Identification and Categorization of Smart Housing Indicators: A Systematic Review and a Conceptual Framework Based on the IPO Model

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Abstract

Now, as technology is becoming embedded in everyday life at an unprecedented pace, smart housing has emerged as an undeniable necessity for the future of human habitation. By enabling a deeper understanding of needs, optimizing resources, and substantially enhancing quality of life, smart housing can respond to the complex challenges of the twenty-first century. Accordingly, this study aimed to identify and systematically review smart housing indicators, categorize the identified criteria, and develop a conceptual framework based on the IPO (Input–Process–Output) model to organize these indicators.
The study employed a review-based approach, using a systematic literature review for data collection and categorical content analysis for data analysis. Focusing on smart housing indicators, five main dimensions were examined: environmental sustainability and energy efficiency, technical efficiency and smart building infrastructure, digital security and trust, user-centeredness and residential quality of life, and governance and economic value.
A systematic review of literature indexed in Scopus indicates that smart housing indicators can be organized within an integrated Input–Process–Output framework. User-centered inputs, including technology acceptance, ease of use, lifestyle compatibility, and quality-of-life enhancement, support smart processes such as technical efficiency, infrastructure integration, digital security, and smart monitoring. These processes ultimately generate meaningful micro- and macro-level outputs, including improved quality of life, service transparency, economic value, environmental sustainability, and energy efficiency.
The findings further indicate that smart housing is not limited to applying emerging technologies in buildings but emerges from the interaction among environmental sustainability, technical efficiency, digital security, user-centeredness, and urban governance.

Keywords

Impact Assessment, IPO Model, Smart Housing, Systematic Literature Review

1.Introduction

In recent decades, the concept of housing has undergone a fundamental transformation, evolving from a merely physical and static space into a dynamic and intelligent system. Smart home refers to a set of technologies, devices, and communication systems that operate within an integrated framework to enhance residents' comfort, security, energy efficiency, and overall quality of life. This technological revolution has not only transformed the way residents interact with their living environments but has also opened new perspectives in urban planning and contemporary lifestyles. Accordingly, the housing sector is one of the major economic sectors and accounts for the largest share of investment (Habibi & Manouchehri, 2023: 188).

The growing importance of smart housing in the contemporary era, particularly in addressing global challenges such as climate change, the need for environmental sustainability, increasing urbanization, and improving quality of life, is undeniable. Smart systems can play a key role in achieving sustainable development goals by reducing energy consumption, optimizing resource management, and enhancing safety and comfort. Moreover, as populations age in many societies, the capabilities of smart housing to support older adults and individuals requiring specialized care have gained critical importance. Therefore, although housing is a highly important issue, it has received limited attention in smart city studies, despite being, like smart city projects, an integral part of a finance-driven urban economy (Listerborn, 2025: 2663).

Smart housing has emerged as a key approach to transforming urban housing into smart and sustainable systems. By connecting devices, sensors, and management systems, these technologies enable real-time monitoring, optimized energy consumption, and improved urban services (Alavi et al., 2018: 590).

The 2020s were characterized by a strong emphasis on integration, sustainability, and citizen-centeredness. During this period, smart urban housing was regarded not only as an intelligent residential unit but also as the fundamental building block of the smart city and an integral component of the smart urban ecosystem (Allam & Jones, 2020: 98). Integration with smart energy grids, intelligent transportation systems, and smart urban services, together with a strong emphasis on sustainability, efficient resource utilization, and active consideration of citizens' needs and participation, are the key characteristics of this emerging approach (Novak et al., 2024).

However, the widespread development and adoption of smart housing also face numerous challenges. Issues such as cybersecurity and data privacy, installation and implementation complexity, high initial costs, interoperability among different platforms, and ensuring ease of use for all population groups remain major barriers that require innovative solutions.

Moreover, in the contemporary era, smart housing has evolved beyond mere technical automation into a complex socio-technical ecosystem that integrates human life, technology, and the urban environment. This transformation requires a comprehensive understanding of the relationships among the various layers of this ecosystem, ranging from user-centered inputs and quality of life to technical and security-related processes, and ultimately to broader economic, environmental, and social outcomes.

Despite the rapid growth of research on smart housing, the existing literature has primarily focused on individual dimensions, such as energy management, the Internet of Things (IoT), security, quality of life, technology adoption, and smart infrastructure. Consequently, smart housing indicators have been presented in a fragmented manner, with varying definitions and without a unified conceptual framework. This fragmentation not only hinders comparisons across studies but also limits a comprehensive understanding of the relationships among these indicators and their roles in shaping smart housing. Furthermore, comprehensive systematic reviews that identify, categorize, and organize smart housing indicators within a coherent conceptual framework remain scarce. As a result, a significant research gap exists regarding the integration of different dimensions and the development of a unified model that explains the relationships among indicators across the Input–Process–Output (IPO) layers based on a systematic review of the scientific literature indexed in Scopus.

To address this gap, the Input–Process–Output (IPO) model provides an appropriate framework for organizing smart housing indicators. By distinguishing contextual factors, operational processes, and final outcomes, the IPO model facilitates the analysis of relationships among indicators and their interactions. From this perspective, the IPO model serves not only as a classification tool but also as a systematic framework for understanding the mechanisms underlying the development and performance of smart housing.

Accordingly, this study aims to identify and systematically review smart housing indicators, re-examine and categorize the identified criteria, and develop a conceptual framework based on the Input–Process–Output (IPO) model for organizing these indicators. In addition to enhancing conceptual coherence within the smart housing literature, the proposed framework provides a solid foundation for the development of future evaluation models in the field of smart housing.

2.Theoretical foundations

This section presents the research background, the evolution of housing within smart cities, the concepts of smart cities and housing, and the fundamental principles of smart housing to establish the conceptual foundation of the study.

2.1.Research Background

A review of the systematic literature review studies indicates that review-based research on smart housing has gradually expanded in recent years. One of the earliest comprehensive systematic literature reviews in this field was conducted by Marikyan et al. (2019), entitled "A Systematic Review of the Smart Home Literature: A User Perspective." By reviewing studies published between 2002 and 2017, this research examined the definitions, characteristics, services, benefits, challenges, and barriers to smart home adoption from the users' perspective. Despite its comprehensive scope, the study primarily focused on analyzing the literature from a user perspective and did not propose a framework for identifying and classifying smart housing indicators.

Subsequently, Sun and Li (2021) conducted a systematic review of Internet of Things (IoT)-based research and proposed a framework for analyzing the evolutionary trajectory of smart homes. Their study primarily focused on the technological, communication, data analytics, and service layers. However, it did not comprehensively identify or systematically organize smart housing evaluation indicators.

Subsequently, Chakraborty et al. (2023), in their study entitled "Smart Home System: A Comprehensive Review", reviewed the evolution of smart home systems, hardware components, communication technologies, and emerging applications. However, their study primarily focused on the technical aspects and architectural design of smart home systems.

More recently, Khan et al. (2024) conducted a systematic literature review to examine current trends, applications, challenges, and future research directions in the field of smart homes. Likewise, Samancioglu et al. (2024) reviewed and classified the characteristics of smart home technologies and users' preferences.

Among domestic studies, Mirpadyab and Etesam (2016), in a study entitled "Identifying Smart Housing Scenarios and Their Relationship with Sustainability", examined the role of smart housing in achieving different dimensions of sustainability. The findings indicated that the adoption of smart technologies in the housing sector can promote sustainability by optimizing energy consumption, improving resource management, enhancing the quality of the residential environment, and increasing the efficiency of building systems. Furthermore, by developing different smart housing scenarios, the authors emphasized the need to simultaneously consider technical, environmental, and managerial dimensions in housing planning and design.

