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PROPERTY MANAGEMENT ENABLED BY ARTIFICIAL INTELLIGENCE POST COVID-19: AN EXPLORATORY REVIEW AND FUTURE PROPOSITIONS

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Abstract. The Covid-19 pandemic outbreak across the globe has disrupted human life and industry. The pandemic has affected every sector, with the real estate sector facing particular challenges. During the pandemic, property management became a crucial task and property managers were challenged to control risks and disruptions faced by their organizations. Recent innovative technologies, including artificial intelligence (AI), have supported many sectors through sudden disruptions; this study was performed to examine the role of AI in the real estate and property management (PM) sectors. For this purpose, a systematic literature review was conducted using structural topic modeling and bibliometric analysis. Using appropriate keywords, the researchers found 175 articles on AI and PM research from 1980 to 2021 in the SCOPUS database. A bibliometric analysis was performed to identify research trends. Structural topic modelling (STM) identified ten emerging thematic topics in AI and PM. A comprehensive framework is proposed, and future research directions discussed.

Keywords: property management, artificial intelligence, real estate management, structural topic modeling, residential management, text mining.

Introduction

The Covid-19 pandemic extends far beyond the heath sector, affecting all professions and sectors. The pandemic initiated some severe economic disruptions worldwide which involved a major global recession, and the real estate markets were likewise affected (Giudice et al., 2020). It can be said that the pandemic moved the boundaries of normality, and, in this context, there emerged a new discussion agenda addressing what must be accomplished for urban space, planning, human settlements, real estate investments, and housing (Tanrıvermiş, 2020). The future market is likely to be affected by the housing requirements that emerged during the Covid-19 pandemic, as living standards and lifestyles are certain to transform, leading to changes in study, job, and leisure needs (De Toro et al., 2021). The pandemic has thus caused significant vulnerability for the real estate sector (Uchehara et al., 2020). According to Barua (2021), the pandemic has been, and continues to become, a challenge for preserving the liquidity of the real estate market.

The real estate market experienced a significant slowdown because of the Covid-19 pandemic, and inevitably affecting prices as well (De Toro et al., 2021). Continuing debates are focused on improving, preserving, and bringing value throughout the supply chain. It is assumed that liquidity pressure is faced by financial institutions, brokers, owners, the construction sector, tenants, and the entire supply chain (Uchehara et al., 2020). Scholars and researchers are thus showing an emerging interest in analyzing the impact of the Covid-19 pandemic on the real estate market (Tian et al., 2021). In this case, there is a crucial need for studies concerning strategic property management and its role in reducing the effect of the epidemic on the real estate sector. The Covid-19 pandemic

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has initiated sudden and severe disruptions, and scholars are keen to see what format and shape of retail real estate business will be sustainable through this crisis (Nanda et al., 2021).

Recently, industry practitioners and scholars have focussed on unpredictable consequences within the real estate sector. Applying price gradient analysis to examine the impact of the pandemic on the housing market showed that the risk is transitory and localized (Cheung et al., 2021). Ling et al. (2020) investigated how the pandemic influenced commercial real estate prices. Similarly, Qian et al. (2021) examined the influence of the Covid-19 pandemic on housing prices in China and reported a 2.47% decrease. Tanrıvermiş (2020) observed that many development schedules were delayed by global supply chain disruptions, affecting the return rates and increased operating costs of the real estate sector in Turkey. Nanda et al. (2021) emphasized the role of technology and digitalization in overcoming the disruptions and risks initiated by the pandemic.

Kabaivanov and Markovska (2021) assessed the role of artificial intelligence (AI) in the real estate market, suggesting and testing a three-stage model for market forecasting and real estate valuation that accounts for individual characteristics and global economic factors that influence property prices. Regarding the real estate sector, Nanda et al. (2021) emphasized that technology can offer various benefits in addressing the challenges associated with spatial inequalities and urbanization. The introduction of mobile technologies and the Internet created massive changes across all sectors. A large quantity of information concerning real estate markets and transactions is available, to which AI and machine learning can offer valuable help in analyzing and processing (Kabaivanov & Markovska, 2021), increasing efficiency, reducing costs, can decrease delays in the planning processes, assist with accurate performance measurement, identify areas and needs of development, reduce the possibility of wild speculation, etc. The development of services, products, and tools with investment in technology can be sustainable and useful concerning revenue and profits (Nanda et al., 2021).

This study, a systematic literature review, was conducted to develop an understanding of previous literature on the role of AI in property management, and its related themes. The research field has several research gaps concerning the total research output and the roles of various technologies in property management. A total of 175 publications were found using the SCOPUS database.

The research was directed by the following three questions:

RQ1: What are the different AI applications used for solving property management problems in the real estate sector?

RQ2: What is the growth and development of the research in the area of property management and artificial intelligence?

RQ3: What are the potential propositions for the studies and research by employing AI applications for property management?

The current study begins with a systematic literature review. Bibliometric analysis is then applied to explore and examine the research trends. After that, thematic topics are generated by structural topic modeling (STM), and these topics discussed towards providing future propositions. Finally, implications are developed in the conclusion.

1. Systematic literature review

In this study, a systematic literature review (SLR) approach was applied to achieve considerable insight into the existing literature on AI and PM, drawing on SLR's scientific, transparent, and replicable procedures (Tranfield et al., 2003). According to Fink (2005), systematic literature review is "a systematic, explicit, comprehensive, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners". Literature review is crucial aspect of academic research, facilitating the development of knowledge-based on existing literature, as is expanding the understanding of any research field requires investigating the breadth and depth of existing knowledge, which is possible by SLR (Xiao & Watson, 2019). SLR entails the extraction of literature with an appropriate and well-defined search process, research questions, extraction, and data presentation (Kitchenham et al., 2009). Furthermore, Okoli and Schabram (2010) stressed that literature review must contribute to the existing knowledge along with focusing on the subject matter by incorporating a dual approach of combining available material with theoretical criticism.

The SLR approach employed in the current study began by defining suitable keywords with which to search for relevant literature (Vinodh et al., 2020). Several researchers were involved in the collection and segregation of literature to mitigate individual bias (Tranfield et al., 2003). The literature found was investigated and discussed thoroughly after employing a comprehensive and detailed methodological approach, which is crucial to any form of literature review (Okoli & Schabram, 2010).

The first stage of the method comprises retrieval of articles by using shortlisted keywords based on a selected field of research of AI and PM from the SCOPUS database. Second, the bibliometric study is conducted by using R and VOSviewer. Next, STM is applied using R to generate ten emerging thematic topics. After that, the generated themes are discussed, and future research propositions are provided. Finally, a research framework is proposed along with a conclusion and implications. Figure 1 depicts the SLR flowchart.

