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Adoption Of Sustainable Digital Technologies in the Real Estate Sector: A Critical Review

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Abstract: Sustainable digital technologies in real estate can greatly help in bringing down the carbon footprint and simultaneously improve the transparency, efficiency, and profitability. This paper presents a systematic literature review of peer-reviewed journal articles and conference proceedings focused on the digitisation of the real estate sector and the role of emerging technologies in enabling sustainable practices. The most relevant 25 research articles from the extant literature were reviewed; and the technology adoption related papers were classified into four categories based on year of publication, country, methodology, and technology. Also, the driving forces that lead to the adoption of digital technologies in Industry 4.0 era and the challenges to the same were identified. Further, the applications of the digital tools in the case sector were discussed. The paper also provides insights into how the real estate sector can go about implementing digital solutions to fall in line with the principles of Industry 4.0.

Keywords: Artificial Intelligence, blockchain, digital transformation, real estate, sustainability

Introduction

The Indian real estate sector creates largest employment (18 %) after agriculture, and it is valued at USD 493 billion. It contributes 7.3 % to India's GDP (Business Standard, 2024). Though the real estate sector drives the economy, it significantly plays a crucial role in energy consumption and greenhouse gas emissions thereby defining the need for sustainability (Borrero-Domínguez et al., 2020; Mironiuc et al., 2021). The industry therefore needs to strike an optimal balance between growth with environmental responsibility. Manual and fragmented workflows which have been practiced traditionally are creating inefficiencies in the new era of technology-driven world. Digitisation and digital transformation, supported by technologies such as IoT, AI, and blockchain, offer significant opportunities to enhance operations and enable data-driven decision-making. These technologies also contribute to sustainability by optimising energy use, improving property management, and modernising real estate transactions. (Siniak et al., 2020; Walacik and Chmielewska, 2024; Ullah et al., 2021).

This study focuses on the critical factors that lead to the adoption of contemporary technologies and obstacles in their implementation. It may be noted that the real estate sector lags in adopting digital innovations on account of various factors. First, the sector's disjointed nature, with multiple internal as well as external stakeholders, decentralized way of performing the operations etc., makes it complex to implement digital systems (Shen et al., 2022; Ullah et al., 2018). To add to this, the growing concerns over data security and privacy are increasing particularly with the increased amount of data generated by IoT sensors and devices as well as AI systems. Budgetary constraints and the lack of technological awareness among key decision-makers also hamper the adoption (Ali et al., 2025; Mungai, 2023; Naeem et al., 2023; Ogungbemi, 2024; Ullah et al., 2018).

This study focuses on the importance of digital transformation in the real estate sector. By identifying the driving forces and challenges, this study provides valuable insights into how the real estate sector can move in the direction of a more sustainable, efficient, and competitive future. By understanding how digital technologies can bring down the environmental impacts in real estate, this study also leads to the larger discourse on sustainability and the United Nations' Sustainable Development Goals (SDGs), in particular SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). The findings of this study will benefit policymakers, investors, and environmentalists apart from industry professionals.

The research objectives of this article are as follows-

R1: To identify the trend, and approaches employed in sustainable technology adoption area in the real estate sector.

R2: To identify the applications of Industry 4.0 tools in the real estate sector?

R3: To identify the factors that impact the digital transformation?

R4: To identify the challenges to the digital transformation?

In a nutshell, this paper attempts to review the extant literature pertaining to sustainability and digital transformation in the case sector and identify the critical factors that lead to the adoption of the state-of-the-art technologies and challenges pertaining to the same.

