2012–2022
Documents (Articles, Reviews, etc.)	22
Annual Growth Rate %	14.87
Document Average Age	3.05
Average citations per doc	14.45
References	1590
Document types	
Article	12
Book chapter	2
Conference paper	4
Review	4
Document contents	
Keywords Plus (ID)	200
Author's Keywords (DE)	103
Authors	
Authors	50
Single-authored docs	5
Co-Authors per Doc	3.05
International co-authorships %	31.82

ments (Table 3). Among all the countries, Australia made the most significant contribution, cumulatively contributing nine documents; the total number of citations reached 283 times, and the average number of citations per document reached 31.44 times. Turkey came in second with four documents, 77 citations, and an average citation of 19.25 per document. In addition, the Netherlands and Malaysia produced 3 documents each, and Pakistan and the United Kingdom produced 2 documents each.

Table 3.

Most productive countries

Country	No. of Documents	Total citations	Average citations per doc
Australia	9	283	31.44
Turkey	4	77	19.25
Netherlands	3	17	5.67
Malaysia	3	16	5.33
Pakistan	2	14	7.00
United Kingdom	2	1	0.50

Note:

The documents identified and included may be co-authored by several scholars from different institutions located in different countries; therefore, the number of documents and total citations corresponding to each country are cumulative.

Table 4 shows the institutions that contributed more than two publications and the leading authors affiliated with those institutions. The 22 identified scientific documents were contributed by scholars from a total of 26 institutions. Among them, the University of New South Wales in Australia has contributed 8 journal articles, ranking first, co-authored by researchers such as Ullah, Sepasgozar, and Shirowzhan. The Near East University in Turkey ranked second and was led by Al-Turjman, who contributed three journal articles; it is worth noting that all three articles were co-authored with Ullah from the University of New South Wales in Australia. The University of Reading Malaysia ranked third, with two journal articles contributed by Lecomte in 2019 and 2020. In addition, Lecomte published one journal article with the University of Quebec in Montreal in Canada in 2022 in the research field of smart real estate [16].

Table 4.

Most productive institutions with leading authors

Institution	Country	N	Leading author(s)	Documents
University of New South Wales	Australia	8	Ullah, Sepasgozar, and Shirowzhan	[1,17–23]
Near East University	Turkey	3	Al-Turjman	[19, 21, 22]
University of Reading Malaysia	Malaysia	2	Lecomte	[24, 25]

Note:

N = number of documents; % = percentage of contributed scientific documents. "Leading authors" refer to authors who have authored (including co-authored) more than two documents with their corresponding affiliated institutions.

2.2.2. Trends in authorship and collaborations

Analysis of authorship and trends in collaboration provides deep insights into the structure and practice of a particular scholarly research field, and the intensity of collaboration between authors and the impact of collaboration on scientific citations vary widely at the international and domestic levels [14].

Research in the field of smart real estate shows a high intensity of author collaboration. As shown in Fig. 3, there are ten groups of collaborative networks, among which the collaborative network centered on Ullah and Sepasgozar has the highest collaboration density and the largest number of scientific publications (Table 3). Furthermore, as illustrated in Fig. 4, seven publications co-authored by Ullah and Sepasgozar (including the co-authorship with Low et al.) ranked among the top ten most cited in the research field; a journal article published in the journal Sustainability in 2018 was cited 66 times, ranking first. The remaining 9 groups of collaborative networks exhibited the characteristics of multiple authors cooperating on a single publication: collaborative networks such as Ahmed et al. [26], Allameh et al. [27], Kempeneer et al. [28], Azmi et al. [29], Sandeep Kumar and Talasila [30] each collaborated on one journal paper; collaborative networks such as Hapuarachchi et al. [31], Aydinoglu and Bovkir [32], Xu and Gade [33], and Su and Li [34] each produced one conference paper collaboratively.

