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Review

Leveraging Smart City Technologies for Enhanced Real Estate Development: An Integrative Review

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Highlights:

What are the main findings?

- Smart technologies are mature enough to leave academic shelves and be utilized in the practical field;
- A total of 131 added values were captured from the investigated technologies, such as site selection using GIS;
- Smart technologies have the highest add values at the operation sub-phase;
- There are no other sufficient alternatives for real estate developers than utilizing smart technologies in real estate development; more smart real estate must be developed in the near future;
- City management and municipalities have a significant role in activating smart technologies and their added values, transitioning cities and real estate into smarter ones.

What is the implication of the main finding?

- City management should invest in big data and geodata, develop a smart infrastructure, activate automated building permits, and create a digital twin for the city.
- Real estate developers should focus on GIS, BIM, Big Data, and AI, significantly impacting the acquisition and conception phases by using GIS for site selection, BIM for design, Big Data for market analysis, and AI for predictive analytics.

Abstract: This study aims to identify the added value of smart city technologies in real estate development, one of the most significant factors that would transform traditional real estate into smart ones. In total, 16 technologies utilized at both levels have been investigated. The research followed an integrative review methodology; the review is based on 168 publications. The compiled results based on metadata analysis displayed the state of each technology's added values and usage in both scales. A total of 131 added values were identified. These added values were categorized based on the real estate life cycle sub-phases and processes. Moreover, the value of the integration between these technologies was revealed. The review and results proved that these technologies are mature enough for practical use; therefore, real estate developers, city management, planners, and experts should focus on implementing them. City management should invest in Big Data and geodata and adopt several technologies based on the aspects required for development. This study can influence stakeholders, enhance their decision-making on which technology would suit their needs, and provide recommendations on who to utilize them. Also, it provides a starting point for stakeholders who aim to establish a road map for incorporating smart technologies in future smart real estate.

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1. Introduction

Smart technologies and solutions are considered the backbone of the smart city (SC) [1,2]. The SC technologies' role goes beyond the traditional objectives of enhancing the quality of life and optimizing urban services [3]. They are keys to facing challenges impacting the cities' economy and vision as well as facilitating sustainable development [3,4]. The future lies in collaboration and integration between SCs, smart real estate (SRE), and smart technologies. Cross-sector and public-private partnerships will be critical in fostering sustainability and innovation [5]. Sometimes, SCs are thought to be only about new technologies that they bring. However, SCs are much more than technology [6]. The label "smart city" is not limited to cities that adopt advanced technology; technology is an important factor that should be focused on [7]. The integration of SC technologies has emerged as a transformative force, reshaping the dynamics of SCs and SRE in extraordinary ways [1]. One of the SC aims is to use technologies to manage urban spaces [8].

It has been proven that there is a significant integration between SC and SRE and a reciprocal relationship between them [1]. Intelligent buildings within SCs are pivotal in establishing sustainable, streamlined, and robust urban ecosystems [9]. Due to SC technologies, many experts imagine SCs as living entities and use organic descriptions [10]. Due to the importance of SC technologies, several steps might be beneficial to adapt: investment in the research and development of SC technology applications, development and commercialization of technologies such as smart buildings to connect various functions throughout the city, utilization of smart technologies in city policy, and encouragement of smart talents to utilize them. Smart talent will be part of the administrative manpower, helping to avoid repeating and reshaping the administrative tasks in SCs due to the introduction of new technologies [7]. Although smart technologies hold immense potential for use in the built environment, their adoption and implementation are currently limited [11].

A SC should utilize its technology to offer the most intelligent and interconnection capabilities [2]. Investing in CS construction leads to enhanced real estate development (RED) as it adds value to the properties, increases the investors' trust, produces profits, and increases market competition. Technological advancements provide essential tools to enhance SC orientations [6]. The construction of SC and SRE heavily depends on the application of advanced technologies at the early stages [7]. Numerous factors, including innovation and advancement in new technologies, determine the value of real estate investment [6]. The real estate market has undergone a digital revolution in the past two decades driven by technological innovations. This transformation is reshaping the activities of real estate specialists, agents, and consultants through data analysis and digital tools. It can be achieved through technological enhancement and adoption in various sector aspects. The shift towards digitalization is fundamentally changing the traditional methods of real estate operations into smarter ones [12]. Real estate is evolving beyond the cyclical undulation of returns. The forefront of its investment decisions highlights the influence of technological trends on the built environment [6]. The sector still adopts property technology (PropTech) 2.0, while 3.0 solutions are emerging [13].

Limited published literature manuscripts mention SC technology and innovation and their role in SRE, which could be because the advocating for adopting new technologies and disruptive innovation has only recently increased, with efforts toward creating SCs [6]. As such, this study aims to comprehensively examine the added value of SC technologies in the RED through an integrative review. As cities shift to smarter ones and integrate technologies, it becomes essential to understand the contributions and synergies that SC technologies bring to the real estate sector. The integrative review aids in filling the gaps in the current understanding of these technologies' role in developing real estate. The review explored a wide range of literature on SC, technology, and SRE in various disciplines. Furthermore, this study aims to contribute to the existing body of knowledge and verify the added values of SC technologies to SRE. The study's significance stems from city planners, urban designers, real estate developers, investors, government, municipalities, and those highly interested in smart technologies, as this study discusses which added values each technology provides, at which phase to utilize them, and how to utilize them through the provided recommendations.

This paper is structured as follows: Section 2 provides an overview of the background. Section 3 explains the study methodology. Section 4 illustrates content and bibliographic analysis. Section 5 provides an integrative review of the selected technologies. Section 6 reveals the study results and discussion. Finally, Section 7 concludes the paper.

2. Background

2.1. Smart Technologies Added Values

The technological revolution has a high value; introducing new technologies brings many added values and consequences for many sectors [10]. SC technologies have transformed connections, influencing RED by promoting smart buildings [14]. The connectivity enhancement optimizes sustainability and improves the residents' quality of life [15]. Incorporating sustainable practices is a key feature of SC technology in RED [16]. Decision-making in SRE is influenced by SC technologies, which make them data-driven [15]. These data are used for decision-making and SRE management [1]. The generated data and their analysis provide insights into investment opportunities, market trends, and buyer preferences, and they help reach informed decisions for several aspects, such as site selection, land-use planning, and project efficiency [15]. Strategic urban planning influenced by smart infrastructure development enhances the appeal and value of real estate properties [17]. Smart technologies contribute to an elevated quality of life in RED [18]. They have countless added values to the real estate industry and its growth by enhancing efficiency, transparency, and accessibility. It has streamlined transactions and operations, improved data analysis and decision-making, and enabled virtual property tours.

Additionally, they have optimized energy usage, supported sustainable practices, and fostered better communication and collaboration among stakeholders [15]. Braesemann and Baum's study [19] revealed that smart technologies are an increasingly important global phenomenon. An analysis of over 7000 PropTech firms shows that data analytics technologies are at the core of this transformation. The findings highlight the efficiency gains from digitalization and the importance of understanding the business value of data generated in real estate transactions.

2.2. Smart Technologies

SC Technologies are one of the most defining features of SCs [2]. They are fundamental tools for creating livable SCs, creating connected systems to detect, capture, and efficiently manage and integrate real-time information accessible within the area [12]. The available SC technologies reveal the degree of urban smartness at the surface level. However, integrating these technologies is the more important aspect, as the effects and value of the integration would be observed on many levels [10]. The information network is critical for constructing SCs [20]. Using information and intelligent processing is only one stage; developing SCs and SREs requires establishing a high-tech information operational system and a sharing platform to analyze collected information. The success of an SC relies heavily on its ability to integrate cutting-edge technologies into its infrastructure. SC's success leads to SRE's success and vice versa [1]. Real estate technology integrates digital platforms and software utilized by various industry participants, such as investors, brokers, owners, and consumers, to enhance operations and decision-making processes [21].

Integrating various SC technologies creates a connected and dynamic smart system, reshaping the SC and impacting SRE's development. The smart technologies are categorized based on their main function, as shown in Figure 1. However, these technologies are not limited to their category, as they can be integrated with other categories as well. Big Data is at the core of this synergy, operating as the information source managing and analyzing data for decision-making processes [17]. Artificial intelligence (AI) uses these data to enhance analytics and automation, optimize resource allocation, and improve operational efficiency; they can be utilized in countless ways. Several sub-technologies branch from AI, such as machine learning (ML) [22,23]. Information and communication technology (ICT), the Internet of Things (IoT), cloud computing, and software as a service (SaaS) are the spine of this smart system network, forming the base for efficient communication, networking, and data exchange [24]. Drones, 3D Scanning, 3D Printing, and Wearable Technologies contribute to the physical transformation of SCs and SRE by automating tasks and advancing construction processes, enabling accurate data collection [15,21,25]. The users' experiences are refined by Virtual Reality (VR) and Augmented Reality (AR), offering immersive insights into property previews [26]. Sensors and actuators are integrated and connected to most technologies to capture situations and statuses such as movement and temperature and provide data based on them [27,28]. The distribution of Sensors and Actuators, along with technologies such as Digital Twins (DT), Building Information Modeling (BIM), and Geographic Information Systems (GIS), ensures the real-time monitoring, management, and optimization of SCs and SRE; they provide insight into an enhanced decision-making [2,15,29]. Smart Contracts and blockchain technology introduce transparency and security, transforming SRE transactions [22]. This integrated web of technologies adopts the creation of smart, sustainable, efficient, and connected SCs and SREs that keep on developing and evolving.

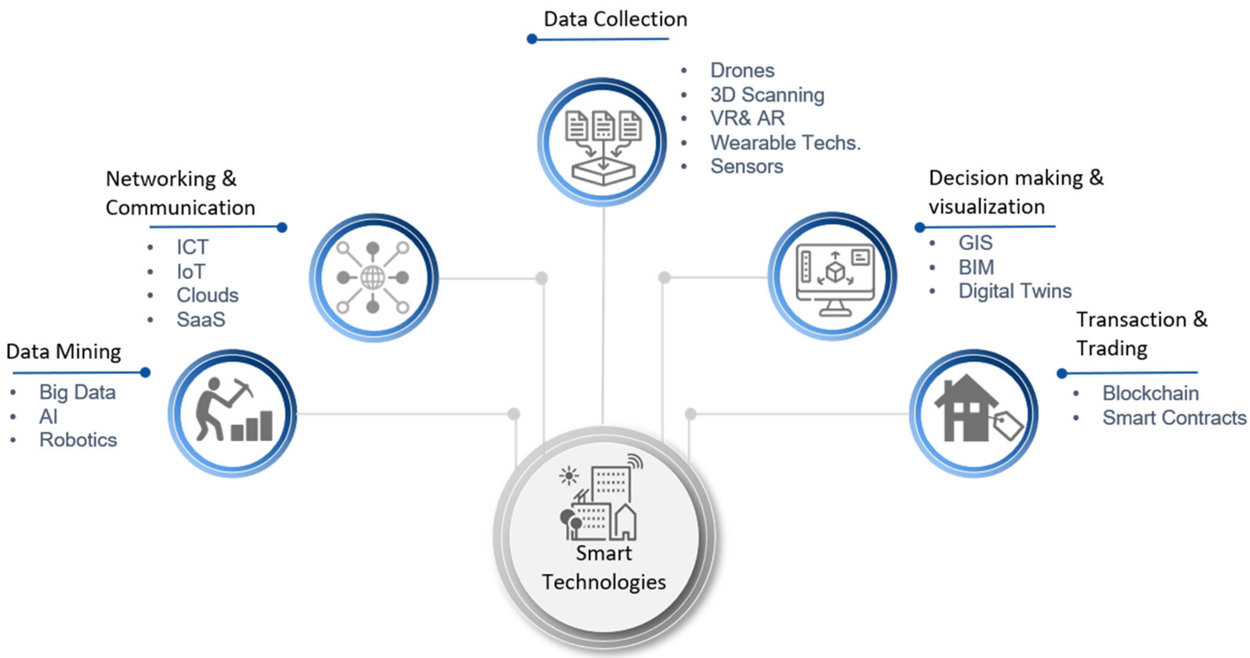

Figure 1. Smart city technologies that impact smart real estate. Source: Author, 2024.

2.3. Smart Real Estate for a Smarter City

The SRE is an important component of SCs, along with smart infrastructure, smart technologies, smart environment, smart energy, smart citizens, and smart governance. The efficiency of SCs is heavily dependent on SRE [1]. Integrating SREs into SCs involves seamlessly incorporating smart building technologies within broader urban contexts through three fundamental integration dimensions: physical integration, which links SRE with city infrastructure; data integration, which enables seamless data exchange and analysis; and functional integration, which aligns building operations with city-level goals [9].

Based on a study conducted by Al-Rimawi and Nadler [1], a framework was developed to evaluate the smartness level of both cities and real estate and to identify the integration level between them; the study tested the framework on seven leading SCs and seven SREs benchmarks worldwide; the benchmarks comparative analysis and evaluation results have revealed that there is a high level of integration between SCs and SRE, and have proven the importance of SRE in increasing the level of city smartness. In another study, another framework was developed for SRE within a SC, and it has been proven that both levels rely on each other and that there is a high integration between them [30]. Additionally, it was proven that in some cases, SRE follows a leading strategy where its level of smartness is higher than that of the SC, influencing the city to increase its smartness [1]. This research sheds light on SRE due to its high importance in activating the city's smartness and its economic and social impact on the city. Due to the lack of literature and studies that are specialized in the SRE aspect, this research attempts to fill the gap in the academic field and to provide a contribution that can be utilized to improve SCs and SRE.

2.4. Real Estate Life Cycle

To adopt smart technologies, implement them, and utilize them in SRE, investigating the real estate life cycle is important to identify at which stage of the real estate life cycle the smart technologies would be utilized and at which process or task. The real estate life cycle refers to one or more repeating events, so describing real estate as a cycle is inaccurate. It is a life span with a defined beginning and end. Nevertheless, it is possible to identify the part of the life span of a cycle when it is a repeated procedure [31]. The concept of an SRE is being developed at all stages of the building's life cycle; however, all intents of classification and categorization tend to separate the real estate development phase from the utilization phase [31,32]. Figure 2 illustrates the main phases and sub-phases, with their milestones and processes to which smart technologies can introduce added values; each step is integral to laying a solid foundation for the subsequent real estate life cycle sub-phase. In reality, these sub-phases often run parallel, overlapping, or in feedback; nevertheless, they are fundamentally suitable regarding analytical aspects [32]. The site is prepared in the land development phase, where the life cycle begins after the land development. The project development phase includes four sub-phases: project acquisition, project conception, project realization and construction, and project marketing. The utilization phase consists of four sub-phases: project occupancy, project operation, project maintenance, and lastly, project clearance and vacancy [30–32]. After the building serves its purpose, the property reaches the post-vacancy stage, where it is decided to either refurbish, redevelop, or demolish it.

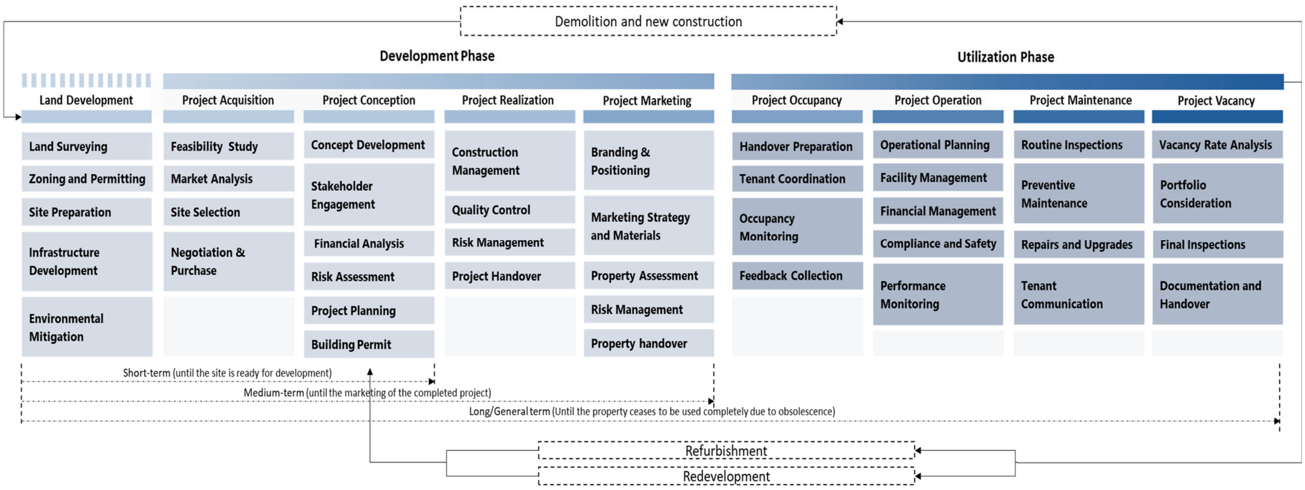

Figure 2. Real estate phases, sub-phases, and processes. Source: Author, 2024. Based on Nadler and Malottki, 2006 [31]; Held, 2010 [32].

Within these main phases, the sub-phases usually extend from the project initiation. There are three phase-oriented terms: the narrow sense of its meaning is in the short term, extending up to the time that the property being developed can be built upon; in the middle sense, only up to the time that the project is marketed; and in the broader or general sense, until it ceases to be used due to obsolescence [32]. The land development phase is the cycle's starting point; it aims to prepare the land for construction and ensure its readiness for the next stage. It includes several tasks and processes, such as land surveying to map the site boundaries, zoning and permitting to comply with laws, site preparation for grading and clearing, infrastructure development for networks and utilities, and environmental mitigation to minimize impact. These processes ensure the land is ready for the next phases and meets all requirements. This phase transforms prepared land into functional and valuable real estate assets [31,33,34]. The focus then moves to project development, starting with the first real estate life cycle sub-phase, project acquisition, which comprises several key processes and steps. This phase begins with conducting a feasibility study where financial, legal, and technical analysis is performed to determine the project's viability [30,32,35]. Followed by a market analysis to assess the market's current conditions, demand for the product, and competition. This sub-phase core is site selection, which, on its part, is concerned with the identification of prospective sites for development [30,32,36].

The second sub-phase in the project development phase is the conception: starting with concept development, formulating comprehensive project concepts, encompassing design elements, and market analyses. Stakeholder engagement is part of this sub-phase to ensure that the key stakeholders are aligned with their goals [32,37]. A preliminary financial analysis estimates costs, revenues, and potential financial returns, assessing the project's profitability prospects. It includes risk assessment that identifies and analyzes potential risks and develops mitigation strategies. The project planning process outlines the project timeline, resources, and key milestones [32]. Finally, building permit approvals are obtained, and compliance with property, user, and building law requirements is thoroughly examined. The short-term is achieved with the acquisition and conception sub-phases [32,36,38].

The project realization and construction sub-phase marks the start of the project's implementation, where it begins to take on its physical form, with several processes and steps, each critical to the successful completion of the project. Construction management ensures that the construction processes align with the approved plans, budget, and timeline [32]. The construction process should also include solutions that enhance energy efficiency, environmental protection, mobility, safety, and security [30]. One important element in construction is quality control measures, which are strictly applied to ensure that the construction meets all standards and specifications. Risk management is an ongoing endeavor, with continuous monitoring and management of risks to address any issues that may arise during the construction phase as early as possible. The culmination of these efforts is the project handover, where the completed property is ready to be transferred to the end-users, and the real estate is ready for the next sub-phase, project marketing, indicating the project's successful realization [32,37,39].

The project marketing sub-phase is the last stage of the project development phase. It starts with branding and positioning, where the establishment of a strong brand image is formulated, and then projects are presented to capture the target market and audience [32]. In this sub-phase, a comprehensive marketing strategy is formulated; it integrates both online and offline approaches. To supplement the marketing process, high-quality sales materials are introduced, including websites and virtual tours that would effectively convey the project's value proposition [31,32,35]. Evaluating property data and information involves gathering detailed property data, benchmarking relative and similar properties, employing several valuation techniques, and determining reliable property values for financial decision-making. Furthermore, it also has provisions for mutual agreement, under which, in consideration of the contractual perspective, negotiations may have to be terminated if necessary. Property handover is achieved and indicates the end of this phase, at which point the property is now ready for occupancy [32,37]. The project development phase is achieved at this stage, meaning the medium-term is achieved [32].

In the utilization phase of a real estate project, the focus shifts from creating and developing a real estate project to managing an existing property to ensure proper operation; this phase's focus areas include tenants and building management, maintenance, repair, modernization, and conversion [32]. It is the first sub-phase within the project utilization phase. It is usually defined by handing over the project to its users. It involves several tasks and procedures to facilitate a seamless transition [30]. This sub-phase exchanges extensive data involving tenant owner contracts and maintenance agreements with property managers and contractors [40]. The first handover activity is documentation, which is required to hand over the building to its new users. Tenant coordination also involves contracting with the tenants or buyers, arranging a meeting to set move-in dates, and meeting any complaints [31,32]. Occupancy monitoring is performed in real time to enable the appropriate occupancy transition and address any issues. Lastly, feedback collection is crucial because it involves collecting feedback from occupants to determine areas where improvements may be made to a building and increase occupants' satisfaction levels [32,41].

