

Extended reality (XR) impacts on real estate market and economic-financial project management of residential built environments: systematic review and analysis

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Abstract

Purpose – Extended reality (XR) technologies are increasingly used in project management and, more recently, in real estate transactions to enhance customization, collaboration, and transparency in decision-making processes. However, the impact of XR on residential real estate market dynamics, including value estimates and economic management of housing projects, has never been explored through systematic reviews providing an integrated perspective. This paper aims to fill this gap by conducting a systematic review of scientific literature.

Design/methodology/approach – This study conducted a systematic review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Records were sourced from Scopus, Web of Science (WoS), and Google Scholar. Based on defined inclusion criteria, 90 scientific papers were thoroughly analysed. A scientometric analysis was implemented, which allowed, among other outcomes, the classification of contributions into two main categories: (1) economic-financial management of housing projects and (2) residential real estate market studies, further subdivided into quantitative and qualitative analyses of XR impacts.

Findings – The results obtained answer three research questions. First, it is shown that XR technologies influence project economics by enhancing customisation and collaboration, resulting in reduced construction costs. In real estate valuation, it emerges that XR boosts transparency, accelerating and positively conditioning the decision-making process. Second, the following key parameters are identified from the literature: purchase price, time on market (TOM), purchase intention, construction cost, and life cycle cost (LCC). Third, the challenges and opportunities of XR application in the analysis fields are defined. XR adoption is challenged by infrastructural barriers and costs but offers opportunities to improve customer engagement and sustainability. Mixed reality (MR) remains underexplored, and significant gaps in correlating key variables persist.

Originality/value – This is the first review exclusively focused on the impacts of XR on residential real estate valuation and the economic management of housing projects. It provides valuable insights for scholars, researchers, and practitioners while highlighting critical gaps and future research directions.

Keywords Extended reality, Virtual reality, Augmented reality, Real estate market, Economic project management, Virtual tour

Paper type Research paper

1. Introduction

Extended Reality (XR) technologies, which include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), are transformative tools designed to digitally replicate physical environments or worlds and create immersive and interactive experiences through advanced sensory stimulation (Azmi *et al.*, 2022; Morimoto *et al.*, 2022). Originally

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The contribution to this paper is the result of the joint work of the authors, to which the paper must be attributed in equal parts.



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conceptualised in the 1960s, VR and AR technologies have experienced significant growth, particularly in the last decade, due to advancements in hardware, decreasing costs, and the proliferation of innovative applications (Cipresso *et al.*, 2018). XR technologies are now widely applied in various fields, including gaming and entertainment (Zyda, 2005), healthcare (Freeman *et al.*, 2017), education (Englund *et al.*, 2017), and architectural design (Song *et al.*, 2017). These tools reshape the digital economy by enhancing visualisation, interactivity, and operational efficiency across sectors (Nieradka, 2019).

Through a systematic review, this study explores the impact of XR technologies on the economic management of residential projects and the real estate market.

Recent research has increasingly focused on XR technologies in the Architecture, Engineering, and Construction (AEC) industry (Chen and Xue, 2022; Prabhakaran *et al.*, 2023). These technologies are central to the digital transformation of construction in Industry 4.0, enhancing communication among stakeholders (Padilla *et al.*, 2018). XR allows designers and builders to create immersive designs that benefit clients (Dargan *et al.*, 2023), with software converting BIM models for immersive experiences throughout the project lifecycle (Safikhani *et al.*, 2022; Abrishami *et al.*, 2020). For instance, the integration of BIM with AR, despite its cost, enhances decision-making for site operators (Um *et al.*, 2023). XR is revolutionizing economic management in residential construction by enabling efficient exploration of design alternatives (Noghabaei *et al.*, 2020; Rashidi *et al.*, 2023). Immersive technologies aid in visualizing projects, estimating costs, and managing stages flexibly (Li *et al.*, 2018; Sacks *et al.*, 2020; Wang *et al.*, 2018). XR models also allow real-time cost impact analysis (Balali *et al.*, 2018). Applications like VR provide immersive visualizations and real-time decision-making support (Wang *et al.*, 2018; Li *et al.*, 2018). However, empirical studies on XR's effect on project time and costs are limited (Chi *et al.*, 2013; Noghabaei *et al.*, 2020; Sacks and Barak, 2008). Casini (2022) highlights the need for more research on XR's quantifiable costs and benefits, particularly in maintenance, while Al-Dhaimesh and Taib (2023) emphasize the lack of studies on AR and BIM's impact on decision-making and economic outcomes. Wang *et al.* (2020) emphasize the need for models to assess the economic impacts of BIM in off-site construction.

The real estate sector has also demonstrated growing interest in implementing XR technologies (Adegoke *et al.*, 2022a). Initially introduced in the early 2000s, XR technologies became widespread after 2020 due to the COVID-19 pandemic, which made virtual tours a necessary and accessible solution (Deep *et al.*, 2023; Nanda and Zhang, 2021). Recent studies show that VR virtual tours in real estate reduce the need for physical travel between properties, saving time and money for both buyers and sellers (Dargan *et al.*, 2023), allow property exploration without physical presence (Sihi, 2018), and offer continuous access to properties, facilitating the sales process (Yu *et al.*, 2021). VR is also a valuable tool for visualizing properties under construction or in the planning stage, particularly those sold before physical realization (Ibrahim *et al.*, 2023). VR virtual tours provide an immersive experience, surpassing static images or video tours, allowing buyers to explore properties interactively at their discretion (Allen *et al.*, 2015). Furthermore, VR adoption has made real estate agencies more efficient by reducing time spent on physical visits and optimizing the selling and renting processes (Adegoke *et al.*, 2022a; Allen *et al.*, 2015; Anderson *et al.*, 2024a; Benefield *et al.*, 2019; Marzano *et al.*, 2015; Miljkovic *et al.*, 2023). As noted by Allen *et al.* (2015), XR technologies increase the perceived value of properties and improve market valuations, facilitating transactions through more effective presentations and optimized sales strategies. Ong *et al.* (2024) highlight that XR enhances the marketability of properties by reducing information asymmetry, increasing both the probability of sale and transaction prices. Similarly, Kamil *et al.* (2021) and Xiong *et al.* (2022) suggest that XR enables a more comprehensive understanding of properties compared to traditional showrooms. However, there are challenges in using XR, including potential exclusion of non-technologically savvy buyers, limitations in the physical experience, possible emotional distance, technical disruptions, hardware limitations, and high initial investment and training costs for real estate agencies (Benefield *et al.*, 2019). The combination of advantages and disadvantages associated with the use of VR may affect the user's perceived value of the property

and, consequently, their willingness to pay (Azmi *et al.*, 2022; Casas-Mateus and Chacon-Sanchez, 2019; Sun *et al.*, 2017). This could influence the price formation mechanism of the property, meaning the process by which the monetary value to be paid for its purchase is determined, based on the interaction between supply and demand. A higher willingness to pay on the part of buyers can, therefore, affect the final price from the demand side (Pangallo and Loberto, 2018). Furthermore, the greater the information deduced from using VR (or other XR technologies), the more competitive the offers can be, sometimes even justifying higher prices for properties viewed through virtual tours (Anderson *et al.*, 2024a). In fact, some studies show that virtual tours can positively impact real estate transaction prices by 2–3% (Carrillo, 2008; Yu *et al.*, 2021). Since VR affects the price formation mechanism, some authors propose hedonic pricing models in which VR tours, although not real estate features in themselves, are considered as such, influencing the price as an independent variable. These models quantify the marginal contribution of VR on the property price, analysing the additional effect (value differential) generated by its presence (Adegoke *et al.*, 2022a, b; Anderson *et al.*, 2024a; Benefield *et al.*, 2019; Hou and Li, 2022; Hsiao *et al.*, 2024; Ong *et al.*, 2024; Xiong *et al.*, 2022; Yu *et al.*, 2021; Yan *et al.*, 2023). In addition to the direct impact of VR technology on sales prices (Allen *et al.*, 2015; Amed *et al.*, 2020; Anderson *et al.*, 2024a; Benefiel *et al.*, 2019), its influence on purchase intention (Ibrahim *et al.*, 2023a; Juan *et al.*, 2018; Yan *et al.*, 2023) and time to market of residential properties (Anderson *et al.*, 2024a; Hou and Li, 2022; Ong *et al.*, 2024; Xiong *et al.*, 2022) has also been demonstrated.

1.1 Related studies

Although there are multiple systematic reviews in the literature on the use of XR technology in the AEC and related fields (Hwang and Shim, 2021; Prabhakaran *et al.*, 2022; Rabby *et al.*, 2022; Sudhakaran *et al.*, 2024; Ullah *et al.*, 2018; Wang *et al.*, 2018), none of them focus exclusively on the influence that such technologies can exert on the main economic-financial and behavioural variables involved in the economic management of residential projects, as well as in the real estate estimation and marketing processes. Table 1 provides a summary of the goals, key findings, and gaps identified in the main pre-existing systematic reviews on XR application in residential construction and real estate markets.

The main gaps identified are summarised below:

- (1) Few works explicitly address the economic and financial impacts of XR on residential projects, studying the effects in terms of key variables such as construction costs, maintenance costs or life cycle costs;
- (2) Limited works explore estimative variables like selling price or time on market (TOM);
- (3) Existing reviews primarily focus on technological or operational benefits rather than economic or appraisal-related impacts;
- (4) The real estate sector, compared to the AEC sector, has fewer studies exploring XR applications, possibly due to its recent adoption.

1.2 Research goals

The gaps identified in the studies in Table 1 justify the need for a focused review on the economic-financial and appraisal-related impacts of XR technologies. This work addresses the underexplored influence of XR on the estimation of construction and management costs of residential properties, the property value assessment, and the market dynamics. By filling these gaps, the study aims to provide valuable insights for researchers, practitioners, and real estate buyers, and offer a more comprehensive understanding of XR's role in the residential real estate sector. Therefore, a systematic review and analysis of the state of the art was implemented in the present work to answer the following research questions:

Table 1. Summary of the goals, key findings, and gaps identified in the main pre-existing systematic reviews on the use of XR technologies in residential construction and real estate markets

Authors	Focus	Key findings	Gaps identified
Ahmed (2018)	AR/VR in construction project management	Highlights benefits for time and cost management	Lacks quantitative or model-based analysis on cost estimation
Al-Dhaimesh and Taib (2023)	Integration of AR with BIM in AEC	Enhanced visualisation and collaboration but technical challenges exist	No focus on VR's impact on cost control or economic management of building projects
Casini (2022)	XR technologies for smart building operation and maintenance	Highlights operational efficiency and safety improvements	Does not address cost control or cost estimation related to XR
Hussin and Bakar (2023)	VR in real estate marketing	Emphasises improved sales strategies, particularly in the Malaysian market	Does not address property valuation variables such as price or time on the market
Prabhakaran <i>et al.</i> (2022)	Challenges of immersive technology in architecture and construction	Identifies barriers to technology adoption, such as cost and accessibility	Limited discussion on the economic implications of XR in cost estimation and management
Rockel <i>et al.</i> (2024)	Advanced technologies (AI, VR) in real estate	Discusses improved user experience and operational efficiency	No exploration of real estate appraisal variables
Safikhani <i>et al.</i> (2022)	Integration of VR and BIM in AEC	Benefits for visualisation and collaboration; notes technical challenges	Lacks focus on cost control or management impacts
Seagraves (2023)	AI, AR/VR, and management automation in real estate	Highlights potential of improving accuracy and efficiency but notes risks	Does not focus on real estate appraisal variables such as price or market value
Ullah <i>et al.</i> (2018)	Digital technology adoption in real estate	Highlights the potential of VR/AR to improve consumer experiences	Lacks a focus on valuation issues like price or market dynamics
Wang <i>et al.</i> (2020)	Digital technologies in off-site construction	Highlights productivity and safety improvements; calls for standardization	Descriptive focus on time and cost savings but not a primary focus
Zhang <i>et al.</i> (2020)	VR applications in the built environment	Identifies application areas like design and project management	Does not explore VR's impact on cost estimation or property valuation
Zhu <i>et al.</i> (2018)	Immersive virtual environments for occupant energy behaviour	Benefits for simulating thermal and visual comfort; identifies technical challenges	Does not address VR's impact on cost estimation or energy-related costs

Source(s): Authors' own creation/work

- RQ1. How do XR technologies influence the dynamics of the residential real estate market and the economic management of housing projects?
- RQ2. What are the main behavioural, economic/financial, and estimative parameters analysed in studies on the application of XR technologies in the residential sector that may be relevant for professionals and scholars dealing with economic project management as well as real estate valuation and marketing?
- RQ3. What are the challenges and opportunities in using XR technologies in the economic management processes of housing projects and residential real estate appraisal?

The paper is structured as follows: [Section 2](#) outlines the methodological approach employed to conduct the systematic review; [Section 3](#) illustrates the main results obtained from the literature search; [Section 4](#) critically analyses these results; [Section 5](#) provides some concluding remarks.

2. Methodology

The methodological approach used to conduct the systematic review is based on the PRISMA protocol – Preferred Reporting Items for Systematic Reviews and Meta-Analyses ([Moher et al., 2009](#); [Page et al., 2021](#)). Academic articles extracted from three major databases (Scopus, Web of Science and Google Scholar) were selected and analysed following defined inclusion/exclusion criteria. The selection of publications was carried out between September 2023 and April 2024. Screening of publications was stopped in April 2024 to allow for in-depth data analysis and the completion of the first draft of the paper (first submitted to this journal in July 2024). Further relevant studies may be considered in future updates of this review.

The following subsections present the inclusion and exclusion criteria for publications in the systematic review and the identification phases of relevant studies via databases.

2.1 Inclusion criteria

The inclusion criteria were defined as follows:

- (1) *Time limitations*: No temporal constraints were applied in the selection of records, as contributions published before 2020 are relatively limited. In fact, most studies were published after 2020, the year when the COVID-19 pandemic significantly accelerated the implementation of XR technologies in the real estate market and building design sectors. The absence of temporal restrictions allowed for a more comprehensive and in-depth review;
- (2) *Document types*: Journal articles, proceeding papers, book chapters, and other literature reviews were included in this work;
- (3) *First-level thematic relevance (Extended Reality)*: both application-focused studies (quantitative research) and theoretical studies (qualitative research) on VR, AR, MR, and the broader concept of XR were included. The selection also encompasses studies specifically addressing virtual tours;
- (4) *Second-level thematic relevance (Housing Design or Residential Real Estate Market)*: the review specifically included studies focusing on XR technologies applied or applicable to housing design and the residential real estate market. To this end, only studies featuring terms such as “real estate,” “housing,” “residential home,” “residential property,” “residential building,” or similar expressions in their title or abstract were selected;
- (5) *Third-level thematic relevance (Economic Management of Residential Projects, Marketing and Real Estate Appraisal)*: the review included studies that reference economic and behavioural terms, concepts, indicators, or indices relevant to the economic management of residential projects, real estate valuation, or real estate marketing (e.g. “price,” “market value,” “willingness to pay,” “time on market,” “cost,” “capitalisation rate,” “appraisal,” “economic evaluation,” etc.). Both records with strong thematic relevance – where economic management or real estate appraisals are a fundamental focus of the work – and those with weak thematic relevance – where potential implications on economic management or real estate appraisals are only mentioned – were included.

2.2 Exclusion criteria

The exclusion criteria were defined as follows:

- (1) *Non-Relevant Fields*: studies exploring XR applications in fields adjacent to housing or construction but unrelated to the scope of this review—such as tourism, gaming and entertainment, medicine and wellness, education, cultural heritage enhancement, energy efficiency in non-residential properties, infrastructure, or non-residential civil buildings—were excluded;
- (2) *Absence of economic and behavioural parameters*: studies that do not mention parameters relevant to the economic management of housing projects, real estate valuation or real estate marketing were excluded.

2.3 Identification phases of studies via databases

Three databases were used to conduct the review: Scopus, Web of Science (WoS) and Google Scholar. Preliminarily, it was checked whether literature reviews on the topic had already been conducted. To this end, the advanced search functions of Scopus and WoS and the query strings shown in Figure 1 were used. To refine the search, an additional inclusion/exclusion criterion was momentarily added to those previously listed, which consisted in identifying any existing systematic reviews on the impact of XR on estimation, marketing or economic management in the residential sector. For these purposes, those records were selected that include terms such as “review”, “literature review” and “systematic review” in the title or abstract. This paper also provides direct links to the Scopus (Scopus – Document search results | Signed in) and WoS (<https://www.webofscience.com/wos/woscc/summary/6b19bcf8-320c-4dfe-86a5-fee1f4976cb5-01269214cf/relevance/1>) pages with the initially identified articles and the query strings used.

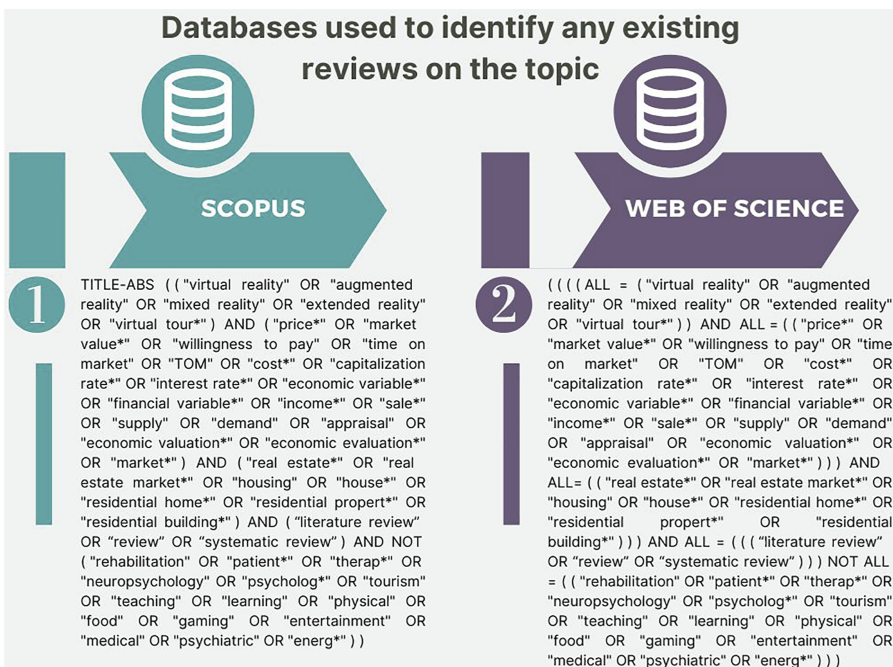


Figure 1. Database and query strings used for the identification of possible systematic reviews of existing literature on the topic (own elaboration). Source(s): Authors' own creation/work

A total of 24 records were identified from the two databases. Of these, only 8 are reviews. However, none of them are relevant to the issues dealt with. After ascertaining the absence of systematic reviews relevant to the topics “real estate valuation and marketing” and “economic management of projects,” the identification phase of potentially eligible records for a new review was initiated, first through the Scopus database, and then through the WoS database. The query strings used are shown in Figure 2. Additionally, direct links to the Scopus (Scopus – Document search results | Signed in) and WoS (<https://www.webofscience.com/wos/woscc/summary/ea16803a-bce7-46b2-a848-dd23abdf419e-df3ca4ad/relevance/1>) pages with the selected articles and the query strings used are provided. This ensures the replicability of the work.