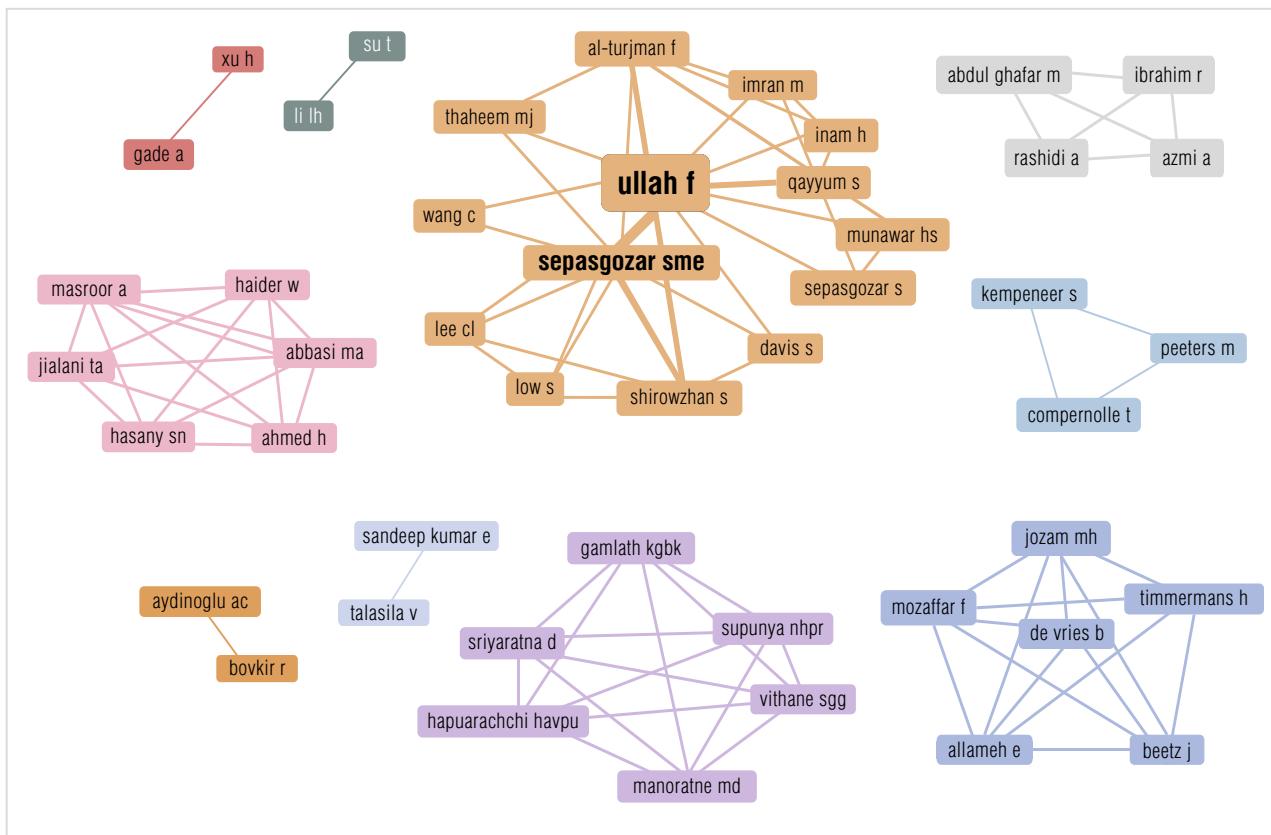


Fig. 3. Collaboration network of authors.