Methodology

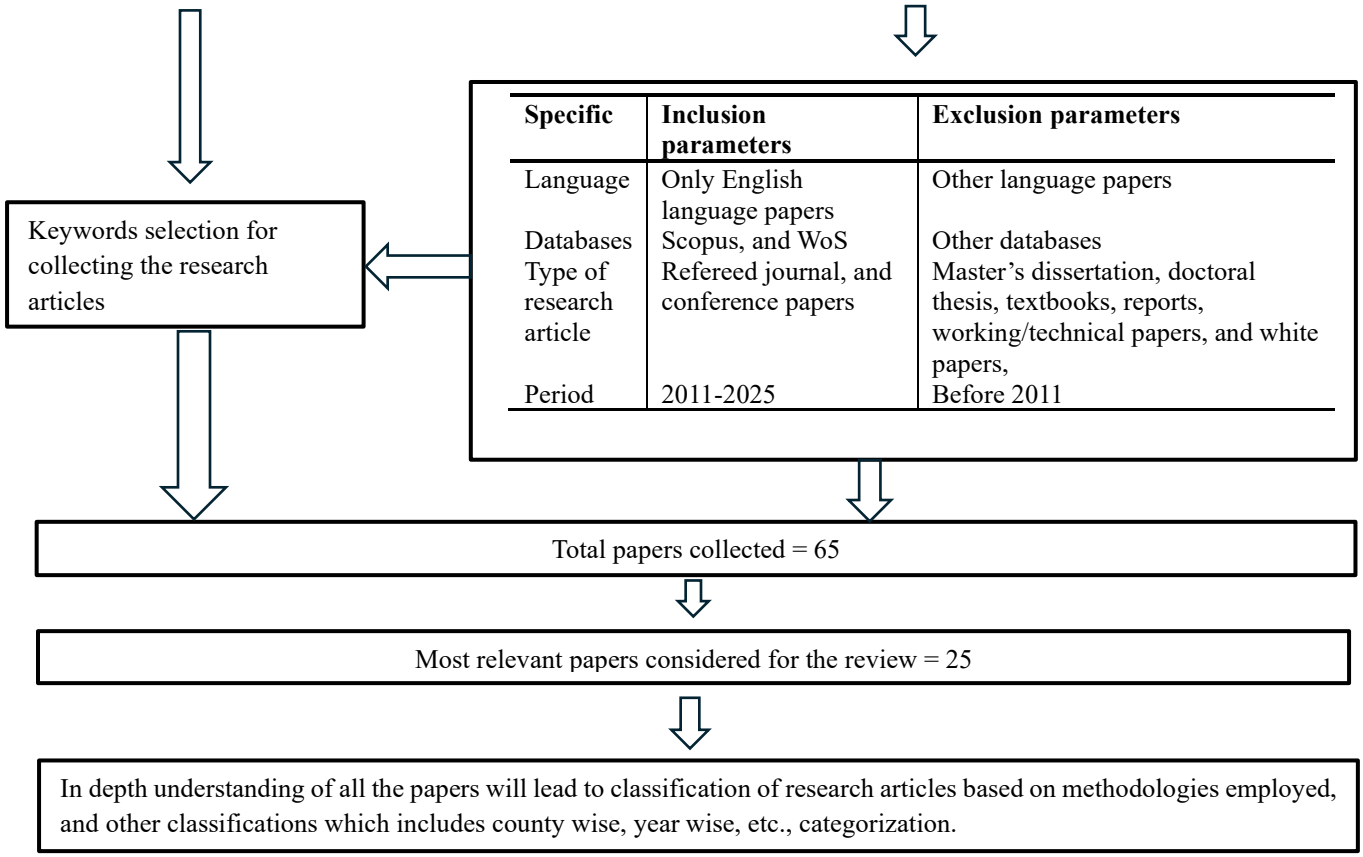
The real estate sector has a considerable negative impact on the environment, and the companies are focusing on the sustainability practices to reduce their environmental footprints (Cajias et al., 2012; Gaussin et al., 2013; Hebb et al., 2010). Due to the proper corporate governance, support from the government, culture, and tools, developed economies can meet their sustainability goals (Pahlevi et al., 2023; Sachs et al., 2019). However, in the developing economies like India sustainable practices are still in the emerging stage. This literature review aims to explore the role and current state of sustainable digital transformation in the real estate sector. Relevant research articles were identified using keywords such as ‘digital transformation’, ‘digitalisation’, ‘sustainability’, ‘environmental performance’, ‘real estate’, ‘society’, ‘social’, and ‘economic’. The framework employed for carrying out this systematic review is shown in Figure 1. Initially, 65 articles were collected out of which 13 most relevant articles related to sustainable real estate and 12 articles pertaining to digital transformation in the case sector are considered in this review. The same are discussed below and the summary of the same is tabulated in Table 1 and Table 2 respectively. Initial screening of 65 publications revealed the presence of saturation, and added fewer marginal insights about sustainability drivers, digital technologies, and the problems of adoption in the real estate sector. Subsequently, a sample size of 25 research articles were finalized based on relevance, thematic saturation, and rigor of the methods but not volume. The chosen works had an appropriate representation of different geographies, methods, and technical visions, covering them all and providing the depth of analysis. This method is in line with the recognized systematic literature review methods of focusing on quality and relevance rather than increasing the sample size.

Critical drivers of and challenges to the digital transformation and applications of Industry 4.0 technologies in the case sector

In this section of the article the critical drivers that are identified through the literature review and challenges to the adoption of digital technologies in the real estate sector are discussed. The shortlisted driving factors are tabulated in Table 3 along with their references and Table 4 focuses on the challenges. Further, Industry 4.0 tools are transforming the case industry by making it more efficient, data-driven, and automated. The industry 4.0 tools which are relevant to the real estate sector and their applications are tabulated in Table 5.

Research questions (RQs):
R1: What are the trends, approaches, employed in sustainable technology adoption area in the real estate sector.
R2: To identify the applications of Industry 4.0 tools in the real estate sector??
R3: What are the factors that impact the digital transformation?
R4: Whay are the challenges to the digital transformation?

Figure 1: Framework employed for the Literature Review



Source: Developed by Authors

Note: Tables and figures are fully developed by the author and do not copy the copyrighted literature in order to synthesize the published literature.