The records identified through the first two databases (Scopus and WoS) were then used for the subsequent steps (screening and inclusion) provided by the PRISMA protocol (Moher *et al.*, 2009; Page *et al.*, 2021). This protocol is summarised in Figure 3. The selection process was completed using the Google Scholar dataset through two distinct yet complementary methods: *manual sampling* and *snowball sampling*. These techniques are commonly employed in systematic reviews (e.g. Prabhakaran *et al.*, 2022; Wang *et al.*, 2020). *Manual sampling* involved the use of specific key phrases searched on Google Scholar, such as “virtual reality and construction cost,” “extended reality and real estate market,” “augmented reality and housing sector,” etc. This approach allowed the identification of 3 studies meeting the inclusion/exclusion criteria. Subsequently, *snowball sampling* was implemented to expand the pool of articles. *Backward snowballing* involved analysing citations included in the references

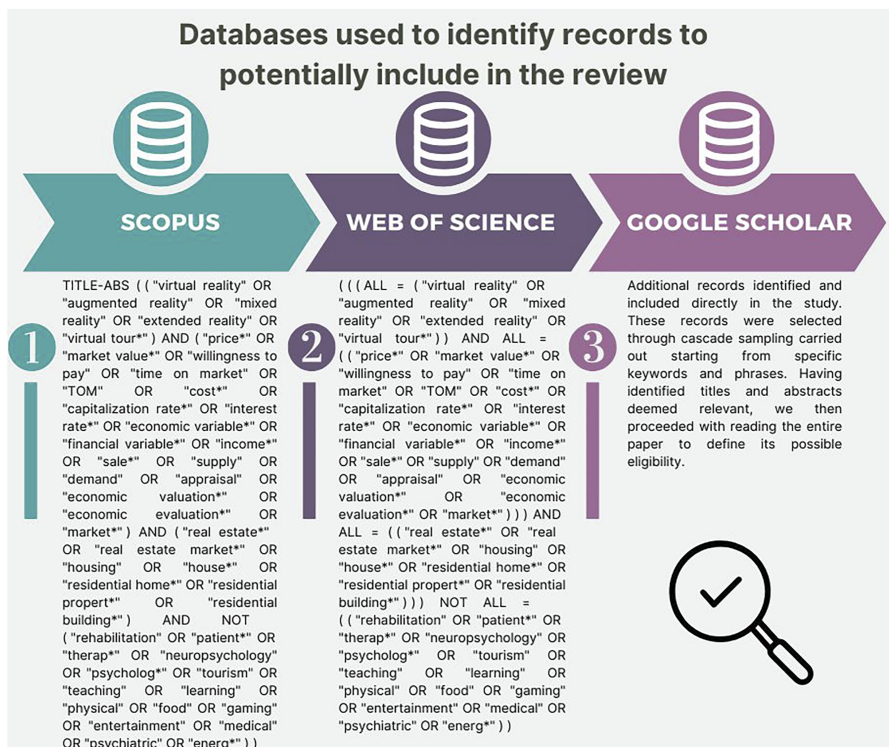


Figure 2. Database and query strings used to identify records possibly to be included in the systematic literature review (own processing). Source(s): Authors' own creation/work

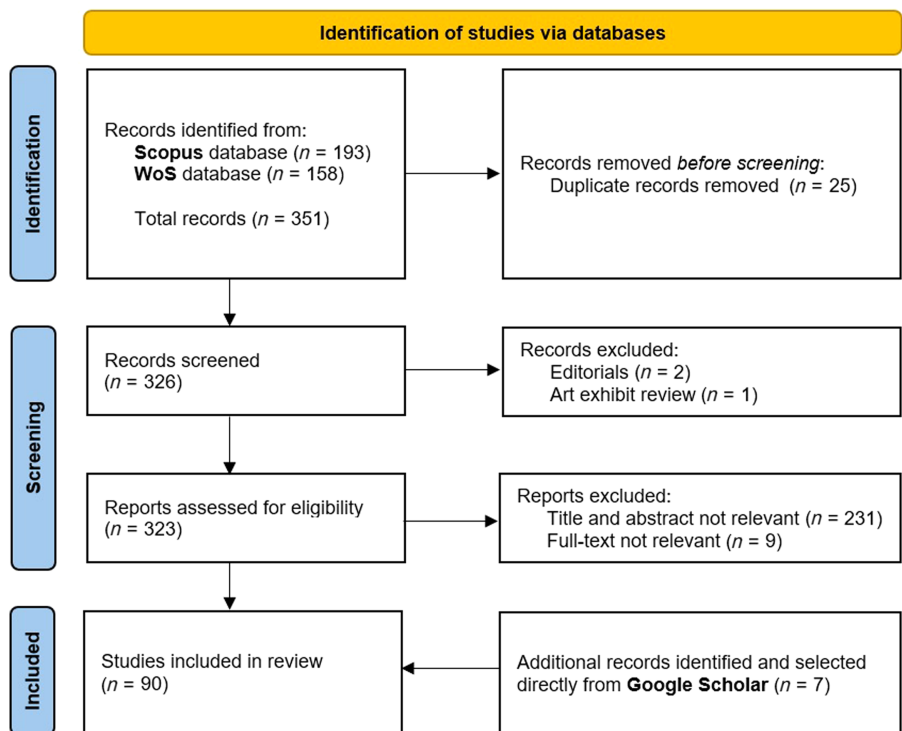


Figure 3. Original re-elaboration of the PRISMA flowchart (Page et al., 2021) representing the literature selection process. Source(s): Figure created by the authors, adapted from Page et al. (2021)

of the already selected studies, while *forward snowballing* identified works citing the initially included articles using tools like the *Cited by* feature in Google Scholar. Thanks to snowball sampling, 4 additional eligible articles were identified. The combined use of these two methods enabled the selection of 7 additional records from Google Scholar.

Following the screening process, a total of 90 records were included in the review, distributed between the three source databases as follows: 39 records come exclusively from Scopus; 19 records come exclusively from WoS; 25 records come from both Scopus and WoS; 7 records come exclusively from Google Scholar.

3. Results

From the 90 selected records, it was possible to implement the following scientometric analysis (see Section 4.1): (1) number of publications per year; (2) number of citations per year; (3) number of publications per country; (4) keyword co-occurrence network mapping; (5) number of publications per document type; (6) source analysis; (7) number of publications per journals; (8) authors with multiple publications on the topic; (9) network of co-citations for authors.

Subsequently, the 90 records included in the review were divided into the following two classes (see section 4.2): (1) publications pertaining to economic management studies of housing projects; (2) publications pertaining to studies of residential real estate valuation and marketing. For each class, the following two subclasses were identified: (1) quantitative analysis of the impact of XR technologies behavioural, economic-financial and estimative

quantities; (2) qualitative analysis of the impact of XR technologies on behavioural, economic-financial and estimative quantities.

Next, from the first sub-class, the most frequently analysed behavioural, economic-financial and estimative variables were identified (see [Section 4.3](#)).

Finally, the key impacts (measurable results) identified in quantitative studies on XR applications in the economic management of housing projects and in residential real estate appraisal and marketing are outlined (see [Section 4.4](#)).

3.1 Analysis of emerging trends in literature

3.1.1 Number of publications per year. A representative graph of the number of publications per year is shown in [Figure 4](#).

The first two publications recorded date back to 1996 ([Neil, 1996](#); [Yamamura et al., 1996](#)). This was followed by a long period in which there were no publications or only one publication per year, except for 2007 and 2011. In this regard, it is worth mentioning that the first experiments in the application of VR in real estate date back to the early 2000s ([Orzechowski et al., 2005](#)). From 2012 onwards, the number of publications starts to grow significantly, reaching a first peak in 2014 with 6 publications ([de Macedo et al., 2014](#); [Issa and El-Hachem, 2014](#); [Jiang, 2014](#); [Kim et al., 2014](#); [Salleh et al., 2014](#); [Xiao, 2014](#)). Starting in 2016, a new phase of publication growth begins, with a peak reached in 2018 with 6 publications ([Deaky and Parv, 2018](#); [Fan and Zhang, 2018](#); [Juan et al., 2018](#); [Sihi, 2018](#); [Zatwarnicka-Madura, 2018](#)). An important peak is reached in 2020 with as many as 15 publications. Recall that 2020 is the year in which the COVID-19 pandemic exploded, affecting the popularity of virtual tours for real estate visits. There are 14 publications in both 2022 and 2023. For 2024, only 4 publications are noted ([Anderson et al., 2024a, b](#); [Hsiao et al., 2024](#); [Ong et al., 2024](#)). However, it should be noted that the databases were only consulted until 30 April 2024.

3.1.2 Number of citations per year. A representative graph of the number of citations per year is shown in [Figure 5](#).

The number of citations also roughly follows the trend in the number of publications, with two important peaks in 2013 (with 252 citations) and 2020 (with 269 citations). For 2013 the work of [Park et al. \(2013\)](#), with 238 citations, should be highlighted, while for 2020 the contributions of [Pleyers and Poncin \(2020\)](#) and [Wang et al. \(2020\)](#), with 135 and 120 citations respectively, should be mentioned.

3.1.3 Number of publications per country. A representative graph of the number of publications per country is shown in [Figure 6](#).

Most of the papers on the subject were produced in China (15), the USA (10), Malaysia (8) and Taiwan (8). It is no coincidence that China and the USA, along with many countries in Asia Pacific, are among the frontrunners in the field of XR technologies.

3.1.4 Keyword co-occurrence network mapping. Using VOSviewer, the co-occurrence network of keywords was mapped, demonstrating interrelationships and dominance (see [Figure 7](#)). The larger the node, the more frequently the keyword occurs. The more intense the colour of the arc, the stronger the connection between the two keywords. Keywords with a frequency of less than 3 were discarded. A total of 39 keywords were identified. It is evident that “virtual reality” (with occurrence 43 and link strength 137) is the keyword most cited and most interrelated to the others. This is followed by “augmented reality” (with 22 occurrences and link strength 52), “architectural design” (with 13 occurrences and link strength 59) and “real estate” (with 12 occurrences and link strength 41). Keywords such as “mixed reality” and “extended reality” do not appear. The co-occurrence analysis using VOSviewer highlighted five main thematic areas: XR applications for architectural design and construction project management (red); XR applications in real estate marketing and impacts on purchasing behaviour (green); XR applications for georeferencing and graphical representation of residential assets (blue); XR technology and urban applications (purple); integration between artificial intelligence and advanced visualisation (yellow). These themes arise from the

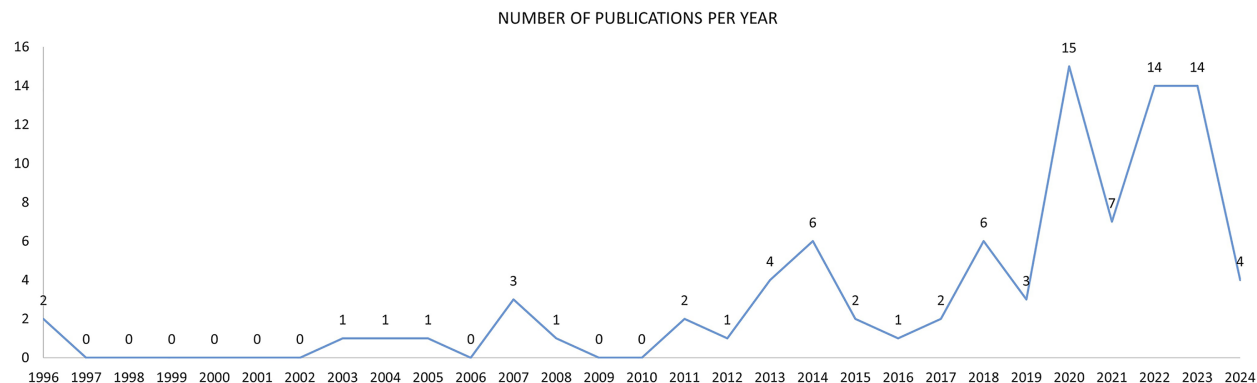


Figure 4. Number of publications per year (own processing). Source(s): Authors' own creation/work

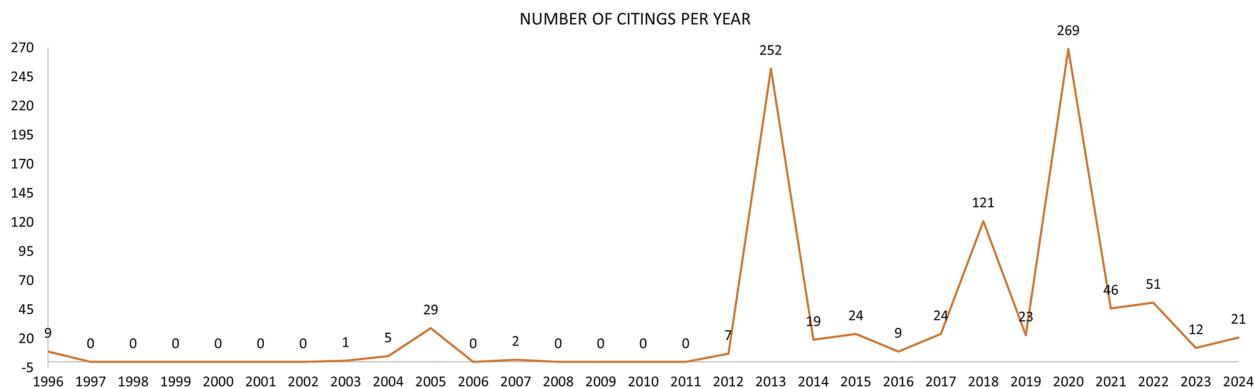


Figure 5. Number of citations per year (own processing). Source(s): Authors' own creation/work

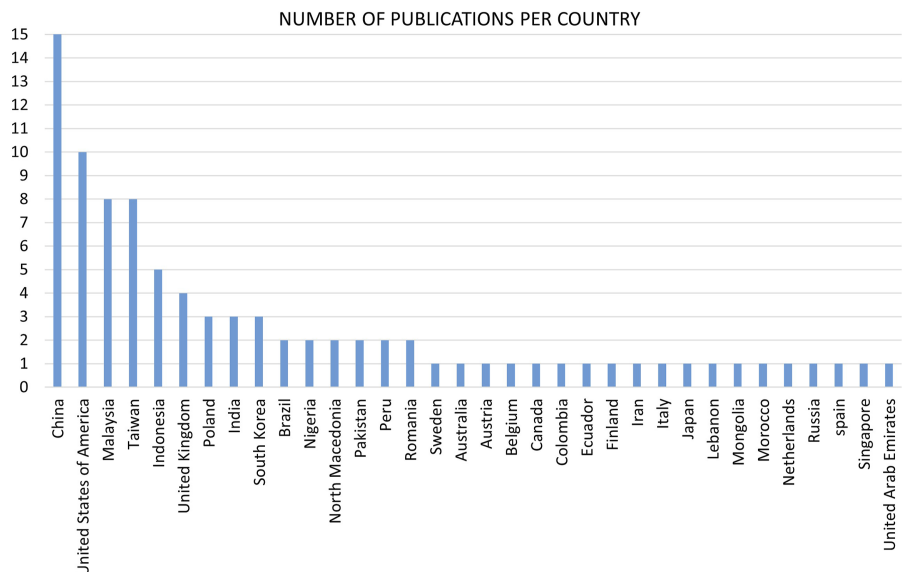


Figure 6. Number of publications per country (own elaboration). Source(s): Authors’ own creation/work

correlation between closely related keywords, grouped by the tool according to their frequent co-occurrence in the selected studies. The clusters indicate a growing focus on using XR as a visualisation tool and a technology with potential strategic applications to optimise costs, improve the perception of real estate value, and enhance potential applications in smart cities. The thematic clusters showcase the potential of XR as a strategic technology for the industry, with future implications for innovation and the personalisation of decision-making processes.

3.1.5 *Number of publications per document type.* Figure 8 shows a representative graph of the number of publications by document type (journal article, book chapter, proceedings paper and review).

Journal article (47) and proceedings paper (41) are the document types with the highest number of contributions on the topic. It is also worth mentioning the presence of a book chapter (Salvo *et al.*, 2022) and a review (Wang *et al.*, 2020). The latter, although not a systematic review on the topic under analysis, offers some important insights. In fact, in this review, it is evaluated how convenient (in terms of lower cost and higher productivity) it is to adopt digital technologies (including VR and AR) in off-site construction. This review has already been presented in the summary in Table 1.

3.1.6 *Source analysis.* Using VOSviewer, it was possible to implement a source analysis of the 97 contributions, identifying the main papers as well as the sources on which they were published. Figure 9 shows the level of relevance of the sources (almost all journals) according to the number of published papers and the representative interconnections in the citation network. The co-occurrence analysis identified five thematic clusters: sustainable built environment and property management (blue), engineering and construction automation (red), real estate marketing and consumer behaviour (green), and technological applications of XR (yellow). These clusters were formed based on the frequent co-occurrence of closely related keywords.

3.1.7 *Number of publications per journals.* Subsequently, the 47 journal articles were distributed among the relevant journals in which they were published, as shown in Figure 10.

The journals with the most publications are: Smart and Sustainable Built Environment, with 3 articles (Adegoke *et al.*, 2022a; Azmi *et al.*, 2022; Sudhakaran *et al.*, 2023); Automation

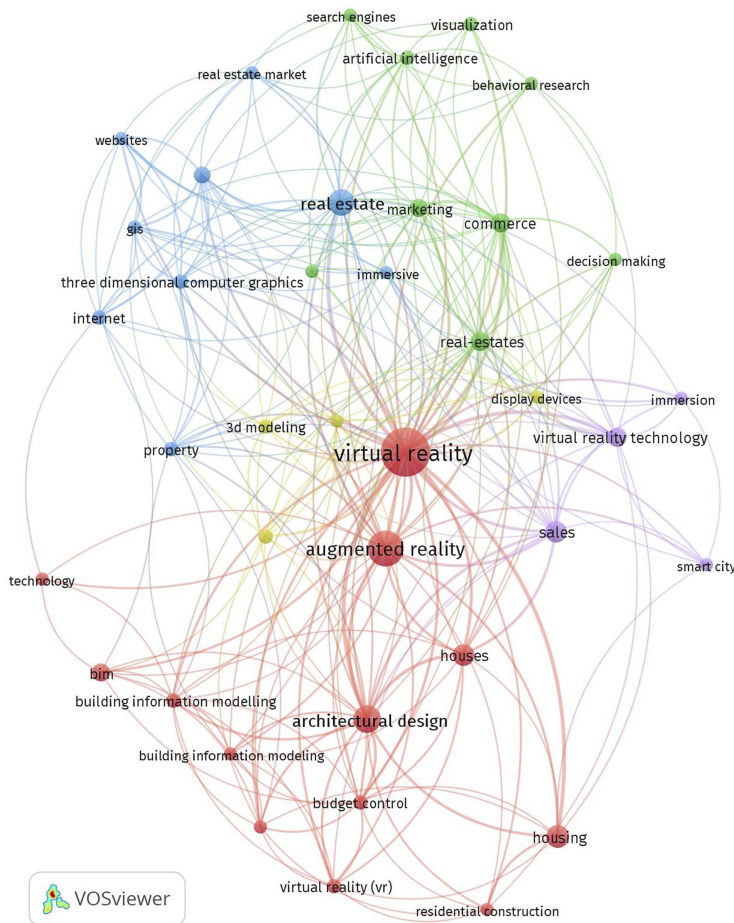


Figure 7. Mapping of the co-occurrence network of keywords (with recurrence greater than or equal to three) obtained through the VOSviewer software. Source(s): Authors' own creation/work

in Construction, with 2 articles (Park *et al.*, 2013; Potseluyko *et al.*, 2022); Journal of Advanced Research in Applied Sciences and Engineering Technology, with 2 articles (Ibrahim *et al.*, 2023a, b); Journal of Real Estate Research, with 2 articles (Allen *et al.*, 2015; Benefield *et al.*, 2019); Journal of Research in Interactive Marketing, with 2 articles (Sihi, 2018; Sun *et al.*, 2023).