Subsequently, Moradi and Rezaei Souq (2025), in a study entitled "Emerging Technologies and Improving Quality of Life in Smart Cities: Challenges and Opportunities of Smart Housing", investigated the challenges of smart housing development and strategies for its advancement using qualitative analysis and the MAXQDA software. The findings revealed that the development of smart housing requires synergy among the public, private, and academic sectors. The authors also identified the formulation of supportive policies, the strengthening of communication and technological infrastructure, and the promotion of public awareness as the key prerequisites for the wider adoption of smart housing. The study further demonstrated that implementing these strategies can enhance energy efficiency, improve security and residents' comfort, and accelerate the adoption of smart technologies in the housing sector.

Subsequently, Moradi, Teymouri, and Mofrad (2025), in a study entitled "Evaluation of Internet of Things Technology in Achieving Smart Housing in Region 6 of Tehran", investigated the role of Internet of Things (IoT) technology in the development and realization of smart housing. The findings indicated that the application of IoT, through the interconnection of smart devices and systems, facilitates improved smart building management, enhanced energy efficiency, improved security, intelligent equipment control, and increased quality of residential services. Furthermore, the study emphasized the importance of developing communication infrastructures, integrating smart systems, and establishing technological foundations for the realization of smart housing.

Accordingly, a critical review of previous studies indicates that existing research has primarily focused on technologies, system architectures, user adoption, security, health, or energy management, with each study addressing only a limited aspect of smart housing. To date, no study has systematically extracted the fragmented indicators available in the literature, analyzed them through content analysis, and organized them within a unified conceptual framework.

Therefore, the novelty of the present study lies in developing an integrated conceptual framework of smart housing indicators. Unlike previous studies that have mainly adopted descriptive or topic-oriented approaches, this research employs a systematic literature review to identify, synthesize, and organize fragmented indicators within the Input–Process–Output (IPO) conceptual framework. The outcome of this process is a coherent structure for understanding the dimensions of smart housing, which can serve as a foundation for developing evaluation models, establishing measurement indicators, and guiding future research in this field.

The Evolution of Housing in Smart Cities

To understand the position of housing within the context of smart cities, it is necessary to examine the conceptual evolution of "smart housing." The conceptual transformation of smart housing can be considered an evolutionary process in which a simple technology-oriented home has evolved into an intelligent, interactive, and data-driven living environment. In the literature, this transformation can generally be traced through three main stages:

In the first stage, the concept of smart housing was primarily associated with automation and basic technologies. In this initial approach, the term "smart home" referred to a residential unit equipped with remote-control technologies that enabled the management of lighting, temperature, security, and energy consumption (Marikyan, 2019). In this perspective, technologies, sensors, and long-range communication networks constitute the core elements of the definition of smart housing, while the primary objective is to enhance operational efficiency and provide basic comfort for residents.

In the second stage, the focus shifted toward services and interaction with residents. Subsequent studies demonstrated that the application of smart technologies in housing is not limited to technical automation;

rather, it should incorporate users' needs and lived experiences. In other words, during this period, smart housing underwent a fundamental shift in its conceptualization, moving beyond an exclusive emphasis on technical functionality and automation toward the provision of targeted services and the enrichment of residents' living experiences. This transition was rooted in research findings indicating that the true value of smart housing technologies lies not merely in the presence of automated devices, but in the ability of these systems to understand, anticipate, and respond to complex and evolving human needs. In this approach, the literature emphasizes the various services that smart housing can provide, leading to a shift in definitions of the "smart home" from a merely instrumental system toward a service-oriented system capable of responding to human needs (Marikyan, 2019, Maalsen, 2019).

At present, in the third stage, characterized by the convergence of artificial intelligence, big data, and urban ecosystems, smart housing has become an inseparable component of the broader metropolitan ecosystem. This stage is defined by the deep integration of smart systems with advanced capabilities of artificial intelligence, big data analytics, and machine learning. Smart housing is no longer merely a collection of connected devices; rather, it has evolved into a central node within a smart urban network. The focus has shifted from "services" toward "learning, predictive, self-optimizing, and adaptive systems." These systems are capable of analyzing residents' behaviors, predicting future needs, making autonomous decisions (such as optimizing energy consumption based on complex patterns), and interacting with other urban systems, including energy networks, transportation systems, and emergency services. This approach transforms housing from a physical space into a living and intelligent ecosystem, significantly enhancing its capacity to provide unprecedented levels of personalization, efficiency, and alignment with residents' lifestyles. At this stage, collected big data serves as the driving force of artificial intelligence, enabling the extraction of actionable insights for more intelligent decision-making (Hussain et al., 2025).

Accordingly, recent studies indicate that the transition from automation to learning-based, predictive, and interaction-oriented systems represents a key part of the evolutionary pathway of smart housing. This approach extends beyond efficient energy resource management and environmental condition control; by analyzing residents' behavioral data, it enables needs prediction, comfort optimization, and autonomous decision-making at a level beyond mere interaction with technology (Recent review studies on the development trends of smart technologies have clearly demonstrated this transformation) (Park & Han, 2025; Marikyan, 2019; Maalsen, 2019).

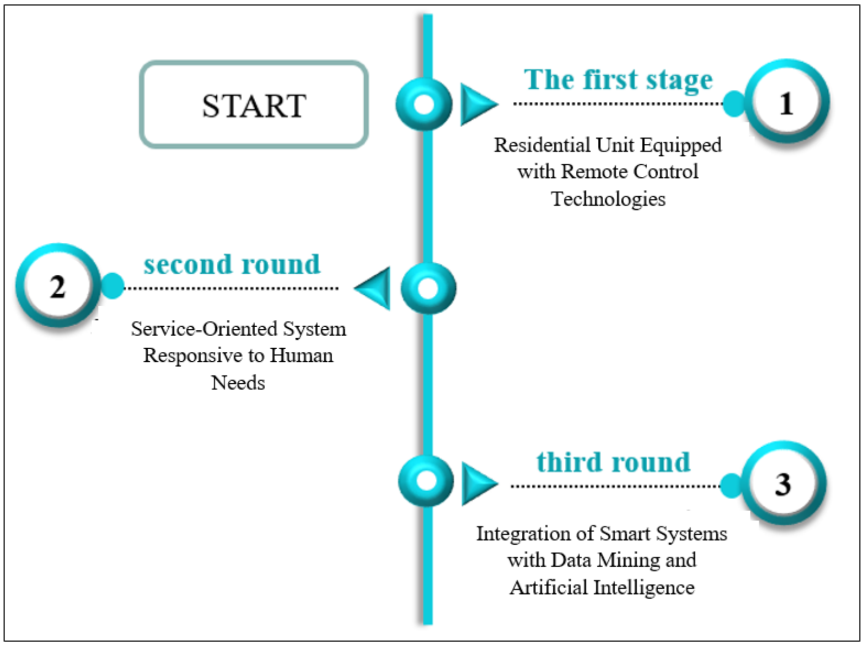

Figure 1. Evolution of housing in smart cities

Concepts of Smart Cities and Housing

Smart cities are people-centered, place-based, and locally oriented; however, they are inevitably influenced by policy decisions made at the national and international levels. Such decisions become even more critical given that emerging technologies may generate new social, ethical, and environmental risks that have the potential to offset their anticipated benefits (Hemlata & Rai, 2025: 293).

People-centered smart cities are committed to placing local communities at the heart of and leading urban digital transformation, while viewing technological advancement as a means rather than an end. However, to fully realize their transformative potential, it is essential to examine how urbanization and technological advancement interact across different regions of the world and generate multifaceted impacts on diverse urban communities (UN-Habitat, 2024: 6).

