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.

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].
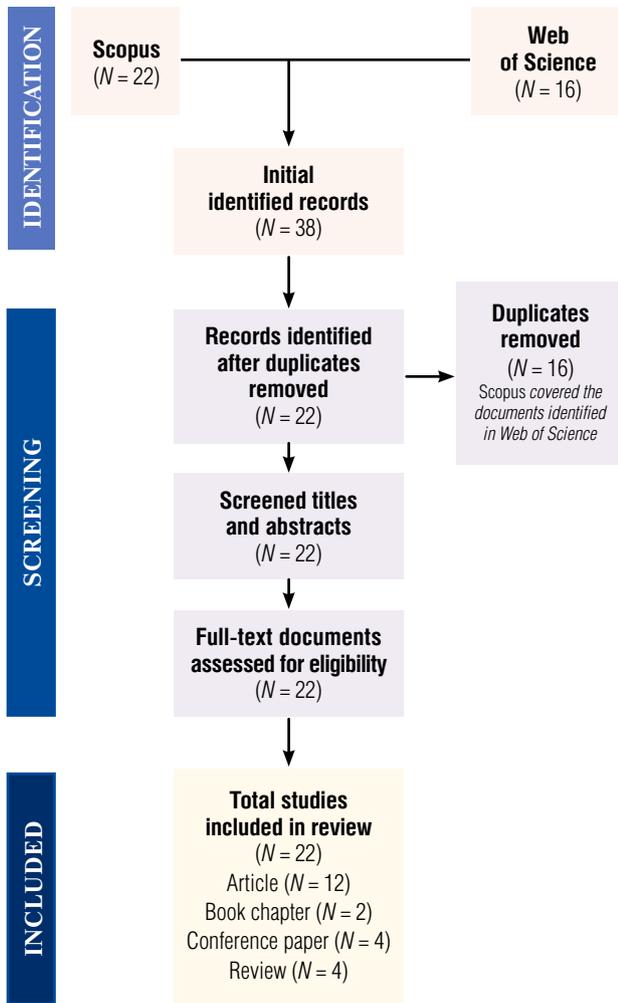
IDENTIFICATION

Scopus
(*N* = 22)

Web of Science
(*N* = 16)

Initial identified records
(*N* = 38)

SCREENING

Records identified after duplicates removed
(*N* = 22)

Duplicates removed
(*N* = 16)
Scopus *covered the documents identified in Web of Science*

Screened titles and abstracts
(*N* = 22)

Full-text documents assessed for eligibility
(*N* = 22)

INCLUDED

Total studies included in review
(*N* = 22)
Article (*N* = 12)
Book chapter (*N* = 2)
Conference paper (*N* = 4)
Review (*N* = 4)

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 bibliometric 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].

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

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"

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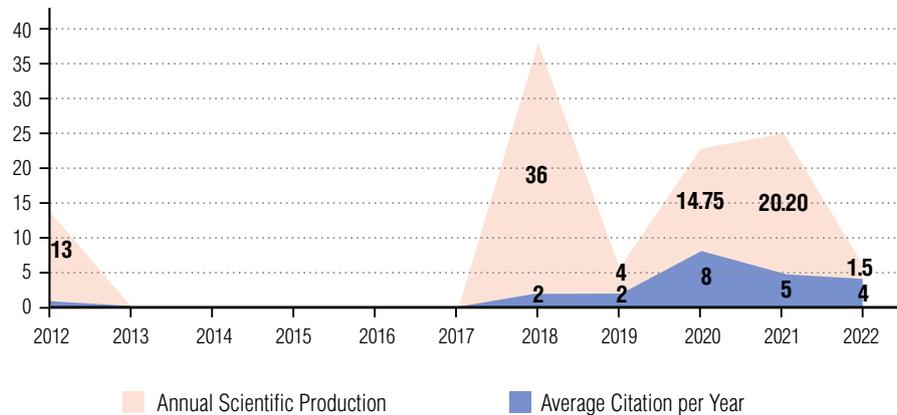
Fig. 2. Annual scientific production and average citations per year.

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 documents (*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 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 arti-

cle with the University of Quebec in Montreal in Canada in 2022 in the research filed of smart real estate [16].

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 coop-

erating 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

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

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.