3.1.8 Authors with multiple publications on the topic. Having identified the most recurrent authors (i.e. with ≥ 2 publications), it was possible to create the graph in Figure 11 representing the number of papers per author. This figure ranks researchers by the number of publications they are involved in, indicating that those listed may not be the primary or first authors. For specific paper citations, please refer to the first author listed in the References section.

3.1.9 Network of co-citations for authors. Finally, Figure 12 presents the network of co-citations for authors who have at least 5 citations. Among the most co-cited authors are Benefield J.D. (16 citations), Jud G.D. (11 citations), Rutherford R.C. (14 citations), Sirmans G.S. (10 citations), Johnson K.H. (11 citations), and Yavas A. (10 citations). The co-citation analysis using VOSviewer identified three main thematic clusters: studies on real estate valuation and

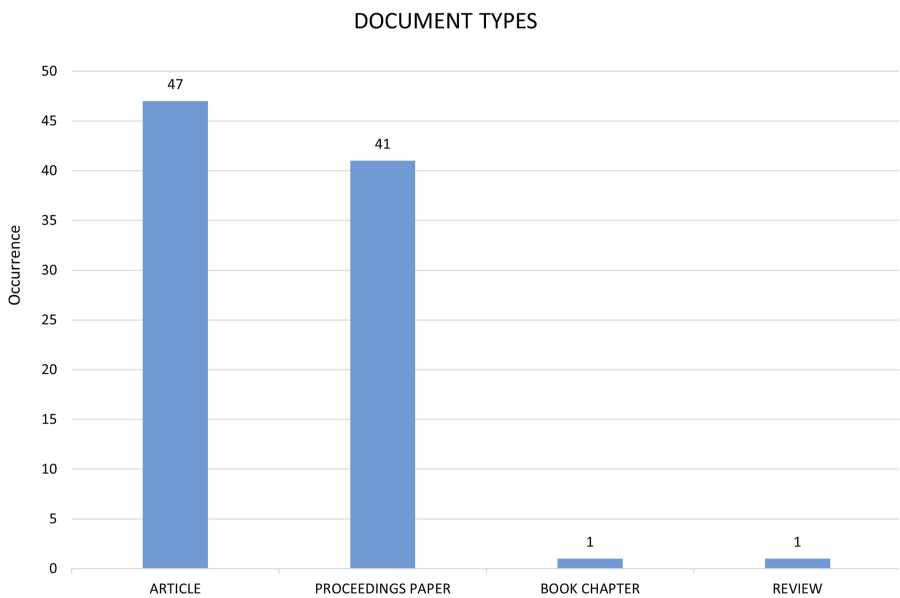


Figure 8. Number of publications by document type (own processing). Source(s): Authors' own creation/work

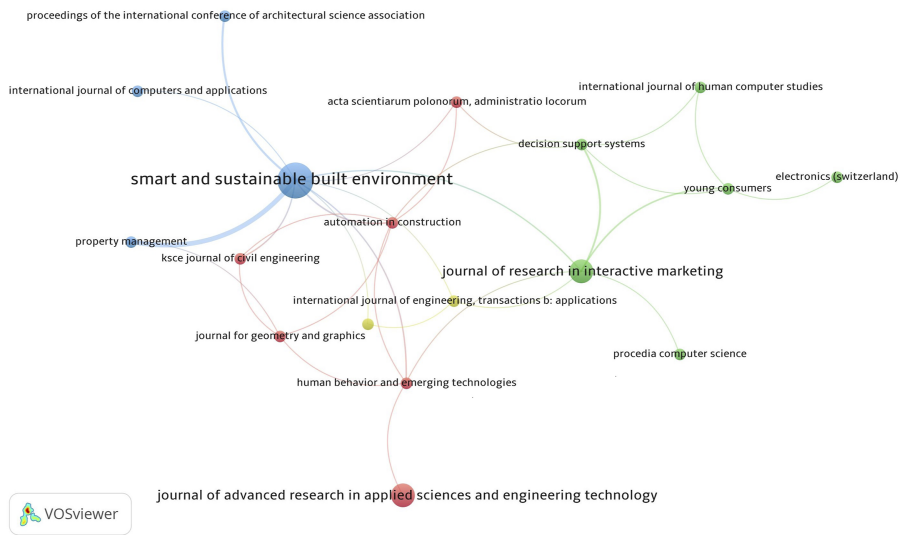


Figure 9. Source Analysis realised using VOSviewer software. Source(s): Authors' own creation/work

market dynamics (green); research on XR and BIM applications in construction project management and cost optimization (red); and works immersive technologies and their technical challenges (blue). These clusters reflect the distinct focus areas in the field, highlighting synergies between real estate economics and XR applications in project management. The

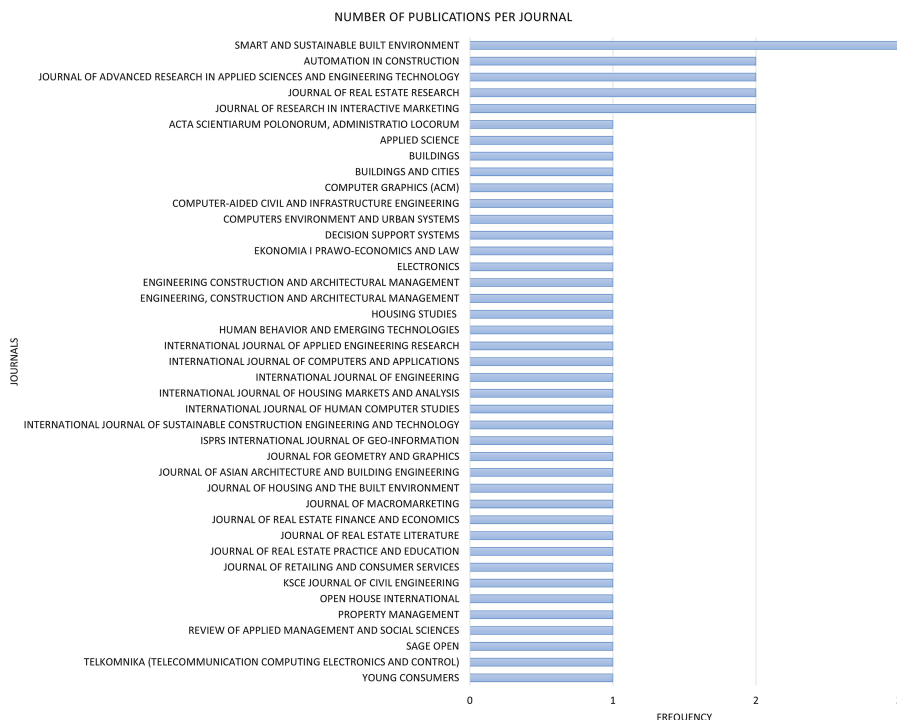


Figure 10. Number of publications per journal (own processing). Source(s): Authors' own creation/work

analysis underscores the growing integration of XR technologies across disciplines and suggests future opportunities for interdisciplinary research bridging technological innovation and economic evaluation.

3.2 Classification of records

[Table A1 \(Appendix\)](#) shows the publications relevant to the economic management of housing projects in which the main behavioural and economic-financial quantities are analysed in quantitative terms. A total of 6 records were selected for this class. [Table A2 \(Appendix\)](#) shows the publications relevant for economic management studies of housing projects in which the main behavioural and economic-financial quantities are analysed only in qualitative terms. A total of 18 records were selected for this class. [Table A3 \(Appendix\)](#) shows the publications relevant to residential property valuation or marketing in which the main behavioural and economic-financial quantities are analysed in quantitative terms. A total of 29 records were selected for this class. Finally, [Table A4 \(Appendix\)](#) shows the publications relevant to residential real estate valuation or marketing in which the main behavioural and economic-financial quantities are analysed only in qualitative terms. A total of 37 records were selected for this class.

3.3 Main behavioural and economic-financial key parameters under study

[Figure 13](#) shows the frequency of use of the behavioural and economic-financial quantities analysed in the quantitative studies on the economic management of housing projects.

The quantities investigated are construction cost (2 times), life cycle cost (1 time), satisfaction level (1 time), data analysis time (1 time) and market value (1 time).

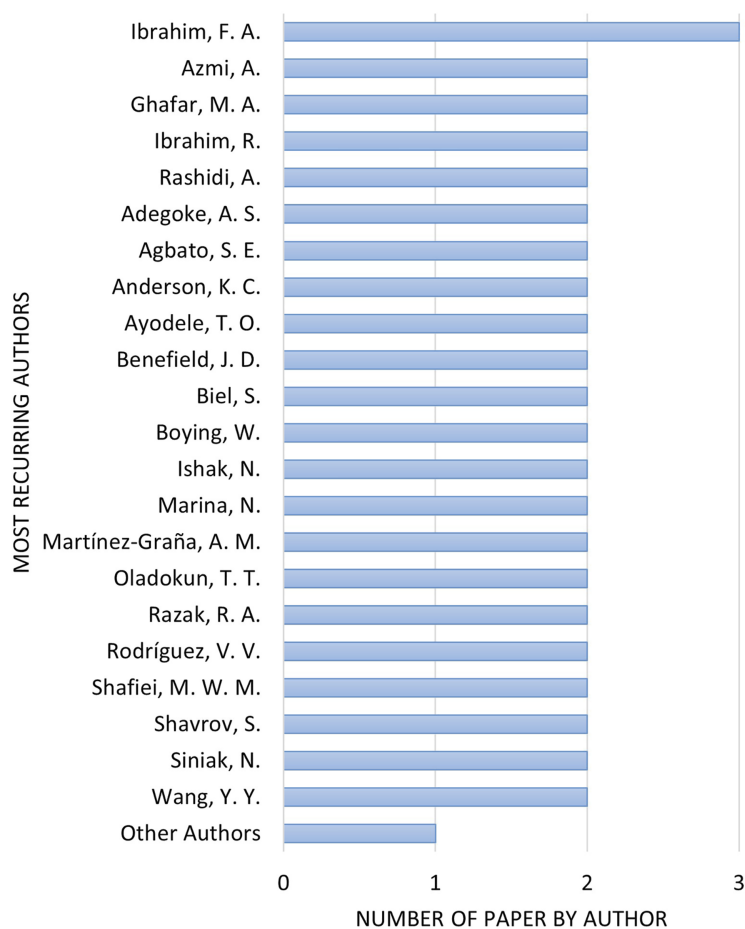


Figure 11. Number of documents per author (own processing). Source(s): Authors’ own creation/work

Figure 14 shows the frequency of use of the behavioural and economic/financial quantities analysed in quantitative studies relevant to residential property valuation and marketing.

The main quantities investigated were purchase price (9 times), Time on Market (8 times), purchase intention (7 times), probability of sale (3 times), perceived value (2 times), and utility (2 times). All other quantities were mentioned only once.

3.4 Impacts

3.4.1 Impacts of XR on economic management of housing projects. The quantitative studies examining XR’s influence on housing project management can be grouped based on key economic management aspects: cost estimation and control, time efficiency, and stakeholder collaboration. These studies highlight measurable impacts of XR technologies on construction project management.

- (1) *Cost Estimation and Control.* Fu et al. (2004) demonstrated that integrating BIM-based life cycle cost estimation with VR can improve forecast accuracy and mitigate significant budget overruns, which typically exceed 50% and affect 75% of government

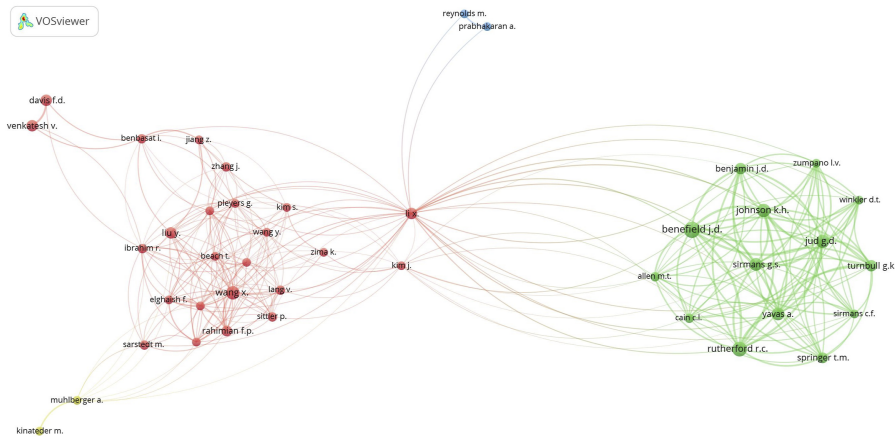


Figure 12. Network of co-citations related to authors with at least 5 active citations realised through the VOSviewer software. Source(s): Authors' own creation/work

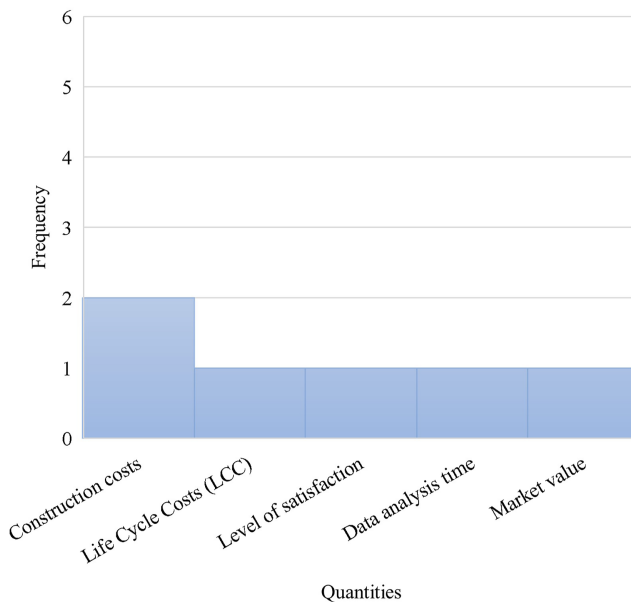


Figure 13. Frequency of use of the analysed quantities in quantitative studies on the economic management of housing projects (own elaboration). Source(s): Authors' own creation/work

projects. Similarly, [Wang and Tung \(2023\)](#) showed that integrating BIM and VR reduced material cost variations by up to 15%, while cutting cost update times from 7–14 days to just a few minutes, enabling more dynamic and efficient budget control. [Salvo et al. \(2022\)](#) reported that using XR in smart building redevelopment projects optimized financial management, supporting decisions that could increase property value by 7–11% through enhanced energy and operational efficiency.

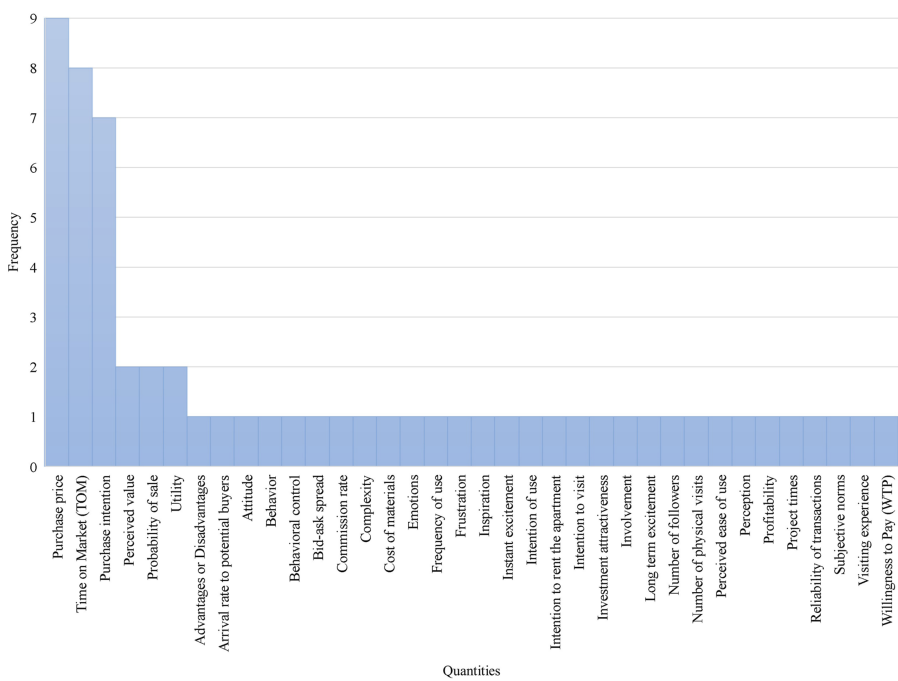


Figure 14. Frequency of use of the analysed quantities in quantitative studies relevant to residential property valuation and marketing (own elaboration). Source(s): Authors’ own creation/work

- (2) *Time Efficiency.* [Ahmed et al. \(2022\)](#) found that advanced VR tools improved the precision of pre-occupancy assessments by shifting user satisfaction responses, thus potentially shortening design times and reducing the overall budget impact. [Xiao \(2014\)](#) showed that using 3D/VR GIS visualization techniques reduced data analysis time, highlighting potential time cost savings for projects requiring detailed 3D representations. These studies collectively underscore XR’s role in expediting decision-making and operational processes, leading to enhanced project efficiency.
- (3) *Stakeholder Collaboration.* [Soliman-Junior et al. \(2022\)](#) highlighted that using collaborative VR tools in social housing retrofit projects improved requirement gathering through real-time adjustments, reducing inefficiencies and post-design change costs. This collaborative approach ensured a more efficient allocation of project budgets and a better understanding of user needs.

3.4.2 Impacts of XR on residential real estate appraisal and marketing. These quantitative studies can be categorised into four areas: price, time on the market, buyer engagement and behaviour, and operational efficiency in marketing strategies. These dimensions illustrate the multifaceted role of XR technologies in reshaping the real estate sector.