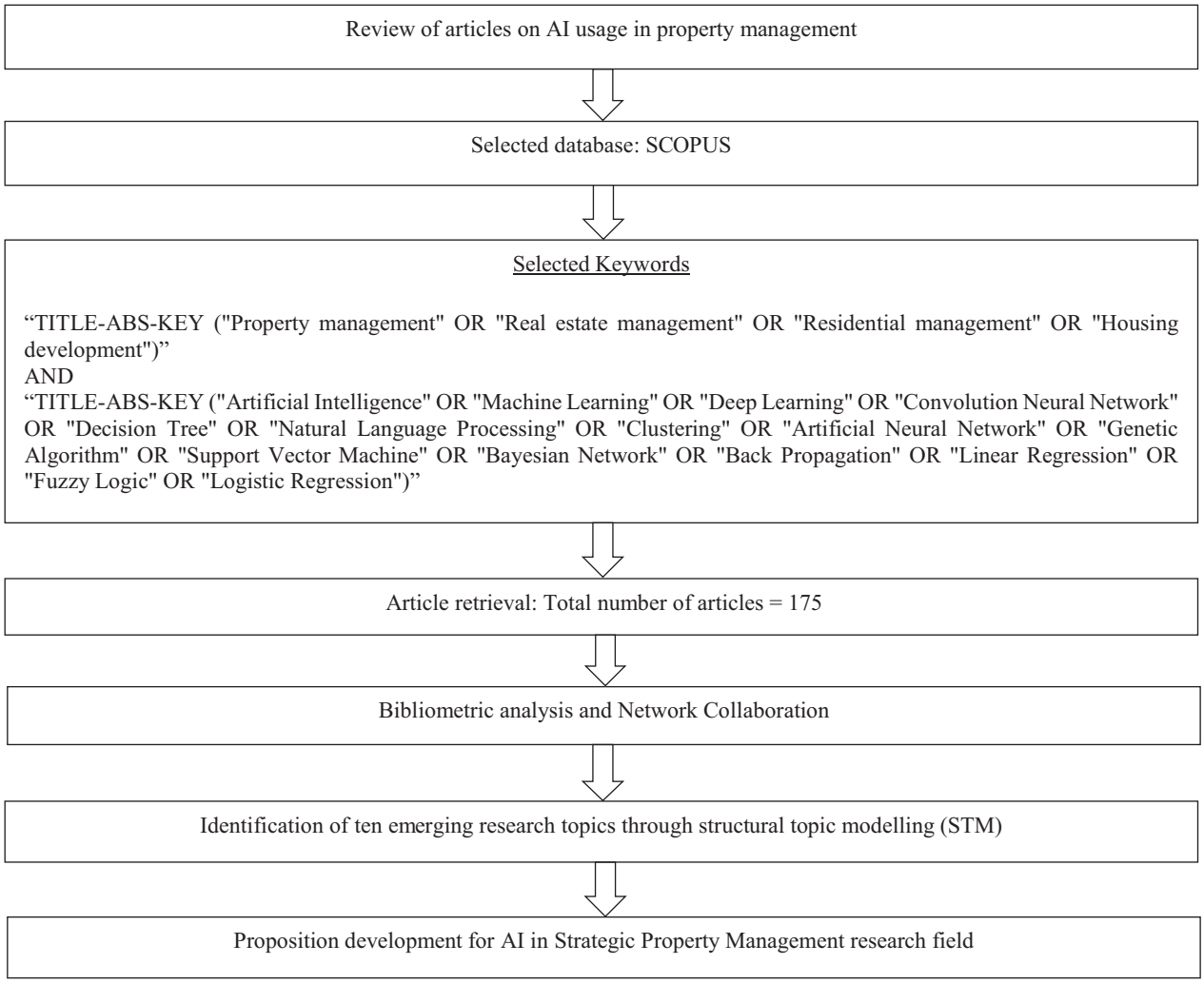

Figure 1. SLR flowchart

2. Bibliometric study

Bibliometric analysis, a "scientific computer-assisted review methodology that helps researchers to recognize fundamental research or authors along with their association by encompassing all the published work in relation to a studied field of research" (De Bellis, 2009), has gained significant recognition in recent years in the business and management research field (Donthu et al., 2021; Khan et al., 2021). It provides a quantitative analysis of publications (Ellegaard & Wallin, 2015) and is used to recognize the major keywords, journals, researchers, affiliations (Wahyuni et al., 2019), and research collaborations among institutions, countries, and researchers (Rejeb et al., 2020). It is often used to obtain and operate upon data based on citation or content analysis (Wallin, 2005). Several tools are widely used for bibliometric analysis, e.g. Pajek, Gephi, Bibexel, R, etc. (Agrawal et al., 2022). R was used in this study, via the Biblioshiny web interface for visual bibliometric analyses. Bibliometric analysis is considered statistically reliable and benefits researchers due to its computerized data treatment because it must incorporate a certain data volume to prove reliability (Ellegaard & Wallin, 2015).

Hence, the current study employed bibliometric analysis to investigate the existing information presented in the literature related to AI in PM. The articles were gathered from the SCOPUS database, and the selected articles span the years 1980 to 2021. The main information of the published articles in the selected field of study is shown in Table 1.

Figure 2 shows the publication rate of articles in the field of AI and PM by year. An increasing and decreasing trend in this field of research is evident since 1994. Up to 2011 fewer than ten articles were published per year in this field. Between 2012 to 2018, an increase and decrease in research output trend is observed. A sharp increase in the number of articles published in the year 2019 from 2018 is evident, which shows increased attention given to this field of research. Furthermore, in 2020 a sharp increase in published articles is apparent from the figure. This growing attention to this field of study could be due

to the severe impact of the Covid-19 pandemic on the real estate sector. However, this area still requires attention to offer solutions for the disruptions occurred in real estate sector.

Table 2 classifies the publications by country. In terms of maximum publications, the USA is the most prominent country. Then, China and Australia showed considerable contribution in AI and PM and became the second and third most prominent countries in this field of research. This table reflects that out of 175 articles selected for this study, 84% were generated from USA and only 28% from China, and rest of the countries are far behind to produce research output in the field of AI and PM. Hence, to advance the research in this field the researchers from other countries must offer significant attention.