Smart city initiatives are often manifestations of broader strategic policy documents that define a desirable vision for the future of cities. Moreover, municipalities around the world are increasingly establishing strategies and targets for key strategic sectors. For example, Cocody (Cameroon) has launched a Green City Plan aimed at reducing urban carbon emissions by 70% by 2030. Similarly, the Global Assessment of Responsible Artificial Intelligence in Cities reported that approximately 30% of municipalities have developed their own artificial intelligence (AI) strategies (UN-Habitat, 2024: 10).

Fundamentals of Smart Housing

Smart housing is an essential component of sustainable urban planning and development within a smart city (Guzueva et al., 2024: 1). In the classical definition, a smart home is an environment in which physical and digital devices operate in an integrated manner to enable monitoring, control, and autonomous decision-making (Gann et al., 2012). Subsequently, this concept evolved in the urban planning and housing literature beyond the notion of a merely technology-enabled home and came to be recognized as an integral component of an intelligent and sustainable housing system.

From a contemporary perspective, smart housing is not merely a collection of technological devices; rather, it is an adaptive socio-technical system that orchestrates the interaction among people, the built environment, and technology within the framework of sustainability, well-being, and resilience (Marikyan et al., 2019).

In other words, smart housing represents a paradigm shift in the way residential spaces are designed, constructed, and managed. Through the deployment of advanced technologies, such as energy management systems, automated household appliances, and sensor networks, smart homes provide a proactive approach to energy conservation (Guzueva et al., 2024: 1).

Until recently, the concept of smart housing was largely confined to the use of building automation systems, electronic device control, and the intelligent management of lighting, heating, cooling, and security. Within this perspective, smart technologies primarily focused on automating building functions and enhancing residents' comfort, with technology serving mainly as a tool for controlling the residential environment (Marikyan et al., 2019: 141).

With the advancement of the Internet of Things (IoT), artificial intelligence (AI), cloud computing, edge computing, big data, and next-generation communication networks, the concept of smart housing has undergone a fundamental transformation. Recent studies suggest that smart housing is no longer merely a collection of interconnected devices; rather, it has evolved into an intelligent, data-driven, and human-centered ecosystem in which continuous interaction among users, sensors, intelligent systems, and digital services enables intelligent decision-making, learning from user behavior, and the delivery of personalized services (Owens et al., 2025).

Within this perspective, artificial intelligence is recognized as the decision-making core of smart housing systems. Unlike earlier generations, in which system functions operated according to predefined rules, the new generation of smart housing systems employs machine learning, deep learning, and real-time data analytics to identify users' behavioral patterns, predict environmental conditions, and make intelligent, self-adaptive decisions for managing energy, security, comfort, and residents' health. Consequently, the concept of smart housing has evolved from automation toward adaptive intelligence and intelligent decision-making. In this context, artificial intelligence enhances urban environments by improving their efficiency, sustainability, and livability. In practice, the application of AI in smart housing systems monitors and optimizes various types of household information, including energy consumption, waste management, and public safety (Rajput, 2024). AI models are also increasingly employed to generate predictive analytics for electricity consumption, traffic patterns, air quality, and other factors that influence quality of life in smart cities (Arabasy et al., 2025: 59).

On the other hand, recent studies indicate that the success of smart housing depends not only on technological advancement but also on user acceptance, trust, privacy protection, information security, ease of use, interoperability among devices, and the quality of user experience. Accordingly, contemporary perspectives regard smart housing as the outcome of the simultaneous interaction of technological, human, social, and managerial dimensions, emphasizing the need to design systems that address users' needs and preferences in addition to achieving technical efficiency (Samancioglu et al., 2024).

Accordingly, contemporary perspectives suggest that the evaluation of smart housing should not rely solely on technological features or smart devices. Instead, it should incorporate a comprehensive set of indicators related to technological infrastructure, managerial processes, human interactions, security, sustainability, service quality, and socio-economic outcomes within an integrated framework. From this perspective, the systematic organization of smart housing indicators into a conceptual framework can provide a robust foundation for the comprehensive assessment and future development of next-generation smart housing.

3.Methodology

This study adopts a review-based research design. In accordance with the research objective, a systematic literature review was first conducted, followed by content analysis of the selected studies to identify the generic indicators influencing smart housing. The purpose of the systematic review was to identify and synthesize the global body of literature and to derive smart housing indicators, categories, and subcategories through the sequential stages of defining the review protocol, literature searching, study selection, analysis, and synthesis. Using an interpretive approach, the qualitative data collected from the literature were analyzed. Subsequently, based on the frequency of occurrence of each smart housing indicator, the qualitative findings were transformed into quantitative data to facilitate subsequent analysis.

The first step in the systematic literature review was to refine the research question and identify the primary search keywords, as a clearly defined research question is essential for the screening and analysis of previous studies (Moghani Rahimi et al., 2025: 270). In the second step, to identify studies relevant to the research question, the selected keywords were searched in international databases, including Scopus. The following search strategy was employed:

TITLE-ABS-KEY ((housing OR "residential building" OR apartment* OR home) AND (smart OR digital OR "Internet of Things" OR AI)) AND (LIMIT-TO (SUBJAREA, "ENVI")).

Using this search strategy, all, or the vast majority, of studies within the environmental sciences whose titles, abstracts, or keywords contained the specified search terms were retrieved. These included journal articles, conference papers, books, theses, dissertations, and other scholarly publications. In the subsequent step, the identified studies were screened for relevance to the research question based on their titles, abstracts, and full-text content. Following the screening process, 38 relevant sources were selected for content analysis. In the final stage, the characteristics of the selected studies were systematically analyzed using an information extraction framework developed in Microsoft Excel.

Since this study adopted a comprehensive systematic literature review, all studies related to smart housing were initially identified. Subsequently, in the final stage, those studies that addressed the objectives of each subsection of the present research were selected for detailed analysis.

In other words, the study selection process was conducted in accordance with the PRISMA 2020 guidelines (Page et al., 2021). In the first stage, relevant studies were identified from the selected databases using the predefined search keywords. Duplicate records were then removed, and the titles and abstracts of the retrieved studies were screened for their relevance to the research objectives. Subsequently, the full texts of the eligible studies were assessed against the predefined inclusion and exclusion criteria. Finally, studies that satisfied all eligibility criteria were selected for the extraction and analysis of smart housing indicators. The inclusion criteria comprised publication in peer-reviewed scientific journals, direct relevance to smart housing indicators, and availability of the full text. Duplicate studies, publications unrelated to the research topic, non-scholarly reports, and studies lacking sufficient information were excluded from the review process.

To analyze the data obtained from the systematic literature review, qualitative content analysis was employed. In this process, the concepts and indicators extracted from the selected studies were first subjected to open coding, after which conceptually similar codes were merged into broader conceptual categories.

Furthermore, the Input-Process-Output (IPO) framework was adopted to organize and analyze the extracted indicators. The IPO model is a well-established conceptual framework for explaining and organizing the components of a system and the functional relationships among them by classifying elements into three categories: Input, Process, and Output (or Outcome). In the present study, this framework was employed to categorize, organize, and interpret the indicators identified through the systematic literature review. Accordingly, indicators representing the prerequisites and contextual factors for smart housing development were classified as Inputs, those associated with implementation and operational activities were categorized as Processes, and those reflecting the outcomes and impacts of smart housing implementation were classified as Outputs.