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.
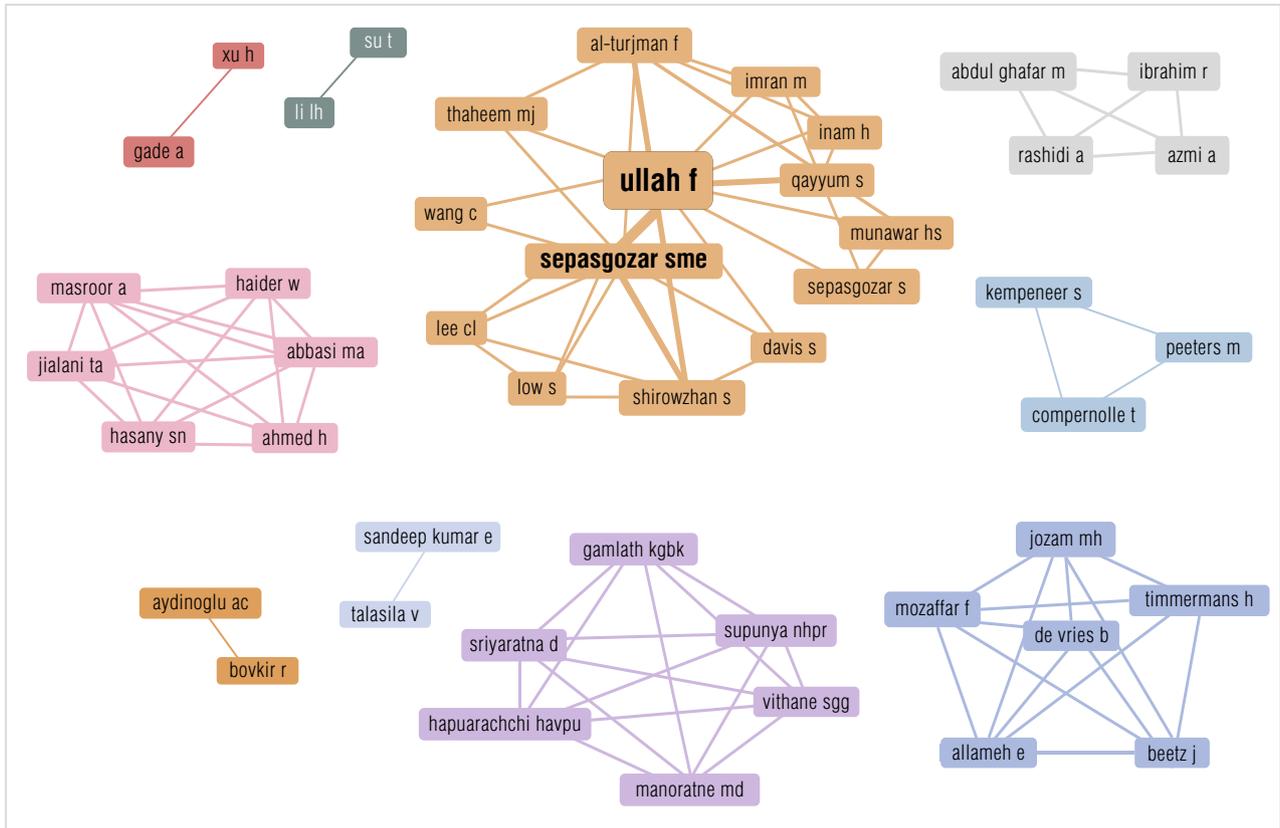
Fig. 3. Collaboration network of authors.

et al. [31], Aydinoglu and Bovkir [32], Xu and Gade [33], and Su and Li [34] each produced one conference paper collaboratively.