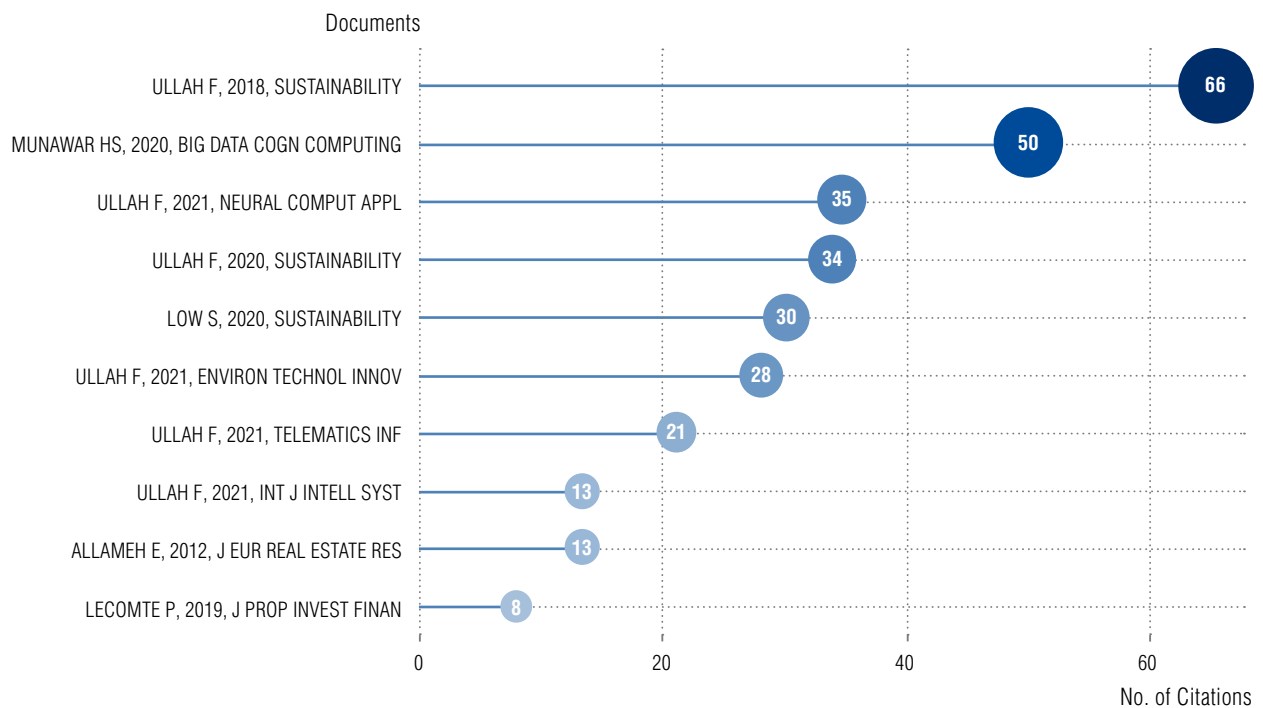


Fig. 4. Most cited documents in the research field of smart real estate.

2.3. Analysis of keyword co-occurrence and thematic evolution

When analyzing the knowledge of the research field, keyword analysis allows for more systematic insights into the current state and trends for future development. Keywords Plus, containing the author’s keywords and words or phrases automatically generated by the computer algorithms that appear frequently in the titles of an article’s references, are recommended for co-occurrence analysis of keywords and the evolution of the research themes [35]. In this section, the conceptual structure map using the multiple correspondence analysis method was employed to distinguish the present research themes by categorizing the selected keywords, whereas the thematic map was used to consult the comprehensiveness of each clustered theme by Keywords Plus, thus summarizing the evolution of themes by the degree of development and relevance of each theme cluster.

The bibliographic metadata contains 200 Keywords Plus spread across 22 scientific documents, 29 of which appeared more than twice and were chosen for keyword co-occurrence analysis and thematic evolution. As shown in Fig. 5, 29 keywords were categorized into four groups according to the conceptual structures, and the detailed categories of keywords and corresponding documents with the highest contribution are summarized in Table 5.

The four different types of themes are distributed in different quadrants according to their degree of development (density on the y-axis) and relevance (centrality on the x-axis): niche themes are located in the upper-left quadrant, motor themes are located in the upper-right quadrant, emerging or declining themes are located in the lower-left quadrant, and basic themes are located in the lower-right quadrant [36]. Shown in Fig. 6, we observe:

The cluster consisting of “deep learning,” “neural networks,” “smart cities,” and “taxation” is the only cluster located in the niche theme quadrant; according to [36], those topics are narrowly focused and peripheral in nature, with strong internal linkages but weak external ties, and thus have only a minimal impact on the research field.