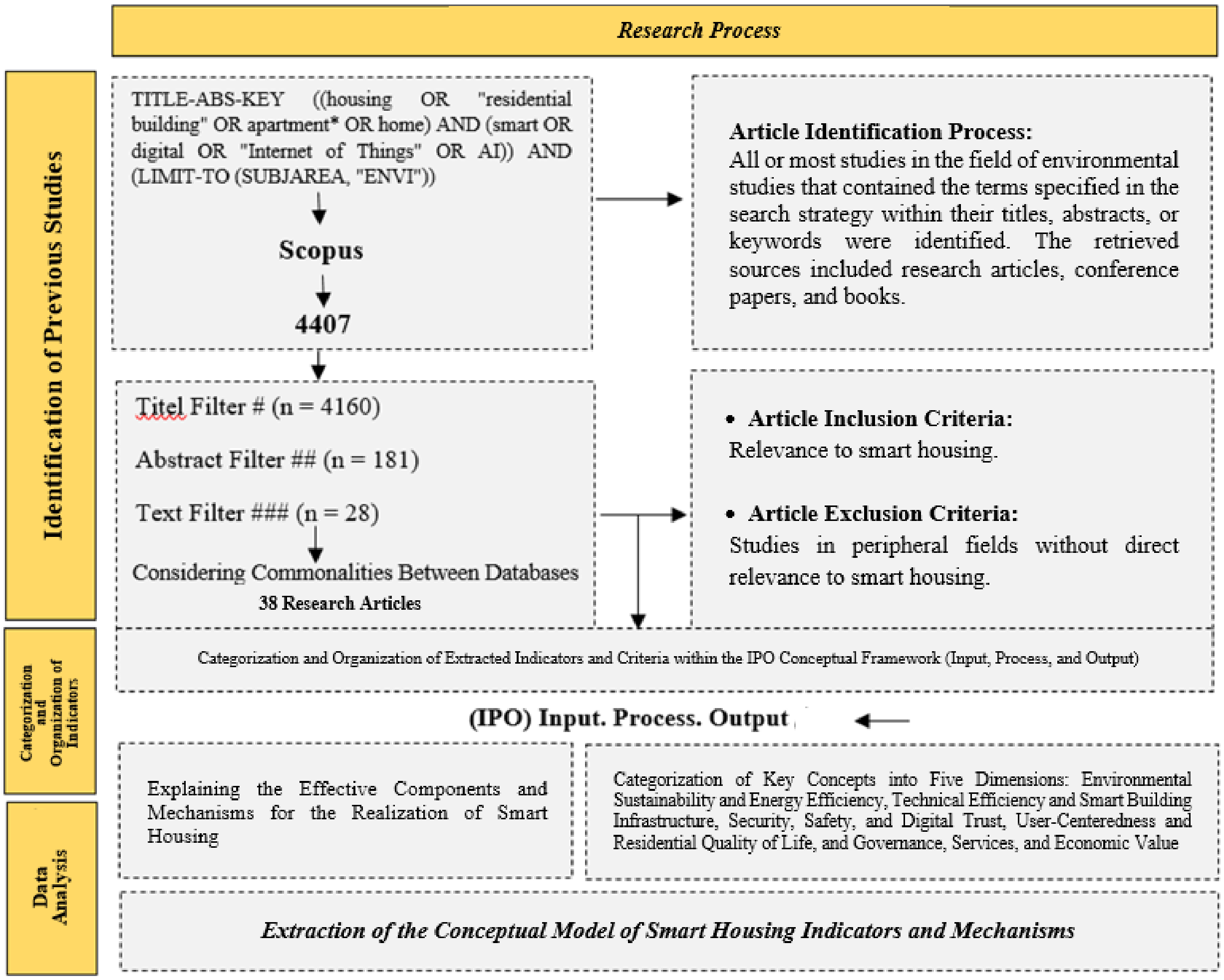

Figure 2. Research process

4.Research Findings

This section presents the systematic review of the theoretical foundations and their content analysis through several stages. The first step in content analysis involves collecting qualitative data from previous studies through methods such as literature review, observation, or interviews. In this study, a systematic literature review was employed to examine previous studies through a library-based approach. Accordingly, an extensive search was initially conducted in the aforementioned databases to identify relevant previous studies. Subsequently, the retrieved studies were screened based on three stages: title, abstract, and full-text content, and eligible studies were identified. Tables (1) and (3) present the smart housing indicators identified and reported in previous studies within this field.

Step 1: Identification of Smart Housing Indicators

This stage of the research aimed to identify the indicators influencing smart housing. Previous studies were identified and data were collected through a library-based approach (systematic literature review), while qualitative content analysis was employed for data analysis. As illustrated in Figure (3), the temporal trend of publications related to smart housing demonstrates a gradual growth followed by a significant acceleration in this research area.

The earliest study identified in the research dataset (following the systematic review process) was published in 2010, indicating the emergence of scientific interest in the concept of smart housing within the research literature. Between 2010 and 2018, the number of studies remained limited and dispersed. This pattern suggests that during this period, smart housing was still in the early stages of conceptual and technological development and was primarily regarded as an emerging research topic.

From 2020 onward, the publication trend increased considerably. This growth can be attributed to the expansion of technologies such as the Internet of Things (IoT), artificial intelligence (AI), smart sensors, and energy management systems in residential environments. These developments have transformed smart housing from a purely technology-oriented concept into an interdisciplinary field interconnected with sustainability, energy efficiency, health, and quality of life.

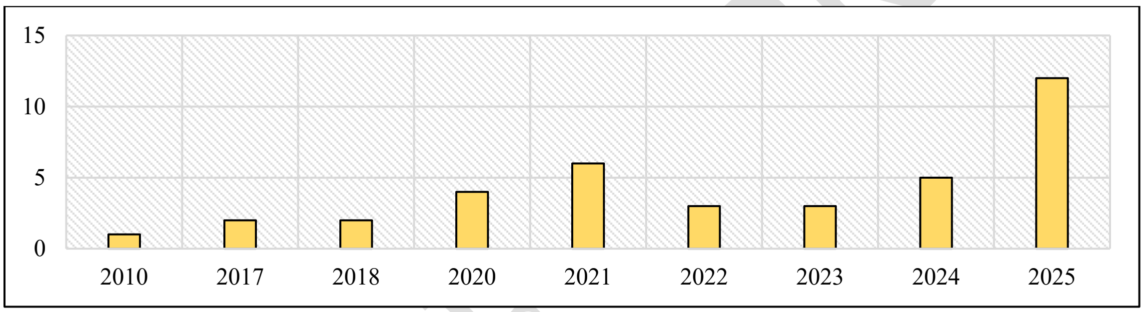

Figure 3. Time analysis of research data

At this stage, following the temporal analysis of the studies, the identified smart housing indicators were organized within the framework of housing-related factors, categorized according to the relevant factors and associated studies. In this process, an interpretive approach was employed to analyze the collected qualitative data. Subsequently, by considering the frequency of occurrence of each factor, qualitative data were transformed into quantitative information through a categorical content analysis approach to facilitate further analysis.

In other words, after the final selection of studies, smart housing-related indicators were extracted from each article and organized based on the published research. Then, by recording the presence or absence of each indicator across the selected studies, the frequency of their occurrence was calculated. This approach enables the identification of the extent to which researchers have addressed different dimensions of smart housing and facilitates the recognition of dominant indicators within the literature.

The results of this stage are presented in Table (1), which illustrates the extracted indicators, related studies, and the frequency of each indicator according to the reviewed research.