- (1) *Price.* Several studies demonstrate that XR technologies influence property prices significantly. [Anderson et al. \(2024a\)](#) found that low-priced properties marketed with VR initially achieved a 7.25% price premium, underscoring the enhanced perceived value that XR tools bring. However, their study also indicated variability in these effects over time and across different property segments, highlighting the need for strategic use of XR in pricing decisions. [Ong et al. \(2024\)](#) found that properties marketed with virtual tours or drone videos achieved a 5.5% higher price. [Yu et al.](#)

- (2021) reported price increases ranging from 2% to 4.5% due to VR integration in real estate listings. [Benefield et al. \(2019\)](#) showed a 3% price increase for lower-priced properties and 1.6% for higher-priced properties through VR virtual tours.
- (2) *Time on Market (TOM)*. The impact of XR on the time properties spend on the market is equally significant. [Ong et al. \(2024\)](#) found that properties marketed with virtual tours or drone videos extended marketing time by about 8 days [Hou and Li \(2022\)](#) found that VR reduces the time on market by an average of 32 days, with an even greater reduction of 67 days (31.5%) for hard-to-sell properties. [Xiong et al. \(2022\)](#) noted a 6.4% reduction in time on market when VR tours were employed, while [Yu et al. \(2021\)](#) observed a slight increase in TOM (3–7 days) in certain cases. Instead, [Benefield et al. \(2019\)](#) noted an associated increase in average time on market by approximately 17.6 days. These findings suggest that while XR can generally accelerate sales, its impact may vary depending on property type and market conditions.
- (3) *Buyer Engagement and Behavior*. XR's ability to enhance buyer engagement and influence behaviour is a recurring theme. [Ibrahim et al. \(2023c\)](#) reported a strong positive correlation ($r = 0.793$) between VR adoption and purchase decisions, emphasizing its role in creating impactful buyer experiences. [Sun et al. \(2023\)](#) found that virtual authenticity (VA) and virtual ideality (VI) increased perceived diagnostic by 20% and inspiration by 25%, respectively, further boosting visit intention. Such studies underline the potential of XR technologies to shape emotional responses, build trust, and drive buyer interest. [Azmi et al. \(2022\)](#) highlighted that the immersive environment of VR significantly increases purchase intention.
- (4) *Operational Efficiency in Marketing Strategies*. The operational benefits of XR technologies are equally transformative for marketing practices. [Deep et al. \(2023\)](#) reported a 54% increase in buyer confidence through VR and AR technologies, which also reduce costs and physical visits. [Xiong et al. \(2022\)](#) demonstrated that VR reduces the bid-ask spread by 2%, improving negotiation outcomes. [Benefield et al. \(2019\)](#) highlighted the dual impact of VR tours in enhancing marketability and supporting brokers.

4. Discussion

4.1 Implications of different XR technologies on the fields of study

XR technologies, such as VR, AR and MR, significantly influence both the economic management of housing projects and residential real estate appraisal and marketing. VR is certainly the most studied technology (78 times in the works analysed, 67 times exclusively). It is widely used to improve the accuracy of economic decisions, especially in the planning and customization phases of buildings ([Wang and Tung, 2023](#)). For example, this technology allows the identification of potential design problems, optimizing resources, and reducing modification times ([Fu et al., 2004](#)). The second most studied technology is AR (30 times in the works analysed, 19 times exclusively), which facilitates interaction with digital models, increasing user engagement and optimizing real estate marketing through the personalization of the experience ([Adegoke et al., 2022b](#); [Ibrahim et al., 2023a](#)). This translates into an increase in transparency and trust in the decision-making process, which is essential for buyers and investors. MR, although less documented (in the works analysed, it has never been analysed exclusively), integrates physical and virtual reality, offering unique opportunities for design exploration and improving collaboration between stakeholders ([Deep et al., 2023](#)). The adoption of XR technologies not only improves communication between designers and stakeholders but also increases transparency in real estate projects, an aspect that fosters trust and efficiency in the management of economic resources ([Fu et al., 2004](#)). Furthermore, their

ability to democratize access to complex data promotes equity and sustainability, making them essential tools to address the challenges of the sector (Adegoke *et al.*, 2022a; Ibrahim *et al.*, 2023b).

4.2 Implications of XR applications integrated with GIS

In 5 of the analysed records, XR technologies were integrated into the GIS environment (Athik and Lee, 2020; Martínez-Graña and Rodríguez, 2016; Rau and Cheng, 2013; Salleh *et al.*, 2014; Xiao, 2014). The integration of XR and GIS is essential to improve spatial analysis and decision-making. Studies such as Xiao's (2014) demonstrate that XR-GIS reduces the time required to analyse geographic data, improving the economic management of projects. This type of implementation allows the simulation of urban use scenarios in real-time, promoting sustainable practices and favouring more inclusive and participatory planning (Salleh *et al.*, 2014). XR-GIS integration offers new opportunities for advanced simulations and sustainability analysis, particularly relevant for densely populated urban contexts (Martínez-Graña and Rodríguez, 2016). XR-GIS tools increase planning efficiency, reducing errors and promoting data-driven decisions. For example, the use of these tools in densely populated urban contexts has improved transparency in decision-making processes and fostered greater environmental awareness among the citizens involved (Salleh *et al.*, 2014). Moreover, these technologies equip real estate professionals with enhanced insights into the spatial context, a critical element for optimizing real estate management.

4.3 Implications of XR applications integrated with BIM

In 10 out of 90 papers, XR technologies have been integrated into BIM design (Amed *et al.*, 2020; Biel, 2021; Fu *et al.*, 2004; Park *et al.*, 2013; Potseluyko *et al.*, 2022; Salvo *et al.*, 2022; Sikarwar and Shelake, 2023; Siniak *et al.*, 2020a; Sun *et al.*, 2017; Wang and Tung, 2023). XR and BIM integration improves project interactivity and management, optimizing time and costs. Fu *et al.* (2004) demonstrate that XR-BIM adoption reduces budget overruns in public projects, while Salvo *et al.* (2022) show that this combination increases the value of buildings by 7–11% thanks to energy and operational improvements. Wang and Tung (2023) highlight that XR-BIM accelerates cost updates, reducing errors and improving economic control. This technological combination represents a unique opportunity to improve the operational efficiency and sustainability of real estate projects. The ability of XR-BIM to provide immersive and interactive simulations allows stakeholders to explore alternative scenarios and identify optimal solutions, reducing waste and inefficiencies (Salvo *et al.*, 2022). In terms of sustainability, projects managed with XR-BIM demonstrate reduced environmental impact and improved urban quality, making this technology a strategic choice for the future (Fu *et al.*, 2004; Wang and Tung, 2023). It is recalled that VR is often referred to as the ninth dimension of BIM, which is crucial in managing processes, as well as enabling the optimal use of resources and the overall improvement of design phases (Szafranko and Jurczak, 2024).

4.4 Key variables affecting or influencing project economic management

Quantitative studies on the economic management of housing projects, as summarised in Table A1, highlight key economic variables. These include construction costs (Salvo *et al.*, 2022; Wang and Tung, 2023) and life cycle costs (LCC) (Fu *et al.*, 2004), which are critical to understanding project financial viability. These variables provide a comprehensive perspective on the profitability and sustainability of real estate investments, supporting improved planning and project management. The reviewed studies reveal significant implications of XR technologies for the economic management of housing projects. Research implications include the need for cost-efficient hybrid solutions, as highlighted by Ahmed *et al.* (2022), and the role of BIM-integrated VR tools in refining life cycle cost (LCC) estimations, which Fu *et al.* (2004) suggest requires further exploration to extend benefits

across diverse contexts. Practical implications emphasize economic efficiency through BIM-VR systems, as shown by [Wang and Tung \(2023\)](#), which streamline cost updates and optimize decision-making. [Salvo et al. \(2022\)](#) demonstrate how Industry 4.0 tools, including VR, enhance redevelopment project returns by increasing property value via energy and operational efficiencies. Social implications include the findings of [Soliman-Junior et al. \(2022\)](#) on collaborative VR tools improving inclusivity in social housing retrofits, and [Xiao's \(2014\)](#) showing reduced data analysis times through 3D/VR GIS visualization, fostering affordable housing solutions. Collectively, these studies advocate balancing technological innovation with accessibility and scalability.

4.5 Impacts identified by qualitative studies on project economic management

Qualitative studies on project economic management highlight the role of XR technologies in improving efficiency and cost control. Regarding research implications, [Park et al. \(2013\)](#) and [Biel \(2021\)](#) show how integration with BIM promotes proactive defect management and waste reduction, while [Li et al. \(2004\)](#) and [Sikarwar and Shelake \(2023\)](#) highlight the need to develop predictive models and standardisations for the use of VR and AR in construction processes. In terms of implications for practice, [Hussamadin et al. \(2020\)](#) and [Tang and Yang \(2007\)](#) demonstrate how VR optimises financial control and collaboration on construction sites, while [Bourhim and Cherkaoui \(2020\)](#) and [Martínez-Graña and Rodríguez \(2016\)](#) highlight its effectiveness in safety and land-use planning simulations. Regarding social implications, [Phommaly and Yu \(2020\)](#) and [Yamamura et al. \(1996\)](#) show how immersive experiences improve design decisions and user satisfaction, contributing to more sustainable and inclusive projects. Overall, XR technologies emerge as fundamental tools to optimise resources, improve collaboration, and promote safe and sustainable environments.

4.6 Key variables affecting or influencing residential real estate appraisal and marketing

In quantitative studies of real estate appraisal and marketing, summarized in [Table A3](#), the most investigated quantities include the sale price, Time on Marketing, and intention to purchase. These quantities are fundamental to understanding the behaviour and decisions of buyers and sellers in the real estate sector. The other quantities (willingness to pay, utility, perceived value, attitudes, behaviours, etc.), although equally important, could be less studied due to the complexity of their analysis and measurement. They are more difficult to quantify than parameters more directly related to the real estate transaction, such as the sale price and the TOM. Quantitative studies on residential real estate appraisal and marketing offer significant insights. For research, [Adegoke et al. \(2022a, b\)](#) and [Benefield et al. \(2019\)](#) focus on factors that influence the adoption of XR technologies, such as perceived value and frequency of use. These studies encourage further investigations into the psychological and cultural mechanisms that determine the effectiveness of such technologies, providing a basis for developing models that integrate economic and behavioural variables. On the practical front, [Anderson et al. \(2024a\)](#) and [Deep et al. \(2023\)](#) demonstrate how virtual tours and AR/VR applications optimise the decision-making process, reducing time on market and increasing transparency in transactions. [Benefield et al. \(2019\)](#) highlight how XR-based strategies can improve market positioning, increasing perceived value and the efficiency of sales operations. For society, [Ibrahim et al. \(2023a, b, c\)](#) and [Sudhakaran et al. \(2023\)](#) highlight the role of XR in promoting deeper engagement and greater acceptance of technological innovations. As highlighted by these studies, the adoption of immersive tools favours a more personalised user experience, making the real estate purchasing process more transparent and inclusive.

4.7 Impacts identified by qualitative studies on residential real estate appraisal and marketing

Qualitative studies emphasize how XR technologies revolutionize real estate marketing and appraisal by enhancing customer engagement and decision-making processes. AR applications, such as virtual brochures ([Adrianto et al., 2016](#)) and interactive property

displays (Setyadi and Rangadara, 2020), improve user experiences while reducing marketing costs. Similarly, VR-based systems enable immersive property visualizations, meeting buyers' emotional and functional needs while facilitating informed decisions (Fan and Zhang, 2018; Wei, 2020). Innovative approaches, such as combining GIS with 3D models, further optimize property management and customer satisfaction (Athick and Lee, 2020). Studies also highlight XR's role in reshaping market dynamics and promoting digital transformation in the real estate sector, driving competitiveness and transparency (Siniak *et al.*, 2020a). However, challenges such as cost barriers and technical expertise need addressing to fully harness XR's potential (Kaufmann and Olaru, 2011).

4.8 Geographic, economic and market disparities and challenges in adopting XR technologies

The application of XR technologies, particularly in virtual tours, project management, and design visualizations, consistently demonstrate significant impacts on real estate and financial project management across advanced regions like the U.S. and China (Hsiao *et al.*, 2024; Yu and Fan, 2023). These impacts include improved buyer engagement and efficiency in decision-making processes. However, in developing regions such as Nigeria, challenges such as economic feasibility, lack of infrastructure, and technical expertise hinder the widespread adoption of these technologies, despite growing awareness of their benefits (Adegoke *et al.*, 2022a, b). These discrepancies highlight the influence of geographic, economic, and infrastructural factors on XR adoption and its effectiveness. For instance, while some studies emphasise cost reductions and enhanced efficiency (Salleh *et al.*, 2014; Siniak *et al.*, 2020a), others underline barriers like resource constraints in emerging markets. This calls for comparative research to explore scalable solutions and tailor XR applications to specific regional contexts, ensuring broader accessibility and impact. Future studies should integrate these insights to refine the global applicability of XR technologies in the real estate and financial domains.

4.9 Answers to the research questions

The analysis of the studies selected for this systematic review enabled the research questions presented in Section 1.2 to be addressed. The key findings are summarized in Table 2.

4.10 Limitations found in the analysed studies

From the analysed studies emerge the following limits:

- (1) *Conflicting results in quantitative analyses.* Quantitative studies often yield divergent results. For instance, the impact of XR technologies on sales prices and time on market (TOM) varies significantly across different geographical contexts. A study conducted in the United States (Yu *et al.*, 2021) reports an increase in TOM (+6%) and sales prices (+3%). In contrast, research in China (Xiong *et al.*, 2022) reports a more moderate decrease in TOM (−6.4%). These discrepancies call for further investigation to identify the underlying causes, which may stem from data collection methods, geographical location, or other factors.
- (2) *Limited focus on behavioural metrics.* Few studies explore metrics such as willingness to pay (WTP), perceived value, or utility. These aspects are essential for understanding buyer behaviour in the real estate sector, adapting marketing strategies, setting optimal property values, and enhancing user experience (Sun *et al.*, 2017). For example, the use of XR technologies for virtual tours could significantly influence WTP, thereby affecting the price formation mechanisms in real estate markets.
- (3) *Limited exploration of some estimation procedures.* Most publications on real estate valuation employ the hedonic price model to estimate market value or TOM (Anderson *et al.*, 2024a; Hsiao *et al.*, 2024; Ong *et al.*, 2024; Xiong *et al.*, 2022). Very few studies

Table 2. Answers to research questions on the use of XR technologies in economic project management and real estate appraisal: summary of key findings

Research questions	Answers
1. How does XR influence project management and real estate valuation?	<i>Economic Project Management</i> - Optimizes project economics through interactive simulation and design customization (Fu <i>et al.</i>, 2004) - Reduces construction costs and improves stakeholder collaboration (Wang and Tung, 2023) <i>Real Estate Appraisal</i> - Increases buyer engagement, enhances transaction transparency, and supports faster, more informed decision-making (Ibrahim <i>et al.</i>, 2023a) - Almost always positively influences sales prices and time on the market (Anderson <i>et al.</i>, 2024a; Benefield <i>et al.</i>, 2019; Hou and Li, 2022)
2. What are the main behavioral, economic, and estimation parameters analyzed?	- <i>Economic Project Management</i>: construction cost and life cycle cost (LCC) - <i>Real Estate Appraisal</i>: purchase price, time on market (TOM) and purchase intention
3. What are the challenges and opportunities in using XR technologies?	- <i>Challenges</i> - Economic and infrastructural barriers, particularly in emerging markets (Adegoke <i>et al.</i>, 2022a) - High cost of XR technologies, limited technical expertise, and inadequate digital infrastructure (Adegoke <i>et al.</i>, 2022b) - Geographic disparities affecting the effectiveness and scalability of XR applications (Adegoke <i>et al.</i>, 2022a, b) - <i>Opportunities</i> - Enhances collaboration among stakeholders, optimizes economic decisions, and improves transparency in transactions (Benefield <i>et al.</i>, 2019; Wang and Tung, 2023) - Adoption of scalable tools could increase accessibility and support global sustainability (Xiong <i>et al.</i>, 2022)
Future Research Directions	- Focus on underexplored variables and more advanced estimation procedures - Greater emphasis on emerging mixed-reality (MR) technologies for future development

Source(s): Authors' own creation/work

utilise alternative procedures, such as the Market Comparison Approach or artificial neural networks or focus on the pricing of individual properties. Comparison-based studies that investigate the effects of XR technologies versus traditional visualisation techniques are exceedingly rare and often prioritise behavioural variables over economic ones.

- (4) *The insufficient number of quantitative studies.* Quantitative studies (35) are significantly fewer than qualitative ones (55). Only six studies adequately examine the economic and financial impacts of XR technologies integrated into the design, maintenance, execution, or management of individual housing units or residential buildings, highlighting a clear gap in this area.

4.11 Areas for future consideration

In light of the identified limitations, future research should focus on:

- (1) Exploring the reasons for discrepancies in results across different geographical contexts, adopting a comparative approach on a global scale.

- (2) Investigating the impact of XR technologies on underexplored behavioural and economic metrics, such as WTP and perceived value, to provide a more comprehensive understanding of buyer behaviour.
- (3) Developing studies centred on alternative methodologies for real estate valuation, expanding analyses to specific properties and combining XR with traditional techniques.
- (4) Increasing the number of quantitative studies on the economic and financial impacts of XR technologies, particularly in the management of residential buildings and individual housing units.

5. Conclusions

In this paper, a systematic literature review was conducted on the impact of extended reality (XR) technologies in the economic management of housing projects, as well as in marketing and residential property appraisals. A total of 90 academic papers were selected from Scopus, Web of Science and Google Scholar, following defined inclusion/exclusion criteria. These papers were divided into two main categories: (1) studies on the economic management of housing projects; (2) studies on residential property valuation and marketing. Each category was further divided into quantitative and qualitative analyses of the impact of XR technologies.

The literature review answered the three research questions.

First, the analysis shows that XR technologies optimize the economic management of projects through interactive simulations and project customizations, improving collaboration and reducing costs. In real estate marketing, the use of XR increases buyer engagement, accelerates decisions and influences prices and times of sale.

Second, it has been shown that, for appraisal and residential marketing studies, the most influential variables are the sale price, the Time on Market (TOM) and the intention to purchase, while for project economic management studies the main variables are construction costs and life cycle cost (LCC).

Third, it emerges that, despite economic and infrastructural barriers in emerging contexts, XR technologies offer the possibility to improve the user experience and promote global sustainability through scalable tools. An opportunity to be seized could be the testing of new MR visors. They can enable the simulation and analysis of real-time scenarios, facilitating informed decision-making during all project phases, from planning to construction and maintenance, thereby optimising processes and reducing financial risks.

The practical implications of this systematic review highlight XR technologies as innovative tools in project management and real estate marketing. These technologies enhance transparency, precision, and collaboration among stakeholders, optimizing decision-making processes and improving market dynamics. However, balancing the costs of implementation with the benefits remains a critical challenge, particularly for smaller organizations. From a research perspective, the review underscores the need for further exploration of underexamined economic and behavioural impacts, such as perceived value and willingness to pay, while advocating for innovative estimation models and comparative studies to address cultural and geographic differences in XR adoption. Societally, XR technologies hold the potential to democratize access to critical information, reduce environmental footprints, and promote inclusivity by supporting informed and sustainable housing decisions, ultimately contributing to more equitable and participatory development practices.

The study is not without limitations. Firstly, the review focused on contributions published mainly in English, potentially excluding relevant papers written in other languages. Secondly, although the databases queried were among the most relevant, it is possible that some important contributions were not taken into account. Consultation of additional databases may increase the sample of selectable contributions in the future.

Finally, the study would like to point out a further cue for future research. To improve the statistical robustness of the discussions carried out and allow for more robust comparative analyses, the number of quantitative studies needs to be increased. In this sense, it is crucial to deepen the analysis of correlations between economic and behavioural variables to better understand the dynamics underlying the adoption of XR technologies.