Table 1. Data information of publications in AI and PM research

Data information	
Period	1980:2021
Sources (Books, Journals, etc.)	140
References	6857
Articles	175
Average years since publication	8.14
Average citations per document	20.01
Types of documents	
Article	131
Review	6
Book chapter	1
Conference review	7
Conference paper	29
Erratum	1
Content of documents	
Author's keywords (DE)	645
Keywords Plus (ID)	1350
Authors	
Authors	538
Authors of multi-authored document	523
Authors of single-authored document	15
Collaboration between authors	
Single-authored document	22
Collaboration index	3.42
Co-authors per document	3.47
Authors per document	3.07

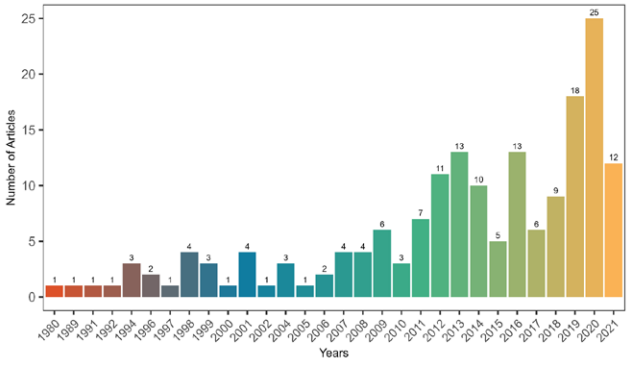

Figure 2. Number of published articles in AI and PM research per year

Table 2. Published articles in AI and PM by countries

Country	Occurrence
USA	148
China	45
Australia	29
UK	14
Canada	13
Turkey	13
Germany	9
South Korea	9
Malaysia	8
Portugal	8

From Table 3, it is observed that the most prominent country concerning a total number of received citations is the USA, followed by Australia and Japan. However, in Table 2, Japan is not among the leading countries to produce a large number of publications, but its average article citation rate is highest among all countries presented in Table 3.

Table 3. Country-wise citations of articles in AI and PM

Country	Total citations	Average article citations
USA	1644	37.36
Australia	543	54.30
Japan	207	103.50
Germany	146	36.50
China	94	5.88
Hong Kong	83	10.38
Korea	83	27.67
Netherlands	73	36.50
Spain	59	29.50
Sweden	53	26.50

Table 4 demonstrates that the journals featuring the greatest number of articles (n = 4) are Land Use Policy and Sustainability in the field of AI and PM. The next journals in the list are the American Journal of Health Promotion, Expert Systems with Applications, Gerontologist, and Habitat International with three published articles each in the field of AI and PM.

Table 4. Influential journals publishing articles in the field of AI in PM

Journals	Articles
Land Use Policy	4
Sustainability (Switzerland)	4
American Journal of Health Promotion	3
Expert Systems with Applications	3
Gerontologist	3
Habitat International	3
Advanced Materials Research	2
International Journal of Housing Markets and Analysis	2
International Journal of Strategic Property Management	2
Journal of Corporate Real Estate	2

Table 5 shows the most prominent authors in the research area of AI and PM, in the sense of having produced the highest number of published articles in the concerned area. The two most prominent authors are Giles-Corti B. and Knuiman M. with five published articles each in AI and PM research field.

Table 5. Most prominent authors with maximum published articles in AI in PM research area

Authors	Articles
Giles-Corti, B.	5
Knuiman, M.	5
Radeloff, V. C.	4
Stewart, S. I.	4
Black, B. S.	3
Hammer, R. B.	3
Kane, J.	3
Liu, Z.	3
Rabins, P. V.	3
Zhang, Y.	3

Table 6 lists the top ten most influential organizations in PM and AI research. It is found that Johns Hopkins University, USA and University of Melbourne, Australia are the leading organizations, as their authors have published six articles in this area. This is followed by other influential universities with four published articles as shown in Table 6.

Table 6. Most influential organizations in the field of AI in PM

Affiliations	Articles
Johns Hopkins University	6
University of Melbourne	6
University of California	5
Cornell University Medical College	4
Harvard School of Public Health	4
Hong Kong Baptist University	4
Johns Hopkins Bloomberg School of Public Health	4
The University of Western Australia	4
University of Salford	4
University of Western Australia	4

Table 7 shows the major keywords in the AI and PM research. In the selected 175 articles in PM and AI, the keyword "housing" occurred 52 times. It is observed that the keywords "female" and "male" occurred 45 and 42 times, respectively. These and other keywords have high recurrence because they were used by most of the studies and appeared multiple times in the selected articles. Also, "male", "female", "adult engagement" is more related to property; that is why these keywords occurred in the search results. Table 7 displays 20 such keywords in the selected field of research and the occurrences of keywords as well. This shows the major keywords used by the authors in their research which appeared in the title, abstract, and keywords of the published papers.

Figure 3 illustrates the "histogram" of the respective keywords in AI and PM research. These keywords were found in the abstracts, title, and keywords of published

Table 7. Top keywords occurred in published papers in AI and PM

Keyword	Frequency of occurrence	Keyword	Frequency of occurrence
Housing	52	Humans	23
Female	45	Aged	19
Male	42	Decision making	17
Human	36	Urban population	15
Adult	34	Artificial intelligence	14
Adolescent	27	Young adult	14
Article	26	Child	13
Middle aged	25	China	13
Regression analysis	24	Public housing	13
United States	24	Property management	12

articles, and they highlight the most commonly used words in the abstracts, title, and keywords. It is illustrated in the figure, that the most prevailing keywords concerning literature are housing, female, male, decision making, artificial intelligence, etc. These keywords were frequent during the course of research and occurred several times. Furthermore, Figure 4 shows the trend topics in the field of AI and PM.

To identify the association between countries and authors, we conducted a network analysis using the VOSviewer package. The authors' collaboration network is presented in Figure 5. There are 535 authors from 175 documents considered in this study. Also, we considered only those authors who wrote at least 2 of the sampled articles, so the number of authors was reduced to 45. It is found that the authors Black B. S. and Rabins P. V. have the highest number of links with other authors, each with four links and a total link strength of 9. However, from Figure 5, it is seen that author collaboration is concentrated into clusters, as authors are not engaged in publishing research with authors of other clusters. Therefore, it creates the need of more collaboration of top authors to conduct and publish research in AI and PM area for increasing the quality of the research in chosen research field.

The 175 documents considered in the study were written in 47 countries. We considered only those countries that produced at least 2 articles, so the number of countries was reduced to 24. Of these, 19 countries form 3 clusters, and the remaining 5 countries are excluded due to lack of connectivity between them. The biggest cluster is the red cluster, containing 7 countries, while the other two clusters (blue and green) contain 6 countries each. It is found that China has a major association with different countries with 9 links and a total link strength of 11 (Figure 6).