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Table 1: Papers Focusing on Sustainability in the Real Estate Sector (Source: Authors)

S. N	Author(s)	Year	Country	Objective	Methodology	Findings	Research gaps
1	Doborovolskiene et al. [12]	2019	Lithuania	To develop composite sustainability index	MADM	1. Environmental criterion was found to be the most significant. 2. Considering the inputs from the additional stakeholders could influence the composite index.	The composite sustainability index was developed for the case sector which was not done by past researchers.
2	Warren-Myers [50]	2012a	Australia and New Zealand	To investigate the management perspective on sustainability	Qualitative analysis	1. Sustainability is very vital for the success of the organizations. 2. Presently, the factors of sustainability are restricted to resource efficiency.	The actual industry scenario related to sustainability was researched.
3	Warren-Myers [51]	2012b	Australia	To explore the association between sustainability and real estate market value	Systematic literature review	It was highlighted that there is a substantial research gap in the extant literature about the relationship between the sustainability aspects and the real estate market value which needs to be addressed.	1. There is a lack of evidence-based research that focuses on sustainability evaluation, especially relationship between the market value and sustainability. 2. There is insufficient quantifiable data of sustainability on market value.
4	Ellison and Brown [14]	2011	UK	To develop sustainability indicators for commercial assets	Systematic literature review	1. Sustainbaility metrics were proposed. 2. The impact of sustainability indicators on society and the environment has been highlighted. 3. The proposed framework will act as guidelines in making effective decisions in the case area.	1.Inconsistency in data reporting by stakeholders was addressed which complicated the measurement of sustainability. 2. Lack of robust and reliable sustainability data in the real estate sector weakens the sustainability focus of the sector; the strategies for the same were highlighted.
5	Kauko [21]	2019	UK	To understand the role of sustainability in urban real estate	Systematic literature review	1. Sustainability thinking promotes innovation in the real estate industry. 2. Practical and social implications of the study were offered.	1. It was suggested the emergence of sustainable practices is unprecedented and need to be explored further. 2. The role of innovation in sustainability was detailed. 3. The scepticism pertaining higher costs of adoption was addressed.

							4. The main research gap of integrating sustainable practices into mainstream real estate analysis was addressed.
6	Masalskyte et al. [28]	2014	Finland	To propose a maturity model focusing on sustainability in the context of corporate real estate management	Grounded theory approach and qualitative analysis	1. The generic sustainability model was proposed. 2. 18 important sustainable practices were discussed. 3. The value of sustainability implementation in the domain case was demonstrated.	1.There is a lack of holistic categorization of CREM practices. 2.The uncertainty related to sustainable CREM elements and their associations was addressed. 3.It was highlighted that even environmentally conscious industries find it difficult to differentiate CREM practices, the strategies for the same were offered.
7	Rogmans and Ghunaim [39]	2016	UAE	To propose an evaluation framework for indicators of sustainability in the case sector	Literature review	1.3 important limitations in the rating system were highlighted. 2. All systems of rating have merits and demerits, and no one is superior in all aspects. 3. The proposed approach may be employed in several industries and can be modified as per the requirements of the stakeholders.	1. A systematic assessment approach for sustainability ratings was proposed. 2. It was highlighted that in the literature there is less focus on actual performance than design. 3. Existing assessments are mainly anecdotal and there is a lack of structured approach for evaluating sustainability in the real estate sector.
8	Apanavičienė et al. [5]	2015	Lithuania	To study the aspects of sustainability in the context of the real estate sector	Case study	1. The methodology for assessing financial viability and sustainability was proposed. 2. The developed model was validated by the entertainment and sports arenas in the form of a case study. 3. The results of multicriteria decision analysis highlighted that positive outcomes of sustainability reduce the financial liability of the operators and owners.	1.There is limited empirical studies on the financial impact of sports facilities and in comprehending their efficacy. 2. The need for evaluation methodologies for financial viability and sustainability was addressed. 3.There is lack of integrated methodologies that balance ecological, community needs and investor responsibilities in the case sector.

9	Mangialardo et al.[27]	2018	Italy	To understand the role of sustainability on the market value of the real estate assets	Case study	1.55 real estate projects were analyzed in Milan's context. 2. Green projects prices were premium as compared to traditional ones. 3. The real estate market appreciated the green certified projects and offered high value compared to non-certified ones.	1. The importance of sustainable practices on the market value was studied. 2. The significance of sustainability was expanded to other segments and areas.
10	Ionașcu et al. [20]	2020	Romania	To understand the role of the real estate sector in achieving sustainable development goals	Content analysis	1. The content analysis of the reports of the companies was conducted to understand the gap between the commitment towards sustainable goals and their actual delivery. 2. There was a substantial gap between the real actions and assumed intentions. 3. Companies lack quality tools, culture, and effective strategies for achieving sustainable goals. 4. The average quality score was found to be 2.99/5 5. The reports highlighted the sustainability intentions qualitatively and a few metrics were indicated quantitatively. 6. The three sustainable goals that were mainly highlighted in the reports were SDG-8, SDG-11, and SDG-13.	The local needs and conditions were not considered in the literature; the same were addressed.
11	Borrero-Domínguez et al. [7]	2020	Spain	To study the success factors of real estate	Ordinary least squares and negative	1. The success varied from project to project.	1.Housers platform projects were focused on bridging the gap in broader platform evaluation.