The project operation sub-phase relates to the continued management of a project after the delivery of a completed project and handover to the end-users for occupancy and utilization. This phase is crucial to ensure that the project runs adequately and meets the user's demands; the facility manager has a significant role to play in this sub-phase. Key operational planning involves preparing efficient plans for property operation. Facility management consists of establishing systems for preserving and administrating the property, encompassing repairs, maintenance, and service provision. Another important component of this sub-phase is financial management—the process of monitoring the property's performance in financial activities, such as budgeting and submitting reports [31,32,40]. Ensuring compliance and safety is part of this sub-phase, where mentoring to all significant regulations and safety standards is provided. In addition to safety, performance monitoring is a continuous process that involves tracking the property's performance and implementing necessary adjustments to enhance operational efficiency [32].

The project maintenance sub-phase is dedicated to the continuous care and enhancement of a project after it is operated [32]. This phase is essential for ensuring the project operates efficiently and effectively throughout its lifecycle. It involves several systematic processes, which include regular routine inspections to detect faults and repair maintenance requirements [31,32]. The other activity type is preventive maintenance, involving proactive measures designed to avert potential issues and extend the property's operational lifespan. Furthermore, this sub-phase encompasses repairs and upgrades, which are critical for preserving the property's condition and ensuring its functionality [32,42]. Tenants' communication is equally important, as it maintains open channels of dialog with tenants, allowing for the rapid resolution of maintenance requests and addressing any concerns they may have. Together, these processes contribute to the long-term success and viability of the project [31,32,43].

The project vacancy and clearance sub-phase represents the last stage in the utilization phase, focusing on the culmination of all project activities and facilitating a seamless transition to the post-vacancy stage [32]. This sub-phase comprises critical steps, including vacancy rate analysis and comparison, which involves assessing the percentage of unoccupied rental units or commercial spaces within a specific real estate market and comparing vacancy rates across similar properties [44]. The vacancy rate influences investors to optimize their portfolio considerations of risk and yields, providing the decision of post-vacancy best action [31]. During that sub-phase, final inspections are performed, which are comprehensive evaluations to ascertain that the property adheres to all established standards and specifications. In addition to these processes, documentation and handover are other important ones, entailing the preparation and transfer of essential documentation, keys, and access codes to the new proprietors or occupants. Additionally, tenant coordination is crucial, as it involves orchestrating with tenants or purchasers to guarantee an orderly transition and proactively address any issues or concerns [32,41,42]. These processes are instrumental in ensuring that the project is concluded with due diligence and readiness for its next cycle. At this stage of the cycle, the long-term goal is achieved. After project clearance and vacancy, the post-vacancy stage repeats the cycle by either refurbishing, redeveloping, or demolishing the property [31].

The refurbishment phase focuses on modernizing and upgrading an existing building without changing its primary purpose; this includes structural repairs, interior and exterior upgrades, and improvements in energy efficiency. Refurbishment enhances the building's value and functionality [31,45]. The project redevelopment involves changing the purpose of an existing building; this process includes assessment and planning to evaluate the property's potential, obtaining necessary approvals, possibly demolishing existing structures, and constructing new ones to meet the new functional requirements. Effective redevelopment can revitalize urban areas and meet market demands [45]. If needed, this may involve selling either the building or the plot of land after demolishing the existing structure. This marks the beginning of a new development phase in the site's life cycle; however, it is not a consistent and regular phase in the cycle [31].

The annual FIBREE survey classifies real estate products into eight categories related to the real estate life cycle; finance focuses on investment and loan markets; markets and platforms list; building technologies; transaction services support transactions with automated micropayments; management and operation, including facility and property management; planning and building, which offer architectural and construction services; and research and evaluation, which provide real estate data services for transparency and research. SC solutions address city needs like digital land title registration and utility microgrids [13].

There is a major effect on when to implement smart technologies and at which phase they are introduced and implemented. The construction of an SC and SRE heavily depends on the application and development of advanced technologies at the early stages [7]. The real estate life cycle phases have different integration approaches to SRE and SC's three integration dimensions [9]. Smart technologies and innovative strategies are implemented throughout the real estate phases, not only in the early stages, as each technology-added value is utilized in the suitable phase based on its capabilities [46]. The real estate phase affects the implementation of smart technologies and their roles. Technologies have different capabilities that can be unlocked based on the real estate phase; several capabilities and roles of technologies are highlighted in the upcoming sections.

3. Materials and Methods

The evolving nature of SC technologies demands continuous exploration and validation of their effects on real estate dynamics. An integrative review was followed in this study because it summarizes and critiques a specific research topic by analyzing previously conducted research studies and incorporating both qualitative and quantitative studies. The information gained is more comprehensive and has helped identify the most beneficial smart technologies that add value to SRE. Figure 3 represents the methodology followed in this study; the integrative review helped identify the most beneficial smart technologies for SRE as well as their impact and added value.

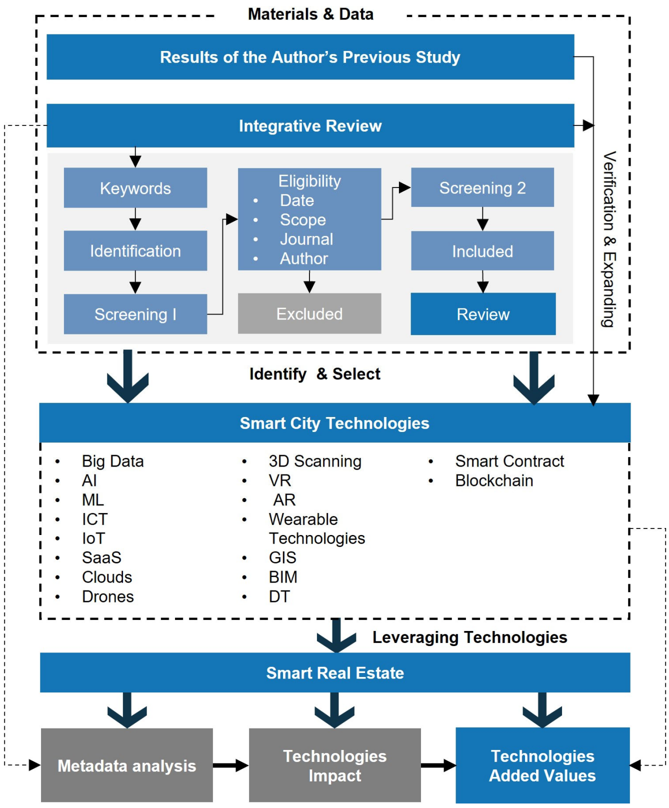

Figure 3. Research methodology. Source: Author, 2024.

The review followed a phased approach. At first, several review papers discussing SC and SRE technologies were examined to obtain some keywords for further steps. Relevant keywords, including smart city, real estate, technologies, development, and the list of technologies mentioned in the previous chapter, were used based on the guiding research question and, thus, results of interest. The keywords were used in conjunction with smart city, real estate, technologies, the listed 16 technologies, and added values in various permutations.

Search engines, including Scopus, Google Scholar, Elsevier, MDPI, Springer, TU Dortmund library online database, and Emerald, were subsequently used to identify relevant articles. These databases were available to the researchers from the university's repository. These databases were chosen because their combined results offer extensive coverage of publications related to this research and would reduce the chance of missing relevant publications.

The publication records include journal articles, books, conference papers, and Ph.D. and master's theses, which were sought based on their recent publication and the availability of specific keywords. The identified articles were synthesized through thematic content analysis to extract key factors and added values of smart technologies on real estate investment and development. The frequency of occurrence of the factors in the sampled literature was also noted, where a higher frequency was deemed the most important among the sampled literature. Accordingly, it represents the integrative review methodology, which includes five stages: elaboration of the guiding question, identification and data collection, records screening, critical analysis of the included studies for eligibility, and presentation of the integrative review. In this study, the guiding question was as follows: what are the added values of smart technologies? At which scale does the technology impact SC or SRE? At which phase of the SRE life cycle would the added value be activated? How to adopt these technologies and activate their added values? Who is responsible for activating these added values?

The searches and publication collection were conducted from 1 September 2023 to 31 August 2024. As shown in Figure 4, a total of 691 articles were found in the eight databases surveyed. After using the PRISMA flow chart, 168 articles were included in this study through the following steps. From all databases, 691 publications were checked and filtered manually, and 133 were excluded due to publication duplications. An additional publication identification was conducted through incremental search, targeting smart technologies and ensuring that all technologies were properly captured; an additional 67 publications were added, resulting in 625 publications that were screened using the including and exclusion criteria. The following inclusion criteria were adopted:

- Relevance to smart technologies: the publication must focus on applying, impacting, or developing at least one smart technology within smart cities or smart real estate.
- Research aspect: theoretical and practical publications were included to comprehensively understand each technology at both levels.
- Availability: including publications that are fully available.
- Publication date: including publications published within the last decade from and after 2013 to ensure current and relevant information.
- Source credibility: including articles from recognized and credible sources, such as academic journals, conference proceedings, reputable publishers, and industry reports.
- Publication Type: including peer-reviewed journal articles, reputable industry publications, and conference reports.
- Methodological diversity: including publications that employ a variety of research methodologies to cover both theoretical and experimental practical sides.
- Peer-reviewed sources: only including articles from peer-reviewed journals for journal articles, which is preferable for conference papers and book resources.
- Language: articles must be published in English; only related journal articles must have at least an abstract in English to ensure accessibility and consistency in analysis.

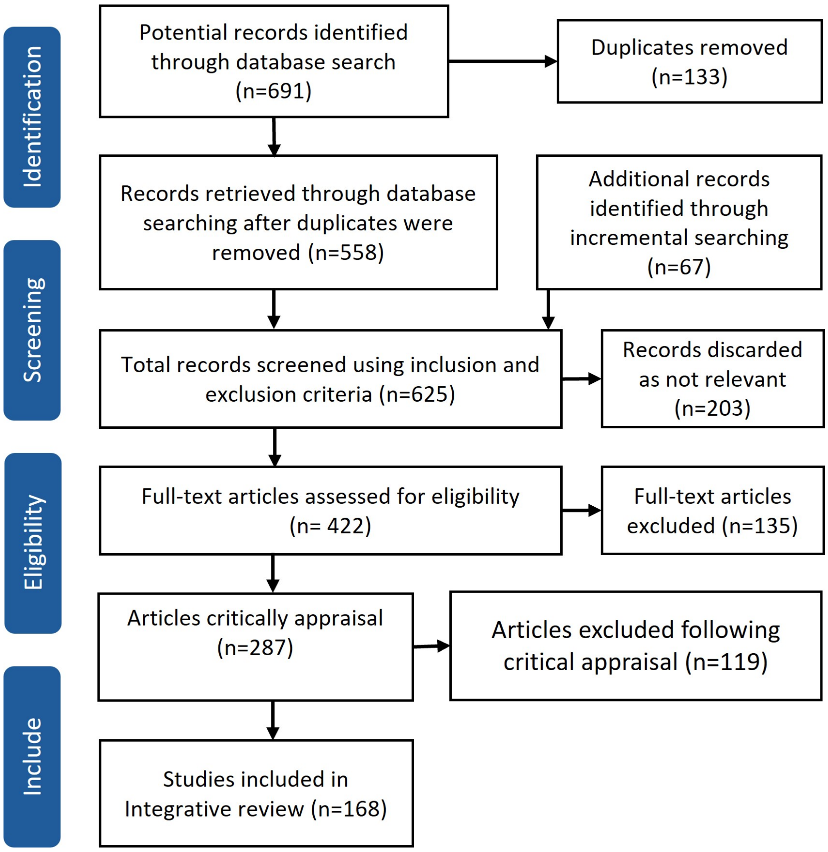

Figure 4. Retrieved articles for an integrative review using PRISMA Char. Source: Author, 2024.

After applying the inclusion and exclusion criteria, 203 publications were excluded; 172 were excluded because they were irrelevant to the research and did not specifically address smart technologies, smart cities, or smart real estate, and 31 publications were not available in full form. In addition to those, 135 full-text publications were excluded from several criteria; 62 publications did not apply to the publication year and were published before 2013, which could include outdated information. A total of 23 non-credible sources such as blogs, opinion pieces, and non-academic websites were excluded. In total, 21 publications that are not available in English were excluded to maintain consistency in the review process unless they were seminal works that provided foundational knowledge and included English abstracts, which apply to 2 selected publications among the 168 selected ones. Capturing peer-reviewed journals was also considered, where journal articles must be peer-reviewed or reputable industry publications. A total of 29 journal articles were excluded, reaching 98% of the selected journal articles that are peer-reviewed. The overall selected publications with various types are 89% peer-reviewed articles, conference papers, and books. Other scholarly publications are reviewed and edited before publication; they do not go through a peer-review process, such as PhD and master's theses. Also, studies in editorial format and letters to the editor were excluded.

After the content analysis, 168 publications were selected based on their high relevance to the purpose of this research and provided content that could answer one guiding question or more; these publications had a full, detailed review. The selected publications were categorized based on the technologies it is investigating; some publications investigate several technologies, and others focus on one technology. Additionally, it was sorted based on the level at which they focused on SC, SRE, or both. Various methodologies were used, enriching the gathered data, as shown in Figure 5.

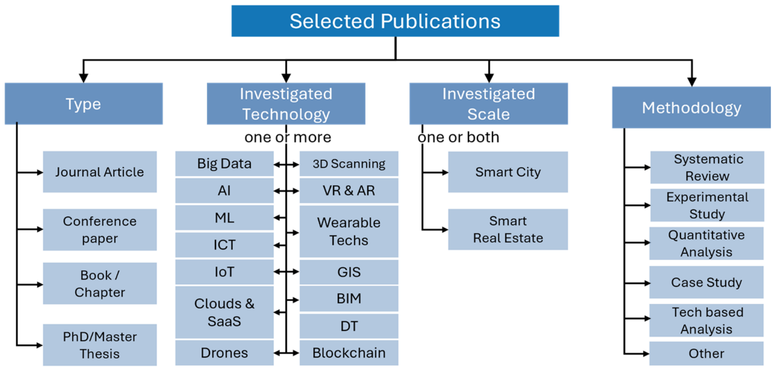

Figure 5. Selected publications categorizations. Source: Author, 2024.

It is also noted that very limited review papers exist on these technologies, especially at the SRE level, which indicates a lack of review focus in this area. To date, no other study has covered the relationship between these technologies, their added values, and their link to the real estate life cycle phases. Furthermore, investigating all 16 technologies together has not been covered by comprehensive reviews, as shown by the results of the current study's search method. Therefore, the comprehensive analysis of these 16 technologies and their added values, as they apply to the real estate domain and its phases, has fallen through a review gap.

The added values of smart technologies were identified through a thematic coding process involving several key steps. Initially, an in-depth analysis of the selected publications (articles, books, conference papers, and PhD theses) was conducted to capture possible added values. These values were then sorted based on the specific technologies and their impact levels (SC or SRE). Additionally, the integration of multiple technologies highlighted new added values. For each publication, a list of investigated technologies, the added values provided, and their impact levels were documented. To facilitate sorting, seven general categories were developed: Governance and Transparency, Decision-Making, Market and Economic Growth, Sustainability, Management, Control and Operation, and User-Oriented. The gathered added values were sorted into these categories. During the initial coding process, duplicate phrases were removed, and synonyms or phrases with the same meaning were identified and merged. Different authors conducted a comprehensive review of the list and cross-verified it for accuracy. Finally, the added values were organized and sorted based on the real estate life cycle phases and processes, specifying which technologies would provide these values, at which phase, by whom, and to which users, which is provided in Section 6. A real estate development expert reviewed and verified this list. This structured approach ensured that the results were practical, mature, and easily adopted and activated by different stakeholders.

4. Content and Bibliographic Analysis

4.1. Publications Targeting Technologies

Upon conducting a comprehensive review of the publications, the identified 16 technologies were classified into five main categories. This classification was based on each technology's principal function within the real estate sector. Some technologies were combined as they integrated and worked together, as indicated by multiple publications. The technologies were classified as the following: data mining (Big Data, AI); networking and communication tools (ICT, IoT, clouds, and SaaS); data collection technologies (drones, 3D Scanning, wearable technologies, VR, and AR); decision-making and visualization (GIS, BIM, DT); and transaction and trading technologies (blockchain and smart contracts). Table 1 illustrates the distribution of publications based on these classifications; several publications targeted more than one technology. These publications are listed based on their citation in the next chapter; it is worth noting that references [47–56] are not part of the selected publications; they are used to give an insight into technologies' global market size and their compound annual growth rate (CAGR). The Supplementary Materials (SM 1 and SM 2) highlight more details of the references.

Table 1. Publications targeting technologies. Source: Author, 2024.

Technologies		Cited References	Count *
Data Minning	Big Data	[18,42,57–79]	25
	AI	[18,23,42,43,61–65,67,70,71,74–77,80–92]	29
Networking and Communication Tools	ICT	[2,30,84,93–105]	16
	IoT	[18,24,27,28,40,42,43,77,83–85,91,106–122]	29
	Clouds and SaaS	[18,71,123–129]	9
Data Collection Technologies	Drones	[18,81,130–139]	12
	3D Scanning	[18,140–146]	8
	Wearable Tech.	[18,140,147–153]	9
	VR and AR	[18,138,140,146,154–160]	12
Decision Making and Visualization	GIS	[2,8,12,42,53,104,109,140,161–173]	20
	BIM	[12,42,91,92,116,120–122,140,145,164,174–191]	29
	DT	[27,79,91,111,152,161,164,183,184,192–196]	15
Transaction and Trading Technologies	Blockchain and Smart Contracts	[13,79,91,113,116,140,197–210]	20

* Within the 168 reviewed publications, several publications investigate more than one technology; the count represents the publications that mentioned the technology, and the same publication can be duplicated in several technologies.

4.2. Bibliographic Analysis

4.2.1. Publication Type

Table 2 represents the four publication types in this study: 138 Journal articles (81%) of the publication study, 17 books and chapters from books (10%), 11 conference papers (7%), and 2 Ph.D./master's thesis (1%).

Table 2. Publication type count and percentage. Source: Author, 2024.

Publication Type	Count	%	References
Journal article	138	82%	[2,12,18,24,28,30,42,43,53,57–65,67–69,72–92,95–107,109,110,112–116,118–145,148,149,151–153,155–161,163–172,174–177,179–181,183,185,189–191,193–198,200,202–205,209–211]
Book/Book Chapter	17	10%	[13,27,93,94,108,111,117,147,150,154,162,173,178,187,188,192,206]
Conference Paper	11	7%	[8,58,66,71,146,182,186,199,201,207,208]
PhD/MSc Thesis	2	1%	[40,70]

4.2.2. Publication Methodology

The reviewed publication contains different methodologies, aims, and approaches. Some publications included reviewing one or more SC technologies, which aid in defying their added values. In addition to the reviewed publication, this research was subjected to several systematic and integrative reviews [18,42,43,60,87,109,169,185,194,198,199,201,206], adding more insight into smart technologies. Some publications were based on experimental methodology or case study analysis, as they applied smart technology and provided results for the added values of these experiments [8,69,71,97,104,106,118,134,157,158,163,177,181,182,188]. Other publications focused on providing new models for the technologies, and some offered techniques for integrating different technologies and overcoming obstacles in their integration [59,63,80,81,92,104,124,127,138,164,168,172,178,184,190,204]. Several publications included multiple approaches. Each was useful in one aspect or another in terms of building a scientific understanding of smart technologies' added values.

4.2.3. Publication Year

Figure 6 represents the publication patterns related to smart technology; it identifies an expansion of research interest in smart technologies in the scientific community in the last decade. The diagram highlights a jump in 2019–2020, which can be due to several reasons. However, it can be a possible effect of the COVID-19 pandemic, as 22 of the selected publications that were published after 2019 have mentioned COVID-19 in their study. The number of publications related to smart technologies followed a growth trend in the following year, peaking in 2022 with 26 selected publications.

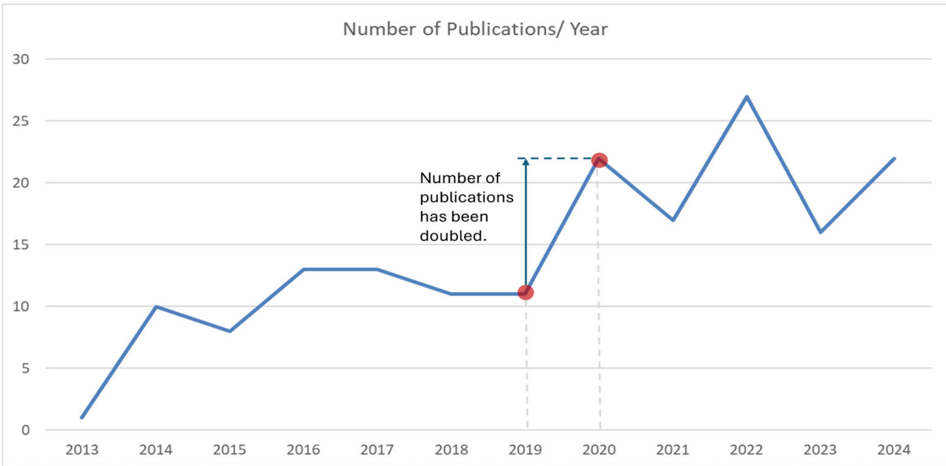

Figure 6. Publications based on the year of publication. Source: Author, 2024.