The merging or declining themes are both weakly developed and peripheral, showing low density and low centrality. Three clusters are located in the quadrant of emerging or declining themes. These are: the cluster containing “sustainability,” “property market,” and “software,” and the cluster composed of “property,” “real estate industry,” “sales,” and the cluster composed of “real estate agents.” According to Table 5, the publications that contributed to those keywords were published between 2018 and 2022, resulting in the emerging themes. It is worth noting that the cluster composed of the single keyword “real estate agents” is less developed than the other two located in the same quadrant.

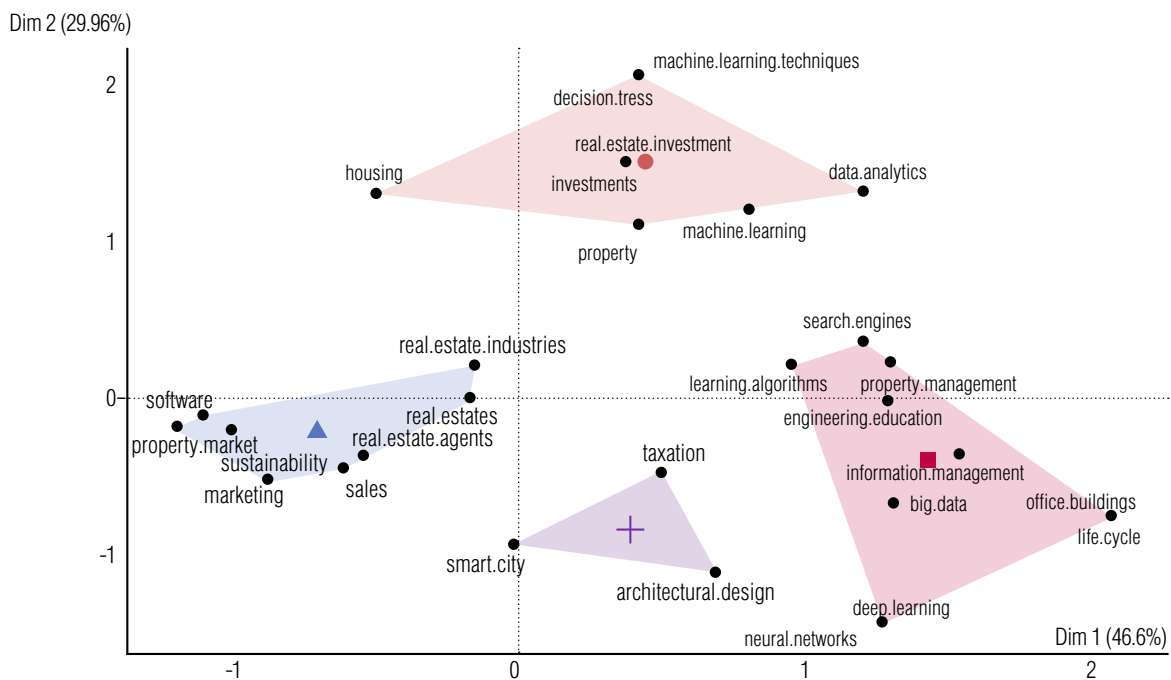


Fig. 5. Conceptual structure map using multiple correspondence analysis (MCA) method.

Table 5.

Categories of keywords and corresponding documents with the highest contribution

Keywords distribution per category	No. of keywords	Time of appearance	Most contributed documents
Category I			
machine learning techniques, decision trees, data analytics, machine learning, property, investments, real estate investment, housing	8	2020	[26, 30]
Category II			
real estate, real estate industries, real estate agents, sales, marketing, sustainability, property market, software	8	2018–2022	[1, 17, 20, 31]
Category III			
search engines, learning algorithms, property management, engineering education, information management, big data, office buildings, life cycle, deep learning, neural networks	10	2020	[18]
Category IV			
taxation, smart city, architectural design	3	2018–2019	[33, 34]

Note:

The most contributed documents were identified by the factorial analysis in the Biblioshiny app, which presents the most weighted documents in influencing the corresponding research category [11].