				crowdfunding and sustainability	binomial regression	2. The development loan projects were found to be more successful than buy-to-selling ones. 3. Total return on the success of the project was found to have a positive impact. 4. Considering the project term and risk level the impact was found to be negative.	2. There is limited research on mass real estate financing.
12	Mironiuc et al. [30]	2021	Romania-28 EU countries	To understand the influence of four dimensions of sustainability on real estate projects prices	2-stage least squares approach	1. The results revealed that there was sensitivity to real estate projects to all the four sustainable dimensions for the countries that were leaders in implementing sustainability. 2. In the less committed countries, corruption and poor governance affected transparency and economic and social dimensions influenced the real estate prices.	1. There is a lack of statistical significance of GINI coefficients. 2. The research on a broader spatial scale which was not by the past researchers.
13	Dobrovolskienė et al. [11]	2021	Lithuania	To examine real estate projects sustainability	MCDM framework	1. Technologcal dimension was included in the development of the sustainability index. 2. A criterion namely, ‘Health and well-being of workers’ was found to be most significant, which belonged to the social dimension. 3. A criterion, namely ‘dust reduction’ was found to be the least important which belonged to the environmental dimension.	1. Limited approaches are available for sustainability assessment. 2. The integration of technology aspect with sustainability is limited.

Table 2: Summary of the Papers Focusing on the Digital Transformation in the Real Estate Sector (Source: Authors)

S. N	Author(s)	Year	Country	Objective	Methodology/ Approach	Technology used	Findings	Research gaps
1	Miljkovic et al. [29]	2023	Austria	To develop a real estate app	Feedforward neural networks and a multilayer perceptron algorithm	AI and VR	1. AI improves accuracy and data processing speed as compared to conventional approaches. 2. Neural network forecasts real estate prices near Boston with a 0.2 % average deviation.	1. How reliability of AI algorithms enhances the performance of the case sector has been detailed. 2. The paper highlights legal compliance and data security issues. 3. The significance of robust data collection methodologies and algorithms was highlighted.
2	Ullah et al. [47]	2021	Australia	To identify barriers to innovation and digitalisation	Qualitative and quantitative analysis	AI, Big data, and VR	1. The important factors in each category of TOE framework. 2. Government policies and incentive is the significant factor influencing digitalization.	1. Challenges related to data accuracy create research opportunities. 2. Barries to the technology adoption in the real estate sector were explored.
3	Saari et al. [2022]	2022	Finland	To explore the role of blockchain in real estate sectot	A systematic literature review	Blockchain	1. The benefits of decentralization are not studied. 3. The organizational and practical applications of blockchain are	The role of blockchain in real estate sector has been explored.

							missing in the literature. 3. The benefits and application of blockchain have been identified.	
4	Walacik and Chmielewska [49]	2024	Poland	To explore the importance of AI-based sustainable real estate sector	Random forest, geoprocessing activities, fuzzy logic, rough set theory, and entropy theory	AI-driven algorithms	1. Random forest was found to be effective in comparison to conventional regression analysis. 2. The significance of non-collinearity was highlighted. 3. AI-powered algorithms are useful in forecasting the prices of real estate prices. 4.AI algorithms can effectively evaluate the importance of energy efficiency solutions on the prices of the property.	1.The lack of universal algorithm for assessing the real estate features was addressed. 2. The need for the advanced methodologies has been highlighted. 3. The barriers in quantifying emotional and behavioral aspects influencing real estate prices were highlighted.
5	Siniak et al. [43]	2020	North Macedonia	To study the influence of PropTech on the growth of the real estate sector	Quantitative analysis	PropTech (AI, Data analytics, Building information modelling, VR, Blockchain, and IOT)	1.PropTech is boon for the growth and competition. 2. There is a need for upskilling the workforce and policy modifications.	1.Te applications of PropTech in the case industry were explored. 2. The impact of PropTech on the workforce was studied. 3. The role of PropTech in

								enhancing the performance of the company was studied.
6	Starr et al. [44]	2021	USA	To understand the impact of PropTech on real estate sector	Literature review	PropTech (AI, Data analytics, Building information modelling, VR, Blockchain, and IOT)	1.There is a need for the integration of several advanced technologies for improving the performance of the sector. 2. There is limited research on the real estate 4.0 technologies. 3. Existing studies lack holistic approach. 4. There is a need to focus on the blockchains role in the case sector.	1.The role of PropTech was detailed in the real estate sector.
7	Liu et al. [2025]	2025	China	The impact of multi-source data analysis and fusion algorithms on the real estate management	Literature review	Data analysis and fusion algorithms	1.There is a need to explore synergies of algorithms in urban applications. 2. Advanced algorithms may be explored for improving accuracy. 3. Further research may focus data processing and interdisciplinary research works.	The challenges to data privacy and data quality were identified.