Table 1. Documentation of mediating factors of smart housing by factors and related studies

Abundance	Aurand	Wilson et al.	Ren & Li	Rasheed et al.	Gomez-Herrera & Anjos	Tomal	de Souza Dutra et al.	Cho & Choi	Emami Javanmard et al.	Shamsuddin & Srinivasan	Korovkina et al.	Anisimova et al.	Dmitrieva	Elazab	Hess et al.	Salvo et al.	Aliero et al.	Mallinson & Shafi	Nascimento, & Fettermann	Motevalli & Seyedian	Ferreira et al.	Listerborn	Parmar& Rai	Strzelecki et al.	Ahmed et al.	Garg et al.	Lagarde et al.	Chieng& Mustapa	Pirinen et al.	Ganugi et al.	Roslan et al.	Mohan et al.	Lin & Chen	Mona et al	Xenakis et al.	Hussain et al.	Habib et al.	Gbran & Alzamil	Experts / Mediating Factors
	2010	2017	2017	2018	2018	2020	2020	2020	2020	2021	2021	2021	2021	2021	2021	2022	2022	2022	2023	2023	2023	2024	2024	2024	2024	2024	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	Year
14			❊		❊				❊			❊	❊	❊			❊			❊		❊	❊				❊									❊	❊	❊	Improved Environmental Performance
11					❊				❊					❊			❊					❊	❊		❊										❊	❊	❊	❊	Smart Energy Management
11	❊		❊		❊				❊			❊	❊				❊					❊				❊					❊							❊	Enhanced Urban Resilience
2																																			❊			❊	Smart Monitoring and Management of Energy Performance and Housing Infrastructure
14	❊			❊		❊				❊	❊		❊	❊				❊		❊									❊						❊	❊	❊	❊	Increased Resident Participation
18			❊	❊	❊	❊	❊	❊		❊	❊	❊		❊		❊	❊					❊	❊			❊			❊								❊	❊	Improved Housing Efficiency and Flexibility
8						❊	❊		❊						❊				❊									❊					❊			❊			Impact of Smart Features on the Economic Value of Housing
3																									❊								❊			❊			Reliability and Operational Stability of Smart Building Systems (Uninterrupted Service Delivery without Failures or Outages)
3						❊															❊														❊				Enhanced User Readiness
13		❊		❊				❊		❊				❊			❊		❊	❊					❊	❊						❊	❊	❊					Performance of AI-Based Security Systems in Monitoring, Detecting, and Preventing Threats within the Residential Environment
1																																		❊					Intelligent and Automated Response to Security Incidents
7		❊								❊				❊			❊		❊														❊	❊					Protection of User Privacy
2																																	❊	❊					Trustworthiness

Abundance	Aurand	Wilson et al.	Ren & Li	Rashed et al.	Gomez-Herrera & Anjos	Tomal	de Souza Dutra et al.	Cho & Choi	Emami Javanmard et al.	Shamsuddin & Srinivasan	Korovkina et al.	Anisimova et al.	Dmitrieva	Elazab	Hess et al.	Salvo et al.	Aliero et al.	Mallinson & Shafi	Nascimento, & Fettermann	Motevalli & Seyedian	Ferreira et al.	Listerborn	Parmar& Rai	Strzelecki et al.	Ahmed et al.	Garg et al.	Lagarde et al.	Chieng& Mustapa	Pirinen et al.	Ganugi et al.	Roslan et al.	Mohan et al.	Lin & Chen	Mona et al	Xenakis et al.	Hussain et al.	Habib et al.	Gbran & Alzamil	Experts / Mediating Factors
	2010	2017	2017	2018	2018	2020	2020	2020	2020	2021	2021	2021	2021	2021	2021	2022	2022	2022	2023	2023	2023	2024	2024	2024	2024	2024	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	**Year**
3														❉				❉															❉						Ease of Use of Smart Technologies
3				❉															❉														❉						Compatibility of Smart Technologies with Users' Lifestyles
2					❉																												❉						Technical Support
7												❉	❉		❉	❉								❉						❉		❉							Enhanced Transparency and Accountability in Urban Service Delivery
6	❉	❉	❉	❉																❉											❉								Improved Quality of Life
4										❉			❉																	❉	❉								Improved Access to Urban Services
1																													❉										Compatibility with Collective Values
2																		❉							❉														Collaboration among Relevant Stakeholders
5		❉												❉			❉	❉	❉																				Increased Residential Comfort and Well-Being
1																	❉																						User Acceptance of Smart Technologies
1													❉																										Remote Monitoring and Control Capabilities
5	❉						❉		❉		❉		❉																										Reduced Operational and Service Costs
1										❉																													Integration of Smart Housing with Urban ICT Infrastructure

Based on a comprehensive review of all previous studies conducted by the authors, and following the confirmation of theoretical saturation at this stage, the identified smart housing indicators were first organized into subcategories and subsequently classified into broader categories based on conceptual similarities. In this section, smart housing indicators were categorized into five main dimensions: environmental sustainability and energy efficiency; technical efficiency and smart building infrastructure; security, safety, and digital trust; user-centeredness and residential quality of life; and governance, services, and economic value.

After identifying the categories and subcategories, the frequency of each subcategory was considered to determine the percentage of occurrence of each category. Subsequently, the findings derived from the content analysis were examined and interpreted. The results of this stage are presented in Table (2). Overall, the frequency distribution of categories indicates that the smart housing literature has shifted in recent years from a technology-oriented approach toward a multidimensional and interdisciplinary perspective. Accordingly, achieving smart housing requires the simultaneous integration of environmental, technical, social, managerial, and economic dimensions. Therefore, the findings of the content analysis demonstrate that none of these dimensions alone is sufficient to explain the concept of smart housing; rather, achieving smart housing requires establishing a balance among all of these categories.

Table 2. Classification of smart housing indicators and expression of the percentage of repetition of each factor

Percentage of Occurrence		**Frequency**	**Subcategory**	**Category**
25.68	9.46	14	Improved Environmental Performance	**Environmental Sustainability and Energy Efficiency**
	7.43	11	Smart Energy Management	
	1.35	2	Smart Monitoring and Management of Energy Performance and Housing Infrastructure	
	7.43	11	Enhanced Urban Resilience	
16.89	12.16	18	Improved Housing Efficiency and Flexibility	**Technical Efficiency and Smart Building Infrastructure**
	2.03	3	Reliability and Operational Stability of Smart Building Systems	
	0.68	1	Remote Monitoring and Control Capabilities	
	0.68	1	Integration of Smart Housing with Urban ICT Infrastructure	
	1.35	2	Technical Support	
15.54	8.78	13	Performance of AI-Based Security Systems	**Security, Safety, and Digital Trust**
	0.68	1	Intelligent and Automated Response to Security Incidents	
	4.73	7	Protection of User Privacy	
	1.35	2	Trustworthiness	
24.32	9.46	14	Increased Resident Participation	**User-Centeredness and Residential Quality of Life**
	2.03	3	Enhanced User Readiness	
	2.03	3	Ease of Use of Smart Technologies	
	2.03	3	Compatibility of Smart Technologies with Users' Lifestyles	
	0.68	1	User Acceptance of Smart Technologies	
	3.38	5	Increased Residential Comfort and Well-Being	
	4.05	6	Improved Quality of Life	
	0.68	1	Compatibility with Collective Values	
17.57	4.73	7	Enhanced Transparency and Accountability in Urban Service Delivery	**Governance, Services, and Economic Value**
	2.70	4	Improved Access to Urban Services	
	1.35	2	Collaboration among Relevant Stakeholders	
	3.38	5	Reduced Operational and Service Costs	
	5.41	8	Impact of Smart Features on the Economic Value of Housing	

As shown in Table (2), based on the coding of indicators and the consolidation of conceptually overlapping themes, five major categories were identified: "Environmental Sustainability and Energy Efficiency," "User-Centeredness and Residential Quality of Life," "Governance, Services, and Economic Value," "Technical Efficiency and Smart Building Infrastructure," and "Security, Safety, and Digital Trust." The frequency distribution of the identified indicators shows that "Environmental Sustainability and Energy Efficiency" received the greatest attention in the literature, accounting for 25.68% of all identified indicators. This finding reflects the dominance of the sustainability discourse in defining and conceptualizing smart housing. Within this category, environmental performance enhancement, intelligent energy management, and urban resilience enhancement were the most frequently reported indicators, suggesting that smart housing is primarily perceived as a means of optimizing resource consumption, mitigating adverse environmental impacts, and strengthening resilience and adaptive capacity to environmental change.