Figure 7 represents the publication content based on the smart technologies categories and their relationship with the publication year. It shows that there has been more focus on smart technologies, especially research related to data mining, decision-making, and visualization. The Supplementary Materials (SM 5) highlight more specifications.

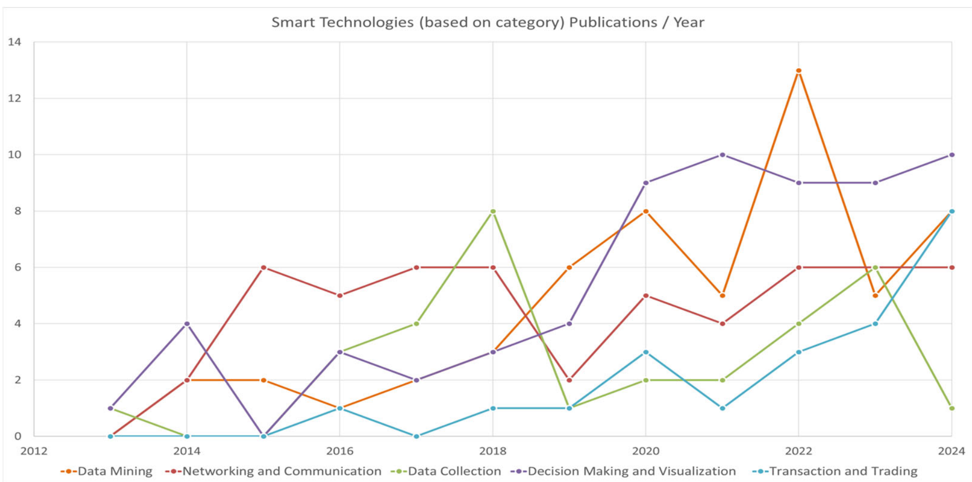

Figure 7. Publications based on smart technology categorization and years. Source: Author 2024.

4.2.4. Author Keywords Analysis

There were 506 distinct keywords and 84 unique keywords, with a minimum of 2 occurrences. The linkages and occurrence of keywords by study authors are illustrated in Figure 8, which depicts keyword relationships and frequencies. Circle size indicates the number of connections a keyword has, and line thickness shows the frequency of keyword co-occurrence. Smart city, IoT, BIM, Big Data, GIS, and real estate were the most frequently used keywords in smart technology research.

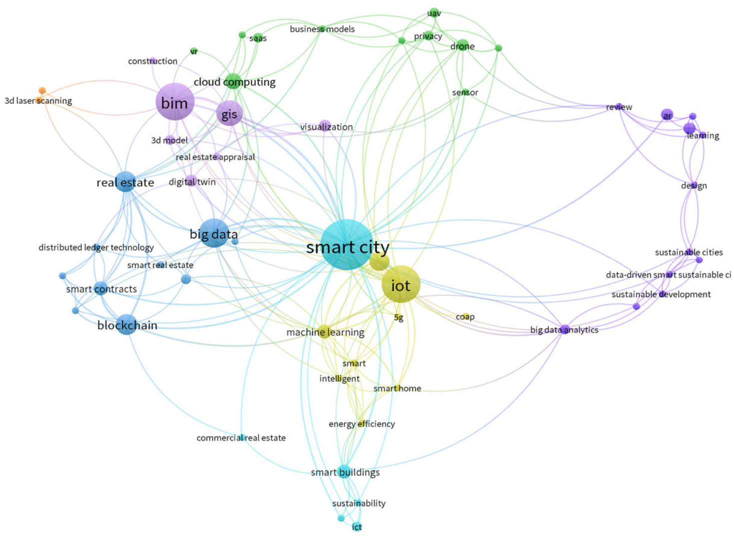

Figure 8. Network visualization map of author keywords using Vosviwer (2 occurrences). Source: Author, 2024.

4.2.5. Co-Authorships Analysis

This study contains 505 co-authors who are not fully connected to the database. Only 35 authors are co-authoring their work, meaning the scholars' network is nearly disconnected. Figure 9 shows the co-occurrence analytical map of keywords within the literature. It is worth mentioning that Fahim Ullah has contributed to the research of various smart technologies, with 7 documents from the selected publication and a link strength of 24.

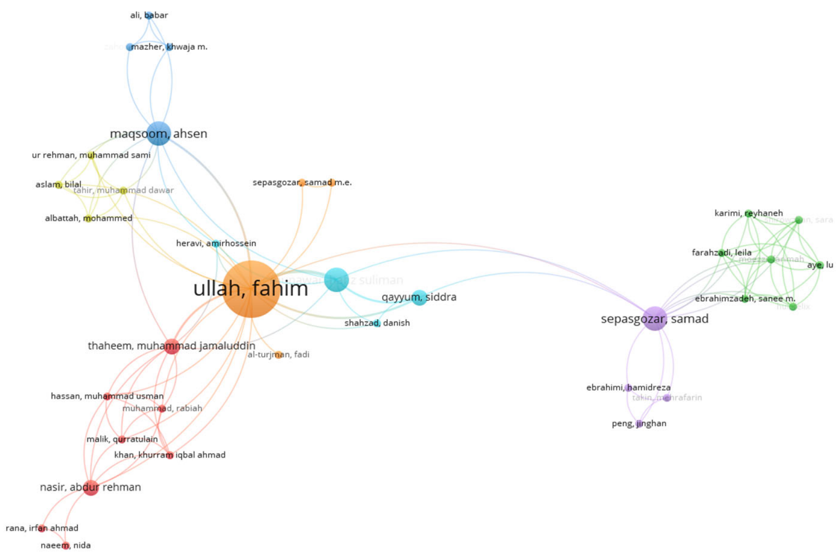

Figure 9. Network for co-authors of 31 items using Vosviwer (only connected). Source: Author, 2024.

5. Integrative Review of Smart Technologies

As mentioned in the methodology, a review of the selected smart technology for its application in real estate has been conducted. Each technology's definition, description, current exploitation, potential opportunities, and added value for SC and real estate are presented. Technology is categorized and grouped as described in Section 4.1.

5.1. Data Mining

5.1.1. Big Data

Big Data refers to an enormous volume of data that traditional software could not process. Big Data was formed to depict interconnected, enormous databases and the procedures utilized to extract knowledge from the existing data [57]. Data can be structural, semi-structural, and sub-structural [57,58]. Huge volumes of data are being gathered, transitioned, and explored in real estate development [59]. Over 2.5 quintillion bytes of data are generated daily, and it is argued that 1.7 MB of data will be created by each person every second in 2020 [60]. Data and Big Data technologies are essential for its growth, and their application fuels the industry's development [61]. Big Data technology provides important support for the construction and development of SC and real estate [62]. Unstructured Big Data is costly, with 95% of businesses producing it. In 2019, they spent $187 billion on data management and analytics [60,63]. It has a global interest, with its market size valued at USD 311.72 billion in 2023 and projected growth at a CAGR of 14.9% from 2023 to 2030 [47]. Big Data is not a freestanding technology; it depends on other technologies and tools, including data analytics, AI, ML, pattern recognition, and other tools [64,65].

Big Data is characterized by its Vs; Wison and Kraus [66] described it by volume for the large data amounts; variety as the data comes from different sources, some of them are unstructured; veracity coming from reliable and unreliable sources; velocity for real-time processing; viability for the ability to process and analyze data. Oluwunmi [57] and Lavalle [67] added value to the previous vs. because of the knowledge it provides. Munawar [60] added visualization by representing it in an understandable way to the final users. Three additional Big Data vs. were added: validity for the importance of accuracy, vulnerability for developing reliable construction models, and volatility for the change in the construction models based on the Big Data sources [64].

The construction of SC is based on data; it is claimed that SC offers intelligent city management [62]. Incorporating sensors and other devices creates enormous amounts of IoT data, which contributes to generating more data. The diverse nature of these data makes it challenging to handle, integrating a range of sources at varying speeds that require Big Data techniques [67]. Big Data platforms play a crucial role in SC planning and construction, offering various advantages [68]. These include managing the entire life cycle of SC data through collection, integration, analysis, and application [62,78]. Its impact on the economy is illustrated by the creation of entirely new business models [68]. Big Data platforms provide real-time corporate credit monitoring [62,78]. Its role in the retail sector, which includes analyzing buyer behavior, allows for fast action to adjust products and their details [68]. It becomes the foundation for smart government decision-making, macro-control, and emergency command; it allows verification across government affairs departments, ensuring data uniqueness, exchange, and sharing [62]. It improves the quality of life and fosters the city's sustainability [68,78]. Data analysis helps reduce energy consumption and greenhouse gas emissions [67]. The platform contributes to predicting health epidemics, analyzing public opinion, and forecasting market trends [62]. Customer complaints can also be analyzed to determine product revenue contributions [68].

Real estate contains a wide dataset, and complicated analyses consume much time without Big Data analytics based on data-mining techniques. It allows professionals to focus on core roles through data-centricity [69]. However, Big Data solutions' complexity and implementation costs pose significant challenges, particularly for smaller players like real estate agents and brokers, who may not see sufficient utility to justify the substantial investment [70]. Big Data provides comprehensive market insights [71], which can benefit RED early phases. The processing and analysis of Big Data offer practical solutions to prevent over-development and effectively address the escalating land prices, fostering diversified development and innovative investment approaches [69]. It places better, more reliable, accessible, and relevant data at the core of decision-making and strategy formulation [71,72]. Additionally, Big Data has evolved into a crucial strategic asset for real estate enterprises, enhancing their competitiveness significantly [69]. It has several advantages in claim, procurement, and project management [64].

Big Data plays a critical role in the marketing phase; it may enable real estate organizations to integrate financial, marketing, saving time, speedy sales, consumer insights, e-commerce, and consumer surveys to obtain a holistic view of business performance and empower real estate owners to understand trends and patterns, which can help overcome inefficiencies and reach target buyers or renters [18,58,69,73]. It can enhance the efficiency of appraisals and enable better risk evaluation in the real estate industry, simplifying applications in valuations and pricing [70]. Enhancing the efficiency of appraisals and enabling better risk evaluation in the real estate industry, simplifying applications in valuations, pricing, cost estimation, and expected returns are major processes that utilize Big Data [70,74,75]. Moreover, using Big Data in real estate marketing has substantially boosted real estate sales [69]. ML and Big Data are used to enhance comprehension of expanding house values. Implementing data-driven techniques helps the real estate market expand. Property managers and investors would have more control over their portfolios and client relationships [65,76].

In terms of SRE management, both analysis and speed are key components. Big Data offers these attributes through what is known as "Big Data analytics" [69]. Big Data systems proved valuable disaster preparedness, management, and response resources. Evaluating the risks of real estate assets and the ability to address the error of appraisals [75]. Disaster risk management authorities leverage Big Data for population monitoring during emergencies. Big Data analysis uses extensive market data that help businesses predict trends and optimize investments. Surveys show that Big Data improves forecast accuracy by 15.2% [77]. Additionally, Big Data supports post-disaster logistics, resource planning, and real-time communication [18]. It helps to make informed decisions about demolition methods, waste management, and resource allocation. The added values of Big Data in RED can extend across various phases, from the initial planning and design to post-operation and user experience optimization [42,62,68].

5.1.2. Artificial Intelligence (AI)

AI offers possible solutions for cognitive issues associated with human intelligence, such as learning, solving problems, and recognizing patterns [76]. It refers to the performance of complex functions, such as those performed by the human brain, but with computers, intelligent programs, and minimal human intervention [43,81]. It continuously adapts to the external environment [61]. It includes AI-equipped robots carrying out complex tasks with accuracy [23]. ML is a subset of AI subdomains that can be used to learn from the data using computational systems [62,74,82]. ML is a set of patterns and techniques taught from data given to the machine to make sense of unknown data and process Big Data to perform specific tasks [43]. They are increasingly appreciated in construction and real estate [81,83]. By 2025, AI revenue is expected to reach $36.8 billion worldwide. By the end of 2018, 75% of development teams have employed AI in one or more real estate business apps or services [18]. The development of AI has evolved through three phases: initial system development, Big Data-driven interaction, and the transition to practical automation using intelligent robots [61].

AI can revolutionize the technology used in SC by facilitating instant analysis of large amounts of data received from various sources, including sensors and IoT devices [81–83]. AI can positively impact major SC domains, including smart governance, transportation, energy, environment, building, and more [83,84]. An unlimited number of AI algorithms can be used in a SC. The choice of algorithms would depend on the SC's specific use cases and requirements. Various AI algorithms can be used in SCs to improve efficiency, sustainability, and Disaster of life [83]. The collected CS data can be used by ML using algorithm development, statistical analysis, and other methods [64]. ML has played a vital role in SC application development, assisting in tasks such as predictive modeling (classification), value estimation (regression), and grouping data (clustering) [82]. Based on Alahi's [83] assessment of over 75 resources and other sources [67,84–86], the added values of AI are countless. However, some major values are improved traffic management, decision-making, enhanced public services, increased transparency, improved urban planning, predictive analysis, increased productivity, energy efficiency, waste management, home automation, safety, and others.

AI can aid in comprehensive feasibility assessment [86,87]. AI and ML offer key insights for SRE investment opportunities [87]. Additionally, they significantly outperform traditional statistical methods in forecasting market trends [88]. AI helps real estate professionals analyze vast data from construction licenses and zoning laws using advanced models and algorithms [89]. Additionally, it improves the predictive analytics process [87,88]. AI can enhance accuracy and optimize design, quality assurance, cost, and safety efficiency [63,65,86,87,89]. AI has several added values in the construction phase; AI enhances resource allocation in construction by analyzing Big Data to track progress and ensure timely completion, reducing costs and material waste [89]. AI plays a crucial role in construction. AI encompasses various techniques and has been applied to predict concrete properties, manage contracts, enhance site safety, monitor BIM-integrated on-demand sites, manage disasters, manage timelines, costs, and human resources on a construction project, and monitor construction processes [43,62]. Additionally, it can enhance the management of complex and uncertain construction projects [92].

Adopting these technologies in real estate would help buyers and sellers learn from data and make informed decisions, enabling customized real estate searches and minimizing errors and regrets [61,70,89]. Real estate industry investors must efficiently make property value estimations [57]. House appraisal viewing can be enhanced through ML, which gives an accurate estimation [74]. Pinter [80] was able to prove the fact that the developed hybrid ML method could estimate the estate price with relatively high accuracy compared to the single ML method. The hybrid ML method could successfully estimate the estate price with high accuracy compared to the single ML method [80]. Moreover, AI improves real estate property appraisal's efficacy, reliability, and clarity [71,90]. AI empowers real estate agents to find probable customers by using a data mining algorithm, working smartly, interacting with clients, and guiding the property selection process [61]. AI and ML allow real estate developers and agents to develop more effective digital marketing campaigns, where certain demographics will be targeted or reached more effectively via platforms [89].

AI supports advanced data analytics and decision-making processes, leading to more efficient facility management [86,91]. It can also analyze users' behavior. Building automation mechanisms and SRE assistive systems can help users have a better quality of life [43]. It enables SRE to adjust to occupants' requirements dynamically [66]. Moreover, it improves customer feedback through AI chatbots, which automate responses to common questions, enhancing customer service in real estate [89]. AI in property management boosts operational efficiency by 17.6% and cuts maintenance costs by 13.2% [77]. Furthermore, AI enhances demolition planning by analyzing data to determine optimal methods and sequences, thereby identifying hazards and improving safety protocols [42].

5.2. Networking and Communication Tools

5.2.1. Information and Communications Technology (ICT)

ICT encompasses more than information technology (IT). The inclusion of "communications" sets it apart from traditional IT. It is related to networks and communications; it combines telecommunications, computers, and essential software, allowing users to manage and understand information [93]. Big Data is a significant component of ICT [96]. ICT can be considered the backbone technology that efficiently transfers data from SC devices to central data centers [2]. ICT is no longer experimental; it is now widely adopted. Urban planning can draw insights from ICT, leveraging innovative methods and technologies [93]. Utilizing contemporary ICT technologies would provide the needs of present and future generations while addressing challenges in public services and urban development [95]. The flow of information from traditional services using radio and television to advanced services through online media reaches ICT applications for communities [93]. Real-time ICT capabilities are accessible via the Internet, delivered as SaaS, Platform-as-a-Service, and Infrastructure-as-a-Service to external users or customers [94].

ICT provides a crucial foundation for integrating various SC technologies, enabling seamless communication and data exchange [97]. The SC growth is linked to the use of ICT [98]. ICT enables many SC potentials [94]. Comprehending SC traits and acknowledging the necessity for robust Big Data and ICT assistance simplifies these technologies' amalgamation, enabling SC application initiation [96]. Scholl [99] considered ICT to be the core of the SC government. It plays a crucial role in creating effective governance. It enhances government functionality through innovation and public management, including developing e-government infrastructures, and reduces city corruption levels [30,93]. ICT enables the collection and analysis of large volumes of data, which aids in informed decision-making and strategic planning [97]. ICT boosts city smartness and smart governance, enhancing decision-making and speeding up bureaucratic and administrative procedures [84]. ICT has become a serious factor in economic growth and led to the creation of a world-class business environment in the evolution of the business environment. It has led to the automation of conventional methods [30,100]. The correlation between IoT devices, ICTs, and smart services would enhance urban sustainability and the environmental domain [30,93]. ICT plays a vital role in tourism development [101]. It can improve policy-making processes, with applications and platforms supporting effective governance [93]. Incorporating it into education would increase the student's participation [102].

ICT is the keystone for smart buildings, which can be integrated into neighborhoods, campuses, districts, cities, and even entire countries, creating a genuinely sustainable built environment [103]. ICT enhances engagement with SC platforms [104]. The advancement of ICT has led to the expansion of the smart buildings market and the change in the SRE. According to the European Commission, smart buildings mean buildings empowered by ICT in the context of merging global Computing and the IoT [95]. The communication infrastructure serves as a pillar of the system within smart buildings. It is key for data flow and efficient connectivity [105]. The optimal advantages of ICT are achieved when smart buildings seamlessly integrate with a city's information and management platform.

This connection enables efficient sharing of input and output resources among neighboring units [95,103]. During the design phase, the energy efficiency of SRE is assessed by simulating and analyzing their digital models. This evaluation considers different factors, such as location and urban infrastructure. The process leverages the most effective technology based on ICT [95]. ICT is essential for achieving significant advancements in controlling and operating buildings effectively. Without this capability, other emerging technologies will lose their effectiveness [103]. Combining ICT and intelligent materials enhances energy savings and represents the optimal approach for improving overall building efficiency [105]. While ICT has a broader impact on SCs, it also directly influences real estate properties by shaping their functionality, value, and desirability [30,95,100,103].

5.2.2. Internet of Things (IoT)

IoT has recently gained significant research attention. It is envisioned as a future Internet component comprising billions of intelligent, interconnected devices. IoT will expand the integration of physical and virtual entities, offering new capabilities for connected devices [106]. IoT involves internet-connected devices that collect data, interconnect, and self-configure, similar to the human nervous system [107,108]. It connects sensors employing the cloud, which enables them to communicate with each other [27,28,43]. IoT generates large amounts of data [27]. The impact of IoT in everyday life will be inevitable [109]. There has been a significant growth trend for connected IoT devices; they increased from 4.9 million in 2015 to 3.9 billion connected devices in 2016 [18]. Implementing an IoT application involves integrating various hardware and software components from a diverse range of ICT [107]. By 2025, the total number of connected IoT devices will be estimated to be 75 billion, with a potential economic impact of USD 11 trillion annually [84]. The global count of IoT devices has significantly grown. There is a pressing need to restructure the IoT as governments and corporations compete for data control [40].