							4. The employed methodology improved real estate management.	
8	Ali [4]	2025	New Zealand	The study the opportunities and challenges to digitalisation	Literature review	AI and blockchain	1.The crucial challenges (societal resistance, cost of implementation, regulatory concerns) were identified. 2.The potential of AI and blockchain were detailed.	The implications were offered to improve decision-making for stakeholders.
9	Al-Rimawi and Nadler [3]	2025	Germany	To study the role of smart city technologies on real estate sector	Literature review	Big data and geodata	1.Smart city technologies may be used in the case sector for enhancing the performance. 2. Big data and geodata are the promising technologies.	1.16 technologies have been studied for their applicability in the case sector.
10	Ullah et al. [46]	2018	Australia	To study the drivers and barriers of smart real estate technology	Literature review	Robotics, AI, AR, wearable technologies, 3D scanning, big data, SaaS, clouds, IoT, drones	1.The needs of four key stakeholders were identified. 2.The needs were mapped with the Technology Acceptance Model (TAM).	This research tried to bridge the gap between the stakeholders and the consumers
11	Adegoke et al. [2]	2022	Nigeria	To assess the factors impacting the adoption decision of VR technology	Mixed methodology (DEMATEL)	VR	Significant six factors were identified; out of which ‘price value’ was found to be the most significant.	1.None of the past studies analysed factors and explored the cause-effect relationship between them.

								2 the implications were offered to the practitioners.
12	Yang et al. [53]	2025	China	To analyse the factors influencing blockchain technology adoption in the real estate sector	Quantitative analysis (PLS-SEM)	Blockchain	1.Data security and privacy, perceived usefulness, and attitude were found to be most significant factors. 2.The BCT has the capability to enhance efficiency, and security. 3. BCT helps in improved title transfer.	1. The TAM was used for the analysis. 2. None of the studies in literature employed PLS-SEM for the analysis of factors.

Table 3: Drivers that impact the Digital Transformation (Source: Authors)

S. N	Drivers	Brief description	References
1	Smart city development and urbanisation	For supporting the infrastructure upliftment and smart city initiatives urban planners and governments drive digital transformation in the case industry.	Huh et al. (2024); Wilson and Wyly (2023)
2	Integration with financial services	The digital technologies have the capabilities to approve loans online, and help in digital mortgages which act as a major driver for digitalisation.	Liermann and Stegmann (2019); Ullah et al. (2018)
3	Efficient and faster transactions	Digital processes such as automated document system and smart contracts save time and are efficient.	Naeem et al. (2023); Starr et al. (2021)
4	Workforce digitalisation	Companies adopt technology for improving productivity and retaining talent as the industry professionals are becoming more digitally skilled.	Chang and Liu (2025); Naeem et al. (2023)
5	Fraud prevention and risk mitigation	In real estate transactions, digital tools such as blockchain reduce fraud and improves security in the real estate transactions.	Abualhamayl et al., (2024); Munawar et al. (2020)
6	Improves decision making	Insights offered by AI and data analytics help in improving the property management and investment decisions.	Bolshakov et al. (2020); Naeem et al. (2023)
7	Government policies and incentives	Regulatory support, grants and tax benefits help the real estate sector in adoption of contemporary technologies.	Voland et al. (2022); Zhang et al. (2023)
8	Portfolio expansion and scalability	Digital tools can help the case sector in expanding globally, managing multiple properties, and scaling operations efficiently.	Liu and Chen (2025); Ullah et al. (2018)
9	Stakeholder and investor demand	Investors from the case sector prefer transparent transactions, data-driven insights, and automated risk analysis which drives the adoption of digital technologies.	Ullah et al. (2018)
10	Changing market dynamics	As the trends are changing such as co-living spaces and remote working, the demand for the digital tools and smarter property management is increasing.	Naeem et al. (2023); Siniak et al. (2020)
11	Sustainability goals	Digital transformation helps the sector to meet the environmental regulations and goals of the sustainability.	Naeem et al. (2023); Tan and Miller (2023)
12	Transparency and regulatory compliance	Financial institutions and governments support the adoption of digital tools which improves anti-money laundering, taxation and reporting.	Gholipour et al. (2023)
13	Customer experience and expectations	Modern tenants and buyers demand for virtual tours, online listing of properties, and digital interactions.	Oluwatofunmi et al. (2021)
14	Competitive pressure	The industries adopt digital tools as it gives them a competitive edge.	Li et al. (2021)
15	Operational savings and cost efficiency	Digitalisation helps to improve asset utilisation, streamline operations, and reduce maintenance costs.	Bolshakov et al. (2020); Tan and Miller (2023)