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
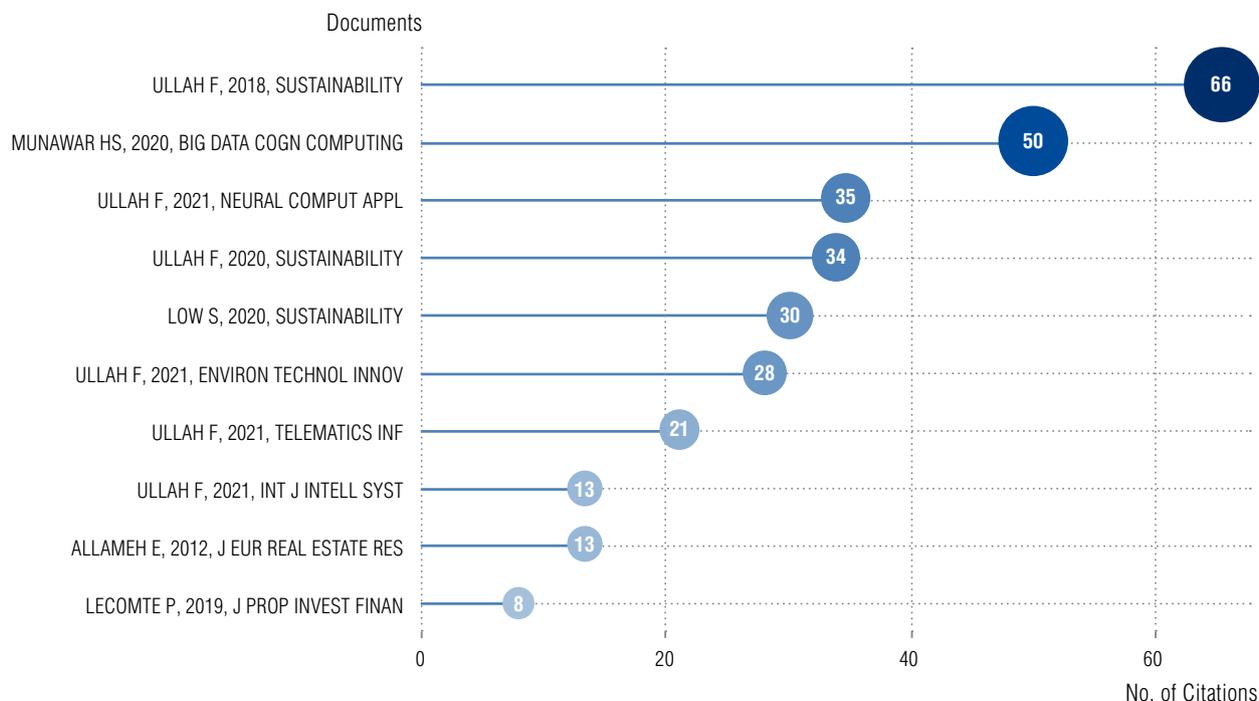
Documents

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

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 publica-

tions 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.

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 development 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.
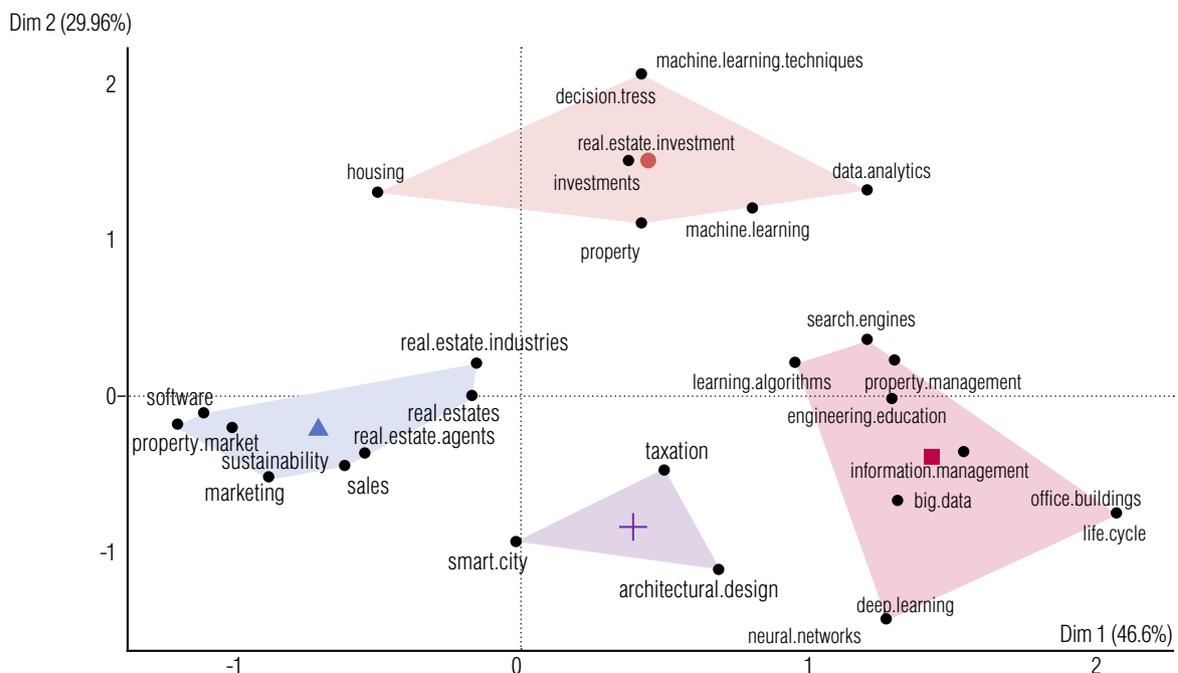
Dim 2 (29.96%)