SCs powered by IoT need an ICT framework for stakeholder communication, regardless of the application or service [83]. The ability to incorporate the latest ICT technologies, IoT devices, and AI algorithms into a city's infrastructure will play a crucial role in the success of an SC and change how cities are being developed and managed [43,83]. IoT architecture has five layers: the perception/sensing layer, the transportation/network layer, the middleware/processing layer, the application layer, and the business layer [24,83–85,109–111]. IoT technologies' impact extends beyond the value of individual products; instead, the product's value is further enhanced when connected to another, creating competitive dynamics and a system [107]. Based on Tang's [112] study that examined 65 cities, 80% of them had adopted some smart sensors. Still, only 12.3% had implemented integrated sensor networks, which had a huge impact on the capabilities of the IoT. Its technologies and applications are spreading rapidly, and this is increasingly reported in different cities [84]. IoT aims to optimize the use of community resources, enhance service quality, and decrease operational and management expenses in SCs [83]. It was found that adopting smart sensors and IoT technologies differs from adopting traditional e-government practices [112]. Smart cities use IoT for decision support, computer vision, and visual data mining, enabling efficient data management and networked interoperability [113]. Integrating IoT solutions and SC frameworks is more complex and broadly used, surpassing the previously used isolated applications [84]. Several resources [67,82,84,85,110,111] have proved that the IoT impacts all SC domains. Some IoT services in different SC domains help increase participation, e-business, Industry 4.0, predictive maintenance, smart grids, sustainable energy harvesting, promoting SRE, traffic management and monitoring of energy consumption, air quality, waste management, noise, and automation of public buildings. By leveraging these technologies, SCs can become more productive, efficient, and sustainable, ultimately enhancing the quality of life for citizens [83]. Its presence in SC aspects, including SRE, is explicit [24,109].

In the realm of SRE and property management, IoT devices play a crucial role [27]. IoT applications boost customer value via monitoring, Big Data analytics, and information sharing [114]. IoT provides real-time data for better decision-making [106]. It keeps users connected and well-informed, which can prevent information-related regrets [18]. Additionally, it facilitates real-time monitoring and control of building systems, improving operational efficiency [91,115,116]. IoT is far more than motion-sensor lighting; it enables the BMS to autonomously sense, communicate, analyze, and react to people or other machines in a non-intrusive manner [117]. It brings numerous applications to SRE, including occupant behavior analysis, security integration with devices, digitized logistics, intelligent communities, proactive maintenance, and smart waste management [118–120]. IoT sensors track occupancy, comfort, and space use, helping facility managers optimize allocation, identify underused areas, and plan efficiently [121,122], which allows buildings to intelligently adapt to users' needs and manage them more efficiently, making sustainable buildings smart. Integrating building management systems with tenants' systems enables a new level of control and efficient monitoring [27]. These devices regulate temperature, humidity, indoor air quality, and lighting, continuously monitoring buildings and their environment [118]. IoT devices monitor temperature, humidity, air quality, and noise levels, helping maintain comfort and identify issues [121]. In terms of financial management, IoT enhances portfolio and liquidity management, providing insights that enable stakeholders to make informed decisions [117].

Integrating IoT in smart buildings improves energy management, security, and device maintenance, enhancing living and working environments. Surveys show a 10.3% reduction in energy use and a 17.5% security boost [77]. It significantly reduces energy consumption, as it allows smart management and control of energy distribution for smarter energy and smart grids [24,120,121]. These devices regulate factors such as temperature, humidity, indoor air quality, and lighting, continuously monitoring buildings and their environment [118]. IoT sensors monitor building systems, detect anomalies, and predict maintenance needs, preventing failures, reducing downtime, and optimizing schedules [121]. Also, it provides early fault diagnosis and tracks real-time maintenance activities [122]. Alabi [28] identified IoT requirements like sensors, controllers, actuators, communication protocols, and data analytics. Real-time monitoring of air-conditioning, security, power, and fire systems provides an advantage for agents, tenants, and property owners [28,40,118,121,211]. Also, IoT plays a role in emergency management by providing real-time crisis monitoring and individual behavior analysis, and it is part of smart evacuation management along with BIM [122]. IoT devices can monitor environmental conditions and structural integrity and provide data to ensure safe demolition practices [42].

5.2.3. Clouds and Software as a Service (SaaS)

Cloud computing is a digital hub of computational assets. It encompasses both the software applications provided as services via the Internet and the physical hardware and system software located in data centers that facilitate these services [124]. Cloud computing enables its users to access data and software applications via the Internet instead of relying on a physical hard drive and without the limitation of local IT infrastructure. Approximately 60% of participants in a US survey expressed their readiness to embrace and invest in cloud computing [18]. The benefits of cloud computing attract large investments; its global market had a valuation of $483.98 billion in 2022, which rose to $569.31 billion in 2023 [48]. SaaS has recently garnered considerable interest as one of the three key elements of cloud computing.

It typically involves applications operating on a Platform as a Service (PaaS), which is built on an Infrastructure as a Service (IaaS) [123]. In the technology sectors, software typically operates as part of SaaS, providing remote access and functionalities through internet services rather than installing it on a user's computer [124]. SaaS encompasses more than its business model; it has distinct development procedures and a specialized computing infrastructure [123]. The adoption of SaaS from 2015 to 2016 increased by 21% [18]. Combining a private cloud and SaaS enhances data sharing and collaboration in construction, improving business management and government services [124,125].

In the context of SC development, Cloud Computing and SaaS contribute substantially. They establish the essential infrastructure that enables the effective gathering, processing, and application of data, which is integral to the administration of diverse urban systems [126]. They aid in cost reduction and support sustainable energy practices in urban areas by enabling energy trading among stakeholders [123,126–128]. Clouds can be utilized to build permit systems for SCs. A cloud-based permit system would provide efficiency, user experience, and security [125]. Fundamentally, incorporating cloud computing and software as a SaaS in the framework of SCs results in enhanced performance and throughput. In turn, it contributes to the augmentation of the quality of life in urban environments [126].

Cloud software provides many benefits to real estate businesses, including scalability, reduced IT costs, flexibility, device integration, and data security [128]. The advantages associated with high-value properties, extended timeframes, and various industry participants are significant. Without the presence of cloud-based solutions, the financial burden of archiving and storing data for these valuable assets would be substantial [129]. It provides scalable data storage and processing and enhances collaboration and data accessibility [71]. Clouds are used in real estate to optimize the total cost of ownership and flexible resource utilization [124]. Moreover, it aids in creating a real estate permit platform [18,124,129]. Federated clouds allow the coordination of multi-site construction projects, increasing interoperability, consistency, flexibility, and trust [127]. Using it and private clouds offers a scientific approach to information management for construction quality supervision [124]. SaaS enables real estate agents to increase business by remote access, which leads to enhanced real estate management such as construction, E-marketing, client management, billing, retailing, lease administration, and maintenance [18]. Cloud-based platforms enable access to real estate agents, consumers, and owners, disseminating essential data such as maintenance and renovation details. They also disclose property financials to stakeholders, thus minimizing regret through increased transparency [18,129]. For investors and property managers, cloud computing and SaaS offer consolidation of large organizations across portfolios through networking, simplify integration of various solutions, and provide scalability for portfolio changes [18].

5.3. Data Collection Technologies

5.3.1. Drones

Drones, also referred to as unmanned aerial vehicles, are highly accurate and typically controlled via a handheld transmitter, a computer-based ground station, or an onboard computer [130]. According to a report by Drone Industry Insights in 2018, the market volume amounted to $14.1 billion, with the prospect of threefold growth by 2024 [49]. Drones offer cost-effective solutions, save time, require intensive labor, and are highly accurate, overcoming conventional methods' shortcomings [131]. Drones have saved the expense of planes and helicopters and offered users and buyers a new perspective for viewing entire cities, neighborhoods, and properties [132].

Drones have become an integral part of SC infrastructure. They enhance the lifestyle and quality of humans by acting as a sustainable resource to the ecosystem [133]. Adopting a drone as a stand-alone technology or combined with other smart technologies such as IoT, AI, ML, and clouds would provide real-time data and efficiently perform complex surveillance tasks in SCs [131]. However, integrating drones with other devices would bring better values and outcomes to the SC [133]. Drones, equipped with computer vision and machine learning, inspect buildings and detect cracks and damages [81,134]. Drones can provide an efficient surveillance system [134]. Various surveillance tasks can address the sustainability issues of SCs and ultimately enhance civilians' quality of life [131]. Drone can provide automated mapping, such as Drone2 mapping for ArcGIS [18]. As the deployment of drones keeps expanding, they are set to influence a variety of sectors, from entertainment to farming and construction to delivery services [138,139]. While drones were originally employed for military purposes, they have recently been incorporated into property and real estate management, providing 3D perspectives and photographic capabilities for data collection [135]. A comprehensive drone-based monitoring system can be designed for various building types and sizes [138,139].

The real estate industry was one of the first to recognize the power of drones; at the beginning of 2015, drones were used in the American real estate industry for the first time [130]. The use of this technology is encouraged to enhance the buying and selling of real estate [136]. According to Kuzma's [130] study, on average, drones are utilized in the real estate sector by 49% globally. The usage is highest in the US at 72%, followed by France at 52% and Germany at 24%. Approximately 72% of agents employ drones for aerial photography, while 48% use them for surveying purposes. Drones are changing the marketing of real estate [137]. They can be used for aerial photography, property marketing, volumetric calculations, 3D pictures, and the development of land surface data [18].

Additionally, they allow agents and property managers to obtain views and present them to potential consumers [136]. Drones provide valuable aerial visuals and zoomable pictures with more comprehensive angles to potential buyers, showcasing inaccessible views of properties. This leads to a better understanding of the property and its surroundings, resulting in time-efficient inspections and increased agent sales. It helps the customers make better-informed decisions and prevent post-purchase regrets [130,136,137]. Drones can quickly scan, monitor, and assess building conditions, accelerating maintenance processes through real-time data sharing. Their small size and light weight allow for speedy and convenient monitoring without disrupting ground or aerial traffic [134].

5.3.2. Three-Dimensional Scanning (3D Scanning)

3D Scanning can be described as a viable method for data collection technology; it can capture shapes and record real-world environments and visual attributes, creating a 3D digital model and producing models for cities and buildings [140,141]. It consists of a point cloud or a polygon mesh, which are geometric samples obtained from the surface of the scanned object [141]. 3D Scanning is extensively used across entertainment, medicine, and engineering industries and aids in prototyping, reverse engineering analysis, and documentation [142]. According to a global market report [50], the 3D scanning market, worth USD 5.51 billion in 2023, is expected to reach USD 12.06 billion by 2032, with a 9.1% CAGR. This growth is accelerated by emerging IoT and wearable technology and the increasing applications in automotive sectors. 3D Scanning is improving, becoming more user-friendly and affordable, making it accessible to beginners, real estate agents, governmental bodies, and other related users [142].

The 3D Scanning technology has a major role in the growth of SCs [143]. It aids in creating precise digital models of cities that are useful for urban planning and infrastructure. These models provide a comprehensive city view, enabling informed decision-making [143,144]. 3D Scanning relates to heritage conservation and recording; scanned 3D models simplify restoration and preservation tasks for government officials and archeological departments [143–145]. 3D Scanning fall into two categories: non-contact scanners, which scan the object without having to come into contact with it or make physical contact with the object, and contact scanners, which require the scanner to touch the object physically. 3D Scanning plays a major role in managing and maintaining infrastructures in cities, leading to increased sustainable development of cities [142–144].

As for the real estate industry, 3D Scanning is applied to create precise and detailed models and images and give real estate market stakeholders a high-quality data source suitable and applicable for construction and design, marketing and sales, renovation, and preservation [140]. Three-Dimensional Scanning technologies include handheld, mobile, and structured light scanners. Handheld scanners like Lidar are employed for as-built drawings; they are useful for updating drawings or recording maintenance and are considered a fast as-built BIM [18]. It also allows construction managers to update data and drawings from the latest multi-dimensional models [142,145]. Mobile laser scanners are gaining popularity in the real estate industry, as they are 50% less costly and allow construction managers to update data and draw revisions efficiently through multi-dimensional models [18]. Takin [146] revealed that advanced visualization tools in online real estate platforms enhance communication between property managers and consumers. They enable consumers to evaluate or consider properties without physically inspecting them. 3D Scanning models and images provide reliable property information to property owners, consumers, and agents; the 3D models provide efficient property walkthroughs and enhance property sales [140]. 3D Scanning scans, combined with building models, assist in providing useful information to customers and boost sales [145]. Such spatial data with such high precision can prevent regrets that may occur due to misunderstandings of the property layout, allowing consumers to plan modifications [18].

5.3.3. Wearable Technologies

Wearable technologies, also known as 'wearables', are electronic devices that can be worn on or incorporated into clothing or wearable accessories used for data collection [147,148]. These devices, primarily utilizing internet connectivity, sensors, and scanners, facilitate instantaneous interaction between the user and the device through one-way or two-way communication channels [18]. These devices include glasses, smart watches, body kits, smart eyewear, hats, walkie-talkies, rings, watches, and bracelets [147,149]. Wearables can increase the security of their users [147]. The global market for wearable technologies has been experiencing substantial growth. As of 2022, the market size was valued at approximately USD 138 billion. The market is projected to expand at a compound annual growth rate CAGR of 13.60% from 2023 to 2032 [51].

As part of the IoT, wearable technologies offer significant value in the context of SCs and SRE. These devices facilitate real-time interaction between the user and the device, thereby enhancing the quality of life in cities [150,151]. These technologies foster individual creativity, merge digital data with social engagement, encourage educational simulations, and document physical experiences for later contemplation [152]. In real estate, wearables have great potential. They can monitor maintenance and equipment, give visual warnings for building parts, and present public data to prospective buyers [150,153]. They can be used in the construction field. Wearables can track worker locations, monitor health indicators, and send emergency alerts. This enhances construction site safety and efficiency, safeguarding workers from risks [140,147]. These devices collect raw, useful information to inform tenants or owners about the property, thus enhancing transparency [18]. This would improve the users' engagement with the building, leading to more informative decision-making [140,153]. Wearable devices enable users to stay linked to a building and obtain real-time updates on maintenance, safety hazards, and other issues [18]. Digital twins enable predictive maintenance and efficient operations by simulating real-time conditions and identifying issues early to reduce downtime and cost [152]. Also, merging wearables with building management systems can offer advantages like detecting faults and providing as-built drawings [140].

5.3.4. Virtual Reality (VR) and Augmented Reality (AR)

While AR and VR are frequently used together, they represent distinct concepts. VR is dedicated to creating entirely virtual environments independent of the real world. On the other hand, AR enhances the real world by overlaying digital elements, resulting in a hybrid of reality and digital simulation [154]. The AR and VR market, valued at $28.5 billion in 2021, is projected to expand to $200.1 billion by 2030, with a CAGR of 24.2% from 2021 to 2030 [52]. VR and AR are a fusion of virtual entities and the real world, facilitating real-time engagement and 3D virtual documentation [155]. They can enhance human–machine interaction [156]. VR and AR technologies are increasingly recognized for their potential to transform SC. Three-Dimensional virtual tours are experienced using VR, which allows for a complete engagement in a virtual space environment [140]. Integrating these technologies in SCs provides a distinctive immersive experience with IoT applications [156]. These technologies are revolutionizing urban spaces and services, thereby contributing to the evolution of SCs [157]. Kaji [155] argued that these technologies are mature enough to come out on academic shelves and should be utilized in the practical field. AR has evolved sufficiently to influence the transformation of cities into smart, digital, and interconnected entities [156]. Its impact is evident in various areas such as disaster management, facilitation of medical services, and city navigation control and improvement. AR offers new opportunities for citizens, helps tackle urbanization issues, aids decision-making, and creates business prospects [155]. VR has facilitated the implementation of services and programs in areas such as law enforcement training, educational initiatives, and urban development planning [156]. However, VR and AR technologies have introduced various cybersecurity challenges. Nevertheless, solutions are being developed across policy, architectural design, and technical domains to address these issues [156,158]. VR and AR are the most prominent technologies creating interactive SC interaction [18,155].

In the digital real estate sector, several data collection technologies, including drones, VR, and AR, are frequently used tools in industry. AR is gaining traction in design review and collaboration due to its ability to create an interactive 3D communication environment [140]. VR and AR enhance customer experience by providing immersive experiences, allowing clients to visualize properties remotely [159]. They enhance home tours, sales, and tenant communication. They assist architectural firms and developers in the pre-visualization process and the creation of virtual showrooms [156,158]. Technologists integrate AR and VR with BIM for collaboration during construction. Consumers can virtually explore properties, aiding their purchase decisions [138,160].

Further opportunities include virtual property showcases, guided visits, interactive visits, virtual staging, architectural visualization, and virtual commerce [18]. Real estate agencies employ these technologies to enrich classified ads and streamline property search processes [140]. VR enhances tenant communication and provides accurate property representations. That is vital as 87% of managers seek improved communication, and misleading ads result in high vacancy rates [18]. Through immersive visual tours, consumers can virtually explore and interact with a property, enhancing their understanding and confidence in purchasing, which reduces post-purchase regrets by providing a realistic experience and information beforehand [146].

5.4. Decision-Making and Visualization

5.4.1. Geographic Information System (GIS)

GIS is a computing system used to collect geographical data, store it in a database, perform data analysis, perform data pattern recognition, and finally, perform data visualization [109]. These data include vector and raster data: georeferenced objects, mathematical, numerical, and combined alphanumeric attribute data [8,161]. It could process both static and dynamic data [8]. The core components to be implemented for a GIS are hardware, software, data, methods, and humans [109]. According to the literature, the value and usefulness of GIS applications depend on the quality of input data available [12,140,162]. The first and most profound aspect of the characterization of GIS is the capability of the model to portray each of the entities by spatial data through its location and shape. It effectively handles user queries, which can be classified into three types: factual, graphical, and spatial [109]. The GIS global market has been experiencing significant growth. In 2021, the industry's worth of around USD 8.91 billion is anticipated to escalate to about USD 25.12 billion by 2030, demonstrating a Compound Annual Growth Rate (CAGR) of 12.2% [53]. It is a comprehensive tool for engineering, safety, and environmental analysis. It transforms the data into operational information insights for infrastructure management and provides 2D and 3D visualization of dynamic sensor data [8].

Although technologies are utilized differently in SCs, geospatial science, and technology are common bases for their smart tools [161,162]. The GIS contribution to various SC domains can be broadly classified as data provision, visualization, and analysis tools [109]. Tools in GIS improve the decision-making processes for urban planners and other stakeholders [140]. Additionally, It has gained significant importance in municipal sectors and in optimizing municipal systems [12,162]. It can detect environmental issues, evaluate urban planning scenarios, reduce traffic congestion, and analyze social services. It also improves land information systems, offers accurate information, and promotes sustainable urban development in dense cities [109,140]. Through detailed and efficient maps, meaningful representations, and distribution of various spatial phenomena, GIS can facilitate the enhancement of decision-making and data management and provide frameworks and visualization [140,161,166,167]. It can be used to assess land sites, and the site selection feature is one of the most significant aspects of the GIS [109,140]. It enhances site boundary mapping with integrated spatial analysis [161,166,167].

Additionally, it improves geospatial information visualization and produces a digital twin of the city [161]. The capabilities of the GIS toolset include features like automated subdivision of land parcels. It not only automates the creation of urban layouts like city blocks, streets, and cadastral lots but also extends roads to new subdivisions [168]. The GIS web server enables data sharing, analysis, and display and facilitates collaborative work online, which is particularly beneficial for SCs [8]. The application of the GIS-based multi-criteria decision analysis techniques provides effective decision support for various scenarios and aids in implementing SC applications [165]. GIS can play a role in IoT-based systems, and their integration brings high value to SCs; their fusion can create a powerful tool for real-time monitoring and rapid response [109]. Real-time GIS is a new approach to enhance SC; it provides real-time geospatial data processing that differs from traditional GIS. These data are generated continuously by IoT devices [2]. It provides powerful tools for archiving and data management [104]. Afaneh and Shahrour [8] documented the five-year experience of utilization of GIS for the data management and visualization of an SC project, SunRise. The project utilized an interactive web application incorporated in ArcGIS to display operational data. The project proved that GIS provides strong tools for gathering and visualizing asset and operational data in SC initiatives.

Once geodata are available, GIS has a significant role in the real estate sector; it is commonly used for dynamic location selection, property valuation, leveraging property features, proximity, and market analysis [140,165]. It helps utilize geodata to create a multidimensional decision-support system for real estate and urban development [167]. GIS facilitates optimizing the use of available land by considering multiple spatial factors [165]. GIS data aids in identifying potential markets for various real estate developments. It enhances real estate analysis by associating geographic location with various data types such as demographics, customer profile, transport network, distance, employment, and climate. Large investors can use GIS databases for portfolio evaluation [140]. GIS helps identify the most suitable locations for development by analyzing various spatial data layers such as land-use, zoning, environmental constraints, and infrastructure availability [166]. GIS facilitates the integration of various data sources, improving the comprehensiveness of valuations [169]. Once it is combined with various data sources and analytical techniques, such as parameterized region growing (PRG), and a heuristic optimization algorithm, it is possible to identify and enhance contiguous areas suitable for development [166]. Depreciating reproduction costs would enhance automated real estate valuation methods [12]. GIS platform quantifies depreciated cost, processes cost information, adds soil value from spatial analysis, returns the property value, and compromises programming [12]. One of the most beneficial added values of GIS is optimal location identification, as it helps developers identify the best locations for new developments by layering geospatial data with demographic and market trends [170]. GIS streamlines the management of real estate assets through better location analysis and data integration [171].