The motor themes exhibit high density and strong centrality; themes locate in this quadrant, suggesting that they are both well-developed and essential for structuring a study topic, as well as tied externally to theories that are relevant to other conceptually related themes [36]. The cluster composed of “machine learning,” “information management,” “data analytics,” “big data,” and “life cycle” possesses the highest devel-

opment degree and relevance degree. The cluster composed of “decision stress,” “housing,” “investments,” “machine learning,” “techniques” and “real estate investment” has a medium degree of relevance and a higher degree of development. Meanwhile, the cluster composed of “architectural design,” “marketing” and “real estate” has a higher degree of relevance and a medium degree of development.

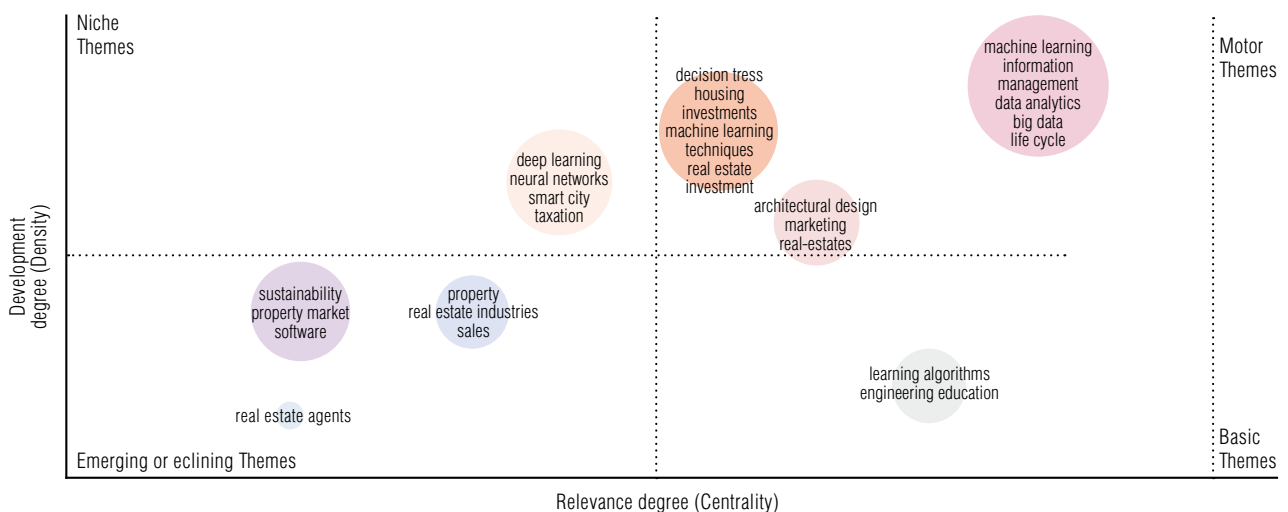


Fig. 6. Thematic map by Keywords Plus.

The keywords “learning algorithms” and “engineering education” formed the only cluster in the quadrant of basic themes, indicating their importance for the research field of smart real estate but not yet fully formed.

By comparing *Fig. 5* and *Fig. 6*, we found that most of the keywords in Categories I and III are either motor themes with a higher degree of development and relevance or basic themes with a higher degree of relevance but have not been explored in depth. Category III overlaps with all keywords of the three clusters located in the quadrant of emerging or declining themes; keywords of Category IV, “smart city” and “taxation,” are located in the niche themes quadrant, and “architectural design” is located in the motor themes quadrant.