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

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 tech-

nology, 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 policymaking. 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

**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].
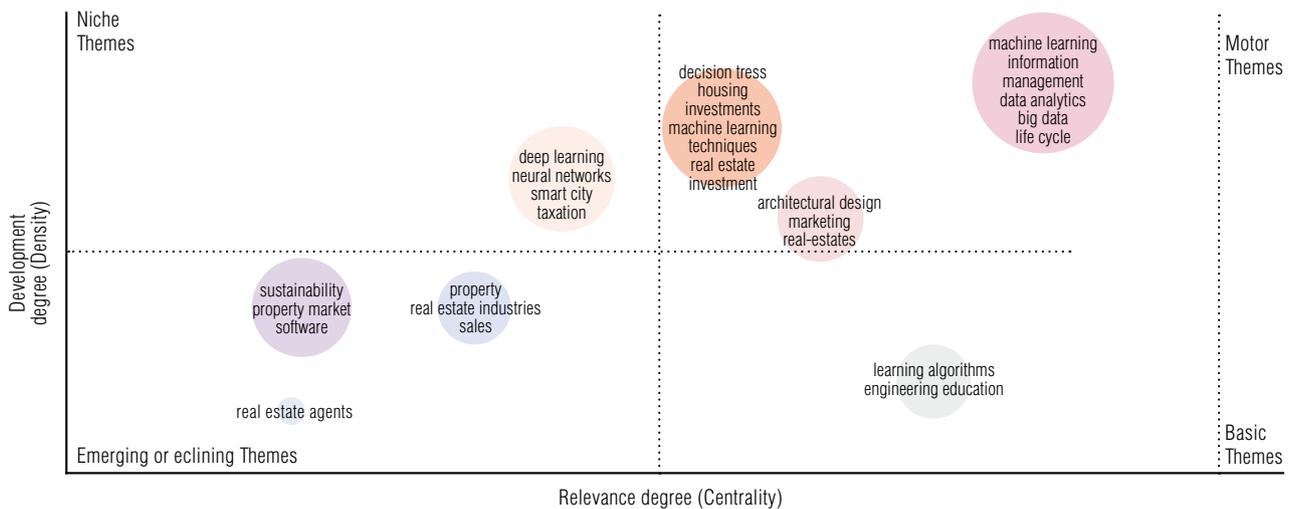

Fig. 6. Thematic map by Keywords Plus.

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. ∎

References

1. Ullah F., Sepasgozar S.M.E., Wang C. (2018) A systematic review of smart real estate technology: Drivers of, and barriers to, the use of digital disruptive technologies and online platforms. *Sustainability*, vol. 10, no. 9, 3142. https://doi.org/10.3390/su10093142

2. Kassner A.J., Cajias M., Zhu B. (2022) The PropTech investors' dilemma — What are the key success factors that secure survival? *Journal of Property Investment & Finance*, vol. 41, no. 1, pp. 76—91. https://doi.org/10.1108/JPIF-01-2022-0007

3. Vassileva B. (2017) Marketing 4.0: How technologies transform marketing organization. *Óbuda University e-Bulletin*, vol. 7, no. 1, pp. 47—56.