The second most prominent category was "User-Centeredness and Residential Quality of Life," accounting for 24.32% of the identified indicators. This finding reflects a conceptual shift from a purely technology-oriented approach toward a human-centered perspective. The high frequency of indicators such as enhanced resident participation, improved quality of life, and enhanced residential comfort suggests that the success of smart housing depends not only on the deployment of advanced technologies but also on users' acceptance, readiness, and engagement with these technologies. Furthermore, the emphasis on aligning smart technologies with residents' lifestyles and shared social values indicates that the social and cultural dimensions of housing are becoming increasingly established within the smart housing literature.

The category "Governance, Services, and Economic Value," accounting for 17.57% of the total indicator occurrences, reflects researchers' growing attention to the institutional and economic implications of smart housing. Indicators such as the impact of smart features on housing economic value, enhanced transparency and accountability in urban service delivery, and reduced operational costs suggest that smart housing should be viewed not only as a physical or technological phenomenon but also as an integral component of urban governance and the housing market. This finding indicates that integrating smart technologies into residential units can generate economic value while improving the efficiency of urban service delivery systems.

The category "Technical Efficiency and Smart Building Infrastructure," representing 16.89% of the identified indicators, primarily relates to the reliability, flexibility, and integration of smart systems. The greater emphasis on improving housing efficiency and flexibility, compared with indicators such as integration with urban ICT infrastructure or remote monitoring and control, suggests that a substantial proportion of existing studies remains focused on the building scale, while the systematic integration of smart housing within the broader urban context has received comparatively less attention. This finding reveals a potential gap in the literature that provides opportunities for future research.

Finally, the category "Security, Safety, and Digital Trust," accounting for 15.54% of the total indicator occurrences, exhibited the lowest relative frequency, although it remains one of the fundamental pillars of smart housing from an operational perspective. This category primarily focuses on the effectiveness of AI-based security systems and the protection of user privacy. Its comparatively lower representation in the literature suggests that legal, ethical, and digital trust issues have not yet received the same level of scholarly attention as the technical and environmental dimensions of smart housing. Figure (4) presents the most frequently reported smart housing indicators identified in the reviewed studies.

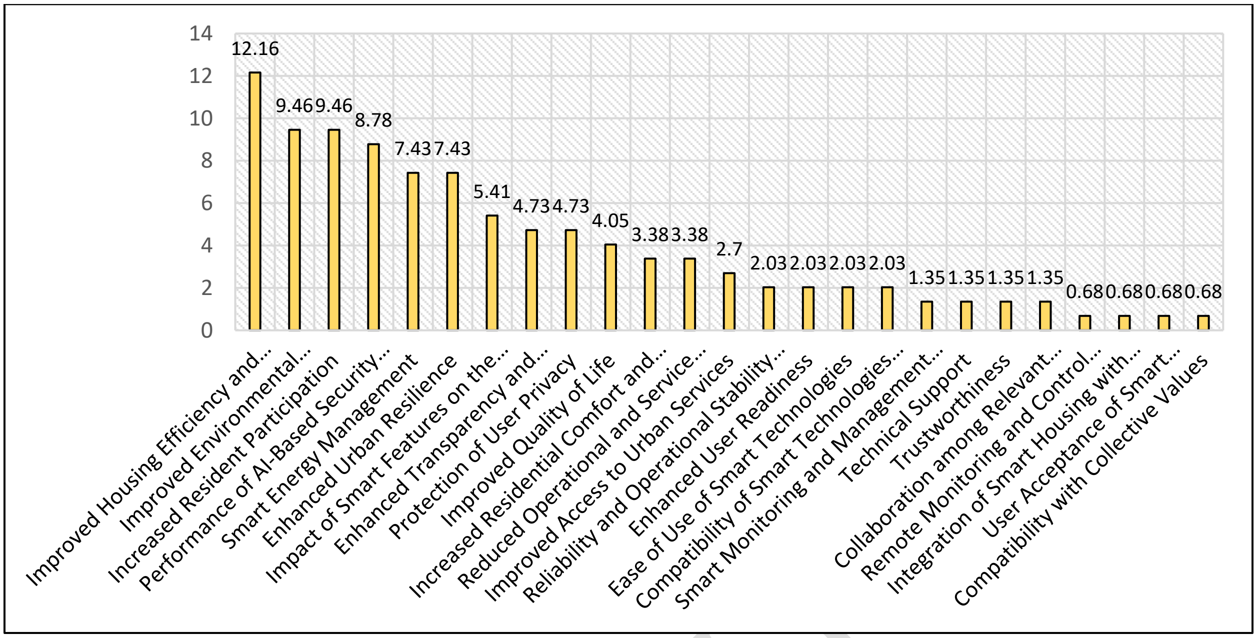

Figure 4. The most frequently repeated smart housing indicators

Overall, the distribution pattern of the identified indicators demonstrates that the smart housing literature is evolving from a purely technology-oriented approach toward a more comprehensive framework that simultaneously incorporates environmental, human, economic, and institutional dimensions. However, the imbalance in the frequency of certain categories indicates the existence of theoretical and research gaps, particularly in the areas of digital trust and institutional integration, which may serve as promising directions for future research.

The findings further indicate that the concept of smart housing in the contemporary scientific literature is inherently multidimensional and integrated. Rather than focusing solely on building technologies, smart housing is increasingly conceptualized through its interconnections with environmental sustainability, quality of life enhancement, institutional effectiveness, and economic value creation. Nevertheless, the distribution of the identified indicators suggests that existing studies have predominantly emphasized environmental and user-centered dimensions, whereas components such as digital trust and institutional integration still require further theoretical development and empirical investigation.

Step 2: Classification and Organization of the Extracted Indicators and Criteria within the Input-Process-Output (IPO) Conceptual Framework

In the previous step, the indicators influencing the realization of smart housing were identified and classified. However, to achieve a deeper understanding of the dynamics underlying smart housing, this step focuses on identifying and categorizing the relationships among the different components of these indicators. To this end, the present study adopts the Input-Process-Output (IPO) conceptual framework to examine these relationships and proposes a conceptual model that explains how technical and human-related indicators are transformed into value-generating outcomes.

As illustrated in Figure (5), the IPO model adopted in this study is based on a three-layer structure that logically guides the flow of value through the following components:

- Input Layer: This layer constitutes the fundamental foundation of the system and comprises two key groups of indicators: "User-Centeredness and Quality of Life" and "Primary Technical Infrastructure." At this level, residents' acceptance of technology, its compatibility with their lifestyles and shared social values, together with the reliability and sustainability of the supporting technical infrastructure, determine both the quantity and the quality of the data entering the processing system. These inputs essentially define the system's "intent" and "operational context," thereby establishing the foundation for the effective functioning of smart housing.