References

- Abrishami, S., Goulding, J. and Rahimian, F. (2020), "Generative BIM workspace for AEC conceptual design automation: prototype development", *Engineering, Construction and Architectural Management*, Vol. 28 No. 2, pp. 482-509, doi: [10.1108/ECAM-04-2020-0256](https://doi.org/10.1108/ECAM-04-2020-0256).
- Adegoke, A.S., Oladokun, T.T., Ayodele, T.O., Agbato, S.E. and Jinadu, A.A. (2022a), "DEMATEL method of analysing the factors influencing the decision to adopt virtual reality technology by real estate firms in Lagos property market", *Smart and Sustainable Built Environment*, Vol. 11 No. 4, pp. 891-917, doi: [10.1108/SASBE-09-2020-0135](https://doi.org/10.1108/SASBE-09-2020-0135).
- Adegoke, A.S., Oladokun, T.T., Ayodele, T.O., Agbato, S.E., Jinadu, A.D. and Olaleye, S.O. (2022b), "Analysing the criteria for measuring the determinants of virtual reality technology adoption in real estate agency practice in Lagos: a DEMATEL method", *Property Management*, Vol. 40 No. 3, pp. 285-301, doi: [10.1108/PM-05-2021-0035](https://doi.org/10.1108/PM-05-2021-0035).
- Adrianto, D., Hidajat, M. and Yesmaya, V. (2016), "Augmented reality using Vuforia for marketing residence", *2016 1st International Conference on Game, Game Art, and Gamification (ICGGAG)*, IEEE, pp. 1-5, doi: [10.1109/ICGGAG.2016.8052642](https://doi.org/10.1109/ICGGAG.2016.8052642).
- Ahmed, S. (2018), "A review on using opportunities of augmented reality and virtual reality in construction project management", *Organization, Technology and Management in Construction: An International Journal*, Vol. 10 No. 1, pp. 1839-1852, doi: [10.2478/otmcj-2018-0012](https://doi.org/10.2478/otmcj-2018-0012).
- Ahmed, K.G., Omar, M.M., Megahed, M. and Alazeezi, S.A. (2022), "Involving young Emirati women in the pre-occupancy evaluation of "modern" housing designs: simple versus advanced participatory tools", *Sage Open*, Vol. 12 No. 2, 21582440221094613, doi: [10.1177/21582440221094613](https://doi.org/10.1177/21582440221094613).
- Al-Dhaimesh, S.H. and Taib, N. (2023), "A review: investigation of augmented reality-BIM benefits in design process in AEC industry", *Informatica*, Vol. 47 No. 5, doi: [10.31449/inf.v47i5.4671](https://doi.org/10.31449/inf.v47i5.4671).
- Allen, M.T., Cadena, A., Rutherford, J. and Rutherford, R.C. (2015), "Effects of real estate brokers' marketing strategies: public open houses, broker open houses, MLS virtual tours, and MLS photographs", *Journal of Real Estate Research*, Vol. 37 No. 3, pp. 343-369, doi: [10.1080/10835547.2015.12091422](https://doi.org/10.1080/10835547.2015.12091422).
- Alvanchi, A., Didehvar, N., Jalilehvand, M., Adami, P. and Shahmir, S. (2021), "Semi-augmented reality, a novel approach to improve customer safety in the pre-sale process of under construction buildings", *International Journal of Engineering*, Vol. 34 No. 10, pp. 2198-2205, doi: [10.5829/IJE.2021.34.10A.01](https://doi.org/10.5829/IJE.2021.34.10A.01).
- Amed, O.B., Lien, L.C., Dolgorsuren, U. and Liu, Y.N. (2020), "Using virtual reality and augmented reality for presale house customer change", *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, IAARC Publications, Vol. 37, pp. 8-15, doi: [10.22260/ISARC2020/0003](https://doi.org/10.22260/ISARC2020/0003).
- Anderson, K.C., Freybote, J. and Manis, K.T. (2024a), "The impact of virtual marketing strategies on the price-TOM relation", *The Journal of Real Estate Finance and Economics*, Vol. 68 No. 2, pp. 218-234, doi: [10.1007/s11146-022-09908-x](https://doi.org/10.1007/s11146-022-09908-x).
- Anderson, K.C., Hansen, H. and Laverie, D. (2024b), "Technology has agency too! Disentangling technology's causal and structural agency in a service system", *Journal of Macromarketing*, Vol. 44 No. 2, pp. 510-533, doi: [10.1177/02761467241238184](https://doi.org/10.1177/02761467241238184).
- Athick, M.A.A.S. and Lee, S.-Y. (2020), "3D virtual reality model for multi-stories building and utilities with different vertical ownership ID's", *ACRS 2020-41st Asian Conference on Remote Sensing* ISBN: 9781713829089, available at: https://www.researchgate.net/publication/353793827_3D_VIRTUAL_REALITY_MODEL_FOR_MULTI-STORIES_BUILDING_

[AND UTILITIES WITH DIFFERENT VERTICAL OWNERSHIP ID's](#) (accessed 18 November 2024).

- Azmi, A., Ibrahim, R., Ghafar, M.A. and Rashidi, A. (2020), "Improving empathic evaluations in virtual reality for marketing of housing projects", *54th International Conference of the Architectural Science Association, ANZAScA 2020*, The Architectural Science Association (ANZAScA), pp. 600-609 ISSN: 2209-3850, ISBN: 9780992383572, available at: <https://anzasca.net/wp-content/uploads/2021/03/62-Improving-empathic-evaluations-in-virtual-reality-for-marketing-of-housing-projects.pdf> (accessed 18 November 2024).
- Azmi, A., Ibrahim, R., Ghafar, M.A. and Rashidi, A. (2022), "Smarter real estate marketing using virtual reality to influence potential homebuyers' emotions and purchase intention", *Smart and Sustainable Built Environment*, Vol. 11 No. 4, pp. 870-890, doi: [10.1108/SASBE-03-2021-0056](https://doi.org/10.1108/SASBE-03-2021-0056).
- Balali, V., Noghabaei, M., Heydarian, A. and Han, K. (2018), "Improved stakeholder communication and visualizations: real-time interaction and cost estimation within immersive virtual environments", *Construction Research Congress 2018*, pp. 522-530, available at: <https://ascelibrary.org/doi/pdf/10.1061/9780784481264.051?download=true> (accessed 18 November 2024).
- Benefield, J., Cain, C. and Gleason, A. (2012), "Visual display of residential property information: some additional evidence", *Journal of Real Estate Practice and Education*, Vol. 15 No. 2, pp. 89-100, doi: [10.1080/10835547.2012.12091710](https://doi.org/10.1080/10835547.2012.12091710).
- Benefield, J.D., Sirmans, C.S. and Sirmans, G.S. (2019), "Observable agent effort and limits to innovation in residential real estate", *Journal of Real Estate Research*, Vol. 41 No. 1, pp. 1-36, doi: [10.1080/10835547.2019.12091517](https://doi.org/10.1080/10835547.2019.12091517).
- Biel, S. (2021), "Concept of using the BIM technology to support the defect management process", *Archives of Civil Engineering*, Vol. 67 No. 2, pp. 209-229, doi: [10.24425/ace.2021.137164](https://doi.org/10.24425/ace.2021.137164).
- Bourhim, E.M. and Cherkaoui, A. (2020), "Efficacy of virtual reality for studying people's pre-evacuation behavior under fire", *International Journal of Human-Computer Studies*, Vol. 142, 102484, doi: [10.1016/j.ijhcs.2020.102484](https://doi.org/10.1016/j.ijhcs.2020.102484).
- Carrillo, P.E. (2008), "Information and real estate transactions: the effects of pictures and virtual tours on home sales", *Department of Economics, The George Washington University, Washington, DC, Luettu*, Vol. 14, p. 2016, available at: https://www.researchgate.net/publication/228466494_Information_and_real_estate_transactions_the_effects_of_pictures_and_virtual_tours_on_home_sales (accessed 18 November 2024).
- Casas-Mateus, D.E. and Chacon-Sanchez, N.V. (2019), "Visualization of emotions experienced in the use of immersive augmented reality technologies for the real estate sector", *Applied Computer Sciences in Engineering: 6th Workshop on Engineering Applications, WEA 2019, Santa Marta, Colombia, October 16-18, 2019, Proceedings 6*, Springer International Publishing, pp. 78-88, doi: [10.1007/978-3-030-31019-6_7](https://doi.org/10.1007/978-3-030-31019-6_7).
- Casini, M. (2022), "Extended reality for smart building operation and maintenance: a review", *Energies*, Vol. 15 No. 10, p. 3785, doi: [10.3390/en15103785](https://doi.org/10.3390/en15103785).
- Chen, S. and Liu, Y.S. (2008), "The study on the digital management system of construction project", *Proceedings of 2008 International Conference on Construction and Real Estate Management*, Vol. 1 and 2, China Architecture and Building Press ISBN 978-7-112-10340-9, available at: <https://www.webofscience.com/wos/alldb/full-record/WOS:000262502700127> (accessed 18 November 2024).
- Chen, K. and Xue, F. (2022), "The renaissance of augmented reality in construction: history, present status and future directions", *Smart and Sustainable Built Environment*, Vol. 11 No. 3, pp. 575-592, doi: [10.1108/SASBE-08-2020-0124](https://doi.org/10.1108/SASBE-08-2020-0124).
- Chi, H.-L., Kang, S.-C. and Wang, X. (2013), "Research trends and opportunities of augmented reality applications in architecture, engineering, and construction", *Automation in Construction*, Vol. 33, pp. 116-122, doi: [10.1016/j.autcon.2012.12.017](https://doi.org/10.1016/j.autcon.2012.12.017).
- Cipresso, P., Giglioli, I.A.C., Raya, M.A. and Riva, G. (2018), "The past, present, and future of virtual and augmented reality research: a network and cluster analysis of the literature", *Frontiers in Psychology*, Vol. 9, p. 2086, doi: [10.3389/fpsyg.2018.02086](https://doi.org/10.3389/fpsyg.2018.02086).

- Dargan, S., Bansal, S., Kumar, M., Mittal, A. and Kumar, K. (2023), "Augmented reality: a comprehensive review", *Archives of Computational Methods in Engineering*, Vol. 30 No. 2, pp. 1057-1080, doi: [10.1007/s11831-022-09831-7](https://doi.org/10.1007/s11831-022-09831-7).
- de Macedo, D.V., Rodrigues, M.A.F., Furtado, J.J.V.P., Furtado, E.S. and Chagas, D.A. (2014), "Using and evaluating augmented reality for mobile data visualization in real estate classified", *International Journal of Computers and Applications*, Vol. 36 No. 1, pp. 7-14, doi: [10.2316/Journal.202.2014.1.202-3737](https://doi.org/10.2316/Journal.202.2014.1.202-3737).
- Deaky, B.A. and Parv, A.L. (2018), "Virtual reality for real estate—a case study", *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, Vol. 399 No. 1, 012013, doi: [10.1088/1757-899X/399/1/012013](https://doi.org/10.1088/1757-899X/399/1/012013).
- Deep, S., Vishnoi, S., Malhotra, R., Mathur, S., Yawale, H., Kumar, A. and Singla, A. (2023), "Influence of augmented reality and virtual reality on real estate investment decisions: understand consumer perspective in Indian AEC industry", *Engineering Construction and Architectural Management*, Vol. 32 No. 2, pp. 1122-1140, doi: [10.1108/ecam-04-2023-0327](https://doi.org/10.1108/ecam-04-2023-0327) available at: <https://www.emerald.com/insight/content/doi/10.1108/ecam-04-2023-0327/full/html?skipTracking=true> (accessed 18 November 2024).
- Dolzhencko, A.V., Grebenik, A.V., Sedashova, M.A. and Rudenskiy, D.S. (2021), "Expanding the capabilities of the ARCHICAD software package for effective solution of construction design tasks", *Journal of Physics: Conference Series*, Vol. 1926 No. 1, 012015, doi: [10.1088/1742-6596/1926/1/012015](https://doi.org/10.1088/1742-6596/1926/1/012015).
- Du, B. and Zhou, L. (2022), "Real estate display system based on virtual reality technology", *International Conference on Machine Learning, Image Processing, Network Security and Data Sciences*, Cham, Springer Nature Switzerland, pp. 123-130, doi: [10.1007/978-3-031-24367-7_11](https://doi.org/10.1007/978-3-031-24367-7_11).
- Englund, C., Olofsson, A.D. and Price, L. (2017), "Teaching with technology in higher education: understanding conceptual change and development in practice", *Higher Education Research and Development*, Vol. 36 No. 1, pp. 73-87, doi: [10.1080/07294360.2016.1171300](https://doi.org/10.1080/07294360.2016.1171300).
- Fan, J.Q. and Zhang, F.Q. (2018), "Research on an immersive interior decoration experience and interactive system based on virtual reality", *2018 11th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, IEEE, pp. 1-5, doi: [10.1109/CISP-BMEI.2018.8633109](https://doi.org/10.1109/CISP-BMEI.2018.8633109).
- Florián Castillo, O.R., Abanto Crisólogo, S.E., Mendoza Bances, S.G. and Becerra, T.I.A. (2023), "Marketing strategies for the brand positioning of a SME in the real estate sector", *Proceedings of The LACCEI International Multi-Conference for Engineering, Education and Technology*, doi: [10.18687/LEIRD2023.1.1.398](https://doi.org/10.18687/LEIRD2023.1.1.398).
- Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B. and Slater, M. (2017), "Virtual reality in the assessment, understanding, and treatment of mental health disorders", *Psychological Medicine*, Vol. 47 No. 14, pp. 2393-2400, doi: [10.1017/S003329171700040X](https://doi.org/10.1017/S003329171700040X).
- Fu, C., Aouad, G., Ponting, A., Lee, A. and Wu, S. (2004), "IFC implementation in lifecycle costing", *Journal of Harbin Institute of Technology*, Vol. 11 No. 4, pp. 437-441, available at: https://www.researchgate.net/publication/28578928_IFC_implementation_in_lifecycle_costing (accessed 18 November 2024).
- Gan, S.Q. and Zhang, H. (2013), "Application of virtual construction technology in green construction", *Applied Mechanics and Materials*, Vol. 368, pp. 1139-1142, doi: [10.4028/www.scientific.net/AMM.368-370.1139](https://doi.org/10.4028/www.scientific.net/AMM.368-370.1139).
- Guo, H.Q. and Qin, Y. (2011), "Application of virtual reality technology in real estate internet marketing", *Proceedings of the 2011 Exchange Conference - International Marketing Science and Information Technology*, pp. 102-106, ISBN 978-0-646-57176-8, available at: <https://www.webofscience.com/wos/allldb/full-record/WOS:000310253400019> (accessed 18 November 2024).
- Hou, X. and Li, G. (2022), "How is virtual reality technology changing housing transactions? New evidence from big data". doi: [10.2139/ssrn.4040877](https://doi.org/10.2139/ssrn.4040877).
- Hsiao, S.H., Wang, Y.Y. and Lin, T.L. (2024), "The impact of low-immersion virtual reality on product sales: insights from the real estate industry", *Decision Support Systems*, Vol. 178, 114131, doi: [10.1016/j.dss.2023.114131](https://doi.org/10.1016/j.dss.2023.114131).

- Hsu, C.Y. (2013), "Building advantage of immersive augmented reality technology for internet marketing", *2012 4th International Conference on Environmental Science and Information Application Technology (ESIAT 2012)*, ISBN 978-1-61275-039-2, available at: <https://www.webofscience.com/wos/alldb/full-record/WOS:000399861400113> (accessed 18 November 2024).
- Hussamadin, R., Mukkavaara, J. and Jansson, G. (2020), "A method to produce and visualize interactive work instructions for modular products within onsite construction", *37th International Symposium on Automation and Robotics in Construction (ISARC 2020)*, International Association on Automation and Robotics in Construction, Kitakyushu, 27-28 October, 2020, pp. 48-55, doi: [10.22260/ISARC2020/0008](https://doi.org/10.22260/ISARC2020/0008).
- Hussin, F.A. and Bakar, A.S.A. (2023), "The adoption of virtual reality technology in real estate marketing: a review", *Journal of Advanced Research in Applied Sciences and Engineering Technology*, Vol. 32 No. 3, pp. 380-399, doi: [10.37934/araset.32.3.380399](https://doi.org/10.37934/araset.32.3.380399).
- Hwang, J. (2007), "Application based on ArcObject inquiry and Google maps demonstration to real estate database", in *Geoinformatics 2007: Geospatial Information Technology and Applications*, Vol. 6754, SPIE, pp. 842-851, doi: [10.1117/12.764972](https://doi.org/10.1117/12.764972).
- Hwang, J.-T. and Liu, H.-C. (2007), "Web-based real estate database inquiry and display with embedded Google Earth/maps", *28th Asian Conference on Remote Sensing 2007*, ISBN 978-161567365-0, available at: <https://www.scopus.com/record/display.uri?eid=2-s2.0-84865657320&origin=resultslist&sort=plf-f&src=s&sid=4c82d17f228c743ae5a0a3beb238114e&sot=b&sdt=b&s=TITLE%28Web-based+real+estate+database+inquiry+and+display+with+embedded+Google+Earth%2Fmaps%29&sl=89&sessionSearchId=4c82d17f228c743ae5a0a3beb238114e&relpos=0#metrics> (accessed 18 November 2024).
- Hwang, N.K. and Shim, S.H. (2021), "Use of virtual reality technology to support the home modification process: a scoping review", *International Journal of Environmental Research and Public Health*, Vol. 18 No. 21, 11096, doi: [10.3390/ijerph182111096](https://doi.org/10.3390/ijerph182111096).
- Ibrahim, F.S.B., Esa, M.B. and Rahman, R.A. (2021), "The adoption of IOT in the Malaysian construction industry: towards construction 4.0", *International Journal of Sustainable Construction Engineering and Technology*, Vol. 12 No. 1, pp. 56-67, available at: <https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/6299> (accessed 18 November 2024).
- Ibrahim, F.A., Boying, W., Abdul Rahim, N.S., Mohd Shafiei, M.W. and Zainol, N.Z. (2023a), "The influence of augmented reality on purchase intention in the Housing Industry", *Human Behavior and Emerging Technologies*, Vol. 2023 No. 1, pp. 5728088-5728111, doi: [10.1155/2023/5728088](https://doi.org/10.1155/2023/5728088).
- Ibrahim, F.A., Boying, W., Shafiei, M.W.M., Razak, R.A. and Ishak, N. (2023b), "Augmented reality (AR) as A promotion tool in influencing housing purchase intention", *Journal of Advanced Research in Applied Sciences and Engineering Technology*, Vol. 29 No. 3, pp. 251-259, doi: [10.37934/araset.29.3.251259](https://doi.org/10.37934/araset.29.3.251259).
- Ibrahim, F.A., Ishak, N., Woon, J.K.Y., Boying, W., Shafiei, M.W.M., Ismail, R. and Razak, R.A. (2023c), "Virtual technology (VR) attractiveness attributes in influencing house buyers' intention to purchase", *Journal of Advanced Research in Applied Sciences and Engineering Technology*, Vol. 29 No. 2, pp. 126-134, doi: [10.37934/araset.29.2.126134](https://doi.org/10.37934/araset.29.2.126134).
- Issa, C.A. and El-Hachem, A. (2014), "Integrated design and construction planning of a high-rise residential building", *Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering*, American Society of Civil Engineers (ASCE), doi: [10.1061/9780784413616.168](https://doi.org/10.1061/9780784413616.168).
- Jiang, R. (2014), "Using unity 3D game development platform to develop low cost online real estate display system", *Advanced Materials Research*, Vol. 981, pp. 213-217, doi: [10.4028/www.scientific.net/AMR.981.213](https://doi.org/10.4028/www.scientific.net/AMR.981.213).
- Juan, Y.K., Chen, H.H. and Chi, H.Y. (2018), "Developing and evaluating a virtual reality-based navigation system for pre-sale housing sales", *Applied Sciences*, Vol. 8 No. 6, p. 952, doi: [10.3390/app8060952](https://doi.org/10.3390/app8060952).