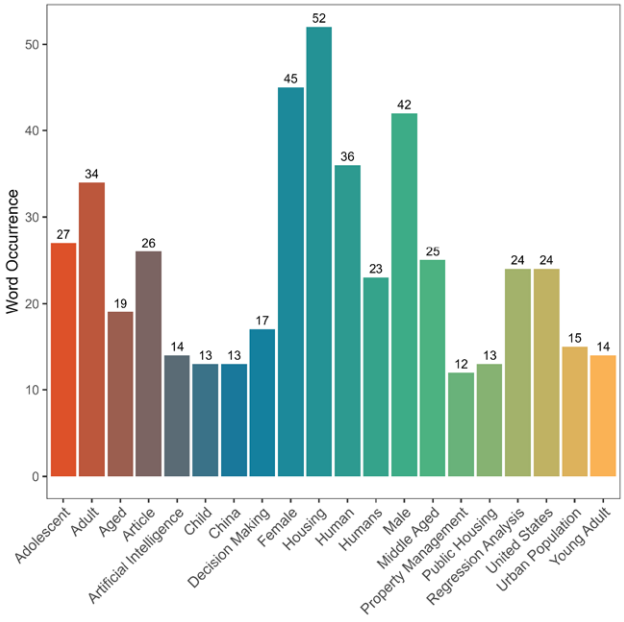

Figure 3. Occurrence of keywords in AI and PM research work

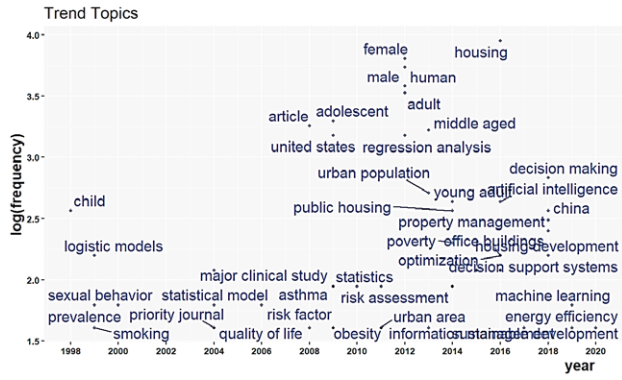

Figure 4. Trend topic of AI and PM research

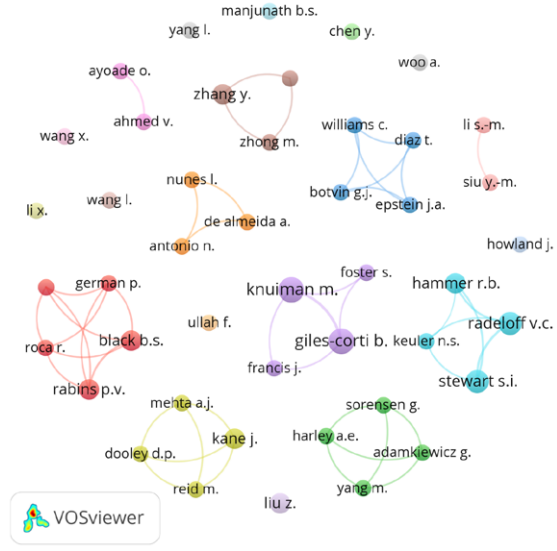

Figure 5. Researchers' network of collaboration in AI and PM research

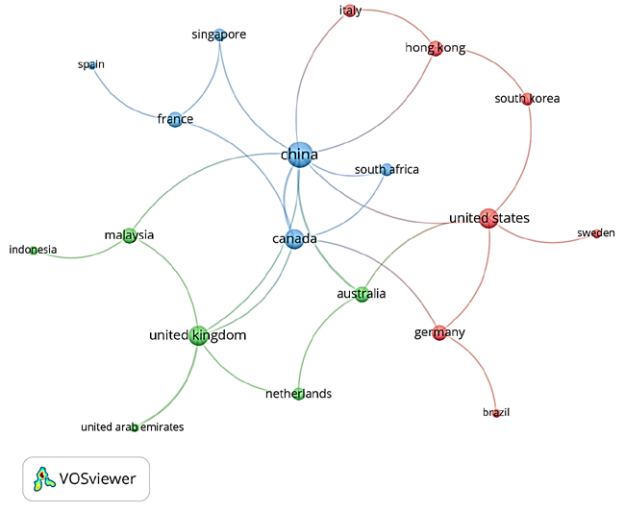

Figure 6. Collaboration network by countries in AI and PM research

3. Structural topic modelling for text analytics

Topic modeling has recently gained importance. It is used by researchers to organize and analyze large volumes of text data (Kuhn, 2018). It categorizes the main themes which are present in an otherwise unstructured and large dataset (Blei, 2012). It is regarded as an "unsupervised machine learning technique" that scans and analyzes text from a set of documents. It automatically clusters word groups, finds related expressions, and investigates different themes that adequately describe the documents collected (Sharma et al., 2021). Structural topic modeling (STM) is a kind of topic modeling that incorporates probabilistic methods to describe collected papers in the form of their topics (Kuhn, 2018). The current study employs the STM generative procedure suggested by Roberts et al. (2019, p. 3) and adopted previously by Naz et al. (2021) and Sharma et al. (2021).

The text from the abstracts, keywords, and titles was used from the selected documents to generate the thematic topics; these were used as input for the STM analysis. Prior to analysis, text cleaning was conducted by eliminating stop words and other commonly used words. Then, non-English words, equations, numbers, and special characters were removed to make the text input consistent with the STM approach. Figure 7 illustrates the thematic topics generated using the inbuilt STM library in R from the 175 selected articles. The generated thematic topics are

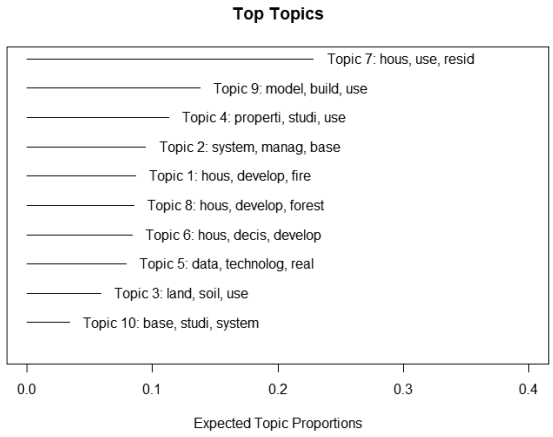

Figure 7. Generated topic labels

property model development analyzing the challenges and risks, customer-centric property management system, optimize resource management, efficient property management system for risk mitigation, management technology in real estate, development of advance decision-making model in property management, sustainable residential development, forest ecosystem development, data driven property development, advance research models in property management.

Table 8 shows the probabilistic distribution of the most commonly used keywords for each derived subject label.