Table 4: Challenges to the Digital Transformation

S. N	Challenges	Brief description	References
1	Generational and cultural barriers	Conventional real-estate businesses and older professionals often offer resistance to technological adoption.	Hassan et al. (2024)
2	Limited infrastructure	In some regions, outdated property management systems and poor internet connectivity delays adoption of technology.	Naeem et al. (2023)
3	Dependency on vendors	Over-dependence on the PropTech companies (third-party) may lead to controlling, monitoring, and customising issues.	Saari et al. (2022)
4	Data standardisation and quality concerns	Inconsistent records of the property and poor data management leads to ineffective usage of digital tools.	Ali et al. (2025)
5	Complexity in implementation	Though AI and blockchain technologies present considerable benefits, complexity involved in the implementation process and lack of understanding of the technologies delays the adoption.	Ullah et al. (2018)
6	Market volatility and economic uncertainty	During uncertain market and economic conditions industries prefer risk management and cost-cutting over investing in the latest technologies.	Ekchamnong et al. (2021)
7	Slow Return on Investment (ROI)	Due to unclear economic returns in the short term, some industries prefer not to invest in the digital technologies.	Oladiran and Dickins (2024)
8	Lack of trust	Many property buyers and sellers prefer offline interactions over online ones due to trust issues in the case sector.	Owusu and Agyemang (2020)
9	Fragmented structure of the industry	The digital transformation is complex in the real estate industry due to the involvement of multiple stakeholders such as regulators, banks, agents, and developers.	Shen et al. (2022)
10	Interoperability issues	With their existing legacy systems, the real estate sector finds it difficult to integrate with the digital technologies.	Bolshakov et al. (2020)
11	Data privacy and cyber security risks	There are issues related to the increased digitalisation such as compliance with the laws of privacy, hacking, and data breaches which act as barriers to their adoption.	Ogungbemi (2024)
12	Regulatory uncertainty	Unclear and evolving regulations around digitalization offer resistance among the decision-makers of the real estate industry.	Starr et al. (2021)
13	Lack of expertise	Many stakeholders lack digital skills and expertise in blockchain, AI, and data analytics which slows the adoption process.	Mungai (2023)
14	Resistance to change	Conventional real estate decision- makers offer reluctance to digital tools and prefer traditional practices.	Kirkwood (2004)
15	High implementation cost	Despite the long-term benefits of the digitization, many companies find it difficult to justify the initial investment which delays the adoption.	Naeem et al. (2023); Ullah et al. (2018).

Table 5: Applications of Industry 4.0 Technologies in the Real Estate Sector

S. N	Technology	Key applications	References
1	Cloud computing and edge computing	Improves integration of smart building, collaboration, and data accessibility.	Ullah et al. (2018)
2	Building information modelling (BIM)	Supports facility management, construction planning, and 3D modelling.	Starr et al. (2021)
3	Virtual & Augmented Reality (VR & AR)	Improves design visualisation, and offers immersive property tours.	Adegoke et al. (2022); Siniak et al. (2020); Ullah et al. (2018)
4	Digital Twin Technology	Enables performance optimisation by creating digital replicas of the properties.	Bolshakov et al. (2020); Naeem et al. (2023); Starr et al. (2021)
5	Blockchain and smart contracts	Automates property agreements, reduces fraud, and secures transactions.	Ali et al. (2025); Saari et al. (2022); Siniak et al. (2020); Starr et al. (2021)
6	AI & Big Data Analytics	Improves decision-making, automates valuation, and evaluates property trends.	Al-Rimawi and Nadler (2025); Ali et al. (2025); Liu et al. (2025); Siniak et al. (2020); Starr et al. (2021); Ullah et al. (2018); Walacik and Chmielewska (2024)
7	Internet of Things (IoT)	Enables predictive maintenance, real-time monitoring, and smart buildings.	Siniak et al. (2020); Ullah et al. (2018)

Source: Authors

Classification of papers

The collected papers on the digital transformation are classified into four categories, namely year wise, country wise, technology wise, and methodology-wise for the deeper understanding of the trends in the real estate sector.

yFigure 2 shows the countryside classification of papers and it may be noted that 12 collected papers belong to the 10 countries, namely Austria, Australia, Finland, Poland, North Macedonia, USA, China, Germany, Nigeria, and New Zealand. China and Australia's research contributions are maximum in the cases sector focusing on the digital transformation with 2 papers each (17 %) and the rest of the 10 countries contributed 1 paper each.

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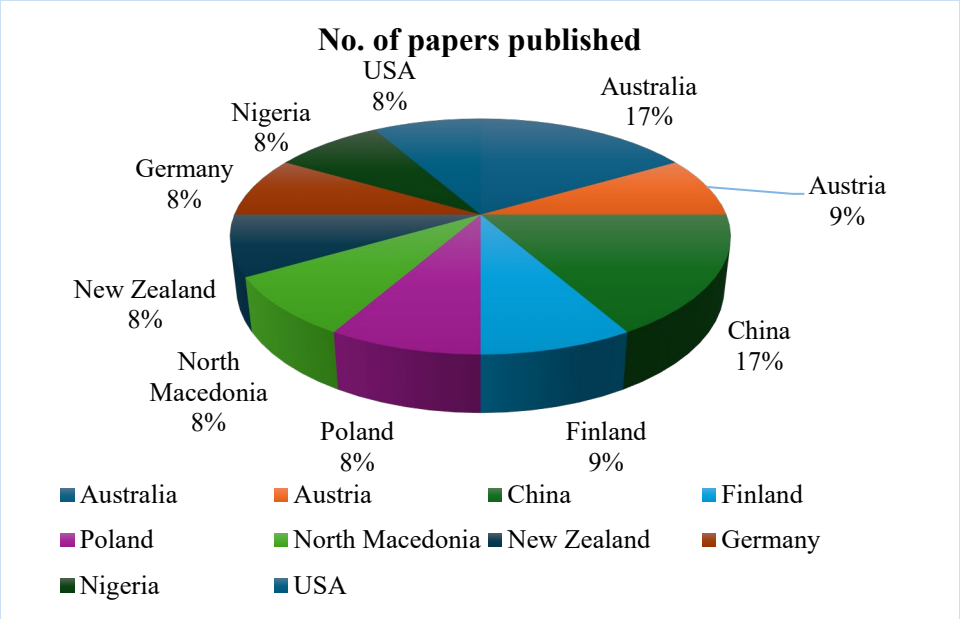
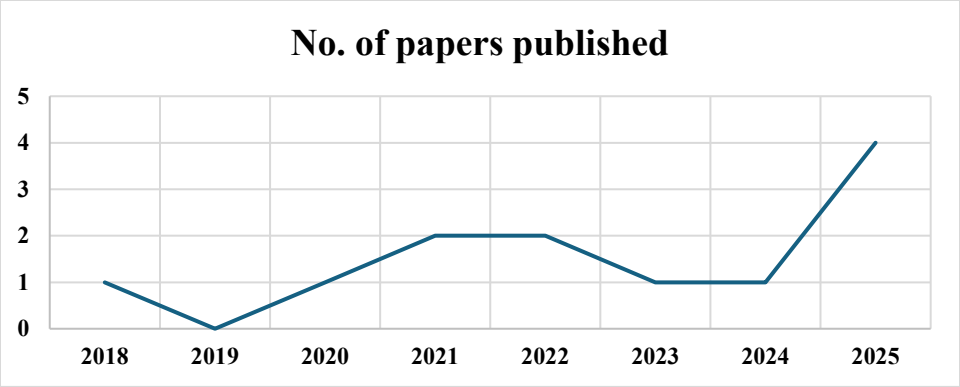
Figure 2: Country-wise Classification of Papers