- Kamil, M.H.F.M., Yahya, N., Abidin, I.S.Z. and Norizan, A.R. (2021), "Development of virtual reality technology: home tour for real estate purchase decision making", *Malaysian Journal of Computer Science*, pp. 85-93, doi: [10.22452/mjcs.sp2021no1.8](https://doi.org/10.22452/mjcs.sp2021no1.8).
- Kaufmann, M. and Olaru, M. (2011), "Factors of resistance to technological changes of SME's in the real estate industry and how to overcome them", in *Management of Technological Changes, BOOK 1* ISBN 978-960-99486-2-3, available at: <https://www.webofscience.com/wos/alldb/full-record/WOS:000306939900165> (accessed 18 November 2024).
- Kaźmierczak, R. (2020), "Geoinformation support system for real estate market", *Acta Scientiarum Polonorum Administratio Locorum*, Vol. 19 No. 2, pp. 85-95, doi: [10.31648/aspal.4782](https://doi.org/10.31648/aspal.4782) available at: <https://www.ceeol.com/search/article-detail?id=855247> (accessed 18 November 2024).
- Kim, S. (2015), "Modeling the real estate information system based on virtual reality technology", *International Journal of Applied Engineering Research*, Vol. 10 No. 10, pp. 27255-27263, available at: https://mail.ripublication.com/ijaer10/ijaerv10n10_223.pdf (accessed 18 November 2024).
- Kim, M.J., Cho, M.E. and Chae, H.H. (2014), "A smart community for placemaking in housing complexes", *Journal of Asian Architecture and Building Engineering*, Vol. 13 No. 3, pp. 539-546, doi: [10.3130/jaabe.13.539](https://doi.org/10.3130/jaabe.13.539).
- Li, M. and Yang, J. (2022), "Digital marketing 4.0 visualization system based on smart buildings under the background of aging and intelligence", *2022 IEEE International Conference on Electrical Engineering, Big Data and Algorithms (EEBDA)*, IEEE, pp. 1-4, doi: [10.1109/EEBDA53927.2022.9744882](https://doi.org/10.1109/EEBDA53927.2022.9744882).
- Li, H., Cao, Y. and Lu, M. (2004), "Semiautomated detection of design errors in 2D drawings using 3D reconstruction", *Computer-Aided Civil and Infrastructure Engineering*, Vol. 19 No. 4, pp. 288-294, doi: [10.1111/j.1467-8667.2004.00355.x](https://doi.org/10.1111/j.1467-8667.2004.00355.x).
- Li, X., Yi, W., Chi, H.-L., Wang, X. and Chan, A.P.C. (2018), "A critical review of virtual and augmented reality (VR/AR) applications in construction safety", *Automation in Construction*, Vol. 86, pp. 150-162, doi: [10.1016/j.autcon.2017.11.003](https://doi.org/10.1016/j.autcon.2017.11.003).
- Luis, Q.N., Alisson, R.L. and de la Torre, S.J. (2021), "Viability of Virtual Reality (VR) and Augmented Reality (AR) in pre-sale of multi-family projects as a strategy for better decision-making in times of change", *19th LACCEI International Multi-Conference for Engineering, Education Caribbean Conference for Engineering and Technology: Prospective and Trends in Technology and Skills for Sustainable Social Development and Leveraging Emerging Technologies to Construct the Future, LACCEI 2021*, available at: <https://laccei.org/LACCEI2021-VirtualEdition/meta/FP356.html> (accessed 18 November 2024).
- Martínez-Graña, A.M. and Valdés Rodríguez, V. (2016), "Remote sensing and GIS applied to the landscape for the environmental restoration of urbanizations by means of 3D virtual reconstruction and visualization (Salamanca, Spain)", *ISPRS International Journal of Geo-Information*, Vol. 5 No. 1, p. 2, doi: [10.3390/ijgi5010002](https://doi.org/10.3390/ijgi5010002).
- Marzano, A., Friel, I., Erkoyuncu, J. and Court, S. (2015), "Design of a virtual reality framework for maintainability and assemblability test of complex systems", *Procedia CIRP*, Vol. 37, pp. 242-247, doi: [10.1016/j.procir.2015.08.067](https://doi.org/10.1016/j.procir.2015.08.067).
- Mendes, N.P. and Santos, E.T. (2022), "Exploratory virtual model: study and evaluation of a low-cost vr-based real estate sales tool", *Journal for Geometry and Graphics*, Vol. 26 No. 1, pp. 171-184 available at: <https://www.heldermann-verlag.de/jgg/jgg26/j26h1mend.pdf> (accessed 18 November 2024).
- Miljkovic, I., Shlyakhetko, O. and Fedushko, S. (2023), "Real estate app development based on AI/VR technologies", *Electronics*, Vol. 12 No. 3, p. 707, doi: [10.3390/electronics12030707](https://doi.org/10.3390/electronics12030707).
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. and Prisma Group, T. (2009), "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement", *Annals of Internal Medicine*, Vol. 151 No. 4, pp. 264-269, doi: [10.7326/0003-4819-151-4-200908180-00135](https://doi.org/10.7326/0003-4819-151-4-200908180-00135).
- Mokhtar, M.N.A.B.D., Ismail, I., Hamzah, W.M.A.F.W., Shamsuddin, S.N.W. and Arsad, M.A.M. (2021), "Real-time dream house decorator in the virtual reality environment", *International*

Conference on Business and Technology, Springer International Publishing, Cham, pp. 525-537, doi: [10.1007/978-3-031-08084-5_38](https://doi.org/10.1007/978-3-031-08084-5_38).

- Mora-Alvarado, M. and Llerena-Izquierdo, J. (2021), "Mobile application of registry information for urban planning context with augmented reality and QR codes", *International Conference on Smart Technologies, Systems and Applications*, Springer International Publishing, Cham, pp. 30-43, doi: [10.1007/978-3-030-99170-8_3](https://doi.org/10.1007/978-3-030-99170-8_3).
- Morimoto, T., Kobayashi, T., Hirata, H., Otani, K., Sugimoto, M., Tsukamoto, M., Yoshihara, T., Ueno, M. and Mawatari, M. (2022), "XR (extended reality: virtual reality, augmented reality, mixed reality) technology in spine medicine: status Quo and Quo Vadis", *Journal of Clinical Medicine*, Vol. 11 No. 2, p. 470, doi: [10.3390/jcm11020470](https://doi.org/10.3390/jcm11020470).
- Mufid, M.R., Tahir, M., Meiyuana, D.B., Dwileksa, A.B. and Kumiaty, E. (2020), "Housing design in planet green Tambora using augmented reality for promotion media", *2020 International Electronics Symposium (IES)*, IEEE, pp. 669-673, doi: [10.1109/IES50839.2020.9231546](https://doi.org/10.1109/IES50839.2020.9231546).
- Nanda, A., Xu, Y. and Zhang, F. (2021), "How would the covid-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization?", *Journal of Urban Management*, Vol. 10 No. 2, pp. 110-124, doi: [10.1016/j.jum.2021.04.001](https://doi.org/10.1016/j.jum.2021.04.001).
- Neil, M.J. (1996), "Architectural virtual reality applications", *ACM SIGGRAPH Computer Graphics*, Vol. 30 No. 4, pp. 53-54, doi: [10.1145/240806.240816](https://doi.org/10.1145/240806.240816).
- Nieradka, P. (2019), "Using virtual reality technologies in the real estate sector", *Annales Universitatis Mariae Curie-Skłodowska, Sectio H Oeconomia*, Vol. 53 No. 2, pp. 45-53, doi: [10.17951/h.2019.53.2.45-53](https://doi.org/10.17951/h.2019.53.2.45-53).
- Noghabaei, M., Heydarian, A., Balali, V. and Han, K. (2020), "Trend analysis on adoption of virtual and augmented reality in the architecture, engineering, and construction industry", *Data*, Vol. 5 No. 1, p. 26, doi: [10.3390/data5010026](https://doi.org/10.3390/data5010026).
- Ong, S.E., Wong, W.C., Wang, D., Lai and C.P. (2024), "The effects of visual technology on price discovery for residential listings and transactions", *International Journal of Housing Markets and Analysis*, Vol. 17 No. 2, pp. 372-394, doi: [10.1108/IJHMA-07-2022-0099](https://doi.org/10.1108/IJHMA-07-2022-0099).
- Orzechowski, M.A., Arentze, T.A., Borgers, A.W.J. and Timmermans, H.J.P. (2005), "Alternate methods of conjoint analysis for estimating housing preference functions: effects of presentation style", *Journal of Housing and the Built Environment*, Vol. 20 No. 4, pp. 349-362, doi: [10.1007/s10901-005-9019-0](https://doi.org/10.1007/s10901-005-9019-0).
- Padilla, L.M., Creem-Regehr, S.H., Hegarty, M. and Stefanucci, J.K. (2018), "Decision making with visualizations: a cognitive framework across disciplines", *Cognitive research: Principles and Implications*, Vol. 3 No. 129, pp. 1-25, doi: [10.1186/s41235-018-0120-9](https://doi.org/10.1186/s41235-018-0120-9).
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. (2021), "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews", *Bmj*, Vol. 372, p. n71, doi: [10.1136/bmj.n71](https://doi.org/10.1136/bmj.n71).
- Pangallo, M. and Loberto, M. (2018), "Home is where the ad is: online interest proxies housing demand", *EPJ Data Science*, Vol. 7 No. 47, doi: [10.1140/epjds/s13688-018-0176-2](https://doi.org/10.1140/epjds/s13688-018-0176-2).
- Park, C.S., Lee, D.Y., Kwon, O.S. and Wang, X. (2013), "A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template", *Automation in Construction*, Vol. 33, pp. 61-71, doi: [10.1016/j.autcon.2012.09.010](https://doi.org/10.1016/j.autcon.2012.09.010).
- Phommaly, K. and Yu, L. (2020), "Research of Virtual reality technology in home design", *Journal of Physics: Conference Series*, Vol. 1624 No. 6, 062017, doi: [10.1088/1742-6596/1624/6/062017](https://doi.org/10.1088/1742-6596/1624/6/062017).
- Pleyers, G. and Poncin, I. (2020), "Non-immersive virtual reality technologies in real estate: how customer experience drives attitudes toward properties and the service provider", *Journal of Retailing and Consumer Services*, Vol. 57, 102175, doi: [10.1016/j.jretconser.2020.102175](https://doi.org/10.1016/j.jretconser.2020.102175).

- Potseluyko, L., Rahimian, F.P., Dawood, N., Elghaish, F. and Hajirasouli, A. (2022), "Game-like interactive environment using BIM-based virtual reality for the timber frame self-build housing sector", *Automation in Construction*, Vol. 142, 104496, doi: [10.1016/j.autcon.2022.104496](https://doi.org/10.1016/j.autcon.2022.104496).
- Prabhakaran, A., Mahamadu, A.M. and Mahdjoubi, L. (2022), "Understanding the challenges of immersive technology use in the architecture and construction industry: a systematic review", *Automation in Construction*, Vol. 137, 104288, doi: [10.1016/j.autcon.2022.104288](https://doi.org/10.1016/j.autcon.2022.104288).
- Prabhakaran, A., Mahamadu, A.M., Mahdjoubi, L., Booth, C. and Aigbavboa, C. (2023), "Virtual reality utility and usefulness in the furniture, fixture and equipment sector: a validation of interactive and distributed immersion", *Smart and Sustainable Built Environment*, Vol. 12 No. 4, pp. 787-819, doi: [10.1108/SASBE-02-2022-0038](https://doi.org/10.1108/SASBE-02-2022-0038).
- Pralhad, G.P., Abhishek, S., Chounde, R., Kachare, T., Deshpande, O. and Tapadiya, P. (2021), "Voice controlled augmented reality for real estate", *2021 International Conference on Artificial Intelligence and Machine Vision (AIMV)*, IEEE, pp. 1-6, doi: [10.1109/AIMV53313.2021.9670978](https://doi.org/10.1109/AIMV53313.2021.9670978).
- Rabby, F., Chimhundu, R. and Hassan, R. (2022), "Digital transformation in real estate marketing: a review", *Big Data: A Road Map for Successful Digital Marketing*, Vol. 39, pp. 39-62, doi: [10.1515/9783110733716-005](https://doi.org/10.1515/9783110733716-005).
- Rashidi, A., Yong, W.Y., Maxwell, D. and Fang, Y. (2023), "Construction planning through 4D BIM-based virtual reality for light steel framing building projects", *Smart and Sustainable Built Environment*, Vol. 12 No. 5, pp. 1153-1173, doi: [10.1108/SASBE-06-2022-0127](https://doi.org/10.1108/SASBE-06-2022-0127).
- Rau, J.Y. and Cheng, C.K. (2013), "A cost-effective strategy for multi-scale photo-realistic building modeling and web-based 3-D GIS applications in real estate", *Computers, Environment and Urban Systems*, Vol. 38, pp. 35-44, doi: [10.1016/j.compenvurbsys.2012.10.006](https://doi.org/10.1016/j.compenvurbsys.2012.10.006).
- Rehman, F., Masood, H., Ul-Hasan, A., Nawaz, R. and Shafait, F. (2020), "An intelligent context aware recommender system for real-estate", *Pattern Recognition and Artificial Intelligence: Third Mediterranean Conference, MedPRAI 2019, Proceedings 3*, December 22-23, 2019, Springer International Publishing, Istanbul, pp. 177-191, doi: [10.1007/978-3-030-37548-5_14](https://doi.org/10.1007/978-3-030-37548-5_14).
- Rockel, G., Rusko, M. and Predajnińska, A. (2024), "Reshaping the world with computer technologies and their impact on the development of processes in the field of real estate trading", *Quality Innovation Prosperity*, Vol. 28 No. 2, doi: [10.12776/qip.v28i2.2024](https://doi.org/10.12776/qip.v28i2.2024).
- Sacks, R. and Barak, R. (2008), "Impact of three-dimensional parametric modeling of buildings on productivity in structural engineering practice", *Automation in Construction*, Vol. 17 No. 4, pp. 439-449, doi: [10.1016/j.autcon.2007.08.003](https://doi.org/10.1016/j.autcon.2007.08.003).
- Sacks, R., Girolami, M. and Brilakis, I. (2020), "Building information modelling, artificial intelligence and construction tech", *Developments in the Built Environment*, Vol. 4, 100011, doi: [10.1016/j.dibe.2020.100011](https://doi.org/10.1016/j.dibe.2020.100011).
- Safikhani, S., Keller, S., Schweiger, G. and Pirker, J. (2022), "Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: systematic review", *International Journal of Digital Earth*, Vol. 15 No. 1, pp. 503-526, doi: [10.1080/17538947.2022.2038291](https://doi.org/10.1080/17538947.2022.2038291).
- Salleh, S.A., Mohd, W.M.N.W. and Sadek, E.S.S.M. (2014), "The improved conceptual design of web-based GIS residential property marketing information system", in Abdul Rahman, A., Boguslawski, P., Anton, F., Said, M. and Omar, K. (Eds), *Geoinformation for Informed Decisions, Lecture Notes in Geoinformation and Cartography*, Springer, Cham, doi: [10.1007/978-3-319-03644-1_17](https://doi.org/10.1007/978-3-319-03644-1_17).
- Salvo, F., De Ruggiero, M. and Tavano, D. (2022), "Smart redevelopment of existing buildings. Use of BIM in economic value judgments", in *Urban Regeneration through Valuation Systems for Innovation*, Springer International Publishing, Cham, pp. 291-301, doi: [10.1007/978-3-031-12814-1_18](https://doi.org/10.1007/978-3-031-12814-1_18).
- Seagraves, P. (2023), "Real Estate Insights: is the AI revolution a real estate boon or bane?", *Journal of Property Investment and Finance*, p. 199, available at: <https://www.emerald.com/insight/content/doi/10.1108/jpif-05-2023-0045/full/html> (accessed 18 November 2024).

- Setyadi, R. and Ranggadara, I. (2020), "Augmented reality using features accelerated segment test for property catalogue", *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, Vol. 18, pp. 140-147, doi: [10.12928/TELKOMNIKA.v18i1.13039](https://doi.org/10.12928/TELKOMNIKA.v18i1.13039).
- Sihi, D. (2018), "Home sweet virtual home", *Journal of Research in Interactive Marketing*, Vol. 12 No. 4, pp. 398-417, doi: [10.1108/JRIM-01-2018-0019](https://doi.org/10.1108/JRIM-01-2018-0019).
- Sikarwar, R.S. and Shelake, A.G. (2023), "Delay analysis of residential construction by using augmented reality and virtual reality", *National conference on Advances in Construction Materials and Management*, Singapore, Springer Nature Singapore, pp. 41-53, doi: [10.1007/978-981-99-2552-0_4](https://doi.org/10.1007/978-981-99-2552-0_4).
- Siniak, N., Kauko, T., Shavrov, S. and Marina, N. (2020a), "The impact of proptech on real estate industry growth", *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, Vol. 869 No. 6, 062041, doi: [10.1088/1757-899X/869/6/062041](https://doi.org/10.1088/1757-899X/869/6/062041).
- Siniak, N., Grencíková, A., Marina, N. and Shavrov, S. (2020b), "The impact of proptech 3.0 on the real estate industry workplaces", *Vplyv Industry 4.0 Na Tvorbu Pracovnych Miest 2019*, Alexander Dubcek University, Trencin, available at: <https://www.lituanistika.lt/content/109944> (accessed 18 November 2024).
- Soliman-Junior, J., Awwal, S., Tzortzopoulos, P., Ayo-Adejuyigbe, M. and Kagioglou, M. (2022), "Eliciting requirements in social housing retrofit projects: tools and processes within a living lab setting", *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, Edmonton, 25-31 July 2022, pp. 468-479, doi: [10.24928/2022/0152](https://doi.org/10.24928/2022/0152).
- Song, H., Chen, F., Peng, Q., Zhang, J. and Gu, P. (2017), "Improvement of user experience using virtual reality in open-architecture product design", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol. 232 No. 13, pp. 2264-2275, doi: [10.1177/095440541771173](https://doi.org/10.1177/095440541771173).
- Sudhakaran, G.M., Prabhakaran, A., Mahamadu, A.M., Booth, C.A. and Wiejak-Roy, G. (2023), "Feeling the Earthship house: eliciting a perspective of posterity through immersive virtual reality", *Smart and Sustainable Built Environment*, doi: [10.1108/SASBE-05-2023-0122](https://doi.org/10.1108/SASBE-05-2023-0122).
- Sudhakaran, G., Prabhakaran, A., Booth, C., Abbey, S., Mahamadu, A.-M., Georgakis, P.E and Pohle, M. (2024), "Entrare nella sicurezza: una revisione sistematica delle applicazioni tecnologiche della realtà estesa nel miglioramento della sicurezza degli utenti vulnerabili della strada", *Smart and Sustainable Built Environment*, Vol. in anticipo sulla stampa, doi: [10.1108/SASBE-10-2023-0321](https://doi.org/10.1108/SASBE-10-2023-0321).
- Sun, T., Xu, Z., Yuan, J., Liu, C. and Ren, A. (2017), "Virtual experiencing and pricing of room views based on BIM and oblique photogrammetry", *Procedia Engineering*, Vol. 196, pp. 1122-1129, doi: [10.1016/j.proeng.2017.08.071](https://doi.org/10.1016/j.proeng.2017.08.071).
- Sun, C., Ye, C., Li, C. and Liu, Y. (2023), "Virtual ideality vs. virtual authenticity: exploring the role of social signals in interactive marketing", *Journal of Research in Interactive Marketing*, Vol. 18 No. 3, pp. 430-445, doi: [10.1108/JRIM-01-2023-0011](https://doi.org/10.1108/JRIM-01-2023-0011).
- Syahputra, M.F., Rinaldi, M., Muchtar, M.A., Andayani, U., Abdullah, D., Sriadhi, S., Iskandar, A., Pitasari, D.R. and Laritmas, S. (2019), "Visualization of virtual house model on property brochure using augmented technology", *Journal of Physics: Conference Series*, Vol. 1235 No. 1, 012105, doi: [10.1088/1742-6596/1235/1/012105](https://doi.org/10.1088/1742-6596/1235/1/012105).
- Szafranko, E. and Jurczak, M. (2024), "Implementability of BIM technology in light of literature studies and analyses of the construction market", *Sustainability*, Vol. 16 No. 3, p. 1083, doi: [10.3390/su16031083](https://doi.org/10.3390/su16031083).
- Tang, M. and Yang, D. (2007), "Real-time visualization in the design context", *Open House International*, Vol. 32 No. 2, pp. 7-16, doi: [10.1108/OHI-02-2007-B0002](https://doi.org/10.1108/OHI-02-2007-B0002).
- Tarpio, J. and Huuhka, S. (2022), "Residents' views on adaptable housing: a virtual reality-based study", *Buildings and Cities*, Vol. 3 No. 1, pp. 93-110, doi: [10.5334/bc.184](https://doi.org/10.5334/bc.184).
- Ullah, F., Sepasgozar, S.M. and Wang, C. (2018), "A systematic review of smart real estate technology: drivers of, and barriers to, the use of digital disruptive technologies and online platforms", *Sustainability*, Vol. 10 No. 9, p. 3142, doi: [10.3390/su10093142](https://doi.org/10.3390/su10093142).