Table 8. Prominent words in each topic

S. No.	Topic	Highest probability words	Frex	Lift
1.	Property model development analyzing the challenges and risks	house, develop, fire, model, spatial, use, energies	fire, crop, energies, distribute, Hongkong, species	climate, crisis, definite, Gediminas, subsystem, Vilnius, wildfire
2.	Customer-centric property management system	system, manage, base, model, decision, research, method	cancel, book, face, system, intelligent, hotel, texture	air photo, demand-manage, overbook, queried, tactic, airport, book
3.	Optimize resource management	land, soil, use, develop, water, house, conserve	soil, conserve, countries, water, land, parcel, agriculture	farm, regular, saturate, Colorado, fresh, impose, meanwhile
4.	Efficient property management system for risk mitigation	properties, studio, use, house, model, manage, factor	intellectual, sale, property, vacant, finance, risk, purpose	asset, Europe, finance, theme, transact, attend, boom
5.	Management technology in real estate	data, technology, real, big, estate, manage, inform	big, patent, technology, real, innovate, motive, field	disrupt, drone, information, recurs, big, come, dimension
6.	Development of advance decision-making model in property management	house, decision, develop, model, price, use, practice	conflict, opposite, competition, organism, decision-making, rout, old	negotiate, obstacle, inderscience, MCDA, opposite, Shenyang, limitations
7.	Sustainable residential development	house, use, residency, health, develop, public, association	smoke, adolescence, fear, mental, asthma, fall, sexual	month, adolescence, asthma, attitude, audit, destiny, diet
8.	Forest ecosystem development	house, develop, forest, edge, association, environment, boundaries	edge, boundaries, bond, fragment, near, nest, habitat	America, interior, overlap, Wisconsin, adjacent, alter, bond
9.	Data-driven property development	model, build, use, house, develop, data, detect	build, segment, detect, extract, remote, road, accuracy	descriptor, formula, fuse, imagery, orthophoto, pixel, relief
10.	Advance research models in property management	base, studio, system, analysis, research, design, structure	steel, vibrate, concrete, bridge, reinforcement, fiber, plate	acid, alloy, blend, degrade, electrochemical, fiber

For instance, as given in Table 8, words with the highest probability that generated topic label 1 are "house", "develop", "fire", "model", "spatial", "use", and "energies". Similarly, Table 8 presents the respective keywords used to generate other topics.

Table 8 also presents two other metrics, namely Frex and Lift. The lift metrics refer to the word occurrence probability restricted to topic divided by the word occurrence probability across the corpus, and it highlights the most common words within a topic (Kuhn, 2018). Though, it is recommended to use Frex metrics which corresponds to the restricted word frequency in a topic divided by word-topic exclusivity (Bischof & Airoldi, 2012).

4. Emerging research themes of AI and strategic property management

4.1. Property model development for analyzing the challenges and risks

In the context of urban growth and development, the pattern of property development has been a major subject of extensive literature (Smersh et al., 2003). Recent research, shaped by the Covid-19 pandemic context, has also gradually emerged to analyze its impact on the real estate market (Tian et al., 2021; Sène et al., 2021). To determine how the pandemic would affect real estate stock returns, Tomal (2021) employed GJR-GARCHX and found that there was a limited effect of the pandemic on real estate stocks. On the other hand, to identify the impact of the Covid-19 pandemic on housing prices, Del Giudice et al. (2020) built a real estate pricing model by which to investigate the short- and mid-term price drops in the real estate market. Tian et al. (2021) regarded the Covid-19 pandemic as a "quasi-natural experiment" and examined the short-term influence of the pandemic on the prices of residential property and land by using the difference in difference model.

Hendershott et al. (2002) developed a vacancy rate model that included supply and demand factors and reported that real rent variation is subjected to changes in the supply and demand factors and the vacancy rate. On the other hand, Redfearn (2005) conducted a study to identify the relationship between terrorism and land markets and performed an experiment by developing a hypothesis to examine housing prices before or after an event. Hallstrom and Smith (2005) measured the impact of a natural disaster, like a hurricane, on housing prices, and used repeat sales prices to propose two regression models. They reported that the prices declined by 19% in the affected area. In contrast, Ling et al. (2020) analyzed the influence of the Covid-19 pandemic on commercial real estate prices and constructed a novel measure with the finding which suggested that the pandemic influenced real estate firms differently, for example the hospitality and retail sectors reacted most negatively while the positive reaction was witnessed in the technology sector. Thus, we propose the following propositions:

Proposition: To investigate the recent instabilities in the property market affected because of the Covid-19 pandemic.

Proposition: To develop models based on AI techniques for analyzing the challenges and risks in the real estate market post-Covid-19 pandemic.

4.2. Customer-centric property management system

The control of information systems and better security in the real estate industry are enabled through system management. This involves improvements to data accuracy, process time, and redundancy. However, the management of properties is considered a major development task, and the ability to achieve this task is still to be improved in the embedded domain (Ciccozzi et al., 2013). In a study conducted by Ling et al. (2020) it was investigated how the shock of the pandemic affected real estate prices; the findings showed that the property investments trust's risk-adjusted returns drastically responded to the growth in contexts affected by the Covid-19 pandemic. It was further reported that management processes and real estate development are also affected by the pandemic. Sanderson and Read (2020) conducted a systematic review of the existing literature while investigating the impact of the Covid-19 pandemic on the property management industry. They focused on the importance of understanding the benefits of customer-centric property management, particularly in the aftermath of the pandemic.

According to Tanrıvermiş (2020), the new policies will force every sector to be structured in the field of asset management and real estate. As digitalization is unavoidable in homes and businesses to manage. Ullah et al. (2018) identified the role of disruptive technologies in identifying the use, barriers, and drivers of technology in smart real estate. The use of innovative technologies is common to the real estate industry and smart cities, as technology has been a characteristic of smartness (Allameh et al., 2011). To succeed, smart cities require smarter management and smart real estate. The technologies are changing and developing over time, so their innovative nature and increasing sociocultural acceptability make real estate smart and sustainable (Paroutis et al., 2014). Wang and Han (2006) presented a property management system framework based on e-business by applying GIS technology within spatial property information management which can incorporate the property information, smart residences information, and user information.

Proposition: To identify the role of AI techniques like Bayesian network, ANN, machine learning in property system management.

Proposition: To develop AI-based models for extensive property management after the Covid-19 pandemic.

4.3. Optimize resource management

The key resources of every organization are called property assets; these comprise buildings and land. In the same

way as financial, human, and information resources contribute to the organization's success, property resources also contribute to it. Property resources are considered as adding value to an organization through creative and effective management (Gibson, 1994). As stated by Goss and Campbell (2008), over the last century, property management has evolved as an occupation emphasizing the value growth of income-generating real estate resources. Ullah et al. (2018) conducted focused on smart real estate management, asserting that it represents the collective management that holds the fundamental principles of consumer-centric, sustainability, and technology adoption at its center. They further emphasized that smart real estate is not confined to infrastructure only but involves resource and asset management as well.

Gross and Wolny-Kucińska (2021) conducted a study on real estate and land management where they focused on resource management and effective management of public areas. Zhang (2021) used big-data simulation and AI to solve issues concerning land venture risk and financial risks. On the other hand, Yu et al. (2021) focused on environmental planning through reuse, recycling, recovery, and reduction. In their study, they used an AI-based hybridized intelligent framework to optimise waste management processes by automated recycling. Majumder and Biswas (2022) stressed the detrimental influence of the pandemic on the real estate sector and asserted on the use of AI-based technologies in recruiting and managing human resources.