Source: Developed by Authors

The year-wise publications of papers are shown in Figure 3. The span of the publication year ranged between 2018 to 2025. The figure clearly highlights that in 2025 the maximum number of papers (4) were published. In 2021 and 2022, 2 papers each were published. However, in rest of the years, only one paper was published except in 2019 in which no research article was documented. It may be inferred that lately; the real estate sector is focusing more on the digitalisation.

Figure 3: Year-wise Classification of Papers



Source: Developed by authors

Figure 4 shows the classification based on the methodology. Mainly five methodologies were employed in the 12 papers under consideration. It may be noted that maximum number of articles focused on the systematic literature review (50 %), followed by the mixed methodology (16.67 %), and quantitative analysis (16.67 %) (2 papers each); whereas neural networks and random forest was employed by 1 paper each.

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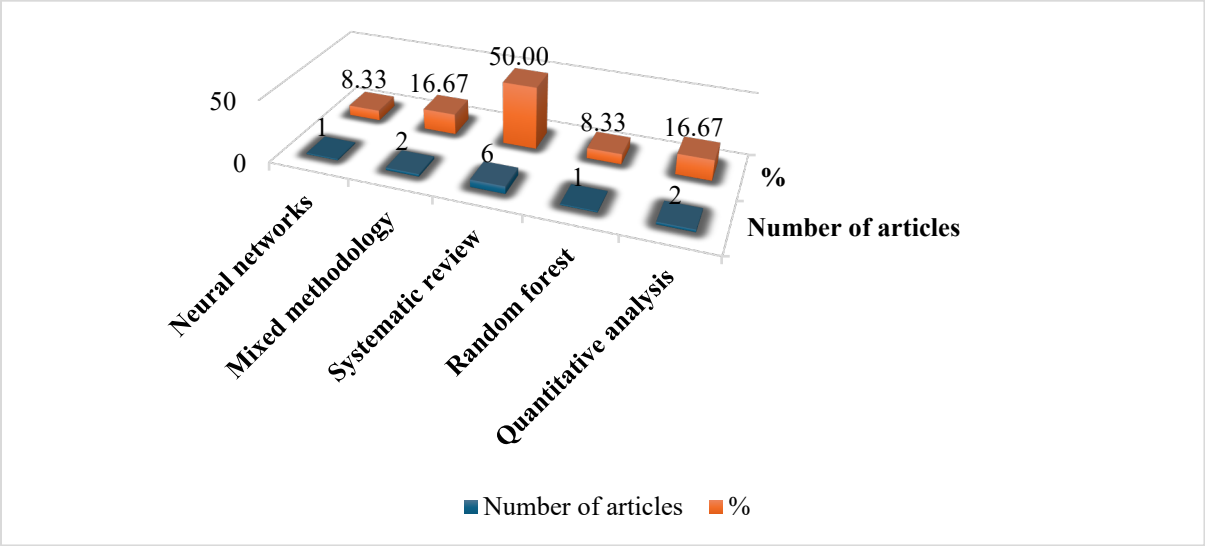
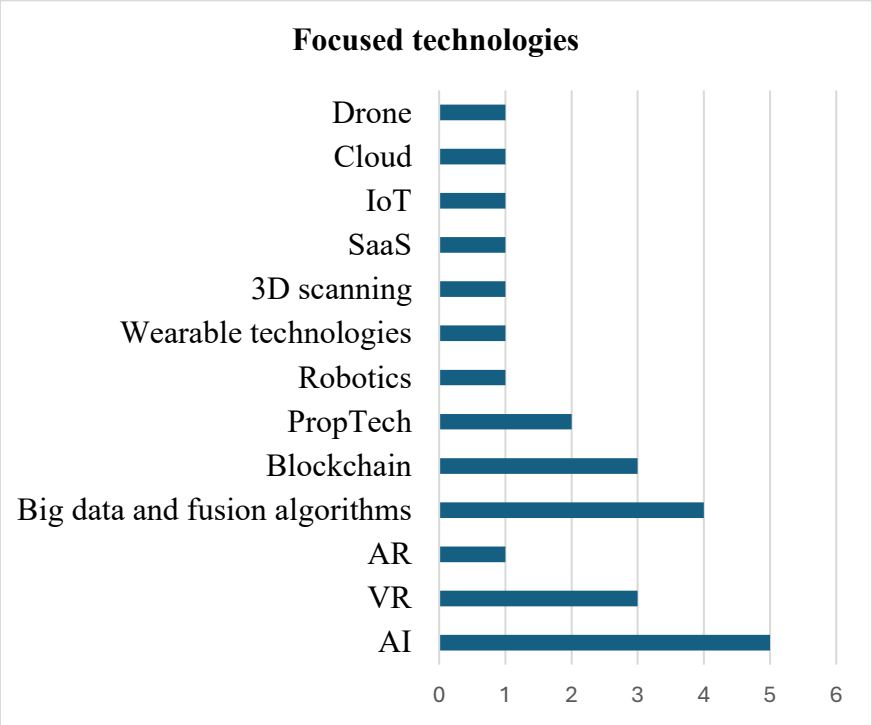
Figure 4: Methodology-wise Classification of Papers