Utilizing GIS-integrated and analyzed multiple datasets allows for thoroughly evaluating landfill sites. It simplifies the identification and ranking of suitable locations [172]. It allows for assessing environmental factors such as proximity, terrain, traffic density, and sunlight exposure [170]. It is crucial in real estate design and planning, especially community management. It allows professionals to assess location impact accurately and make knowledge-based decisions [140]. It offers detailed spatial data to support spatial modeling and better decision-making for real estate professionals [170,171]. GIS transparentizes spatial priorities, helps prevent important property types' displacement, and supports empirical-based commercial planning [167].

GIS modeling can set up an information system for all construction phases and create an efficient project documentation archive [163]. GIS 3D modeling is vital in construction, managing large projects, and providing crucial data. It performs geometry computations, updates schedules, and links 2D drawings with databases, ensuring safe execution and hazard mitigation [163]. Additionally, it enhances data quality and visualization for sales promotion, enabling effective object searches and providing a comprehensive digital synopsis for real estate agents [12,165]. A suitable computer procedure on GIS platforms can interact with the BIM model, reading its fields, adding cost items, and considering land value [12]. GIS and BIM integration would unleash more potential of these technologies [164]. This integration can significantly enhance the planning process management during the design and construction stages and improve data-sharing practices between procurement and construction process tools [173]. GIS facilitates the integration of various data sources, improving the management process [171]. It can aid in the demolition processes and be used to analyze spatial data and plan demolition activities more efficiently [42].

5.4.2. Building Information Modeling (BIM)

BIM is a digital tool representing a building's physical and functional traits, serving as a common information source [140]. It represents building elements such as beams, columns, and walls as smart 3D objects that include embedded data such as geometry details, energy use data, and lifecycle cost information [174]. BIM was first used in the architecture, engineering, and construction (AEC) industry; BIM supports decision-making across a building's life cycle, from design and construction to operation, maintenance, and demolition [12,116,175,184]. The pace of its implementation in AEC has seen a significant rise over the past decade, with an enhanced focus on sustainable construction [185]. BIM aids engineers in design management, 2D/3D visualization, and collaborative evaluation of design options concerning cost, constructability, and engineering factors. A study suggests that the global BIM market, worth US$6.6 billion in 2022, is projected to grow at a 16.4% CAGR to reach US$22.1 billion by 2030 [54]. BIM implementation has seen significant growth in developed economies, with usage rising from 28% to 71% in North America (2007–2012), 13% to 69% in the UK (2011–2019), and 90% in Germany [185].

SC information modeling uses BIM for reality simulation, which is driven by interactive and archived data. The implementation of BIM in SC needs experts to handle software, oversee infrastructure, create DTs, develop management tools, process sensor data, and use city models for asset management and emergencies [186]. It has a significant role in creating DT for the city [164]. It optimizes construction, reduces human error, minimizes claims and document circulation, and saves time and effort. The data gathered aids in managing the SC for optimal economic and environmental benefits [187]. BIM helps tackle the challenges of growing urban populations and accelerated urbanization [188]. The data and information available in digital format through BIM can be modified, replicated, and shared with project stakeholders [145,189,190]. BIM can be integrated with other technologies, such as GIS, AI, and IoT, which can further enhance the functionality and efficiency of SCs [191]. Integrating BIM with SC technologies can help address data privacy and security challenges. It can also aid in developing governance, regulations, and policies for SCs [188]. BIM and GIS are jointly used in SC applications, including flood damage assessment, low-energy design, emergency management, site layout optimization, and supply chain management [164]. BIM enhances urban real estate management in SCs by improving facility coordination, planning, and lifecycle management and promoting sustainability through energy and waste reduction [120,121,176,177,186].

BIM is a new paradigm for real estate that allows for the design, building, and management of built assets in a digital environment. It can support different phases of real estate through its lifecycle by facilitating the exchange of information between various real estate stakeholders [91,176,178,179]. Additionally, it provides extensive data for project stakeholders, enabling evaluation of component quantities, budget viability, and the impact of design modifications on project scope and timeline [174]. It enhances the real estate business response to market demand, resulting in a higher return on investment [180]. BIM is useful in the economic aspect represented by the 5D, particularly in cost quantification, attracting appraisers' attention. Thus, enhanced cost analysis control, faster data compilation and calculation, cost estimation, and savings in costs and staff time [12,181]. Also, 5D BIMs can directly generate takeoffs, counts, and measurements from a model, benefiting quantity surveyors with reliable cost advice [181]. BIM enhances real estate valuation by providing detailed data throughout a building's lifecycle. It reduces uncertainties in valuation methods and can be used to develop ML-based valuation models, evaluate 3D factors, and estimate cost approach-based valuation components [181]. It improves data sharing in procurement and construction processes [174].

The integration of BIM and AI can enhance construction management. This combination can effectively manage the complexity and uncertainty often associated with construction projects, leading to smarter and more efficient construction management practices, a critical aspect of urban development [92]. Also, it engages the technical customer for project phases and the operator for facility management [186]. BIM provides data on room dimensions, occupancy, and utilization, enabling facility managers to optimize space allocation and track occupancy rates [121,183]. BIM can provide several added values during the operation and maintenance phases, such as smart evacuation management, intelligent asset management, smart maintenance modeling, clash detection, and remote access for operations management. BIM benefits are most noticeable during the concept design phase [91,187]. It aims to streamline labor-intensive tasks, ensure process correctness, enhance management effectiveness, and support decision-making and simulated construction operations [176]. BIM integrates maintenance schedules and requirements, allowing facility managers to access manuals and service histories for more effective planning and scheduling [121,183]. It offers a comprehensive and current record of a building's components and systems. This aids facility managers in tracking assets, planning maintenance, and analyzing lifecycles for efficient management [91,120,121].

Due to BIM's limited spatial analysis capabilities, building data are often input into a GIS tool to support the diversity of spatial relationships between topographic and temporary objects [174]. Integrating BIM and GIS improves property identification, cadastral boundary representation, and complex building visualization [190]. Additionally, their integration improves energy management, operation and maintenance management, and space management; Yu and Liu [182] pioneered the integration of GIS and BIM for real estate valuation. These technologies can be integrated to identify specific property units, accurately depict cadastral boundaries, and provide a detailed representation of complex buildings [190]. Integrating BIM with 3D Scanning with BIM enhances real estate services by offering quicker, precise building surveys and data models, aiding property stakeholders. BIM aids renovation and retrofitting by accurately representing existing buildings and systems. Facility managers can assess changes, plan renovations, and evaluate retrofitting feasibility. Integrating BIM with IoT provides real-time data for monitoring and analysis, enhancing efficiency, maintenance, energy management, safety, and long-term planning in facility management [121,122]. It helps plan and manage demolition by providing detailed 3D models and data about the building structure [42].

5.4.3. Digital Twin (DT)

DT is at the forefront of technological innovation and data integration [192]. DT is a dynamic, evolving system that bridges the physical and digital realms by combining various techniques such as ML and analytics and harnessing sensor and IoT real-time data to create a virtual replica of a physical object or process [193]. This concurrent depiction facilitates thorough observation, examination, and enhancement of the physical entity throughout its lifecycle [194]. DT fundamentally comprises three elements: a physical object, its virtual model, and a two-way data and information flow between them [27,111]. DT persistently evolves and adjusts per the physical object's state [27]. This integrated, multi-physical, multilevel, probabilistic simulation utilizes the best available physical models and sensor updates to mirror the life of its real-world counterpart [192,193]. The essence of the DT lies in its capacity to address "what if" scenarios, primarily facilitated by simulation [193]. The global digital twin market was valued at USD 11.13 billion in 2022. It is expected to grow at a CAGR of 37.5% from 2023 to 2030. This growth is driven by the increasing adoption of IoT and cloud platforms [55]. DT will likely affect most enterprises worldwide [111]. In order to make a DT operational, six steps are essential: forming a virtual replica of a physical item, processing data for design decisions, simulating product response virtually, guiding the physical item for desired operation, establishing a secure, real-time link between the physical and virtual items, and gathering diverse product data from multiple sources [193].

The DT is undoubtedly a new starting point for constructing up-to-date SCs [195]. It plays an essential role in developing sustainable SCs [194]. A city DT is a virtual model of city systems and assets throughout their lifecycles. The need for DTC arises from the growing demand for real-time, semantically rich city models for urban resilience and SC development [184]. Cities based on DT have broad prospects for economic transformation, urban smart management, and public smart services so that users and the built environment can develop more coordinately. [195] It enhances CSs by offering a holistic city view, improving data visualization and analytics, supporting diagnostics and prognostics for hazard prevention, and employing spatial computing, image processing, and simulation algorithms for urban sensing and immersive virtual experiences [161]. The DT real-time data monitoring and transmission capabilities integrate insights from urban sensing and immersive virtual technologies, spatiotemporal fusion algorithms, and visualization modeling tools. This integration aids in the governance and management of sustainable urban networks [194]. Cities based on DTs integrate various technologies such as BIM, GIS, and robotics [184]. Cloud-based smart remote operations, systems based on computer vision, and interconnected DT supplement the analytics of SCs [194]. DT simulations can unveil emergent behaviors and mitigate unforeseen, adverse effects on physical systems and objects [184]. DT requires 3D building models for city management analysis and decision-making to form a city-scale model. Therefore, the fusion of BIM and GIS is crucial for city DT, integrating BIM-produced building models into a GIS for visualization and analysis [164]. The increasing adoption of the IoT is ideal for enterprises to leverage DT platforms to boost their services and platforms [111]. DT can be created at any building or city life cycle phase. However, it reaches the best value when created in the early stages [193].

DT in the real estate sector tracks all changes, their timings, reporters, associated issues, and resolutions throughout the construction process [193]. DT could potentially enhance efficiency via predictive analytics and mitigate the numerous obstacles in the construction sector. It encompasses lifecycle management, real-time monitoring, performance decision-making, scenario prediction, efficiency enhancement, and betterment of cyber-physical systems [152,193]. It Influences the physical twin [27]. DT reflects both current and historical behavior and aids in enhancing the success of businesses, products, services, and processes [193]. It enhances analytics through real-time data visualization, improves decision confidence with information, and supports accurate diagnostics and prognostics [27,111]. DT enables efficient data management and ensures that all information is current and easy [79,113]. It aids in predictive maintenance and operational optimization [91]. DT technology also proposes efficient design, construction, and use of buildings, enables real-time control and digitization, and enhances urban infrastructure by employing a wide range of sensory and data-acquisition systems [111]. It offers cost reduction, enhanced productivity and collaboration, improved safety, and optimized performance and revenue sustainability. It maintains and updates information like project documents, timelines, and material specifications acquired during the building's lifecycle and includes a risk and emergency warning system [27,193].

Furthermore, DT integrates technologies such as IoT, AI, Big Data, and cloud computing [111]. DT utilizes IoT real-time data to propose recommendations for enhancing similar structures' design, construction, and usage [193]. DT can transform urban governance by integrating IoT, blockchain, and AI [196]. In the IoT world, AI will enhance the functionalities of DT capabilities, forming dynamic software models of physical entities or systems. These models use sensor data to comprehend their state, react to alterations, enhance operations, and create value. Integrating IoT, cloud, ML, and DT enhances product quality and efficiency [111]. Based on the research of Abdelalim et al. [183], a comparison is made between the traditional approach to facilities management of any building and the new approach using BIM and DT, especially for megaprojects; it illustrates the enhancement and added values in information accessibility, data entry, collaboration, and communication, maintenance practices, analytical capabilities, life-cycle management, cost savings and efficiency, and user experience. It shows that utilizing smart technologies plays a pivotal role in reshaping building management.

5.5. Transaction and Trading Technologies: Blockchain and Smart Contracts

A blockchain is a cutting-edge technology that records all transactions and other data, such as financial records, digital occurrences, or simply entries in a database [197,198]. The data are also difficult to manipulate once recorded while they remain open for anyone to view, ensuring transparency and security [140,199]. The blockchain unit is called a block, and each block comprises two sections: a data section for transactions and a header section for the previous block's hash pointer [197]. These blocks are connected through cryptography [140]. Blockchain refers to a digital ledger technology that takes place without validation by a trusted third party [200]. Blockchain investments are among the top 10 PropTech investments globally [198]. It has raised interest all over the world [200]. According to the research, the blockchain global market was forecasted to reach USD 17.46 billion in 2023 and projected a CAGR of 87.7% from 2023 to 2030 [56]. Smart contract architecture aims to decompose legacy systems into discrete, independently deployable services. These contracts leverage the inherent features of blockchain technology by being programmed and stored on the blockchain. Accordingly, their potential applications cover a broad range of application areas [201].

Blockchains are a good candidate for securing smart contracts [198]. Smart contracts inherit the advantages of blockchains where they are public and verifiable in the sense that they are programmed and stored in the blockchain [201]. Smart contracts play a significant role in blockchain applications; these programs enable certain activities, such as buying cryptocurrency. They can be identified as digital agreements and protocols within which the parties perform their jobs [202]. They are specific agreements in the context of cryptographically secured digital economies securing resources according to previously defined rules. They prescribe conditions and sanctions, enforcing them automatically, benefiting various areas by eliminating the need for intermediaries [197]. Combining blockchain with smart contracts can improve procedures, allow EU transactions, and enable the interconnection between public administration [202,203].

New avenues in using technology in SCs have emerged, such as blockchain technology [198], which can help SC develop sharing services [203]. The government or a private organization provides assets to the real estate market. An admin manages the system but cannot alter blockchain records [197]. End-to-end encryption in blockchains relies on public and private keys [198]. Blockchain technology offers many benefits, including rapidity, dependability, unchangeability, traceability, transparency, decentralization, and trustworthiness [197]. It achieves decentralized governance systems [113]. This technology can strengthen the security of these transactions and reduce time. However, to avoid reducing parties' rights, it has special features, such as the possibility of being amended [79,202,204]. Blockchains have been investigated in SCs for various purposes ranging from designing SCs to their real estate relational value, real estate, land registration, creating and securing DT, value calculations, trust enhancement in real estate, and logistics sharing [198].

Blockchain enables trust-free relationships. It addresses trust issues in transactions, allowing an economic system to operate independently of individuals [203].

The real estate industry widely benefits from Blockchain as it develops decentralized applications and smart contracts, guaranteeing safe and transparent transactions. It increases the effectiveness and attractiveness of online services and helps Proptech companies and agents or owners. It also has the ability to convert traditional real estate into SRE [198,203]. A smart contract enables the execution of actual estate transactions, oversees the compliance with rental agreements, oversees the regular processes of property management such as collection of rents, and organizes real estate, a decentralized and explicable record of assets in a public land registry [201,205]. The transparent ledger makes verifying land ownership and transfers ownership easier, automates processes, and reduces time and costs in land title administration [206–208]. It improves efficiency, safety, and cost savings. Real estate management faces issues like high transaction fees, lack of transparency, the participation of a third party for verification, verification problems, time-consuming transactions, fraud, and lengthy administrative processes [91,113,116,197,199,204,206,208,209]. Blockchain addresses these issues by offering speed, reliability, immutability, traceability, transparency, decentralization, and trust [113,197,200,202,208,209]. Its immutability, combined with private and public keys and smart contracts, enables a secure and efficient transfer of ownership [197]. Additionally, it includes some technologies and techniques, such as immutable record management and time-stamped [13,140,197,202,210]. Collaborative smart contracts are an advanced form of smart contracts that provide parties with simultaneous access to a distributed ledger and synchronized processing of contracts, including, for example, the purchase and sale of real estate. Over time, cooperative, smart contracts in real estate deals will grow and provide new opportunities for all stakeholders [204].

5.6. Smart Technologies Integration

This study detected the value of technology's integration in several forms and categories. Many references proved that integrating these technologies would unleash more abilities for them and provide more beneficial values for both SCs and real estate. Integrating ICT and IoT in SCs provides real-time information sharing, making cities more sustainable [93]. Cloud technology supports ICT solutions for SCs and real estate collaboration [24]. Combining ICT with GIS forms Geoinformation and communication technology (GeoICT), a relatively new and rapidly growing application area that has become common to improve the sustainability of urban areas and the development of smart cities. GeoICT is crucial in supporting ICT implementation, which integrates geographical information science and technology to assist in analysis and decision-making within SCs [104]. Real-time GIS and IoT analysis, integrated with Big Data, are elements of ICT that result in cost reductions and enhanced quality of living [93,109,114]. Integrating AI, IoT, and geospatial data optimizes resource savings, considering occupants' habits and context [43]. IoT and blockchain offer a decentralized network for SCs, ensuring privacy [24,40]. IoT and GIS have advantages in various sectors, including enhancing decision-making and monitoring systems [109]. The technologies used in urban sensing collect geospatial information through IoT sensors integrated with SC software to enhance urban effectiveness [113]. Applying Big Data and ML with BIM provides prospects for improvement in the construction sector [62]. This integration enlarges the scale of the real estate market and optimizes a portfolio [65,76]. Consequently, the IoT and BIM integration streamlines planning, construction, and maintenance, reducing time and costs. Real-time data enhance predictive maintenance and remote diagnosing, thus enhancing efficiency and information flow [120,121,183]. According to the literature, BIM, integrated with IoT, blockchain, Big Data, AI, and cloud computing, is key to the sustainable development of SCs [188]. BIM and GIS integration improve all real estate phases and assist with planning during the design and construction phases. Second, their integration is crucial for the development of DT for the SC and real estate [164,174]. Zihao et al. [116] have introduced the so-called "Cup-of-Water theory," which suggests that integrating BIM, IoT, and blockchain can manage and store data securely, transparently, and conveniently at any stage of a building's life cycle. It can significantly improve data management and operational efficiency in building projects. These technologies can interoperate to develop a decentralized common data environment (DCDE), thus improving productivity and collaboration on shared information. Integrating DT with IoT, AI, Big Data, and cloud computing improves structures' design, construction, and operation [111,122,164,193]. The potential benefits of integrating these technologies are unlimited, as they are being expanded and improved with specificity on their compatibility. As a result, new integration possibilities and technologies can always be developed. Integrating various technologies significantly enhances the metaverse, a complex and progressive environment in which different techniques come into play. This virtual domain is implemented by integrating VR, AR, blockchain, ML, AI, and other solutions. These technologies add distinct values to the modern world; they create a rich, energetic, and interactive digital space with high prospects for the real estate industry [212]. Figure 10 illustrates the integration of these technologies.

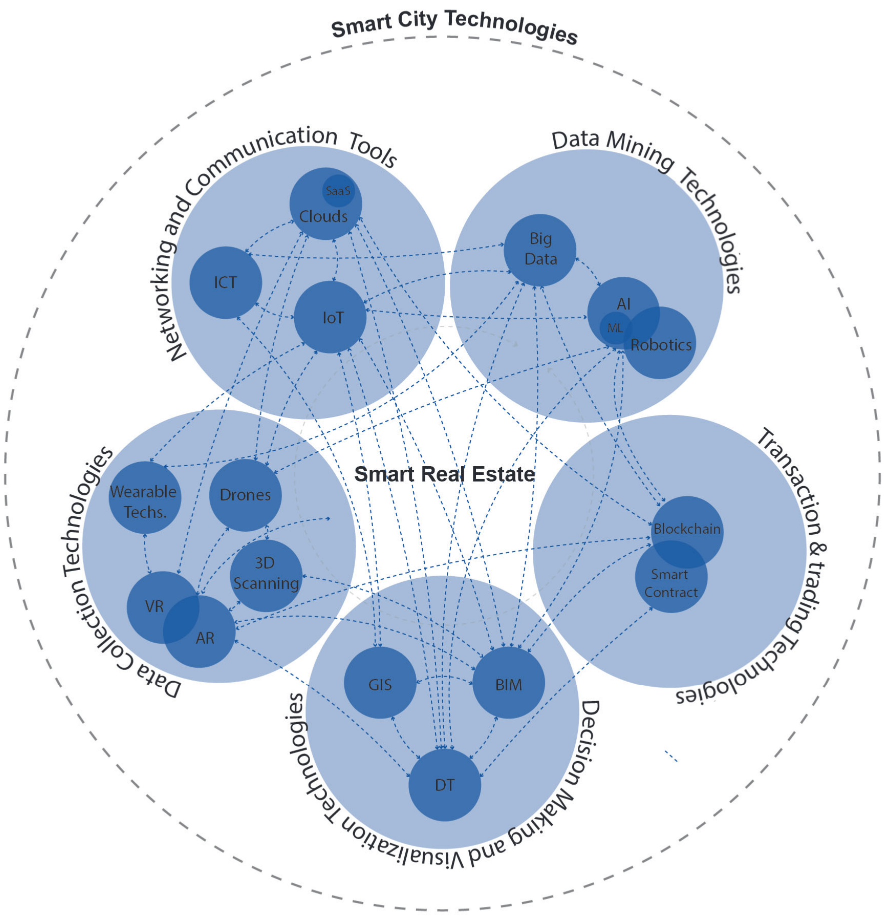

Figure 10. Integration of smart technologies. Source: Author, 2024.