Proposition: There is a dearth of studies in the real estate sector concerning resource management using AI based techniques. Therefore, future studies should attempt to fill this gap.

Proposition: To identify various AI-based technologies in managing resources in the real estate sector.

4.4. Efficient property management system for risk mitigation

Scarrett (1983) defined property management as "organizing an efficient system as well as directing, coordinating and controlling all the skills available towards maximizing income from a property and at the same time ensuring maximum protection of its fabric from deterioration and wastage through proper upkeep and maintenance." Efficient property management needs suitable planning and security that important items are allocated properly prior to property construction. Along with this, the aim of property investment is to gain the highest returns which are obtained in the manner of service delivered or rent (Baharum et al., 2009). Ratcliffe (2000) used the scenario method to examine the practices, principles, and pitfalls of scenario building with the objective of presenting techniques to study future property development, investment, and management decisions, along with land use policy formulation. Oyedele (2013) examined the processes of property management and suggested some modern methods for exploiting practices of property management in some developed countries.

Moreover, Quoquab et al. (2022) examined the greenwashing factor in sustainable property development in the context of a developing country like Malaysia. They conducted three studies in order to produce a new measure of greenwashing in sustainable property development and discovered that it is a multi-dimensional construct with dimensions that are incorrect or misleading statements. Moreoever, the absence of greenwashing activities is not ensured by green certification by the housing developers (Sivadasan et al., 2020). On the other hand, Li et al. (2021) combined a hedonic price model and a machine learning technology–extreme gradient boosting–to examine the significant impact of influential variables on housing prices. A complementary study by Allan et al. (2021) analyzed the influence of the pandemic on rent dynamics of commercial property. For this, they used timely proprietary data and applied regression analysis for various cities in the Asia–Pacific region.

Proposition: To identify the factors affecting property management during or after the Covid-19 pandemic.

Proposition: To identify the strategies and AI-based risk mitigation methods to eliminate disruptions post-pandemic.

4.5. Management of technology in real estate

A transformation in global industries has occurred with the development of recent digital technologies. Along with this, the real estate industry is also trying to catch up and develop recent innovations, however, the real estate industry is still lagging and needs to improve its technology curve (Ullah et al., 2019). To address this concern, Ullah et al. (2019) studied the concept of the technology acceptance model and presented a conceptual "real estate stakeholders technology acceptance model" to report on the major requirements of the real estate industry's four major stakeholders. Shim and Hwang (2018) proposed a kernel-based GTWAR model to case study housing prices in China by integrating the basic principle of support vector machine regression into a model with temporally and spatially varying coefficients. Vatansever et al. (2020) aimed to investigate homogenous housing market areas in Turkey and to forecast house sale price indices. For this purpose, they proposed an autoregressive model based on a fuzzy clustering approach. Kauko et al. (2002) applied neural network modelling to investigate several dimensions of housing submarket formation by revealing patterns in data; they reported the classification ability of two neural network techniques–learning vector quantities and self-organizing maps.

Likewise, Abidoye et al. (2019) investigated the role of AI in forecasting property price index by using an artificial neural network, autoregressive integrated moving average (ARIMA), and support vector machine model. Ayoade et al. (2019) evaluated the implications of financial interoperability linked with new consumers in property development and identified the significance of the "Community Land Trust Shared Equity Housing Model".

A broader approach was taken by Moro et al. (2020), who combined five forecast combination techniques and proposed a combined model to forecast property sales using time series data and by modelling using the Box–Jenkins, exponential softening, and ANN techniques. Zlateva et al. (2011) assessed the investment risks in real estate for sustainable regional development and proposed a fuzzy logic model as a hierarchical system with various variables.

Proposition: To identify different digital technologies for strategic property management and report the technology accepting capabilities of the real estate industry.

Proposition: To instill technology management in the real estate industry by using several AI-based techniques to mitigate the risks associated with the pandemic or other natural calamities.

4.6. Development of advance decision-making models in property management

According to Oyedele (2013), strategic solutions for effective property management are essential to achieve the highest profits on property investment, specifically during the phase of worldwide economic crisis. This is significant at the time of the global economic crisis caused by the Covid-19 pandemic as well. As described by Cheng (1998), "property management seeks to control property interests having regard to the short and long term objectives of the estate owner and particularly to the purpose for which the interest is held: to negotiate lettings and to indicate and negotiate rent reviews and lease renewals, to oversee physical maintenance and enforcement of lease covenants, to be mindful of the necessity of upgrading and merging interest where possible, to recognize opportunities for the development of potential and to fulfill the owner's legal and social duties to the community". Moreover, regarding existing built facility management, taking appropriate decisions is a crucial activity for facilities and property managers (Langston & Smith, 2012). For this purpose, they developed a model named iconCUR with the application of additive management and multi-criteria decision analysis to provide solutions for property management decisions (Langston & Smith, 2012).

Samsura et al. (2010) developed game models to predict and analyse the behaviour of factors in the decision-making process by using game-theoretic modelling approaches on land and property development in the Netherlands. Similarly, Langston (2013) established a decision-making model that is applied to choose between competitive designs of buildings through the index of sustainability, and identified four parameters that maximise wealth, resources and utility, and minimise impact. Furthermore, Li et al. (2012) developed a novel model to investigate the effects of integrated property and rail development and presented a heuristic solution algorithm. Hsu and Juan (2016) established AdaptSTAR model based on artificial neural networks (ANN) for the reuse of vacant buildings in urban areas. Nevertheless, for a long time, the construction industry has been timid to implement new technologies in property management, and it hence requires an AI-based decision-support system that tackles the risks and market uncertainty (Berggren et al., 2021).

Proposition: To provide decision models involving actions and strategies for the management of vacant property for the sustainable urban environment.

Proposition: To establish data-driven models using AI-based techniques for sustainable management of property to be used at the time of crisis such as the Covid-19 pandemic.

4.7. Sustainable residential development

In the developing world, there has been a dramatic urban expansion. As reported by the United Nations (2015), between 1950 to 2015, in developing nations, the total urban population grew tenfold, and the urban share also increased from 17% to 50. Urbanisation rates were compared between developed and developing nations, revealing that urban expansion is growing considerably faster in developing countries at present (Jedwab & Vollrath, 2015). The rapid growth of population and urbanisation in a developing nation drives residential development (Aluko, 2010). However, the physical expansion and growth of cities bring several problems like environmental pollution, unplanned urban sprawl, deterioration, general urban decay, and lack of modern basic facilities. Paroutis et al. (2014) suggested that smart city solutions can solve problems associated with unsustainable and insecure energy sources. For this purpose, emerging technologies or AI can play a significant role in creating sustainable residential development.