Source: Developed by authors

Figure 5 shows the classification of the papers based on the technologies employed in the case sector. 13 technologies were researched by the 12 studies and AI is the most popular technology research by the past studies (5 papers), big data and fusion algorithm (4 papers). VR and blockchain were discussed in three studies each, followed by PropTech which was highlighted in 2 papers; and rest of the tools received the least attention (1 paper each).

Figure 5: Technology-wise Classification of Papers



Source: Developed by authors

General methodological protection of the research against some internal biases was implemented by several methodological precautions. First, the inclusion and exclusion criteria were well defined in terms of the time of publication, language, databases, and types of documents to be used to reduce selection bias. Second, search terms were in various databases of Scopus, Web of Science to avoid database and key word bias. Third, the shortlisted articles were assessed individually on the issues of relevance to the themes of sustainability and digital transformation, which minimized the risks of confirmation bias. Lastly, the synthesis of the findings was performed using a comparative analysis across different methodologies, countries and technologies instead of using solitary research and this allowed to guarantee balanced interpretation and enhancement of internal validity of the review.

Discussion and Conclusion

This is a methodical review of the literature, which offers a summarized insight into how environmentally friendly digital technologies are redefining the real estate industry. The results show that the digital transformation is being primarily motivated no longer by the efficiency and the cost reduction, but by the sustainability goals, regulatory forces, and the changing expectations of the stakeholders. The emergence of technologies including artificial intelligence, blockchain, IoT, BIM, and data-driven decision-making is presenting an outcome of energy optimization, transparency, lifecycle asset management, and data-driven decision-making, directly relating digitalisation to sustainability results.

Another important lesson that came out of the review is that research is unevenly distributed around the globe. The majority of empirical and conceptual research is established in developed economies and these economies have advanced digital infrastructure, sustainability policies and regulations. Conversely developing economies, especially India, with their real estate markets skyrocketing and contributing majorly to environmental isues are not supported with associated research. This point is an acute research gap and a case of the relevance of context-related influences, including governance structures, market informality, and readiness for digital adoption in influencing the desired outcome.

The discussion of drivers and predicaments indicates a structural struggle of the real estate industry. Although smart city programs, government subsidies, investor demand, transparency needs, and operational efficiency are driving digital implementation up, enduring challenges within digital implementation including disjointed industry framework, extreme initial investment cost, data quality issues, information security concerns, and resistance to change have remained to slow large-scale adoption. These results indicate that technological preparedness is not a panacea to success; organizational culture, leadership commitment, availability of skills, and clarity of regulations also play a decisive role in introducing digital potential to sustainable performance.

Sustainably, digital transformation has quantifiable positive effects on the environment supporting predictive maintenance, a decline in material waste, resulting in reduced energy use and enhanced reporting of ESG measures. Nevertheless, the review suggests that the benefits are not fully used because of the lack of introduction of digital transformation plans and sustainability frameworks on the organizational level. This underlines the necessity of a holistic approach where sustainability goals are not addressed as a forceful consequence of digital roadmaps.

In the synthesis of the results of various researches, the special care was taken in reducing internal biases based on trends in publication, concentration of region, and methodology trends. The triangulation of the results was done between different methods, and no results of a single study were used to make any conclusions. The conclusions made based on this review are analytically faithful and methodologically sound in consideration of the contextual constraints and focus on findings convergence.

To recapitulate, sustainable online transformation in real estate is a complex process, which is affected by technological, institutional, and socio-economic influences. This paper closes gaps between inconsistent results of the available literature and provides a rational narrative that connects Industry 4.0 technologies to sustainability objectives. These insights lay a foundation to consider pursuing future empirical studies, especially in emerging economies and which can contain viable recommendations to guide policymakers and practitioners on how to align real estate development with the objectives covered in the Sustainable Development Goals.

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