- Process Layer: This layer represents the core of the system and serves as the engine that transforms inputs into outputs. The indicators within this layer include "Smart Management" (energy management, monitoring, and control), "Digital Security and Safety" (security systems and privacy protection), and "System Integration" (integration with urban ICT infrastructure and institutional collaboration). At this stage, the raw input data are processed through intelligent algorithms and operational protocols and transformed into actionable operational decisions. The "integration with urban ICT infrastructure" plays a pivotal role in this layer, serving as a critical interface that enables smart housing to interact seamlessly with the broader urban ecosystem.
- Output/Outcome Layer: This layer represents the final achievements and tangible added value generated by the system. The outcomes are defined across two main dimensions: "Environmental Impacts and Resilience" (including improved energy performance and enhanced urban resilience) and "Residential, Economic, and Governance Outcomes" (including increased comfort, reduced costs, increased housing value, and enhanced service transparency). This layer reflects the quantitative and qualitative indicators resulting from the intelligent operation and performance of the system.

This systemic analysis provides a framework for understanding the causal relationships within smart housing and serves as a basis for the comprehensive assessment of the impacts of smart technologies on various residential, environmental, and economic dimensions.

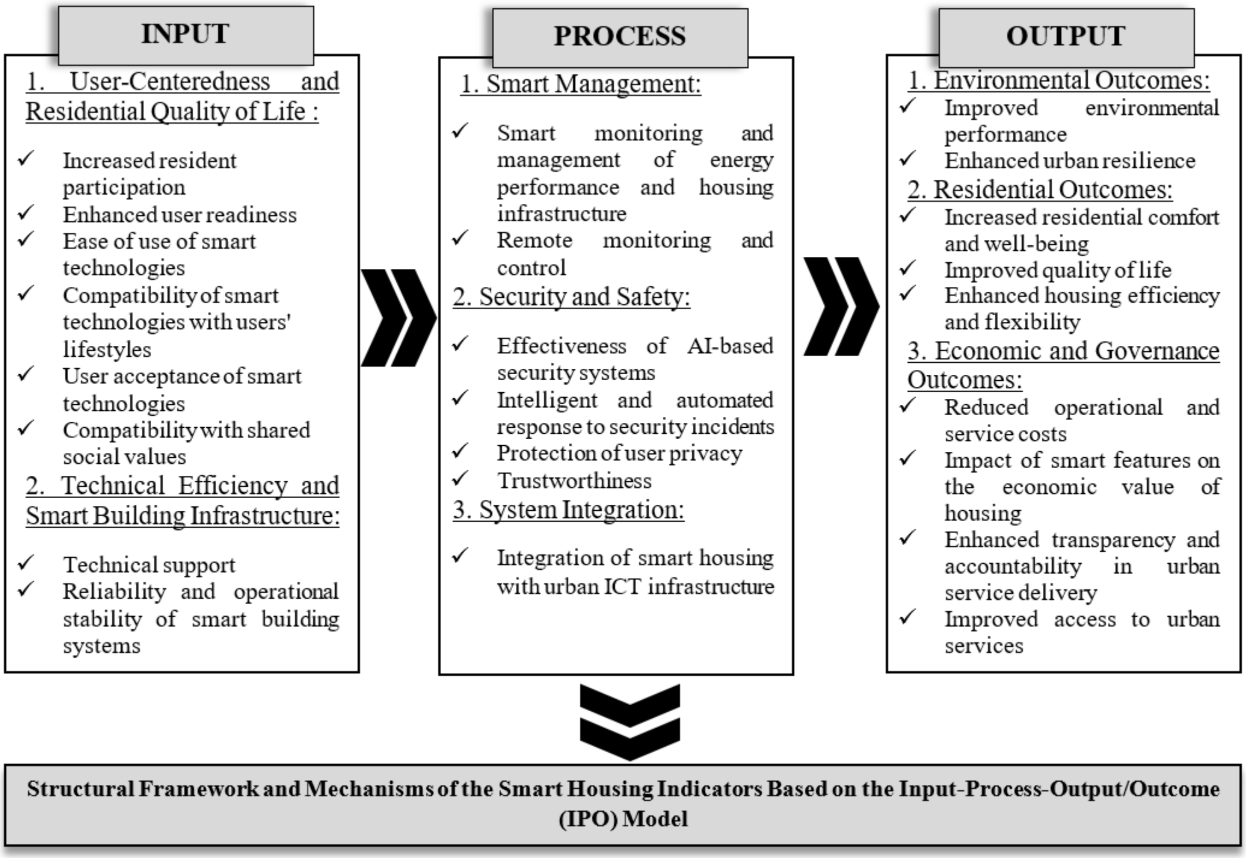

Figure 5. Structural pattern and mechanisms of effect of smart housing indicators of the IPO model

5.Discussion

The present study, by employing the Input-Process-Output/Outcome (IPO) model and relying on indicators extracted from a systematic literature review, developed an integrated conceptual model for categorizing and organizing the identified indicators and criteria. The main objective of this study was to identify and review smart housing indicators through a systematic approach, reinterpret and classify the extracted criteria, and propose a conceptual framework based on the IPO model (Input, Process, Output/Outcome) for organizing these indicators.

In the proposed model, which is based on the IPO framework, the smart housing system is redefined as a "value conversion engine." From this perspective, input indicators (Input) are considered "tuning parameters" that guide and regulate the overall behavior of the system; processes (Process) function as "mediating operators" responsible for optimizing data and transforming them into operational intelligence; and outputs (Output/Outcome) emerge as "systemic outcomes."

Accordingly, Figure (6) illustrates the synergistic relationships among smart housing indicators and mechanisms, in which each input, process, and output is organically interconnected. Therefore, strategic success in smart housing depends on the intelligent management of the interaction between "technical complexities" and "human needs." This analysis confirms that without a precise understanding of mediating mechanisms (such as security and integration), investments in smart technologies may merely result in the creation of "data silos". In contrast, the adoption of the IPO model enables the development of a sustainable, adaptive, and value-generating ecosystem capable of addressing future challenges facing smart cities.

A significant feature of this model is the existence of a feedback loop between outputs and inputs. This feedback mechanism demonstrates that the outcomes generated by smart housing performance can provide a basis for the modification, optimization, and further development of smart infrastructures and processes.

Consequently, the model moves beyond a linear structure and represents a continuous learning and improvement cycle for the advancement of smart housing.
Overall, the proposed conceptual model demonstrates that smart housing is a dynamic and integrated system in which technological and infrastructural inputs are transformed through managerial and operational processes into a range of economic, social, environmental, and well-being outcomes. Therefore, the proposed framework not only categorizes smart housing indicators but also reveals the logical relationships among them.