Allameh et al. (2011) identified technological changes affecting real estate management and the concept of smart cities in building sustainable residential development. Smart technologies are aimed at consumer satisfaction (Dalén & Krämer, 2017), ease of use, wellbeing, personalization, and enhanced productivity (Paroutis et al., 2014). Moreover, Ko et al. (2019) analysed the impact of information and communications technology (ICT) on the sustainability of rural communities by assessing digital literacy and other economic vitality factors and found that ICT infrastructure helps in improving digital literacy and strengthening community cohesion. Currently, there is a great focus on establishing smart cities worldwide (Nanda et al., 2021). By the exploiting emerging technologies, the transformation of cities is being done and it enables residential development.

Proposition: To identify the AI-based technologies creating sustainable residential development.

Proposition: To examine the success rate of AI technologies in creating property development and mitigating sudden risks and disruptions to establish residential development.

4.8. Forest ecosystem development

Several detrimental ecological impacts are caused by urbanization. These impacts include harming forests, negative impact upon the ecosystem, and impairing rivers

(Sena et al., 2021). The loss of forests is driven by the development of suburban and urban areas, and this development also cause fragmentation across peri-urban and urban areas as forest land is transformed into the residential, commercial, and industrial area (Miller, 2012). The negative outcomes of deforestation are not unknown, and they lead to severe consequences for real estate markets as well. As a solution, Kroeger et al. (2014) emphasized urban reforestation to diminish ozone pollution. They suggested that planting urban forests offers enhanced services for air quality. Many studies have been conducted to examine the development of forests and the role of AI. Holzinger et al. (2021) stressed the potential of AI in providing enormous advantages to the environment and humanity. AI can provide significant assistance in finding solutions for the most critical challenges concerning forest ecosystem and agriculture. Tiyasha et al. (2021) developed a hybrid tree-based AI model for the prediction of river-dissolved oxygen to examine river health. Hamidi et al. (2021) used AI, artificial neural networks, and multilayer perceptron to develop an AI-based model for forest planning and management.

Proposition: To conduct studies concerning the detrimental impact of residential development on forest management.

Proposition: There is a dearth of literature in developing AI-based models to mitigate risks associated with real estate development and deforestation.

4.9. Data-driven property development

In the commercial real estate context, where properties are taken as an investment asset, and property management techniques are adopted, markets became more competitive. In the real estate market, firms must support their business models with a strategic environment to meet the needs of consumers and to facilitate necessary service delivery (Palm, 2013). This competitiveness has driven the real estate industry to build its approach towards service orientation (Palm, 2011). Subsequently, the real estate industry will be forced to develop strategies to prepare for meeting these new challenges. According to Ge et al. (2003), artificial neural network models have been successfully applied in various real estate markets worldwide and offered more reliable and accurate estimates along with greater pace.

In this technological age, because of the demand for property evaluation services provided by real estate markets, it is imperative for practitioners and researchers of real estate to get acquainted with AI (Yalpir, 2014). Kaur and Solomon (2022) analysed technology acceptance and property service automation in property management of commercial real estate in India and identified the nine most significant automated property management functions. Ferreira et al. (2016) used a multiple-criterion decision analysis framework to estimate residential housing values by utilising the knowledge and skills of residential real estate professionals. They showed how measuring attractiveness by a category-based evaluation technique and cognitive mapping enables an assessment of suitable sale/offer prices and gives strength to current valuation approaches like hedonic modeling.

Proposition: To compare the strength and limitations of various existing AI models in strategic property management.

Proposition: To develop or conduct more studies by establishing new models to solve strategic property management problems using AI techniques after the Covid-19 pandemic.

4.10. Advance research models in property management

Property management is critical for safeguarding monetary value and for the life cycle of properties, hence it is a crucial segment of real estate management (Oyedele, 2013). Various studies proposed research models to provide solutions for property problems and to enable strategic property management. Stewart et al. (2004) developed a special-purpose genetic algorithm to the spatial planning problems where various land uses must be distributed across a geographical region which comprises a range of constraints and conflicting management objectives. Then (2005) proposed a proactive property management model focussing on achieving corporate business plans by integrating facilities services management and real estate provision. Ciccozzi et al. (2013) followed the model-driven engineering of embedded systems to support the entire round-trip process of property management.

Heywood and Kenley (2008) developed a model from the literature of strategic management, corporate real estate, and organizational competitiveness to propose a model for the relationship between an organization's sustainable competitive advantage and corporate real estate management. Mert and Yilmaz (2009) discussed the factors of property location quality and its importance in the current scenario of real estate sector growth and fast housing development. For this purpose, they applied a fuzzy modelling approach to grade neighbourhood level based on property location quality. Becker et al. (2019) aimed at developing an automated as-is capturing process and data integration into building information modeling for property management of existing buildings.

Proposition: To provide effective property management models based on ANN, optimization algorithms, and other AI-based techniques.

Proposition: To employ automated modelling methods in future research works to provide an understanding of models and techniques involving a combined approach for strategic property management.

Figure 8 shows the application of AI techniques in PM. It is evident from the figure that the application of many AI techniques like deep learning, Bayesian network, fuzzy logic, etc. is limited. These techniques are already abundantly used in other fields. Hence, future studies can incorporate these techniques to solve issues concerning property management.

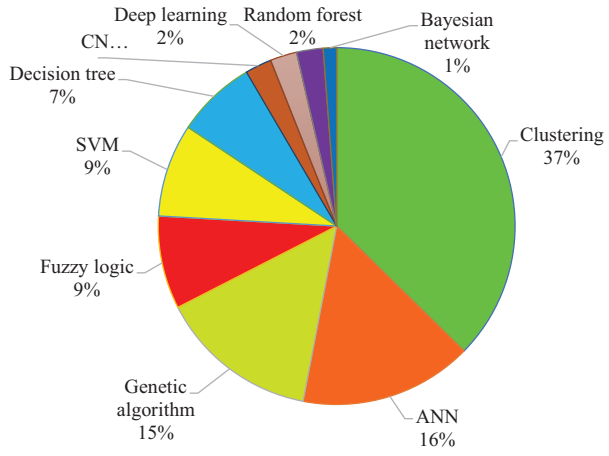

Figure 8. Applications of AI techniques in PM

5. Discussion and proposed research model

To identify the role of AI in property management, the current study was performed by employing the SLR and STM approaches. This study also investigated the impact of the Covid-19 pandemic on property management and the real estate sector. First, the study employed bibliometric analysis to identify the current state of research in the selected field of research. It was apparent from the annual publication rates (Figure 2) that a major increase in the production of articles in AI and PM has occurred since 2019. This shows that this area started receiving attention recently, and the impact of the Covid-19 pandemic on real estate sector has created need for more publications in this area. Therefore, the study reflects the crucial need for research progress in AI and PM and has provided future research proposals to be considered for the research in this field.