6. Results and Discussion

6.1. Added Values

The integrative review of the 168 publications proved that smart technologies add numerous added values to real estate. After coding the added values, 131 added values were identified. The impact of smart technologies and added values differs based on real estate phases. Figure 11 illustrates the most beneficial technologies that added value and their contribution based on the real estate phase. In some subphases, such as the acquisition, conception, and operation, the technologies have more added value, such as utilizing GIS for site selection. Compared with technologies, they have a lower impact on other phases, such as the vacancy and project demolition stage. Some added values indirectly impact the real estate at the city level, or they affect all the real estate phases. Those added values were listed under the city management category.

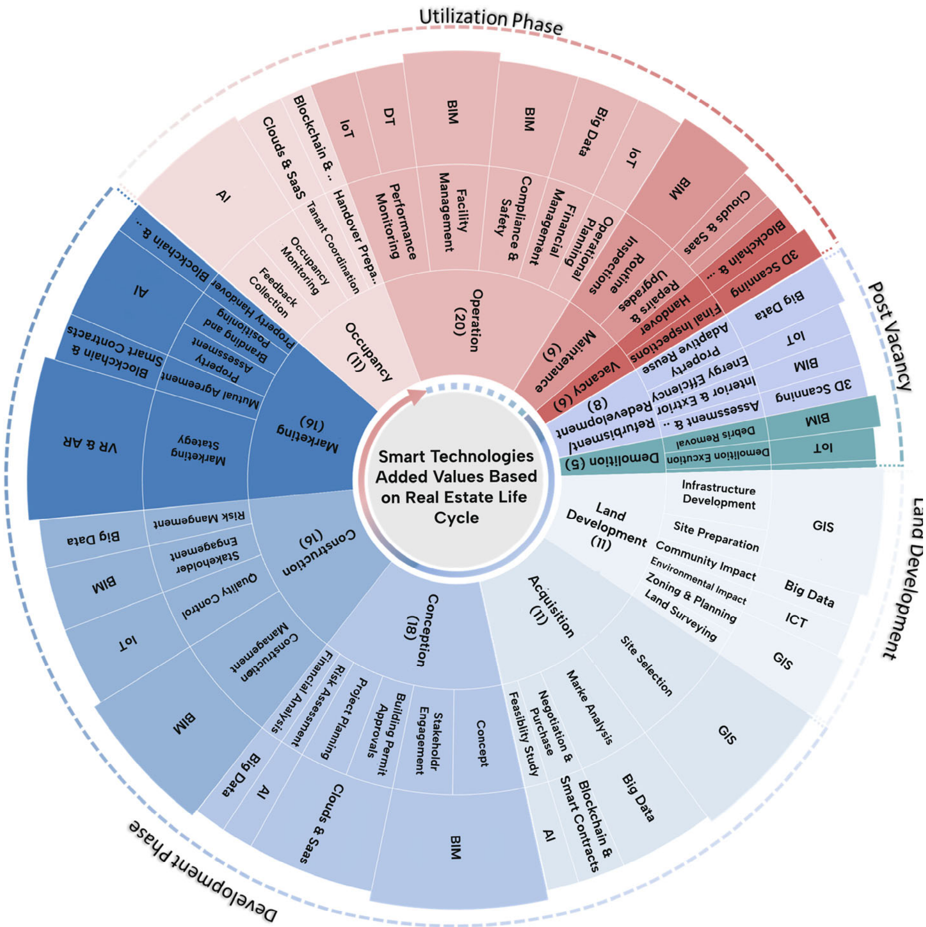

Figure 11. Smart technologies and their added values based on real estate phases. Source: Author, 2024.

Tables 3–6 represent the 131 added values of smart technologies categorized based on the real estate life cycle, with the two main phases of project development and utilization. The added values were listed based on the sub-phases and their processes and tasks. Additionally, project diminution was investigated. It identifies which technologies can achieve that value, who is the responsible stakeholder for providing it, and the users who benefit from that added value.

Table 3. Technologies and their added values at the land development phase, the responsible stakeholder to activate them, and the users. Source: Author, 2024.

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Land Development		Land Surveying	Enhance boundary and detailed topographic mapping with integrated spatial analysis	GIS, Drones	Municipal authorities (urban planners, surveyors)	Real estate developers, municipal authorities
		Zoning and Planning	Enhance analysis of zoning and land-use data and simulate various scenarios	GIS, BIM	Municipal authorities (urban planners)	Real estate developers, municipal authorities, investors
			Improve communication with zoning and permitting authorities	ICT	Municipal authorities, technology providers	Real estate developers, municipal authorities
		Site Preparation	Improve site conditions and constraints analysis	Big Data, GIS	Municipal authorities (urban planners, architects, surveyors)	Real estate developers, municipal authorities
			Coordinate and manage site preparation activities	ICT, GIS, BIM	Municipal authorities, construction managers	Real estate developers, municipal authorities
			Facilitate and enhance site clearing and grading	Drones, 3D Scanning, GIS	Construction managers, surveyors	Real estate developers, municipal authorities
		Infrastructure Development	Improve Infrastructure network management and planning	ICT, IoT, VR and AR, GIS	Municipal authorities (urban planners), technology providers	Real estate developers, municipal authorities, investors
			Coordinate infrastructure development activities	GIS, BIM	Municipal authorities, construction managers, technology providers	Real estate developers, municipal authorities
			Develop and create e-government infrastructure	ICT, Blockchain and Smart Contracts	Municipal authorities, technology providers	Real estate developers, investors, citizens
			Optimize municipal systems and provide geodata	ICT, GIS	Municipal authorities, technology providers	Real estate developers
			Improve essential data access and transparency	Big Data, ICT, Clouds, and SaaS	Municipal authorities, technology providers	Real estate developers, investors
		Environmental Impact Assessment	Provide a simulation of environmental impacts and help mitigate hazards	VR and AR, GIS, BIM, DT	Municipal authorities (environmental scientists, urban planners)	Real estate developers, municipal authorities, investors
		Community Impact Assessment	Increase participation	ICT, IoT	Municipal authorities	Real estate developers, investors, citizens
			Facilitate communication with the stakeholders	ICT	Municipal authorities (urban planners)	Real estate developers, municipal authorities, investors,

* These results are based on metadata analysis, highlighting the technologies that significantly achieve that added value. These technologies can contribute to other added values and have different abilities. The responsibility is not only for the highlighted stakeholders, but those are the key ones, and their significant role is in the scope of smart cities and smart real estate. This applies to Tables 3–6. ** The provider, the stakeholder responsible for activating these added values, can delegate the responsibility to an external expert to activate these added values highlighted between brackets. This applies to Tables 3–6.

Table 4. Technologies and their added values at the project development phase, the responsible stakeholder to activate them, and the users. Source: Author, 2024.

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Development Phase	Project Acquisition Sub-Phase	Feasibility Study	Provide a comprehensive feasibility assessment	Big Data, AI, BIM	Real estate developers (financial experts)	Investors, real estate developers, financial institutions.
			Enhance land valuation	Big Data, AI, GIS	Municipal authorities, real estate developers, (valuation experts)	Investors, real estate developers, financial institutions.
			Deliver comprehensive market insights and investment opportunities	Big Data, AI	Municipal authorities, real estate developers (market analysts)	Real estate developers, investors, municipal authorities
		Market Analysis	Provide advanced data pattern detection and grouping	Big Data, AI, IoT, GIS, BIM	Municipal authorities, real estate developers (data scientists, analysts, database administrators)	Real estate developers
			Offer predictive analysis	AI, GIS, DT	Municipal authorities, real estate developers, (data analysts)	Real estate developers, municipal authorities, investors
		Site Selection	Enhance site evaluations with high-resolution images and 3D models	Drones, 3D Scanning, GIS, DT	Municipal authorities, technology providers	Real estate developers
			Enhance land surface data development	Drones, 3D Scanning, GIS	Municipal authorities, technology providers	Real estate developers, urban planners
			Assess location impact	VR and AR, GIS	Municipal authorities, real estate developers (urban planners, environmentalists, impact analysts)	Investors, citizen
			Facilitate site selection and compersion between multiple sites based on criteria	GIS	Municipal authorities, real estate developers	Investors
		Negotiation and Purchase	Transparent land registry	ICT, Blockchain and Smart Contracts	Municipal authorities, land management authorities	Real estate developers, investors
			Enhance facilitation of mutual agreements	Blockchain and Smart Contracts	Real estate developers	Investors

Table 4. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Development Phase	**Project Conception Sub-Phase**	Concept Development	Enhance initial concept development with spatial data	GIS	Real estate developers (urban planners), municipal authorities	Real estate developers, investors
			Optimize design, data, and drawing revisions	3D Scanning, BIM, DT	Real estate developers (architects, engineers, and design team)	Contractors
			Optimize site layout	GIS, BIM	Real estate developers (urban planners, architects)	Investors
			Enhance urban planning with scenario evaluations and predictions	GIS, DT	Municipal authorities, real estate developers (urban planners)	Real estate developers, municipal authorities, investors
			Enhance project visualization	GIS, BIM, DT	Real estate developers	Real estate developers, investors
		Stakeholder Engagement	Improve decision-making and strategy formulation	Big Data, AI, Drones, 3D Scanning, GIS, BIM, DT	Municipal authorities, real estate developers	Real estate developers, municipal authorities, investors
			Automate agreements and ensure all parties are informed	Blockchain and Smart Contracts	Municipal authorities, real estate developers	Real estate developers, investors
			Enhance stakeholder collaboration and understanding with shared models	BIM	Real estate developers (BIM specialists)	Real estate developers, investors
		Financial Analysis	Accurate cost estimation	Big Data, AI, BIM	Real estate developers (financial analysts)	Real estate developers, investors
			Mitigate and identify potential economic downturns	Big Data, IoT, AI, VR and AR	Real estate developers (economists, financial analysts)	Real estate developers, investors, citizens
		Risk Assessment	Identify potential risks like natural disasters	Big Data, IoT, AI, VR and AR	Municipal authorities, real estate developers (risk analysts)	Real estate developers, municipal authorities, investors, citizens
			Mitigate risk warning system/hazard	GIS, BIM, DT	Municipal authorities, real estate developers (risk analysts, hazard response teams)	Municipal authorities, public safety, citizens
		Project Planning	Optimize resource planning	Big Data, GIS, Clouds and SaaS, BIM	Resource managers, construction managers, technology providers	Real estate developers
			Enhance real estate lifecycle planning and management	IoT, BIM, DT	Real estate developers, facility managers,(maintenance teams, digital twin experts)	Investors, real estate developers, maintenance staff
			Foster intelligent data management	Big Data, AI, Clouds and SaaS, GIS	Municipal authorities, real estate developers, technology providers	Real estate developers, citizens, policymakers
		Building Permit Approvals	Enhance building permit systems	Clouds and SaaS	Municipal authorities, technology providers	Real estate developers
			Provide accurate models for permit applications.	BIM	Real estate developers (BIM specialists)	Municipal authorities
			Enhance approval process automation, ensuring compliance	Blockchain and Smart Contracts	Municipal authorities, technology providers	Real estate developers, investors

Table 4. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Development Phase	**Project Realization and Construction Sub-Phase**	Construction Management	Improve procurement management	Big Data, AI, Clouds and SaaS, BIM	Real estate developers, contractors(project managers, procurement specialists)	Real estate developers, contractors, construction teams
			Improve supply chain management	BIM, Blockchain and Smart Contracts	Real estate developers, supply chain managers, technology providers	Real estate developers, retailers, suppliers
			Optimize construction management and progress tracking	AI, BIM, Wearable Techs	Real estate developers, contractors, construction team (BIM specialists)	Real estate developers, contractors
			Streamline coordination of multi-site construction projects	Clouds and SaaS, BIM	Real estate developers, contractors(project managers)	Real estate developers, construction teams, investors
			Increase construction site safety and efficiency	Wearable Techs., Drones, BIM	Contractors (safety officers)	Real estate developers, construction workers
		Quality Control	Digitize logistics management	Big Data, IoT, Blockchain and Smart Contracts	Contractors, technology providers (logistics companies, supply chain experts)	Real estate developers, consumers
			Optimize quality monitoring through data collection and analysis	AI, ICT	Contractors (construction managers, quality assurance team)	Real estate developers, investors
			Ensure construction quality with aerial inspections	Drones, 3D Scanning	Contractors (construction managers, quality assurance team)	Real estate developers, investors
			Enhance construction Information sharing and collaboration	IoT, BIM, ICT	Real estate developers, contractors (construction managers)	Investors, project teams, decision-makers
		Risk Management	Improve disaster management	Big Data, AI, VR and AR, GIS, DT	Municipal authorities, construction managers, technology providers (risk analysts)	Real estate developers, citizens, businesses, public safety
			Follow up and enhance project timeline monitoring	ICT, IoT, BIM	Real estate developers, construction managers, (data analysts)	Project managers, maintenance teams, investor
			Improve record management	Big Data, 3D Scanning, BIM, Blockchain	Municipal authorities, contractors, and construction managers (record keepers)	Real estate developers, legal entities, researchers, historical preservation
			Safeguard workers from risks	Wearable Techs.	Contractors and construction managers	Workers
		Construction Closeout	Update data and blueprints	3D Scanning, BIM	Real estate developers, construction managers, (architects, engineers)	Construction teams, maintenance staff, investors
			Enhance the creation of as-built drawings	Wearable Techs., BIM, 3D Scanning, Drones	Real estate developers, construction managers, (architects, engineers)	Construction teams, maintenance staff, investors
			Enhance platforms for documenting and managing the handover process.	ICT	Municipal authorities, real estate developers	Investors

Table 4. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Development Phase	Project Marketing Sub-Phase	Branding and Positioning	Enhance customer targeting and identification	Big Data, AI	Real estate developers (marketing teams)	Real estate developers, investors
			Property search processes	Clouds and SaaS, VR and AR, AI	Real estate developers, technology providers	Investors
		Marketing Strategy and Materials	Enhance view acquisition for agents and facility managers	Drones, AR and VR	Real estate developers, facility manager	Investors, tenants
			Provide virtual tours and walkthroughs	3D Scanning, VR and AR	Real estate developers (marketing teams), technology providers	Investors, remote clients
			Optimize marketing campaigns by analyzing consumer data and market trends	Big Data, AI	Real estate developers (marketing teams, data analysts)	Real estate agent, investor, consumer
			Enhance property marketing and promotion	Clouds and SaaS, VR and AR, AI, Drones, ICT	Real estate developers (marketing teams)	Real estate developers, investors
			Expansion of the smart buildings market	ICT	Real estate developers, technology providers	Investors, tenants, environment experts
			Generate business prospects and e-business opportunities	IoT, VR and AR, Big Data	Real estate developers, technology providers	Investors
		Property Assessment and Valuation	Improve property valuation and assessment	Big Data, AI, ICT, BIM, 3D Scanning, VR and AR	Real estate developers (analysts, appraisers)	Real estate developers, investors
			Timely estimations of property values	IoT, Clouds and SaaS, BIM	Real estate developers (analysts, appraisers)	Investors
			Efficiency and accuracy of appraisals	Big Data, AI	Real estate developers (analysts, appraisers), technology providers	Investors
		Mutual Agreement	Automate real estate transactions	Blockchain and Smart Contracts	Real estate developers	Investors
			Eliminate third-party involvement in real estate transactions	Blockchain and Smart Contracts	Real estate developers	Investors
			Increase trust	Big Data, Blockchain and Smart Contracts	Municipal authorities, real estate developers	Investors, citizens
		Property Handover	Ease real estate registration	Blockchain and Smart Contracts	Municipal authorities, real estate developers	Investors
			Improve the transfer of ownership	Blockchain and Smart Contracts	Municipal authorities, real estate developers	Investors

Table 5. Technologies and their added values at the project utilization phase, the responsible stakeholder to activate it, and the users. Source: Author, 2024.

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Utilization Phase	Project Occupancy Sub-Phase	Handover Preparation	Provide platforms for managing handover documentation	ICT	Real estate developers	Real estate developers
			Enforce lease agreements	Blockchain and Smart Contracts	Facility managers	Property owners, tenants
		Tenants Coordination	Facilitate user-building connectivity	Clouds and SaaS, Wearable Techs., VR and AR	Facility managers, technology providers	Facility managers, investors, visitors
			Assist in tracking occupancy rates	Big Data, IoT, BIM	Municipal authorities, real estate developers, facility managers	Investors
		Occupancy Monitoring	Enhance occupancy monitoring	IoT, DT, AI, Wearable Techs	Technology providers, facility managers, control system engineers	Facility managers (security personnel), investors
			Occupancy comfort monitoring	AI, IoT	Facility managers	Tenants
			Responsive actions based on users' behaviors	Big Data, AI, Wearable Techs	Technology providers, facility managers,	Tenants
		Feedback Collection	Enhance user experience	IoT, Clouds and SaaS, Wearable Techs., VR and AR	Facility managers, technology providers, (UX designers)	Citizens, visitors
			Increase transparency	Big Data, AI, ICT	Facility managers, technology providers	Municipal authorities, tenants, citizens
			Improve customer feedback via AI chatbots	AI	Real estate developers	Tenants
			Minimize errors and regrets	Drones, 3D Scanning, VR and AR, BIM, DT, Blockchain and Smart Contracts, AI	Real estate developers, technology providers, facility managers, quality assurance teams	Tenants

Table 5. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Utilization Phase	Project Operation Sub-Phase	Operational Planning	Upgrade building automation	ICT, IoT, BIM, DT	Facility managers, technology providers (building automation specialists)	Facility managers, tenants, investors
			Increase users' productivity and efficiency	Big Data, AI, IoT, Clouds and SaaS	Technology providers, facility managers	Tenants, employees
			Enhance space utilization and management	IoT, BIM, DT	Facility managers	Tenants, investors
		Facility Management	Improve building management	Big Data, IoT, Clouds and SaaS, Wearable Techs., BIM, DT	Facility managers, technology providers	Tenants, maintenance staff
			Maximize efficiency in the use of building resources	AI, ICT, Clouds and SaaS, BIM, DT	Municipal authorities, real estate developers, technology providers	Citizens, tenants, investors
			Endorse remote access for operations management	IoT, BIM	Facility managers	Facility managers, investors
			Improve waste management	AI, IoT, BIM	Municipal authorities (waste management companies), facility manager	Tenants, sanitation workers
		Financial Management	Refine portfolio management	Big Data, Clouds& SaaS	Real estate developers (portfolio managers, financial analysts)	Real estate developers, investors
			Boost valuation management	Big Data, AI	Real estate developers (appraisers)	Real estate developers, investors
			Analyze financial performance and optimize budgeting	Big Data, AI &Robotics, BIM	Real estate developers (appraisers)	Real estate developers, investors
			Automate lease agreements and payment processes	Blockchain and Smart Contracts	Facility managers	Investors, tenants

Table 5. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Utilization Phase	Project Operation Sub-Phase	Compliance and Safety	Increase security and safety	AI, IoT, Clouds and SaaS, Wearable techs, BIM	Facility managers, security agencies, technology providers	Tenants, citizens, visitors
			Facilitate real-time monitoring and efficient surveillance	BIM, IoT, DT, AI	Facility managers	Tenants, citizens, visitors
			Foster smart evacuation management	BIM, IoT	Facility managers	Tenants, citizens, visitors
			Secure digital twin	Blockchain and Smart Contracts	Technology providers	Facility managers, investors
		Performance Monitoring	Increase energy conservation/efficiency assessment/management	IoT, ICT, AI, BIM, DT	Facility managers, technology providers	Property owners, tenants
			Reduce operation cost	ICT, DT, VR and AR	Facility managers, technology providers	Investors, investors
			Improve environmental monitoring	IoT, BIM	Municipal authorities (environmental agencies), facility manager	Municipal authorities, investors
			Optimize building performance	AI, VR and AR, BIM, DT	Facility managers (energy analysts, optimization algorithms)	Investors, tenants
			Facilitate real-time data collection	Big Data, AI, IoT, Clouds and SaaS, Wearable techs.	Facility managers, technology providers	Real estate developers, investors, facility managers, tenant

Table 5. *Cont.*

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Project Utilization Phase	Project Maintenance Sub-Phase	Routine Inspections	Optimize schedule and document inspection process	BIM, Clouds and SaaS	Facility managers, technology providers	Investors, tenants
		Preventive Maintenance	Enhance maintenance planning, scheduling, and smart maintenance modeling	IoT, BIM, DT	Facility managers (maintenance teams)	Investors, facility managers, tenants
			Assist early fault diagnosis	IoT, BIM	Facility managers (maintenance teams), technology providers	Investors, facility manager
		Repairs and Upgrades	Enhance fault detection	IoT, AI, Wearable devices	Facility managers (maintenance teams), technology providers	Investors, safety personnel, maintenance staff.
			Facilitate real-time maintenance activities monitoring	IoT, Wearable Devices, BIM, DT	Facility managers (maintenance teams), technology providers	Investors, facility managers, tenants
		Tenants Communication	Refine sharing services	Clouds and SaaS, Drones, 3D Scanning, Wearable Techs., Blockchain and Smart Contracts	Real estate developers, facility manager	Investors, facility managers, tenants
	Project Vacancy Sub-Phase	Vacancy Analysis	Improve vacancy rate analysis	Big Data, AI	Real estate developers, facility manager	Investors
			Optimize portfolio consideration and enhance decisions in post-vacancy actions	AI, BIM, GIS, 3D Scanning	Real estate developers, facility manager	Investors
		Final Inspections	Improve building condition assessment	3D Scanning	Facility managers, building inspectors, and facility managers	Investors, tenants, maintenance staff
			Endorse heritage preservation and restoration	3D Scanning, Drones	Real estate developers, cultural heritage organizations, architects, and historians	Municipal authorities, citizens, tourists
		Documentation and Handover	Boost depreciated cost management	BIM	Real estate accountants, facility manager	Real estate developers, investors
			Refine terminate contracts	Blockchain and Smart Contracts	Real estate accountants, facility manager	Investors, tenants

Table 6. Technologies and their added values at the post-vacancy phase, the responsible stakeholder to activate it, and the beneficiaries. Source: Author, 2024.