4. Shirowzhan S., Tan W., Sepasgozar S.M. (2020) Digital twin and cyberGIS for improving connectivity and measuring the impact of infrastructure construction planning in smart cities. *ISPRS International Journal of Geo-Information*, vol. 9, no. 4, 240. https://doi.org/10.3390/ijgi9040240

5. Starr C.W., Saginor J., Worzala E. (2020) The rise of PropTech: Emerging industrial technologies and their impact on real estate. *Journal of Property Investment & Finance*, vol. 39, no. 2, pp. 157—169. https://doi.org/10.1108/JPIF-08-2020-0090

6. Dash G., Kiefer K., Paul J. (2021) Marketing-to-Millennials: Marketing 4.0, customer satisfaction and purchase intention. *Journal of Business Research*, vol. 122, pp. 608—620. https://doi.org/10.1016/j.jbusres.2020.10.016

7. Page M.J., McKenzie J.E., Bossuyt P.M. et al. (2021) The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ*, vol. 372(n71). https://doi.org/10.1136/bmj.n71

8. Higgins J.P., Thomas J., Chandler J., Cumpston M., Li T., Page M.J., Welch V.A. (editors) (2019) *Cochrane handbook for systematic reviews of interventions*. 2nd Edition. Chichester (UK): John Wiley & Sons.

9. Archer L.B. (1984) Systematic method for designers. *Developments in design methodology* (ed. N. Cross), pp. 57—82. New York: John Wiley & Sons.

10. Peffers K., Tuunanen T., Rothenberger M.A., et al. (2007) A design science research methodology for information systems research. *Journal of management information systems*, vol. 24(3), pp. 45—77.

11. Aria M., Cuccurullo C. (2017) Bibliometrix: An R-Tool for comprehensive science mapping analysis. *Journal of Informetrics*, vol. 11, no. 4, pp. 959—975. https://doi.org/10.1016/j.joi.2017.08.007

12. Zhu J., Liu W. (2020) A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics*, vol. 123, no. 1, pp. 321–335. https://doi.org/10.1007/s11192-020-03387-8

13. Linnenluecke M.K., Marrone M., Singh A.K. (2020) Conducting systematic literature reviews and bibliometric analyses. *Australian Journal of Management*, vol. 45, no. 2, pp. 175–194. https://doi.org/10.1177/0312896219877678

14. Demaine J. (2022) Fractionalization of research impact reveals global trends in university collaboration. *Scientometrics*, vol. 127, no. 5, pp. 2235–2247. https://doi.org/10.1007/s11192-021-04246-w

15. Anand A., Kringelum L.B., Madsen C.Ø., Selivanovskikh L. (2021) Interorganizational learning: A bibliometric review and research agenda. *The Learning Organization*, vol. 28, no. 2, pp. 111–136. https://doi.org/10.1108/TLO-02-2020-0023

16. Lecomte P. (2022) On the economic nature of behavioural control in smart real estate. *Journal of General Management*. https://doi.org/10.1177/03063070221131980

17. Low S., Ullah F., Shirowzhan S., Sepasgozar S.M., Lin Lee C. (2020) Smart digital marketing capabilities for sustainable property development: A case of Malaysia. *Sustainability*, vol. 12, no. 13, 5402. https://doi.org/10.3390/su12135402

18. Munawar H.S., Qayyum S., Ullah F., Sepasgozar S. (2020) Big data and its applications in smart real estate and the disaster management life cycle: A systematic analysis. *Big Data and Cognitive Computing*, vol. 4, no. 2, 4. https://doi.org/10.3390/bdcc4020004

19. Ullah F., Al-Turjman F. (2023) A conceptual framework for blockchain smart contract adoption to manage real estate deals in smart cities. *Neural Computing and Applications*, vol. 35, pp. 5033–5054. https://doi.org/10.1007/s00521-021-05800-6

20. Ullah F., Sepasgozar S.M.E. (2020) Key factors influencing purchase or rent decisions in smart real estate investments: A system dynamics approach using online forum thread data. *Sustainability*, vol. 12, no. 11, 4382. https://doi.org/10.3390/su12114382

21. Ullah F., Al-Turjman F., Qayyum S., Inam H., Imran M. (2021) Advertising through UAVs: Optimized path system for delivering smart real-estate advertisement materials. *International Journal of Intelligent Systems*, vol. 36, no. 7, pp. 3429–3463. https://doi.org/10.1002/int.22422

22. Ullah F., Sepasgozar S.M.E., Thaheem M.J., Al-Turjman F. (2021) Barriers to the digitalisation and innovation of Australian Smart Real Estate: A managerial perspective on the technology non-adoption. *Environmental Technology and Innovation*, vol. 22, article 101527. https://doi.org/10.1016/j.eti.2021.101527