Furthermore, the study adopted SLR and STM approaches to investigate the existing knowledge of the research area in AI and PM. The generated thematic topics were identified such as Property model development, System management in property, Resource management, Property management, Technology management in real estate, Decision models in property management, Residential development, Forest development, Data-driven property development, and Research models in property management. After a rigorous review of literature, we found an important contribution of AI applications in property management and forecasting in the real estate sector, however, there is still a long way to catch up with the emerging and smart technologies for them to find full use in the real estate sector. The worldwide real estate market is behind the times when it comes to technological advancements (Ullah et al., 2018, 2019), but investing in real estate technologies is growing instead of relying solely on traditional methods (Ullah et al., 2018).

According to Kabaivanov and Markovska (2021), time-series analysis can apprehend those characteristics of investigated data that would otherwise be overlooked or not completely studied. AI-based methods like neural networks are used to examine financial time series over long periods of time (Yu & Yan, 2020), so, with similar algorithms, real estate markets can be investigated (Kabaivanov & Markovska, 2021). As stated by Viriato (2019), the topics based on AI can be seen frequently incorporate statements, academic journals, and popular media, however, the adoption of new technologies in the real estate industry is rather slow. That process is only just a beginning, and the areas in which AI could have the most impact are not clear yet. In real estate studies, automated tools will enable smooth planning, tracing, and finishing of relocation activities smoothly. The real estate business and its people must be ready to tackle future disruptions, apart from Covid-19, through AI and innovative technology (Tanrıvermiş, 2020).

Concerning property management, Hui et al. (2011) identified the impact of property management on property prices; their findings revealed that people are willing to pay more for properties managed by the company's property management strategy. On the other hand, the role of AI and intelligent technology is stressed in creating an intelligent building with enhanced productivity. It was reported that, in intelligent building property management, information technology will play a crucial role. Intelligent residence property management has been progressively becoming a focus of research for property managers (Yang & Peng, 2001). Wang and Tang (2020) asserted that adaptation of innovative and diverse technologies seems important in asset management and facility-real estate with blockchains, the Internet of Things (IoT), prop-tech, teleconferencing, and BIM–CAFM ("Building Information Model–Computer Aided Facilities Management") systems. In this context, the anticipation of the rise in AI-enabled or smart buildings and technologies that deliver less contact in structures and buildings is likely to be common. However, for property firms, the major problem ahead is how to realise intelligent information property management (Wang & Han, 2006).

Furthermore, it is crucial to analyze the risks and challenges that the Covid-19 pandemic has brought to property management. We discovered that, throughout the Covid-19 epidemic, the majority of real estate studies were focussed on house costs. Although Cheung et al. (2021) stressed that, during the Covid-19 epidemic, only a few studies looked at direct real estate price trends, while the majority of them looked at it as a whole. On the other hand, Uchehara et al. (2020) assessed the Covid-19 impact in sustaining the liquidity value in the real estate market and focussed on the tenants. Their findings suggested that the real estate chain became vulnerable due to the pandemic's impact and created challenges concerning the unpredictability of economic recovery. Nevertheless, their study provided insight into the risk mitigation approach for unforeseen future events caused by the pandemic. Kabaivanov and Markovska (2021) stressed that detecting the rapid change in volatility and market turbulence is crucial to developing an effective investment strategy. A significant amount of time was taken to consider the real estate processes and, therefore, detecting problems at

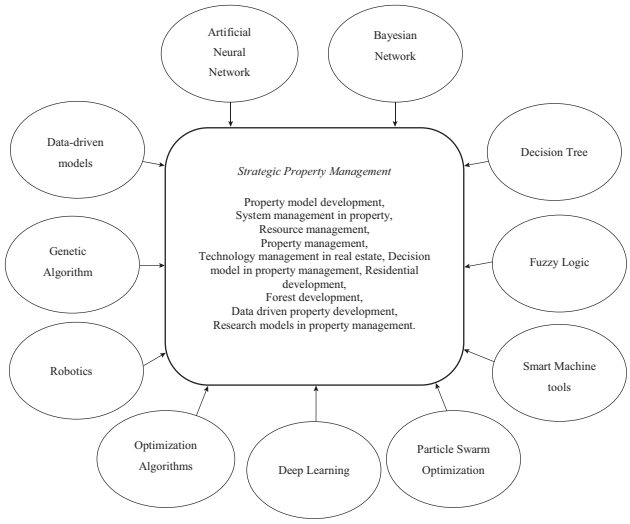

Figure 9. A proposed research framework for AI and PM

an early stage is crucial: this has created a discussion on the use of neural networks as early warning systems to identify such issues (Wang et al., 2020).

It is therefore determined that machine learning and AI can offer a competitive advantage in the real estate markets (Kabaivanov & Markovska, 2021), and can help in generating solutions for sudden and severe disruptions caused by pandemics. This study proposed a research framework (Figure 9) that depicts the incorporation of AI-based techniques and ten emerging research themes for PM.

Implications

This research was carried out to determine the function of AI in property management, with an emphasis on the implications of the Covid-19 pandemic on strategic property management. The study was conducted using structural topic modeling and bibliometric analysis to investigate existing literature on AI and PM. A systematic literature review was carried out based on the generated thematic topics by structural topic modeling. The findings of this research will assist managers to exploit existing AI technologies in the real estate sector for property management. The firms can implement AI techniques to diminish the sudden risk of any virus outbreak and to create resilience in real estate property management. Through this study, we identified that there is a dearth of literature concerning AI and PM and the use of AI in generated thematic topics, so this study will help researchers to identify the gap in the literature. This study will help researchers by providing future research propositions under each thematic topics discussed above.

Conclusions

The Covid-19 pandemic that began in the year 2020 has disturbed the functions and processing of almost every sector. The most affected sectors were those which involve public dealing. The real estate sector was among those sectors which got significantly influenced by the pandemic. The real estate sector involves property management, resource management, property investment, risks related to tenants, etc. This study focused on the solutions provided by AI for strategic property management and how AI can help firms in the real estate sector to deal with disruptions caused by pandemics. Hence, this study provided a systematic literature review for a better understanding of the existing literature in AI and PM. The current study provided a thorough evaluation of the studies conducted in the field of AI and PM over the period 1980–2021. To perform a systematic literature review, STM and bibliometric analysis were used. The thematic themes were generated by using STM and reviewed and discussed in detail. The corresponding themes are Property model development, System management in property, Resource management, Property management, Technology management in real estate, Decision model in property management, Residential development, Forest development, Data driven property development, and Research models in property management. This study will provide a better understanding in the field of AI and PM following the Covid-19 pandemic.

Future studies can develop their research by incorporating the proposals provided in this study. The AI based models must be developed to identify and solve other issues of the real estate sector as well and not just price forecasting. Future studies must examine the challenges and barriers of incorporating AI in PM.

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