Conclusion

Innovative technology is important and influential, and the development of technology has driven the transformation of the industry. As pointed out by [37], the driving force of transformation is strategy, not technology, and it applies to the real estate industry. This study provides a systematic review of the digital transformation of the real estate industry, focusing on the aspect of smart real estate. It provides a comprehensive understanding of current trends in theoretical development, taking “smart real estate” as a research field, and it guides academic scholars with future research directions and industry practitioners with strategy or policy-making. The key findings are summarized as follows:

- i. Research on smart real estate is a relatively new research field. The relevant literature first appeared in 2012 and has shown a rapid growth trend since 2018.
- ii. The University of New South Wales in Australia made the most contributions to this field of study, followed

by the Near East University in Turkey and the University of Reading in Malaysia. There appeared to be significant gaps in this research field in other developed regions such as the European Union as well as in emerging economies such as China and Russia.

- iii. Research in the field of smart real estate exhibits a strong co-authorship characteristic, with the most prominent contributions coming from a collaborative network of Ullah, Sepasgozar, and Shirowzhan et al., including the total number of publications and citations.
- iv. Through two different bibliometric mapping methods that categorized and clustered themes using the Keywords Plus, we found that keywords from two categories, such as “machine learning techniques,” “decision trees” and “data analytics” from Category I, and “information management,” “big data” and “life cycle” from Category III, have a higher degree of thematic development and relevance.

The study employing the bibliometric analysis method provides the most objective results for a systematic review, which avoids the bias of individual subjective factors. Nevertheless, there are two major limitations that need to be acknowledged. First, the digital transformation of real estate is a very broad concept and involves a number of related research fields such as smart city, property technology (ProTech), digital real estate, smart housing and smart homes, etc.; thus it is highly recommended for future researchers to compare and summarize all related research concepts or frameworks. Second, Scopus and Web of Science were limited as sources of scientific documents; other bibliographic databases, such as Google Scholar and ProQuest, should be researched in the future for the development of bibliometric studies. ■

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Настоящее и будущее цифровой трансформации индустрии недвижимости: Систематический обзор «умной» недвижимости

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Аннотация

Вклад индустрии недвижимости в глобальную и региональную экономику весьма значителен, однако в условиях современных развивающихся цифровых технологий и цифровой экономики цифровая трансформация индустрии недвижимости отстает от других отраслей. С одной стороны, это связано с устоявшимися процессами и системами, имеющими отношение к восходящей и нисходящей индустриям недвижимости, а с другой стороны – с тем, что цифровые технологии разрушают традиционные способы ведения бизнеса, подвергая отрасль влиянию факторов неопределенности. Цифровая трансформация индустрии недвижимости – это широкая и развивающаяся концепция. Различные смежные области исследований связаны с внедрением и применением различных инновационных технологий в промышленности. Данное исследование представляет собой систематический обзор, посвященный области интеллектуальной недвижимости, на основе библиометрического анализа с использованием PRISMA. Библиометрический анализ проведен в RStudio с использованием 22 научных документов, опубликованных с 2012 по 2022 годы и проиндексированных в Scopus и Web of Science. Полученные результаты позволили сделать следующие выводы. Во-первых, исследования в области «умной» недвижимости по-прежнему

являются новой, но быстро развивающейся областью. Во-вторых, лишь ограниченное число академических институтов из нескольких стран, таких как Университет Нового Южного Уэльса в Австралии, внесли значительный вклад в данную область знаний. В-третьих, исследование демонстрирует специфические характеристики сети сотрудничества, что приводит к высокой концентрации авторов и цитируемости. В-четвертых, исследовательские темы, связанные с обработкой данных, такие как «машинное обучение», «управление информацией», «аналитика данных» и «большие данные», демонстрируют высокую степень плотности исследований и их ведущую роль.

Ключевые слова: «умная» недвижимость, цифровая трансформация, цифровая экономика, инновационные технологии, обработка данных, технологии недвижимости (PropTech), систематический обзор, библиометрический анализ, PRISMA, RStudio

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