23. Ullah F., Sepasgozar S.M.E., Shirowzhan S., Davis S. (2021) Modelling users' perception of the online real estate platforms in a digitally disruptive environment: An integrated KANO-SISQual approach. *Telematics and Informatics*, vol. 63, article 101660. https://doi.org/10.1016/j.tele.2021.101660

24. Lecomte P. (2019) New boundaries: Conceptual framework for the analysis of commercial real estate in smart cities. *Journal of Property Investment and Finance*, vol. 37, no. 1, pp. 118–135. https://doi.org/10.1108/JPIF-10-2018-0083

25. Lecomte P. (2020) iSpace: principles for a phenomenology of space user in smart real estate. *Journal of Property Investment and Finance*, vol. 38, no. 4, pp. 271–290. https://doi.org/10.1108/JPIF-07-2019-0091

26. Ahmed H., Jilani T.A., Haider W., Hasany S.N., Abbasi M.A., Masroor A. (2020) Producing standard rules for smart real estate property buying decisions based on web scraping technology and machine learning techniques. *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 3, pp. 489–505. https://doi.org/10.14569/IJACSA.2020.0110363

27. Allameh E., Jozam M.H., de Vries B., Timmermans H., Beetz J., Mozaffar F. (2012) The role of smart home in smart real estate. *Journal of European Real Estate Research*, vol. 5, no. 2, pp. 156–170. https://doi.org/10.1108/17539261211250726

28. Kempeneer S., Peeters M., Compernolle T. (2021) Bringing the user back in the building: An analysis of ESG in real estate and a behavioral framework to guide future research. *Sustainability*, vol. 13, no. 6, 3239. https://doi.org/10.3390/su13063239

29. Azmi A., Ibrahim R., Abdul Ghafar M., Rashidi A. (2022) Smarter real estate marketing using virtual reality to influence potential homebuyers' emotions and purchase intention. *Smart and Sustainable Built Environment*, vol. 11, no. 4, pp. 870−890. https://doi.org/10.1108/SASBE-03-2021-0056

30. Sandeep Kumar E., Talasila V. (2020) A combined data analytics and network science approach for smart real estate investment: Towards affordable housing. *Smart Governance for Cities: Perspectives and Experiences. EAI/Springer Innovations in Communication and Computing* (ed. N. Lopes). Springer, Cham. https://doi.org/10.1007/978-3-030-22070-9_8

31. Hapuarachchi H.A.V.P.U., Manoratne M.D., Gamlath K.G.B.K., Vithane S.G., Sriyaratna D., Supunya N.R. (2022) Realty scout − smart system for real estate analysis & forecasting with interactive user interface. Proceedings of the *2022 IEEE 7th International Conference for Convergence in Technology (I2CT 2022), Pune, India, 7−9 April 2022*, pp. 56−61.

32. Aydinoglu A.C., Bovkir R. (2020) Developing a mobile application for smart real estate information. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLIV-4/W3-2020, pp. 89−94. https://doi.org/10.5194/isprs-archives-XLIV-4-W3-2020-89-2020

33. Xu H., Gade A. (2017) Smart real estate assessments using structured deep neural networks. Proceedings of the *2017 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computed, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation, San Francisco, CA, USA, 04−08 August 2017*, pp. 1−7. https://doi.org/10.1109/UIC-ATC.2017.8397560.

34. Su T., Li L.H. (2019) BIM - Based machine learning engine for smart real estate appraisal. Proceedings of the *2nd International Conference on Sustainable Smart Manufacturing (S2M 2019), Manchester, United Kingdom, 9−11 April 2019*, pp. 63−68.

35. Zhang J., Yu Q., Zheng F., Long C., Lu Z., Duan Z. (2016) Comparing keywords plus of WoS and author keywords: A case study of patient adherence research. *Journal of the Association for Information Science and Technology*, vol. 67, no. 4, pp. 967−972. https://doi.org/10.1002/asi.23437

36. Cobo M.J., López-Herrera A.G., Herrera-Viedma E., Herrera F. (2011) An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the fuzzy sets theory field. *Journal of Informetrics*, vol. 5, no. 1, pp. 146−166. https://doi.org/10.1016/j.joi.2010.10.002

37. Kane G.C., Palmer D., Phillips A.N., Kiron D., Buckley N. (2015) *Strategy, not technology, drives digital transformation*. MIT Sloan Management Review and Deloitte University Press.

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