Main Phase	Sub Phase	Process/Task	Added Value *	Technologies	Provider **	User
Post-Vacancy	Refurbishment/Redevelopment	Assessment and Planning	Enhance structural condition assessments with high-precision scanning	IoT, BIM, 3D Scanning	Contractors (structural engineers, construction managers)	Real estate developers, tenants, investors
		Interior and Exterior Upgrades	Enhance the esthetic and functional aspects of the building	BIM, VR and AR, 3D Scanning	Contractors, real estate developers (architects, interior designers, construction managers)	Real estate developers, tenants, investors
			Enhance and provide detailed models for design and planning upgrades	BIM	Contractors, real estate developers (architects, interior designers, construction managers)	Real estate developers, tenants, investors
		Energy Efficiency Improvements	Enhance sustainability by adopting energy consumption reduction measures	IoT, AI, Big Data	Real estate developers (energy consultants), construction managers	Real estate developers, municipal authorities, tenants,
			Enhance analysis of energy consumption patterns and issue detection	Big Data, IoT	Real estate developers (energy consultants), construction managers	Real estate developers, municipal authorities, tenants,
		Property Adaptive Reuse	Spatial analysis to evaluate property potential.	GIS	Municipal authorities, real estate developers, (urban planners, architects)	Real estate developers, municipal authorities, investors
			Analyze market trends and demands to identify the suitable building reuse	Big Data	Municipal authorities, real estate developers, (urban planners, architects)	Real estate developers, municipal authorities, investors
			Simulate redevelopment scenarios	BIM, DT	Municipal authorities, real estate developers, (urban planners, architects)	Real estate developers, municipal authorities, investors
	Project Demolition	Safety Measures	Enhance mapping of safety zones and hazards	GIS, BIM	Municipal authorities, contractors	Municipal authorities, investor
		Demolition Execution	Enhance construction renovation and preservation Process	3D Scanning, BIM	Municipal authorities, contractors	Real estate developers, contractors, investors, historical preservation
			Optimize planning and management of demolition processes	AI, ICT, IoT, BIM	Municipal authorities, contractors	Real estate developers, contractors, investors
		Debris Removal and Recycling	Enhance decision-making for demolition methods and waste management	Big Data, BIM	Municipal authorities, contractors	Municipal authorities, investors
			Optimize demolition waste management	AI, ICT	Municipal authorities, contractors, real estate developers	Municipal authorities

A stakeholder analysis was performed on the reviewed publications. Several stakeholders were identified: municipal authorities representing public and governmental stakeholders and various departments, specialties, and experts. The private stakeholders included real estate developers and agents and various experts such as analysts, appraisers, portfolio managers, and other real estate professionals. These stakeholders were distinguished to better understand their roles as the focus of the real estate phase. Technology and service providers are significant in all these added values. An additional stakeholder is the facility manager. In several cases, stakeholders delegate the task to an expert; it can be an external expert highlighted between brackets (stakeholder) in Tables 3–6. There are countless beneficiaries of the added value of smart technologies: investors, including consumers (buyers/sellers), and property owners. Additional beneficiaries such as tenants, citizens, policymakers, legal entities, and others are identified. This represents these stakeholders based on the real estate phases and process and identifies the technologies that would provide that added value. For the land development phase, 14 added values were identified.

Table 4 represents technologies added values at the project development phase with 61 added values, with the most added values among other phases.

Table 5 represents the added values of the technologies at the project utilization phase with 43 added values; the project operation sub-phase has the highest added values among all subphases with 20 added values.

Table 6 represents the added values the investigated technologies provide after the building serves its purpose. The investors optimize their portfolio, considering aspects of risk and yields and the best action to take, such as refurbishment, redevelopment, or demolition. For project refurbishment or redevelopment, there are eight added values that investigated technologies provide. Moreover, for the demolition process, five identified added values are offered by smart technologies. As noticed in Tables 1–6, the added values are more detectable in the earlier stages, which might influence the investors and real estate developers to reset the building life cycle and to achieve smarter and more sustainable real estate.

Figure 12 identifies the main added values of the smart technologies based on the publication reviews. These are the most characteristic ones, and as presented in Tables 3–6, these technologies are not limited to these added values. It only highlights the main capabilities and the niche in which each technology is valuable.

Based on the analysis of the added values and their relationship with real estate cycle phases, Figure 13 illustrates that the project development phase has higher added values based on count and has the highest impact on project conception and operation sub-phases. As explained earlier, based on the publication review, introducing the smart technology would have the highest impact when introduced in early phases. They would utilize these technologies based on their abilities throughout the real estate cycle. The lowest percentage at the latest phases might influence real estate developers to redevelop existing buildings to benefit from smart technologies and develop smarter buildings.

Figure 14 represents the impact of each technology based on the real estate phases; it shows that some technologies converge for several phases, such as AI and other technologies. The added values of other technologies are significantly different from one stage to another; GIS is one example, as it has significant added values at the land development and acquisition phases, which includes identifying a suitable site and much lower or no impact in other phases. The figure verifies that each technology has a different role within the real estate life cycle, and it is important to utilize them based on the phase.

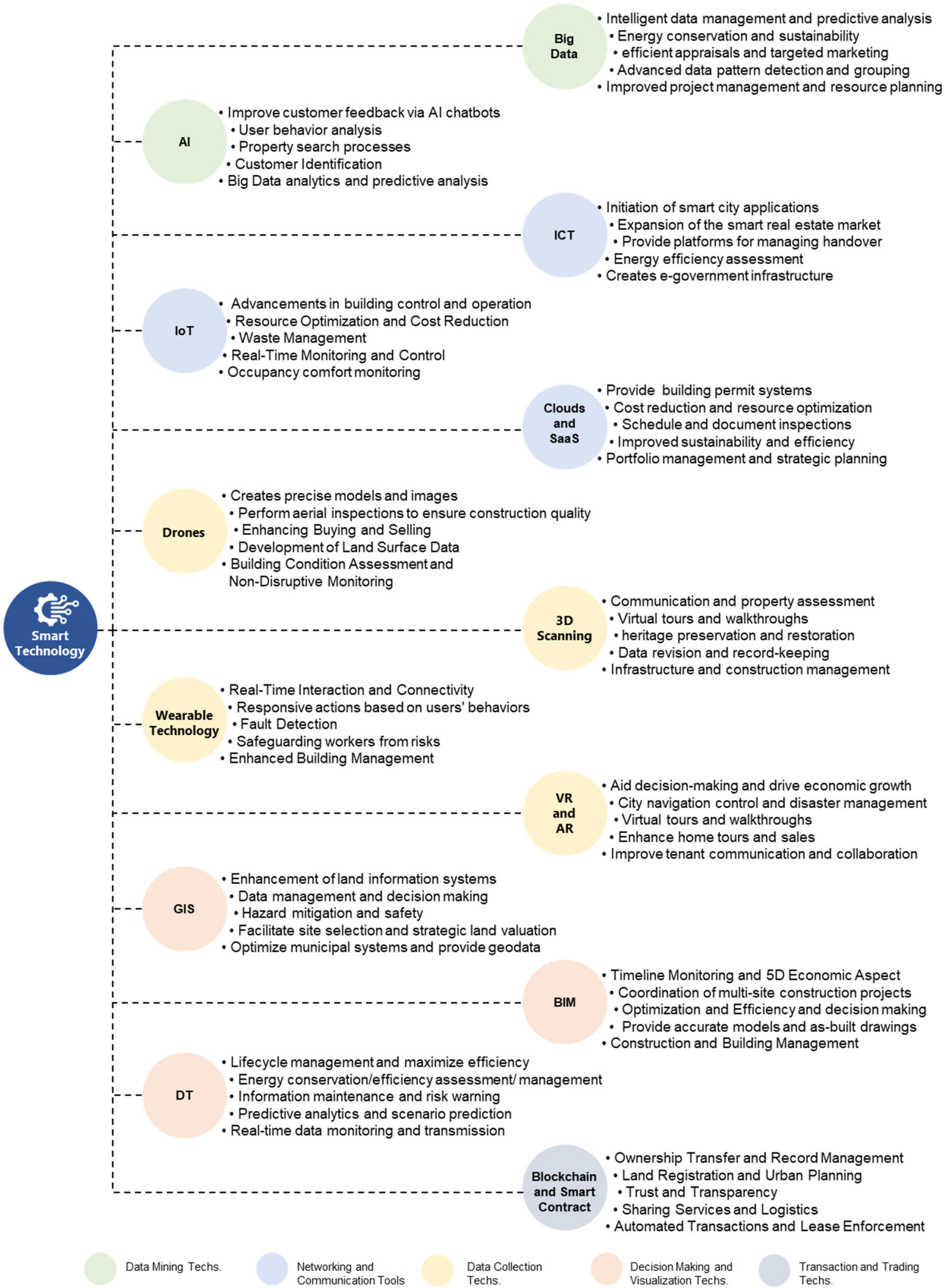

Figure 12. Smart technologies, their main added values, and characteristics. Source: Author 2024.

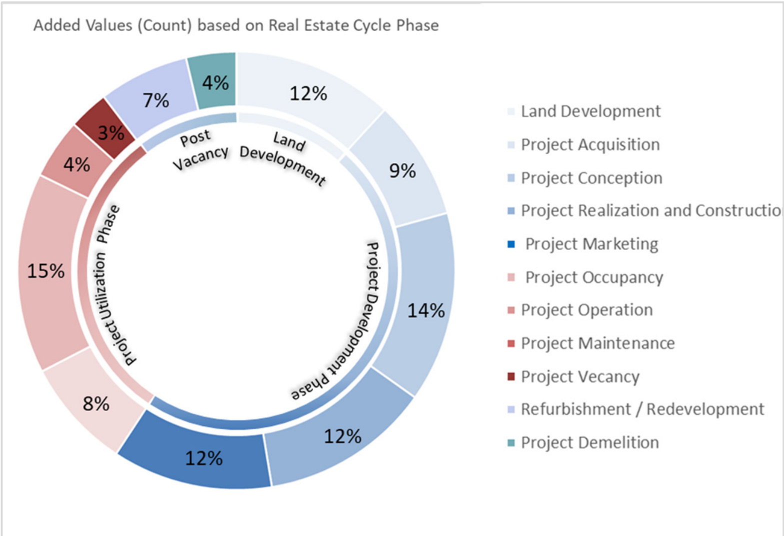

Figure 13. Added values and their percentages based on the phase. Source: Author, 2024.

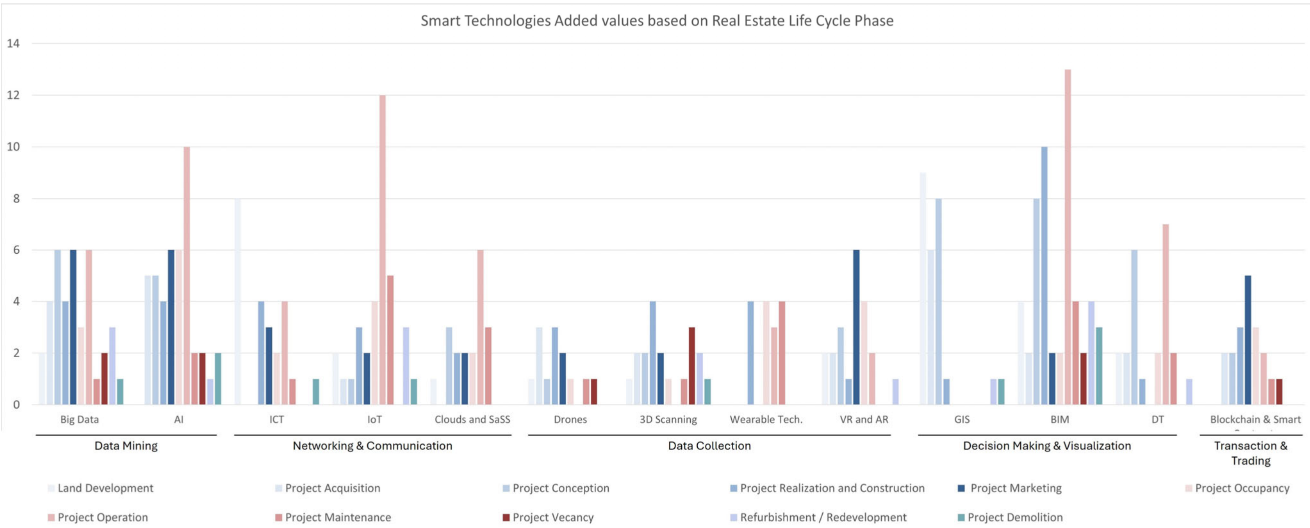

Figure 14. Technologies and their added values based on the phases. Source: Author, 2024.

Figure 15 illustrates the technology's main function group; the added value of each technology to the real estate life cycle and its impact on each phase.

Figure 16 represents the identified stakeholders' impact in activating the added values of smart technologies. Government agencies play a significant role in activating these technologies. It can indicate the important role of city management; when the city management invests in geo and Big Data, several added values are activated, making them available for real estate developers, agents, and other beneficiaries. On the other hand, it shows that different stakeholders have the ability to activate several added values and enhance the technologies' activities.

The role and impact of the stakeholders are different based on the real estate life cycle phase, as illustrated in Figure 17; each role is critical so the other stakeholders can carry out their tasks efficiently. The governmental entities and municipalities' role is concentrated in the land development phase, as their role provides the basis that the private stakeholders would utilize, such as providing geodata, developing a DT for the city, and investing in ICT infrastructure. The real estate developer's role is focused on the project accusation and conception phases, where the contractor and construction manager's main role would be in the project construction. Following that, the real estate agent would be involved in the project marketing, handing over the property to new consumers and tents. Afterward, the facility manager's role would be essential in the utilization phase, especially in the building operation phase. The technology provider's role is based on several phases, as their role is key to activating the added values of smart technologies.

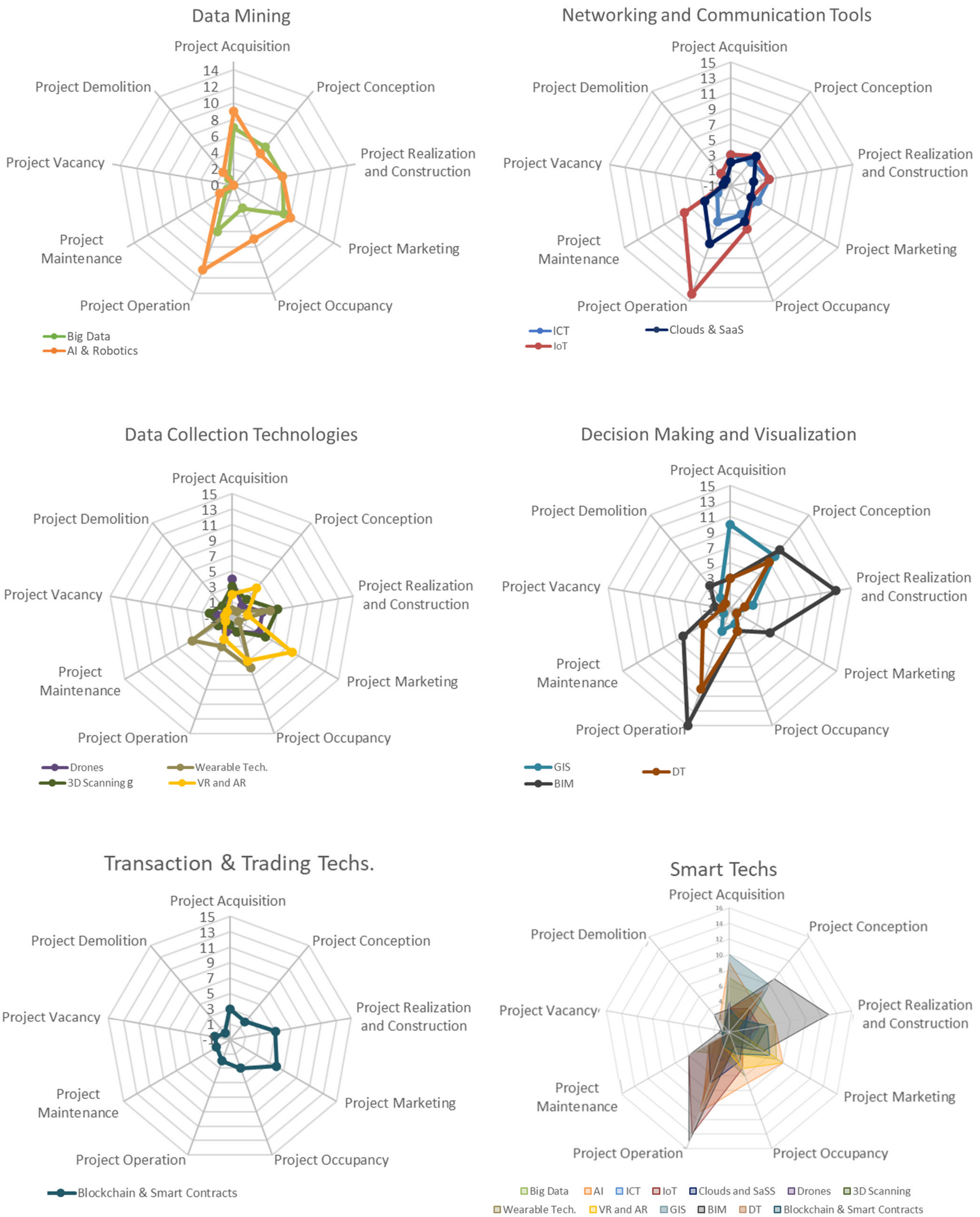

Figure 15. Technologies and their added values count based on the phases. Source: Author, 2024.

Figure 16. Stakeholder impact in activating technologies and their added values. Source: Author, 2024.

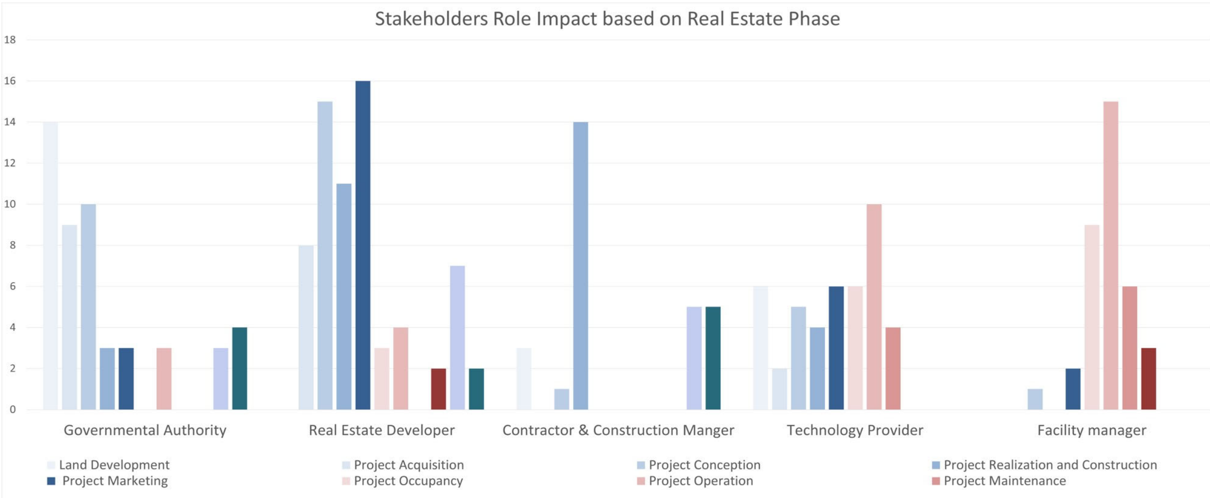

Figure 17. Stakeholders' roles and impact based on the real estate life cycle phases. Source: Author, 2024.