- Um, J., min Park, J., yeon Park, S. and Yilmaz, G. (2023), "Low-cost mobile augmented reality service for building information modeling", *Automation in Construction*, Vol. 146, 104662, doi: [10.1016/j.autcon.2022.104662](https://doi.org/10.1016/j.autcon.2022.104662).
- Wang, K.C. and Tung, S.H. (2023), "Cost estimation model based on building information modeling and virtual reality for customizing presold homes", *KSCE Journal of Civil Engineering*, Vol. 27 No. 4, pp. 1397-1411, doi: [10.1007/s12205-023-0825-2](https://doi.org/10.1007/s12205-023-0825-2).
- Wang, P., Wu, P., Wang, J., Chi, H.-L. and Wang, X. (2018), "A critical review of the use of virtual reality in construction engineering education and training", *International Journal of Environmental Research and Public Health*, Vol. 15 No. 6, p. 1204, doi: [10.3390/ijerph15061204](https://doi.org/10.3390/ijerph15061204).
- Wang, M., Wang, C.C., Sepasgozar, S. and Zlatanova, S. (2020), "A systematic review of digital technology adoption in off-site construction: current status and future direction towards industry 4.0", *Buildings*, Vol. 10 No. 11, p. 204, doi: [10.3390/buildings10110204](https://doi.org/10.3390/buildings10110204).
- Wei, J. (2020), "Research and realization of real estate sales system based on VR technology", *2020 International Conference on Intelligent Transportation, Big Data and Smart City (ICITBS)*, IEEE, pp. 779-782, doi: [10.1109/ICITBS49701.2020.00170](https://doi.org/10.1109/ICITBS49701.2020.00170).
- Xiao, Yi (2014), "The building of three-dimensional geographic information system based on virtual reality", *Applied Mechanics and Materials*, Vol. 443, pp. 35-38, doi: [10.4028/www.scientific.net/AMM.443.35](https://doi.org/10.4028/www.scientific.net/AMM.443.35).
- Xiong, C., Cheung, K.S., Levy, D.S. and Allen, M. (2022), "The effect of virtual reality on the marketing of residential property", *Housing Studies*, Vol. 39 No. 3, pp. 671-694, doi: [10.1080/02673037.2022.2074971](https://doi.org/10.1080/02673037.2022.2074971).
- Yamamura, A., Hatanaka, T. and Nomura, J. (1996), "Kitchen layout design in virtual environments", *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, American Society of Mechanical Engineers, Vol. 80494, V001T01A041, doi: [10.1115/96-DETC/DFM-1415](https://doi.org/10.1115/96-DETC/DFM-1415).
- Yan, Z., Meng, Z. and Tan, Y. (2023), "Virtual reality in online real estate platforms: the what and the how", available at: <https://ssrn.com/abstract=3802243>
- Yousaf, M., Mohsin, A. and Ali, S. (2023), "An empirical analysis of non-immersive virtual reality on behavioral intentions: moderating role of openness to experience", *Review of Managerial Science*, Vol. 6 No. 2, pp. 275-290, doi: [10.47067/ramss.v6i2.322](https://doi.org/10.47067/ramss.v6i2.322).
- Yu, B. and Fan, F. (2023), "Generation Z's response to the virtual reality advertising in China", *Young Consumers*, Vol. 24 No. 3, pp. 367-377, doi: [10.1108/YC-07-2022-1558](https://doi.org/10.1108/YC-07-2022-1558).
- Yu, W., Ma, Z., Pant, G. and Hu, J. (2021), "The effect of virtual tours on house price and time on market", *Journal of Real Estate Literature*, Vol. 28 No. 2, pp. 133-149, doi: [10.1080/09277544.2021.1876433](https://doi.org/10.1080/09277544.2021.1876433).
- Zatwarnicka-Madura, B. (2018), "Gender roles and online marketing communications in real estate markets", *Ekonomia i Prawo. Economics and Law*, Vol. 17 No. 4, pp. 459-469, doi: [10.12775/eip.2018.033](https://doi.org/10.12775/eip.2018.033), available at: <https://www.ceeol.com/search/article-detail?id=728782> (accessed 18 November 2024).
- Zhang, Y., Liu, H., Kang, S.C. and Al-Hussein, M. (2020), "Virtual reality applications for the built environment: research trends and opportunities", *Automation in Construction*, Vol. 118, 103311, doi: [10.1016/j.autcon.2020.103311](https://doi.org/10.1016/j.autcon.2020.103311).
- Zhang, Y., Wang, J., Ahmad, R. and Li, X. (2022), "Integrating lean production strategies, virtual reality technique and building information modeling method for mass customization in cabinet manufacturing", *Engineering Construction and Architectural Management*, Vol. 29 No. 10, pp. 3970-3996, doi: [10.1108/ECAM-11-2020-0955](https://doi.org/10.1108/ECAM-11-2020-0955).
- Zhu, Y., Saeidi, S., Rizzuto, T., Roetzel, A. and Kooima, R. (2018), "Potential and challenges of immersive virtual environments for occupant energy behavior modeling and validation: a literature review", *Journal of Building Engineering*, Vol. 19, pp. 302-319, doi: [10.1016/j.jobe.2018.05.017](https://doi.org/10.1016/j.jobe.2018.05.017).
- Zyda, M. (2005), "From visual simulation to virtual reality to games", *Computer*, Vol. 38 No. 9, pp. 25-32, doi: [10.1109/MC.2005.297](https://doi.org/10.1109/MC.2005.297).

Table A1. Publications relevant to the economic management of housing projects (quantitative studies)

No	Author(s)	Goal of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
1	Ahmed et al. (2022)	This study investigates the effectiveness of participatory design tools for young women in the United Arab Emirates, using a questionnaire to compare conventional tools (drawings) with advanced VR tools in assessing housing designs	The main measurable outcome is a shift in satisfaction responses. In some cases, VR transformed positive responses into neutrality or dissatisfaction compared to traditional drawings. This heightened perceptual accuracy suggests that VR can improve the precision of pre-occupancy analysis and make the design process more efficient, potentially shortening design time	Advanced VR tools have proven effective in the pre-occupancy assessment process of homes, but they involve significant costs and resources, impacting the project's overall budget. A "hybrid" solution that combines the use of VR with conventional tools could represent a valid alternative to keep both costs and implementation times under control	Level of satisfaction
2	Fu et al. (2004)	Implementation of a BIM-based life cycle cost estimation tool with 3D virtual reality view	The study suggests that adopting the proposed tool could improve the accuracy of budget forecasts, contributing to the full absorption of spending overruns, which typically exceed 50% and affect about 75% of government projects	Implementing advanced BIM tools with 3D virtual reality visualisation can improve life cycle cost (LCC) estimation and financial management of construction projects, helping to reduce significant budget overruns and promoting more efficient use of economic resources in the construction industry	Life Cycle Costs (LCC)
3	Salvo et al. (2022)	Examine the adoption of BIM and Industry 4.0 technologies (digitisation, smart building, virtual reality) in the real estate sector to improve management and cost optimisation	Adopting technologies like BIM and VR for smart building redevelopment enables precise cost estimation, optimizes financial management, and supports Highest and Best Use (HBU), potentially increasing property value by 7–11% through energy and operational efficiency	The implementation of Industry 4.0 tools in redevelopment projects facilitates the economic decision-making process, and maximizing the return on investment	Construction Costs; market value

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Table A1. Continued

No	Author(s)	Goal of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
4	Soliman-Junior et al. (2022)	Through a living lab approach, examine the use of VR and AR during the retrofit of social housing and evaluate their impact on the value generated	The study highlights that the use of collaborative tools such as Virtual Reality (VR) and “value cards” (cards for prioritizing user values) in living labs for social housing retrofit projects improved requirement gathering, enabling real-time design adjustments and thus reducing inefficiencies	This approach can reduce costs resulting from post-design changes and ensure more efficient use of the project budget through an early understanding of user needs	Perceived value
5	Wang and Tung (2023)	Developing a BIM-VR system for the design and cost estimation of changes during house construction	In the case study, the choice of materials resulted in cost variations of up to 15% compared to the initial budget, reducing update times from 7–14 days to a few minutes	The study shows that integrating BIM and VR in home customization reduces errors and cost update times, optimizes decision-making, and improves economic control, making financial project management more efficient and budget-compliant	Construction Costs
6	Xiao (2014)	Study of the application of 3D/VR GIS visualisation techniques for reducing time costs in data analysis	The results show that using the proposed algorithm to visualize the real scene leads to a reduction in the time required for rendering	The proposed algorithm reduces the analysis time of geographic data in 3D/VR environments, implying a potential reduction in operating costs in construction projects requiring detailed 3D representations	Data analysis time

Source(s): Authors’ own creation/work

Table A2. Publications relevant to the economic management of housing projects (qualitative studies)

No	Author(s)	Goal of the study	Qualitative results/implications
1	Biel (2021)	Using BIM and AR to support the defect management process during the acceptance of flats in multi-family residential buildings	The MWBIM application can support the process of defect management and cost estimation during the acceptance of flats
2	Bourhim and Cherkaoui (2020)	Using Virtual Reality to simulate people's behaviour during fire emergencies in high-rise residential buildings	VR simulation of fire emergencies can be effective. Moreover, the suggested approach is less costly and demanding than fire evacuation drills in the physical environment
3	Chen and Liu (2008)	Construction of an Internet-based digital construction project management system and dynamic database, also using VR and IDSS technologies	Increased efficiency in terms of cost, time, quality, safety and sustainability
4	Dolzhencko et al. (2021)	Developing a library of parametric objects, which can also be visualised in a virtual reality environment, to simplify planning, management and cost control in the construction of wall barriers in residential buildings	The application can simplify planning, management and cost control
5	Gan and Zhang (2013)	Presentation of virtual construction technologies and their role in the industrialisation of houses	Virtual house building technologies can contribute to cost optimisation
6	Hussamadin et al. (2020)	Using VR technology to improve communication and interpretation of work instructions during construction, reducing guesswork and improving collaboration between skilled workers	VR technology can improve communication and interpretation of work instructions during construction, reducing time and costs
7	Ibrahim et al. (2021)	Review of IoT adoption in the Malaysian construction industry, also focusing on AR technology	The correct adoption of IoT in the construction industry can improve efficiency and reduce risks, construction time and costs
8	Issa and El-Hachem (2014)	Present an integrated system for visualising construction activities in 3D using virtual reality	VR technology makes it possible to model and visualise the design effect of any changes to the building configuration and calculate the effect on costs
9	Li et al. (2004)	Implementation of VR techniques to diagnose and reduce design errors	VR techniques can identify and reduce design errors in construction, also having an important impact on costs
10	Martínez-Graña and Rodríguez (2016)	Use of GIS, remote sensing and virtual visualisation for modelling the landscape impact of construction	Remote sensing and GIS techniques enable a 3D visualisation of urbanisation and related landscape restoration through virtual reality simulation. This approach offers a low-cost understanding of the landscape context prior to intervention
11	Mokhtar et al. (2021)	Developing an application for virtual home interior decoration	The application allows users to virtually explore and decorate home interiors, increasing their marketability
12	Park et al. (2013)	Propose a defect management system in construction that integrates ontologies and augmented reality with BIM and avoids cost overruns	The proposed system enables proactive defect management during construction and avoids cost overruns

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Table A2. Continued

No	Author(s)	Goal of the study	Qualitative results/implications
13	Phommaly and Yu (2020)	Applying Virtual Reality technology in home interior design to provide a more realistic and immersive representation of furniture proposals	VR technology can improve the home interior design experience, speed up design time and ensure optimal cost control
14	Sikarwar and Shelake (2023)	Examining the use of Augmented and Virtual Reality in reducing delays in construction projects in India	The use of AR and VR can improve coordination in construction projects, reducing delays and costs
15	Tang and Yang (2007)	Integration of low-cost virtual reality into the architectural design process	Integrating VR into the architectural design process can improve work efficiency and cost control
16	Wang <i>et al.</i> (2020)	Evaluation of digital technologies (including AR and VR) used in off-site construction	Digital technologies, such as AR and VR, can improve efficiency and safety in off-site construction, saving time and costs
17	Yamamura <i>et al.</i> (1996)	Describing a kitchen layout design system supported by virtual reality	The VR system allows customers to virtually experience the layout of their kitchen, facilitating design decisions and enabling cost control
18	Zhang <i>et al.</i> (2022)	Developing a production information system for the construction industry	Proposal for a system to improve efficiency in the production of customised houses

Source(s): Authors' own creation/work

Table A3. Publications relevant to residential property valuation or marketing (quantitative studies)

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
1	Adegoke <i>et al.</i> (2022a)	Analysing the factors influencing real estate agencies' decision to adopt VR technology	The study found that the intention to use VR in real estate firms is primarily influenced by performance expectations, ease of use, social influence, facilitating conditions, hedonic motivation, and price value, with the latter exerting the highest causal influence ($R_i - C_j = 0.1284$)	The study raises awareness among real estate firms about factors impacting VR adoption and supports the Nigerian Institution of Estate Surveyors and Valuers in promoting VR integration in agency practices	Intention to use, Performance expectation, Effort expectation, Social influence, Facilitating conditions, Hedonic motivation, Perceived value

(continued)

Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
2	Adegoke et al. (2022b)	Analysing the criteria used in measuring the determinants of VR technology adoption in real estate agencies in Lagos	The study shows that VR adoption is primarily influenced by the perceived value of output quality ($R_i + C_j$ value of 2.0621), the frequency and actual number of uses (maximum $R_i + C_j$ value of 2.6172), and social influence (subjective norms with $R_i - C_j$ of 0.0549)	Real estate agencies could justify VR adoption costs if it improves service effectiveness and customer satisfaction, with economic return closely tied to the frequency of use and the intensity of technology adoption by agents	Perceived usefulness, Relative advantage, Perceived ease of use, Complexity, Subjective norms, Behavioural control, Production quality (to measure perceived value), Frequency of use
3	Allen et al. (2015)	Investigating the effect of sales strategies (including property visualisation via low-immersive MLS virtual tours) on the pricing of residential properties using Singapore data	Marketing strategies such as public open houses, broker open houses, MLS virtual tours, and MLS photography can increase home sale prices by up to 10.2%, or approximately \$21,600 on a median home price of \$211,649. Broker open houses boost the likelihood of sale by 4.6%, and MLS virtual tours by 4.7%. Conversely, public open houses reduce the probability of sale by 6.1%	Marketing strategies such as MLS photography, virtual tours, and broker open houses enhance the perceived value of residential properties, improving the reliability of market valuation and suggesting that brokers strategically use these techniques to position properties and optimize the sales process effectively	Sales Probability, Sales Price, Time on Market (TOM)
4	Amed et al. (2020)	Develop an AR/VR system for the presentation and management of pre-sales houses, allowing the modification of materials, design and construction programme in real time according to the client's needs (including economic needs)	The study shows that the use of VR and AR in pre-sale real estate projects allows customers to make changes to materials and design, increasing the perceived value of properties and reducing the risk of subsequent changes, with considerable cost savings compared to traditional methods	VR and AR improve transparency and perception of quality, facilitating a more precise evaluation and making pre-sale properties more attractive to customers, thanks to greater customization and involvement in the project	Pre-sales price, Cost of materials, Project timescale

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
5	Anderson et al. (2024a)	Examine the effect of specific brokerage strategies, including MLS (low-immersive) virtual tours, on prices and Time on Market (TOM)	Virtual tours significantly increase the selling price of occupied properties, with a 7.25% premium for low-priced properties using VR in the first few days on the market, although this percentage decreases to -4.8% for properties that are on the market for a long time; high-end properties show an inverse effect, with initial discounts of up to -9.8% that convert into premiums of up to 5.3% for long periods on the market	Virtual tours prove to be an effective tool to increase the perceived value and competitiveness of difficult-to-show properties, with variable effects on price and timing of sale, suggesting that their use should be strategic and oriented to the price target and the type of occupant to maximize the economic and marketing return	Sales price, Time on Market (TOM)
6	Azmi et al. (2022)	Investigating the potential of virtual reality (VR), for residential real estate marketing, to influence home purchase intention	The virtual atmosphere in VR positively influences buyers' pleasure emotions, significantly increasing purchase intention (with a coefficient $\beta = 0.857$ for pleasure). However, the lack of free movement and tactile sensation reduces VR's effectiveness in replicating the real environment, as arousal does not have a relevant impact on purchase intention ($p > 0.05$)	Enhancing VR with sound, tactile feedback, and natural movement is crucial for creating a more realistic and engaging simulation, paving the way for a digital transformation in user-centred real estate marketing	Purchase intention

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
7	Azmi et al. (2020)	Assessing the potential of virtual reality as a pre-purchase evaluation tool for potential property buyers	The study reveals that, although similar emotions are evoked, the virtual reality environment scores lower in atmospheric evaluation compared to the real environment (average score of 5.51 vs. 6.06) and shows a slight reduction in purchase intention (5.56 vs. 5.96), indicating that enhancing the quality of the VR experience is necessary to achieve an equivalent impact	The paper highlights the practical implications of using virtual reality in housing design evaluation, making projects more empathic, user-centred, and able to meet the emotional and social needs of potential homebuyers	Emotions, purchase intention
8	Benefield et al. (2012)	Analysing the impact of satellite imagery, as a support tool for virtual tours, on price and market time of real estate properties	The results show that, while satellite images do not affect residential property prices, they have a statistically significant, albeit economically modest, positive impact on sale times. This suggests that including satellite images can slightly accelerate property marketing by enhancing overall perception	The practical implications for the residential real estate sector suggest that integrating additional, unique visual data like satellite images could enhance marketing strategies by providing prospective buyers with a broader context, potentially improving buyer engagement and decision-making efficiency	Buying and selling prices, Time on Market (TOM)
9	Benefield et al. (2019)	Assessing the impact of the introduction of VR virtual tours in the residential brokerage market	The main finding of the study highlights that the use of virtual tours, as a measure of agent effort, increases property sale prices by 3% for lower-priced homes and 1.6% for higher-priced homes, without significantly affecting the agent's commission rate. However, it also increases the average time on market by approximately 17.6 days	The study suggests that virtual tours can create a conflict of interest, as agents incur costs that may not be fully offset by immediate commissions, although long-term use could benefit agents by enhancing market positioning	Sales Prices, Time on Market (TOM), Commission Rate

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
10	Casas-Mateus and Chacon-Sanchez (2019)	Assessing the effect of using virtual environments on emotional perception in real estate	The main impact of the study shows that the use of immersive environments built with AutoCAD and Unity increases normalized levels of 4 out of 5 emotions, reducing costs for real estate companies by eliminating the need to construct physical model homes	The implications for real estate valuation and marketing highlight that, through emotional analysis, it is possible to enhance the user experience by customizing the immersive environment based on buyer preferences, potentially increasing engagement and interest	Involvement, Frustration, Instant excitement, Long-term excitement
11	Deep <i>et al.</i> (2023)	Investigating the effect of AR and VR on the real estate investment decision-making process and identifying latent variables influencing this process	AR and VR technologies significantly influence real estate investment decisions by enhancing value perception, innovative appeal, transaction trustworthiness, and ease of property interaction. Adopting these technologies increases potential buyers' confidence by 54%, reducing costs and time associated with physical visits	AR and VR technologies facilitate more informed purchasing decisions, reduce perceived risks, and increase transparency, creating an immersive buying experience that attracts investors with an improved perception of value and innovation, thus strengthening the real estate sector as an innovative and trustworthy market	Perception of value, Investment attractiveness, Reliability of transactions, Effortless involvement
12	Hou and Li (2022)	Examining the effect of VR technology on housing mobility and property transactions using an endogenous regression model	The VR technology reduces the time on market (TOM) of homes by about 32 days on average, with a greater reduction (67 days, or 31.5%) for homes in difficulty selling	VR technology speeds up real estate transactions and improves sales efficiency, even in challenging times, such as the pandemic, as VR viewings can replace on-site visits	Time on Market (TOM)
13	Hsiao <i>et al.</i> (2024)	Analysing the impact of VR signals on real estate transactions in different price ranges	The use of low-immersion VR in real estate tours increases sales profits by up to 19.7% for low-tier properties, while mid-tier properties see an 8.2% profit increase, highlighting a significant positive impact of VR on revenues, with less relevant effects for high-tier properties	The adoption of VR technology could transform the way online property viewings and presentations are conducted, potentially shortening decision times and influencing buyer confidence in an increasingly digital real estate market	House prices, real estate profitability

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
14	Ibrahim et al. (2023a)	Investigating the effect of marketing communication channels through the adoption of AR in home buying	The use of augmented reality (AR) in real estate marketing significantly increases purchase intention, showing that preference and liking for AR home models have a positive impact on purchasing intent, with a moderate correlation of $r = 0.655$ for AR preference and $r = 0.621$ for AR's effectiveness as an advertising tool	The adoption of AR in real estate marketing allows potential buyers to better visualize property layouts, enhancing engagement and decision-making beyond the limitations of traditional tools like brochures and 3D models	Purchase intention
15	Ibrahim et al. (2023b)	Exploring the relationship between AR applications and the purchase intention of potential home buyers	The study shows that using augmented reality (AR) technology in real estate promotion has a significant impact on purchase intention, with a moderate positive correlation between AR and potential buyers' purchase intentions	The study suggests that AR could become an essential promotional tool for real estate developers by providing an immersive visual experience that builds trust and purchase intention, bridging the information gap between buyers and sellers	Purchase intention
16	Ibrahim et al. (2023c)	Analysing the relationship between channel characteristics and home buyers' purchase intention through VR	The main result of the study indicates that adopting VR for virtual home model visualization in the pre-purchase phase significantly improves potential buyers' purchase intention, as evidenced by a very strong positive correlation (value $r = 0.793$), demonstrating a significant relationship between VR usage and purchasing decisions	The using VR as a marketing tool could become essential for real estate companies, enhancing user experience and shortening the decision-making time through immersive environment simulation	Purchase intention

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
17	Juan <i>et al.</i> (2018)	Assessing the effect of VR on project understanding and purchase intention in the Taiwanese real estate sector through a VR navigation system	The main result of the study is that using the VR-based navigation system for pre-sale housing significantly improved clients' project understanding and purchase intention, with an average increase of 1.27 points (on a 5-point Likert scale) compared to traditional navigation	The study's implications suggest that integrating VR in real estate marketing can reduce the cognitive gap between pre-sale representations and final products, offering clients an immersive experience that enhances their satisfaction and confidence in purchase decisions	Purchase intention
18	Mora-Alvarado and Llerena-Izquierdo (2021)	Developing a mobile application to obtain property information via augmented reality and QR codes	The study showed an 88% user interest in using the BuildingQR application for real estate information management, with an 84% perceived ease of use and a user satisfaction level exceeding 90%	The research demonstrates that technologies like augmented reality and QR codes can enhance transparency and accessibility of real estate information, promoting the adoption of digital solutions in urban planning and smart city development	Property prices
19	Ong <i>et al.</i> (2024)	Estimating the effect of the agent's efforts, via virtual tours, on prices and the duration of the real estate transaction	The study found that properties with virtual tours or drone videos sell at 5.5 and 0.5% higher prices, resulting in premiums of S\$64,680 and S\$5,880 compared to properties without these technologies; however, marketing time extends by about 8 days for properties with virtual tours	The use of visual technologies enhances the marketability of properties by reducing informational asymmetries, increasing the probability of sale, and transaction prices; additionally, it supports targeted strategies in market segments that value higher informational transparency	Buyer arrival rate, Probability of sale, Transaction prices, Time on M Market (TOM)

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
20	Orzechowski et al. (2005)	Comparing the use of verbal descriptions and multimedia representations (virtual reality) in the assessment of housing preferences	The study found no significant differences in estimated housing preferences between verbal descriptions and multimedia representations (virtual reality), but multimedia presentation showed higher reliability with lower error variance and 53% correct predictions for control profiles	Less costly verbal descriptions of housing attributes may suffice to obtain valid preferences in real estate, while accuracy can improve with the use of multimedia visualizations	Utility
21	Pleyers and Poncin (2020)	To examine, through a questionnaire, the effects of non-immersive VR experience on consumer attitudes and experience of visiting a real estate website	The use of non-immersive VR technology for property visits, compared to photos, significantly increases the presence experience (with average scores of 3.94 compared to 3.33) and emotional involvement (4.72 compared to 3.98), improving both the intention to actually visit and the positive attitude towards the real estate agency (with average increases of 3.81 compared to 3.33 respectively)	The results suggest that the implementation of non-immersive VR virtual tours can represent an effective differentiation tool for real estate agencies, strengthening the user experience and improving the perception and trust of customers towards the agency and the properties presented	Attitudes towards products and the agency
22	Sihi (2018)	Exploring the impacts of digital technologies, in particular VR and AR, on consumers' purchasing decision-making process	The use of VR and AR technologies in the search and selection phases of real estate purchases significantly accelerates the process, with 90% of buyers and over 75% of agents considering virtual tours helpful in reducing physical visits and saving time	The integration of VR and AR technologies in real estate marketing not only makes the evaluation process more efficient but also requires real estate agents to provide realistic and personalized virtual experiences to remain competitive and enhance the buyer's experience	Purchase intention

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
23	Sudhakaran et al. (2023)	Investigating the perception of Earthship low-cost buildings among young people in the UK using VR technology	The study shows that after using virtual reality, young people's positive perception of Earthship Houses as a sustainable, long-term housing option increased from 23% to 67%, indicating a significant impact of virtual reality on awareness and acceptance of innovative housing concepts	Virtual reality technologies enhance property understanding and can facilitate the valuation and marketing of sustainable housing solutions, providing immersive experiences that make innovative housing concepts more tangible and comprehensible, increasing potential buyer interest	Attitude
24	Sun et al. (2023)	Investigating the roles of virtual authenticity and virtual ideality in shaping consumer responses, as well as the role of social signals in the VR context applied to real estate service platforms	The main result of the study shows that virtual authenticity (VA) increases perceived diagnosticity by 20%, while virtual ideality (VI) boosts consumer inspiration by 25%, both positively influencing visit intention	Real estate marketing platforms can use VA to provide detailed and realistic property information, while VI can be used to enhance inspiration, fostering greater customer engagement in future visits	Perceived Diagnostics, Inspiration, Intention to Visit
25	Sun et al. (2017)	Developing a method to assess the influence of room views on flat prices	The main result of the study shows that the integration of BIM and oblique photogrammetry allows for a preliminary assessment of room view prices in residential buildings, with virtual experiences revealing up to a 30% price variation between rooms with different views	Residential real estate marketing can leverage this technology to provide potential buyers with immersive experiences of room views, thus enabling a more accurate evaluation of willingness to pay and optimizing sale prices	Willingness to Pay (WTP)
26	Xiong et al. (2022)	Investigating how emerging technologies, such as VR, influence real estate purchase decisions, using real estate transaction data	The study shows that: a 1% increase in followers on a real estate portal leads to 21% more physical visits; VR tours reduce the time to sell by 6.4% and the bid-ask spread by 2%	These findings suggest that VR technology enhances the home-buying process, increasing buyer engagement and streamlining property transactions	Number of followers, Number of physical visits, Time on Market (TOM), Bid-ask spread

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Table A3. Continued

No	Author(s)	Goals of the study	Results/Impacts	Implications	Behavioural or economic-financial quantities
27	Yousaf et al. (2023)	Examining the impact of VR in real estate and the effects of offering consumers a non-immersive experience through an existing technology	Using non-immersive VR for property tours increased consumer visit intention by 33.6% and improved property knowledge perception	The study highlights that offering enhanced VR experiences to customers strengthens the perception of service and fosters brand loyalty, with the real estate VR market expected to exceed \$2.5 billion by 2025, giving those who adopt these technologies an edge	Visiting Experience, Attitudes, Behavioural Intentions
28	Yu and Fan (2023)	Assessing young consumers' response to flat advertising via VR in China	The study finds that the informational richness and sense of presence offered by VR technology increase rental intentions by 38.6% among young users, demonstrating a significant positive impact on engagement	Integrating VR into real estate marketing strategies enables rental service providers to create interactive experiences that attract young consumers, thereby enhancing the appeal of advertised apartments	Intention to rent the flat
29	Yu et al. (2021)	Studying the impact of virtual tours on TOM and real estate sales price using matching methods and 2SLS models	The study shows that integrating virtual tours in real estate listings increases the selling price by 2–4.5% and extends the average time on the market by about 3–7 days, although the effect on time varies depending on the specific sample used	The findings suggest that the use of virtual tours not only enhances property value perception among buyers but also represents a marketing strategy that can increase property appeal, supporting a higher price and extended visibility	Sales price, Time on Market (TOM)
Source(s): Authors' own creation/work					

Table A4. Publications relevant to residential property valuation or marketing (qualitative studies)

No	Author(s)	Goals of the study	Qualitative results/implications
1	Adrianto <i>et al.</i> (2016)	Using Augmented Reality as an interactive marketing tool to promote real estate products through virtual brochures	AR application increases customer interest and reduces production costs
2	Alvanchi <i>et al.</i> (2021)	Propose a new method (augmented semi-reality) to address safety issues in the pre-sales marketing process of buildings under construction	Real estate agents rated the method positively for its ability to attract customers' attention and facilitate the decision-making process
3	Anderson <i>et al.</i> (2024a)	Application of Augmented Reality in the real estate sector to improve customers' buying experience, increase sales, reduce TOM and lower prices	The application of AR can improve the buyers' experience and facilitate the sale of property
4	Anderson <i>et al.</i> (2024b)	Studying how VR virtual tours influence the residential property market by impacting the perceived value of homes	VR virtual tours greatly influence the perception of value
5	Athick and Lee (2020)	Joint use of 3D virtual models (low-immersive VR) and GIS for visualisation and registration of real estate and underground utilities	The proposed approach, based on GIS, VR-3D and surveying technologies, enables more accurate recording of properties and more efficient management of underground utilities
6	de Macedo <i>et al.</i> (2014)	Developing an application for displaying real estate advertisements via mobile augmented reality	The application allows users to view property listings on geographical maps, enriching the property search and selection experience
7	Deaky and Parv (2018)	Presenting a VR implementation for real estate developers, emphasising immersion and use within projects to be built and saving time and money for sellers and buyers	Enhancing the real estate presentation experience with the use of VR
8	Du and Zhou (2022)	Develop a virtual real estate visualisation system and evaluate user satisfaction	The virtual real estate viewing system has received positive feedback from users and is therefore able to attract potential buyers
9	Fan and Zhang (2018)	Using VR technology to allow consumers to explore property interiors virtually, facilitating the purchase decision-making process	VR technology can enhance the visualisation and interaction experience of property interiors, better meeting the emotional and social needs of potential buyers
10	Florián Castillo <i>et al.</i> (2023)	Determining different marketing strategies for an SME in the real estate sector, using a mixed methodology and a non-experimental cross-sectional design	Strategies such as corporate video marketing, social media response automation, alliances with industry companies and 360° virtual tours can increase customer acquisition and position the company's brand
11	Guo and Qin (2011)	Proposing a way to improve the competitiveness of real estate companies by using VR technology in online marketing	VR technology can improve corporate image and marketing capability
12	Hsu (2013)	Developing a real estate marketing website using AR technology to improve the user experience and increase business opportunities for marketing companies	AR technology can improve user experience in real estate marketing
13	Hwang (2007)	Implementing a query interface for real estate websites with spatial analysis and virtual reality functionality	The interface offers a spatial solution for queries and demonstrates real estate information in advanced visual ways, saving time and costs

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Table A4. Continued

No	Author(s)	Goals of the study	Qualitative results/implications
14	Hwang and Liu (2007)	Developing a query interface for real estate listings (including VR models of dwellings) based on geographical zones	The interface allows users to query real estate listings according to geographical areas, enriching the search with contextual spatial information
15	Jiang (2014)	Developing a low-cost online system for real estate marketing using Unity 3D	The proposed system offers a cost-effective solution for online real estate marketing, exploiting virtual reality technologies to improve the effectiveness of communication
16	Kaufmann and Olaru (2011)	Identifying factors contributing to the reluctance of SMEs to implement new marketing possibilities in the real estate sector (including VR/AR tools)	Main factors: lack of IT knowledge, costs perceived as too high, lack of time, lack of factual information
17	Kaźmierczak (2020)	Developing an automated information system for real estate market participants based on GNSS positioning and AR technologies to provide filtered information in real time while visiting a property	The proposed system allows real estate market participants to access filtered information in real time while visiting a property, thus improving the search experience and reducing brokerage costs
18	Kim (2015)	Using VR technology to allow consumers to explore property interiors virtually, facilitating the purchase decision-making process	VR technology can reduce costs and effort in acquiring property information, allowing consumers to virtually explore the interior and exterior spaces of properties
19	Kim et al. (2014)	Assessing the activation of housing communities through the “smart” paradigm and the use of mobile augmented reality	The use of mobile augmented reality can help create new types of housing communities, creating value and facilitating interactions and economic, social and environmental sustainability
20	Li and Yang (2022)	Analysis of the application of an intelligent decision support system in the digital marketing visualisation system for intelligent buildings	Creation of a visualisation system for the digital marketing of intelligent buildings
21	Luis et al. (2021)	Developing procedures for the real estate pre-sale phase through the use of technological tools to create an immersive experience for end customers, facilitating informed decision-making	The use of technology tools can improve the real estate sales experience and facilitate informed decisions by customers
22	Mendes and Santos (2022)	Developing an exploratory virtual model (EVM) as an alternative to sales displays for the real estate industry	EVM can replace the traditional architectural model with less cost and time
23	Miljkovic et al. (2023)	Exploring the advantages and disadvantages, including economic ones, of artificial intelligence and virtual reality technologies in real estate	AI and VR technologies can benefit the real estate market
24	Mufid et al. (2020)	Using Augmented Reality as an interactive marketing medium to promote real estate products	AR can be an interactive marketing medium to promote real estate products and increase demand
25	Neil (1996)	Using VR technology to assist customers in identifying their preferences and customising the details of new constructions	VR technology allows customers to customise the details of new residential buildings, enhancing the buying experience and customer satisfaction

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Table A4. Continued

No	Author(s)	Goals of the study	Qualitative results/implications
26	Potseluyko <i>et al.</i> (2022)	Exploring the application of BIM, gamification and VR for the visualisation and customisation of prefabricated houses	The combined use of BIM, gamification and VR can improve customer satisfaction and increase sales
27	Pralhad <i>et al.</i> (2021)	Design a method to project a house onto an image target and allow the user to explore the interior of the house using augmented reality	AR software can help real estate developers overcome challenges in attracting customers and improving their shopping experiences
28	Rau and Cheng (2013)	Propose a 3D GIS-based virtual building modelling strategy for the real estate market	The proposed application is efficient, cost-effective, and a useful support for decision-makers
29	Rehman <i>et al.</i> (2020)	Develop a property recommendation system based on GORU and Cosinus Weighted Similarity to provide relevant suggestions to users when searching for properties online via VR virtual tours	The proposed system outperforms various RNN-based solutions and baselines in providing relevant suggestions to users when searching for properties online
30	Salleh <i>et al.</i> (2014)	Designing a Residential Real Estate Marketing Information System based on web GIS and VR	Integration of web GIS with virtual reality technologies is successful, but requires improvements in query management and 3D visualisation
31	Setyadi and Ranggadara (2020)	Using Augmented Reality as an interactive marketing medium to promote real estate products	AR can be a valuable interactive marketing medium to promote real estate products
32	Siniak <i>et al.</i> (2020a)	Exploring PropTech applications (including AR and VR) in the real estate industry	Real estate technologies are changing industry dynamics and market transparency
33	Siniak <i>et al.</i> (2020b)	Examine emerging trends related to the digital transformation of the real estate sector, with a focus on PropTech and its implications	PropTech is influencing the digital transformation of the real estate sector and has significant implications for the market, competitiveness and labour
34	Syahputra <i>et al.</i> (2019)	Using Augmented Reality as an interactive marketing tool to promote real estate products through virtual brochures	AR can be used to create interactive virtual brochures that increase customer interest and reduce production costs
35	Tarpio and Huuhka (2022)	Assessing the value residents place on housing adaptability through the use of semi-immersive virtual reality (3D-CAVE)	VR facilitates the selection of accommodations with adaptable characteristics, influencing their potential purchase
36	Wei (2020)	Using VR technology to allow consumers to explore property interiors virtually, facilitating the purchase decision-making process	VR technology can improve the experience of viewing property interiors, facilitating the purchase decision-making process for consumers and reducing marketing costs
37	Zatwarnicka-Madura (2018)	Identifying current real estate marketing strategies, examining the gender roles of suppliers and customers and evaluating the use of virtual reality in marketing communications	Identification of key trends in real estate marketing communication. Adoption of VR technologies to reach young people

Source(s): Authors' own creation/work

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