Figure 18 illustrates the relationship between public and private stakeholders and the technologies they utilize. According to the research, public stakeholders, who include government agencies and municipal authorities, utilize GIS, ICT, and Big Data. The research detected that public stakeholders can influence AI. The research found that public stakeholders can provide several added values for a smarter city and real estate, benefiting several users. Figure 18 illustrates the milestones that the public stakeholders can provide.

- Develop a smart infrastructure by upgrading infrastructure networks, ensuring proper fiberoptic coverage, high-speed internet, and robust communication networks across the city. Implement IoT devices by deploying sensors and smart devices to collect real-time data on city operations. Develop a centralized platform to integrate and manage data from various sources. Smart Seoul 2015 [213] is a good example of smart ICT that provides suitable services and urban management;
- Invest in Big Data and Geodata by developing open data portals where geospatial data and big data are accessible to both the public and private sectors, promoting transparency and encouraging innovation. Ensuring that data are available in standardized formats for easy integration and analysis across different platforms and applications. Promote collaboration between public and private stakeholders to share data and insights, leading to more comprehensive and accurate datasets. Advanced analytics like AI can be used to analyze data and provide training to enhance data literacy among public sector employees. The New York Open Data portal is a suitable

example as it provides extensive geospatial data on various layers, supporting real estate developers and urban planners with improved transparency [214,215];

- Activate automated building permits using Cloud and SaaS technologies by developing a cloud-based platform for submitting and processing permits. Automate code compliance with software that checks building plans against local regulations and provides training and support to ensure that city officials and the public can effectively use them. For example, New York has piloted a cloud-based building permit system to streamline the permitting process [125];
- Create a digital twin for the city by collecting data from various sources, including IoT sensors, GISs, and existing urban databases. Use modeling tools to develop the digital twin model. Integrate this model with urban planning and management tools to enhance decision-making. Engage stakeholders in developing and using the digital twin to ensure it meets their needs. For example, the Virtual Singapore project provides a 3D city model for urban planning and management [216].

The role of public stakeholders is to develop the city and create a base that the SRE can connect to and develop before the real estate cycle is initiated. They also improve the land development phase, making a solid base for smarter real estate. They impact the acquisition and conception sub-phases. Once the public stakeholders provide the mentioned technologies and data, they will enhance and encourage the private stakeholders to adopt smart technologies. The private stakeholders utilize most of the illustrated technologies:

- Real estate developers' technology utilization is more focused on GIS, BIM, Big Data, and AI; the real estate developers' main impact is significant in the early sub-phases: acquisition, conception, and construction. Real estate developers should adopt GIS for site selection to analyze land-use, zoning, and environmental impact. Implement BIM for design and construction to create detailed 3D models. Leverage Big Data for market analysis to understand market trends and customer preferences. Also, utilize AI for predictive analytics to predict project outcomes and manage risks effectively;
- The contractors' and construction managers' impact is mainly in the project construction sub-phase; they mostly utilize BIM, Big Data, and AI. They utilize BIM for project coordination to manage documentation and streamline coordination efforts. Apply Big Data for resource management to optimize allocation and scheduling. Adopt AI for site monitoring to ensure safety compliance, with applications including data collecting and site planning. Implement wearable technologies to monitor workers' safety, track vital signs, and ensure compliance with safety protocols;
- The real estate agent's role is most significant in the project marketing sub-phase utilizing several technologies. Use BIM for property visualization to create detailed models that enhance visualization for potential buyers. Implement VR and AR for immersive tours, providing virtual and augmented reality experiences. Utilize drones for aerial photography to capture images and videos for marketing purposes. Leverage Big Data and AI for targeted marketing by analyzing customer data to target potential buyers effectively. Adopt blockchain and smart contracts to secure real estate transactions and automate deal processes;
- Once the property is ready for occupancy, the role of facility managers starts; their impact is mostly in the utilization phase and has a higher impact on the project occupancy and operation sub-pashes. Implement BIM for facility management to improve data accuracy and accessibility. Develop digital twins to simulate and optimize building performance, allowing for real-time monitoring and management of building systems. Integrate IoT devices to monitor and control systems. Apply AI for predictive maintenance to predict equipment failures and optimize maintenance schedules. Wearable technologies are used to connect the facility with its users.

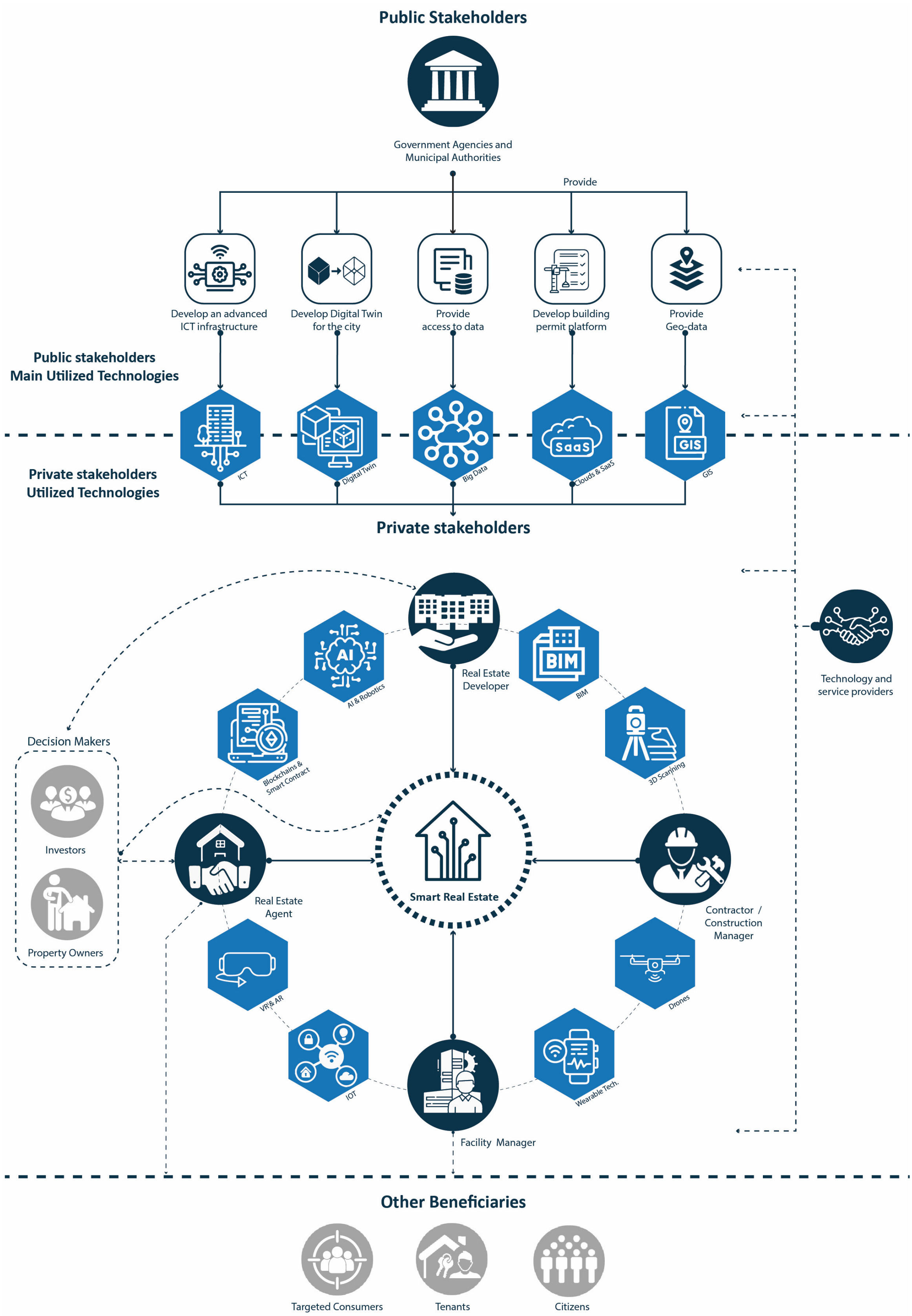

Figure 18. Public and private stakeholders relationships and their utilized technologies. Source: Author, 2024.

Based on the reviewed publications and results, several potential limitations and challenges in implementing the investigated technologies were detected:

- Data availability and existing infrastructure: the city's role is critical as limited data and geodata can significantly affect the ability of several technologies. Additionally, the existing infrastructure might not be suitable and smart enough to adopt smart technologies, such as having reliable and high-speed internet connectivity, which is essential for technologies like cloud computing and IoT;
- Data privacy and management: users may fear that their personal data collected by IoT devices, AI, and other technologies could be misused or inadequately protected. Ensuring the security and privacy of collected data is critical;
- Cost and investment: smart technologies have high initial costs, and for some technologies, the return on investment (ROI) and their added values may take time to materialize, making it challenging to justify the initial investment;
- Integration complexity: synergy and compatibility issues when integrating various technologies such as AI, IoT, and blockchain can be complex due to different standards and protocols. Additionally, the existing infrastructure may not be compatible with new technologies, requiring significant upgrades;
- Regulatory and legal issues: adhering to regulations related to data protection, building codes, and environmental standards can be challenging.
- User acceptance and training: stakeholders may resist adopting new technologies due to a lack of understanding or fear of change. Adequate training is necessary to ensure that users can effectively utilize new technologies;
- Expertise and implementation: limited experts and authors investigating and interested in the field, especially SRE. Additionally, implementing technologies without sufficient knowledge can lead to lower added values, or some Technologies may remain in the academic field without being tested and developed;
- Contextual challenges: feasibility and scalability of technologies can vary significantly based on the context. Developed cities often have better infrastructure and investment capacity, while developing cities may face greater challenges due to limited resources and infrastructure gaps.

6.2. Discussion

The research was able to fill the gap in the literature; it has captured the different roles and impacts of each technology based on the real estate life cycle, and this would give stakeholders a better understanding of which of these technologies they should focus on and at which stage according to their framework. It was found that the added values are higher at the project acquisition, conception, and operation sub-phases, with a lower impact on the project vacancy and demolition sub-phase, which might influence real estate developers to consider redeveloping traditional buildings and start the cycle with a smart approach from the acquisition sub-phase or even land development. The results proved that smart city technologies significantly added value to smart real estate; GIS technologies had the highest impact on the land development phase and project acquisition sub-phase, especially in the site selection process. At the project's conception, both BIM and GIS had a high impact. BIM technologies had significant added value for project realization and construction. Other technologies, such as VR, AR, and AI, had the highest impact on project marketing, especially in targeting potential consumers and virtually showcasing the property. For the utilization, AI, IoT, and wearable tech had an impact on the occupancy sub-phase for the operation sub-phase, where the technologies had the most significant effect and added value in the utilization phase; BIM, DT, AI, and IoT had a leading role in It. The maintenance sub-phase technologies such as DT, BIM, and IoT were utilized. BIM and 3D scanning had a significant role in the project refurbishment and redevelopment, where the cycle would reset to conception. For project vacancy and demolition, the added values of smart technologies were limited and had a minor impact.

Some added values are most common among the selected smart technologies, such as improved decision-making and minimizing errors and regrets. Other added values are more specific to one or two technologies, such as efficient transfer of ownership. That indicates that with proper planning and management, these technologies can be utilized based on real estate development requirements. The added values of the research technologies are not limited to these values; these are based on the publication's integrative review. There are other capabilities that the literature review might not have covered yet, and these technologies are being upgraded constantly.

In this research, the technologies were grouped based on function groups; however, these technologies are integrated into practice, and their added values are continuously being developed; therefore, they can be part of different groups and add to various aspects. Also, their added value can be increased by integrating with others. There can be unlimited benefits from these technologies' integration, as they are continuously being developed and updated to be more compatible, allowing for new integration patterns and the establishment of new technologies.

This research established that smart technologies can significantly impact the city, the real estate development, and its market, transforming them into more sustainable, smarter, managed, and secure ones. Many publications have argued that these technologies are mature enough for practical use, not just for academic study, and should be utilized. Others have taken the initiative to implement these technologies and define their benefits on both the real estate and city levels. It was proven that these technologies can create a major shift in the real estate industry.

An important factor that would affect adopting the added values is the context; the feasibility and scalability of the added values significantly differ between developed and developing cities due to varying infrastructural, economic, and regulatory contexts. As mentioned earlier, developed cities, with their advanced infrastructure and financial resources, can more easily implement and integrate smart technologies supported by well-established regulatory frameworks and higher stakeholder acceptance. In contrast, developing cities face challenges such as limited infrastructure and financial constraints, which slow the adoption of advanced technologies. For example, enhanced boundary and detailed topographic mapping are highly feasible in developed cities due to access to advanced GIS and remote sensing technologies. In contrast, developing cities face limitations in data availability. Similarly, automated approval processes for building permits are feasible in developed cities with existing digital infrastructure, whereas developing cities require significant investment in digital infrastructure and regulatory adaptation. Smart building technologies can be fully integrated in developed cities, enhancing energy management, security, and user experience, but financial constraints and limited infrastructure hinder their adoption in developing cities. Approaches such as international partnerships, open-source tools, and targeted initiatives can improve the feasibility and scalability of these technologies in developing contexts, with a phased approach considering local conditions and introducing incremental improvements.

Several stakeholders were identified; they can activate the added values of these technologies based on the real estate life cycle phase. According to the results, government agencies and municipal authorities had a high impact on activating the added values; their role was more visible in the land development phase; by providing a suitable smart infrastructure, Big Data, and geodata, they would provide the basis that the private stakeholders can utilize. However, they had lower benefits than other beneficiaries, which might limit the city's contribution and activate these added values. Still, the added value to the city and public authorities would compensate for the necessary implementation costs in the long run. Based on the research, it is recommended that smart technologies should be integrated into city management, fostering a skilled workforce that efficiently adapts administrative roles to new tech. City management should invest more in creating Big Data and geodata and provide them to private stakeholders. It should adopt GIS, develop a digital twin for the city, provide a building permit platform, and invest in ICT infrastructure; this will not only transform the city into a smarter one, but it will also make the city ready to integrate with smart building and provide the required data and tools for real estate developers and other private stakeholders to utilize, with this integration not only the building will be more sustainable and reduce its energy consumption, but it will also improve city management including waste, energy, and data management at city scale.

Real estate developers should adopt the investigated technologies and focus on AI, Big Data, IoT, BIM, and GIS. Leveraging these technologies would transform real estate into a smart one, enhance the real estate development process at a lower cost and faster way, and improve collaboration with city management on data-driven urban development. Once geodata are available, GIS would be critical for proper site selection, aligning projects with city sustainability goals, and enhancing the property value. Data-driven decision-making provides real estate developers with accurate forecasting and personalized property recommendations stemming from robust data analysis using Big Data and AI. They should integrate smart buildings with IoT-enabled features. Embracing BIM is one of the critical technologies used by real estate developers. It has added value for several phases, offering accurate cost estimates, enhancing collaboration, providing visual representations of projects, and improving return on investment.

Based on the results, contractors and construction managers should fully embrace BIM technologies during the construction sub-phase. By doing so, they can streamline project management, enhance collaboration, and ensure accurate as-built documentation. BIM minimizes the risk of receiving unforeseen expenses, enhancing resource management and achieving better project results. For the facility managers, AI, IoT, DT, BIM, and wearable technologies are the most crucial in the utilization phase. There is sufficient literature evidence and compelling arguments for the importance for facility managers to consider how smart technologies can be incorporated into their buildings to optimize facility performance and tenant satisfaction. Implement real-time monitoring, responsive actions, and efficient surveillance. Embrace automation, optimize energy conservation, and streamline maintenance processes. By doing so, they are able to cut operating expenses, increase safety, and guarantee smooth operations.

7. Conclusions

The real estate sector significantly contributes to the global market and economy, and smart technologies are key in shaping real estate industries and customers' behavior. Smart technologies offer multiple kinds of tools and services to various stakeholders, including city management, planners, developers, real estate agents, and customers. These can raise the levels of expertise and efficiency of day-to-day management, operations, decision-making, monitoring, sustainability, and other aspects.

This article explored the added value of smart city technologies in real estate development. An integrative review of 16 technologies: Big Data, artificial intelligence, information and communications technology, Internet of Things, clouds and software as a service, drones, 3D Scanning, wearable technologies, Virtual Reality and Augmented Reality, Geographic Information Systems, Building Information Modeling, Digital Twin, blockchain and smart contracts. The review included 168 publications from the last decade, chosen based on selection criteria. The publications included scientific articles, conference papers, book chapters, and thesis manuscripts. These technologies were sorted into five function groups: data mining technologies, networking and communication tools, data collection technologies, decision-making and visualization, as well as transaction and trading technologies. The focus was on the added value of these technologies on smart city and real estate levels. The analysis of the selected publication revealed a spik in publication years 2019–2020. There were 84 unique keywords with at least two occurrences; the most frequent keywords among the publications were Smart City, IoT, BIM, Big Data, GIS, and real estate. The scholars' network is almost disconnected, with only 24 collaborations out of 505.

Based on metadata, the review of the publications revealed 131 added values of smart technologies on real estate; these added values were categorized into 48 processes and tasks based on their impact on the real estate life cycle phases and sub-phases: the land development phase, which is before the initiation of the real estate life cycle, includes two main phases of project development, which include project acquisition, project conception, project realization and construction, and project marketing. The utilization phase consists of four sub-phases: project occupancy, project operation, project maintenance, and lastly, project clearance and vacancy. In the post-vacancy phase, the real estate cycle has three paths that the stakeholders would choose based on their requirements: project refurbishment, project redevelopment, or project demolition. The study revealed that smart technologies' most significant added value is in the conception and operation sub-phases. Smart city technologies substantially improve smart real estate; these technologies are incorporated and progressively improve their added value, unleashing new values. Their use impacts the city and real estate development, leading to improved sustainability and secure real estate. Many argue that these technologies are ready for practical use, not just academic study, and their implementation can majorly shift the real estate industry. Thus, it is suggested that planners, real estate developers, and specialists concentrate on implementing these technologies for future integration.

Based on investigation publications and views on the current practices and published research, alongside the identified technologies, added values, stakeholders, and the impact of the selected technology on different real estate life cycles, where stakeholders and decision-makers can utilize and follow to activate these added values. This article provided beneficial starting points for future studies on smart technologies that add value to real estate. This review presents state-of-the-art information and reveals contradictions or inconsistencies in the literature on smart technologies. It can reference how to utilize these technologies and at which real estate phase and sub-phase to employ them for smarter real estate and cities. The stakeholder analysis proved that both government and private stakeholders are responsible for adapting these smart technologies and are key players in activating the technology-added values. The study has revealed processes and steps that the public authorities should take to improve the city's smartness and provide elements such as big data and geodata for real estate developers and investors to develop smarter real estate. The results provided which technologies each should stakeholder invest in and at which stage to reach the ultimate results; for example, the governmental entities should invest in Geographic Information Systems at the land development phase, real estate developers should invest in artificial intelligence, Virtual Reality, and Augmented Reality at the marketing stage, and to utilize Building Information Modeling at conception and post-vacancy phases, but the contractors should invest in it at the construction sub-phase. The different stakeholders and stages illustrate that to develop efficient smart real estate, there should be a coherent and comprehensive framework that considers all the stakeholders and their roles in all the technologies and reflects their utilizations during the proper real estate life cycle. This study was able to fill the gap in the literature about smart technologies' added values, especially in real estate; it can be crucial for practitioners and scholars who aim to design and establish a road map for incorporating smart technologies in future smart real estate within smart cities. It provides a clear road map and framework for real estate developers, contractors, city planners, investors, facility managers, and other stakeholders to identify which smart technology is needed and which phase of the project life cycle to utilize. It has also provided recommendations and steps for each stakeholder to activate the captured smart technologies and added values to increase cities' and real estate's smartness levels.

Future research can expand on current findings by incorporating new publications, upgrades of existing technologies, and the latest technologies that will be developed. It can also involve experimental studies to test the effectiveness and impact of these technologies in real estate, providing empirical results to support theoretical claims. Additionally, addressing the current disconnect in the scholarly network by establishing a well-connected research network can enhance collaboration and innovation in smart real estate, contributing to the development of smarter cities.

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Abbreviations

The following abbreviations are used in this manuscript:

SC	Smart City
SRE	Smart real estate
RED	Real estate development
PropTech	Property technology
AI	Artificial intelligence
ML	machine learning
ICT	Information and communication technology
IOT	Internet of Things
SaaS	software as a service
VR	Virtual Reality
AR	Augmented Reality
DT	Digital Twins
BIM	Building Information Modeling
GIS	Geographic Information Systems
CAGR	compound annual growth rate
COVID-19	Coronavirus disease-2019
SM	Supplementary Materials
DCDE	develop a decentralized common data environment
ROI	return on investment

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