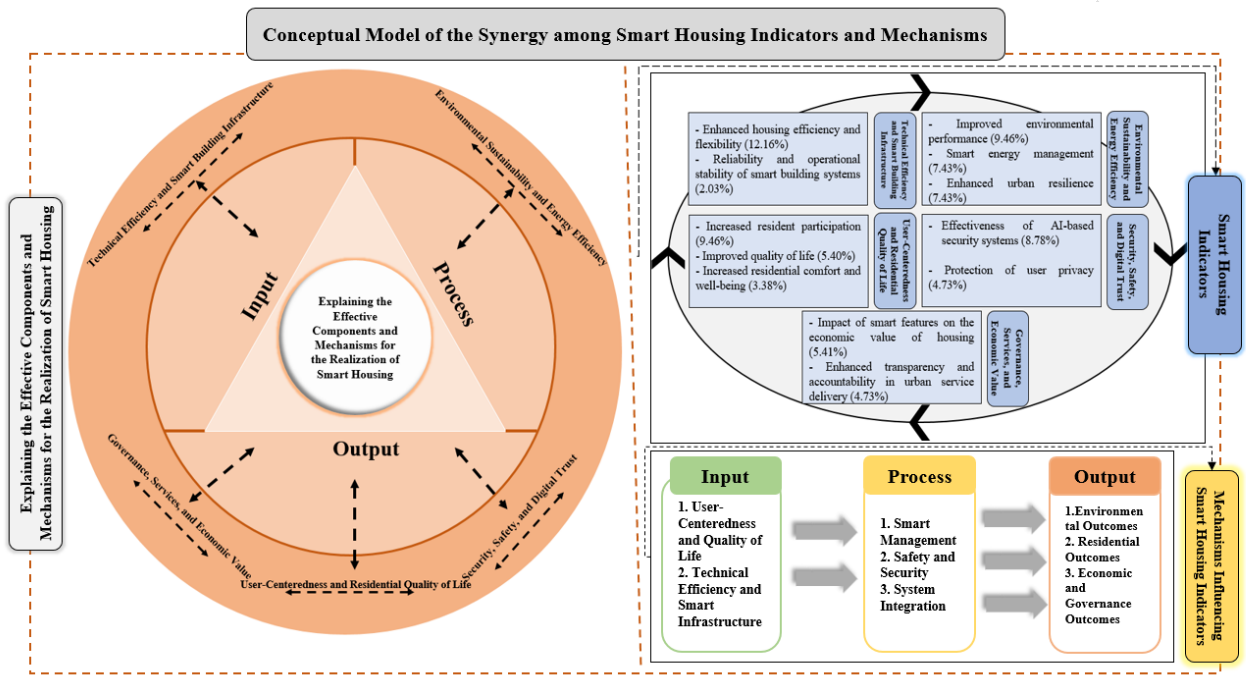

Figure 6. Conceptual model of smart housing indicators and mechanisms

6.Conclusion

Smart housing is a residential ecosystem that leverages advanced digital technologies and smart infrastructure to enhance quality of life, optimize energy consumption, and improve environmental resilience. This concept extends beyond the physical building by integrating the interactions among residents, technology, the environment, and urban governance structures within a unified framework. However, no previous study has systematically reviewed the theoretical foundations, synthesized the published literature through content analysis, and identified the key indicators influencing smart housing. Most existing studies have examined only a limited number of these factors. Therefore, this study aims to identify and systematically review smart housing indicators, re-examine and classify the identified criteria, and develop a conceptual framework based on the Input-Process-Output (IPO) model to organize these indicators. A systematic literature review of studies indexed in Scopus revealed that smart housing indicators can be organized into a coherent Input-Process-Output (IPO) framework. Specifically, user-centered inputs, including technology acceptance, ease of use, compatibility with users' lifestyles, and quality-of-life enhancement, provide the foundation for smart processes such as technical efficiency, infrastructure integration, digital security, and smart monitoring. These processes ultimately generate meaningful outcomes at both the micro and macro levels, including improved quality of life, enhanced transparency in service delivery, increased economic value, environmental sustainability, and energy efficiency.

The findings indicate that the concept of smart housing is not limited to the application of advanced technologies within buildings; rather, it emerges from the dynamic interaction among environmental sustainability, technical efficiency, digital security, user-centeredness, and urban governance. The distribution of indicator frequencies further reveals that "Environmental Sustainability and Energy Efficiency" and "User-Centeredness and Residential Quality of Life" account for the largest share of the reviewed studies, reflecting a paradigm shift in the smart housing discourse from a purely technology-driven perspective toward a more human-centered and environmentally resilient approach.

A comparison of the present findings with previous studies also demonstrates that, although considerable research has been conducted on smart housing, existing studies have generally examined the concept from specific perspectives. For instance, Marikyan et al. (2019) focused on the user perspective by investigating technology acceptance, benefits, and barriers to smart homes, whereas the present study extends beyond a user-centered perspective by systematically identifying and organizing a comprehensive set of indicators influencing smart housing. Similarly, Sun et al. (2023) primarily emphasized technological dimensions, system architectures, the Internet of Things (IoT), and communication infrastructures, whereas the framework proposed in this study examines technology in conjunction with environmental, functional, human, and governance dimensions.

Furthermore, the studies by Khan et al. (2024) and Samancioglu et al. (2024) highlighted emerging trends, applications, and user preferences, emphasizing the importance of technological factors and social acceptance. Nevertheless, a comprehensive framework for systematically classifying and integrating smart housing indicators remains absent from the existing literature. Within the Iranian context, Mirpadyab and Etesam (2016) emphasized the relationship between smart housing and sustainability, whereas Moradi and Rezaei Souq (2025) and Moradi, Teymouri, and Mofrad (2025) primarily focused on implementation requirements, Internet of Things (IoT) technologies, infrastructure, and the role of emerging technologies in improving quality of life. While confirming the significance of the indicators identified in previous studies, the present research provides a more comprehensive and integrated perspective on smart housing. By conducting a systematic review of smart housing indicators and sub-indicators, this study moves beyond previous approaches to examine the complex interactions among environmental sustainability, technical efficiency, digital security, user-centeredness, and governance within a unified conceptual framework.

A key innovation of this study is the integration of the Input-Process-Output (IPO) model as a structural-systemic framework. Unlike previous studies that have primarily focused on individual components or examined relationships in isolation, this research employs an impact analysis matrix to identify and qualitatively and quantitatively assess the value transformation mechanisms within the smart housing ecosystem. This approach provides a deeper understanding of systemic dynamics and the principal drivers of value creation.

Moreover, the prominent role of the "Security, Safety, and Digital Trust" dimension indicates that, with the rapid advancement of artificial intelligence (AI) and the integration of ICT infrastructure, concerns related to privacy, trustworthiness, and cybersecurity have become fundamental pillars of smart housing. Likewise, the "Governance, Services, and Economic Value" dimension highlights that smart housing cannot be effectively realized without robust institutional frameworks, transparent urban service delivery, and sustainable economic models. In this regard, the proposed IPO framework successfully clarifies the relationships among the identified indicators, demonstrating that some components function as regulating inputs, others as process mediators, and the remainder as strategic outcomes. This distinction enables a more precise understanding of the underlying mechanisms of influence and facilitates the prioritization of key indicators.

From a theoretical perspective, this study contributes to the development of a comprehensive analytical framework for smart housing by synthesizing indicators derived from the existing literature and organizing them within a coherent conceptual model. Accordingly, the realization of smart housing requires a system-oriented and integrated approach, in which technology, people, the environment, and governance structures are considered simultaneously and in a coordinated manner. A one-dimensional focus on technology or energy efficiency alone, without considering social acceptance, digital security, and governance mechanisms, is likely to result in an incomplete representation of smart housing. In other words, smart housing becomes an effective and sustainable solution for the future of cities only when technology is regarded not as an end in itself, but as a means of improving quality of life, enhancing efficiency, and strengthening urban governance.

From this perspective, future research should undertake comparative studies across different countries and cities to distinguish universally applicable indicators from those shaped by specific cultural, institutional, and economic contexts, an issue that is fundamental to the localization of the proposed IPO framework. In addition, greater attention should be given to intangible dimensions such as digital trust, technology acceptance, ease of use, and the lived experiences of residents through rigorous qualitative and mixed-methods approaches, as these human-centered factors ultimately determine the success or failure of smart housing initiatives. Furthermore, given the importance of system integration, future studies should investigate the role of open platforms, stakeholder collaboration, and the compatibility of urban ICT infrastructure with smart housing requirements to better explain the underlying process mechanisms. Finally, addressing ethical considerations, privacy protection, resilience against cyber threats, and the potential application of generative artificial intelligence (Generative AI) for the design and optimization of smart services offers promising directions for future research. Such efforts can transform smart housing from a purely technological solution into a comprehensive strategy for enhancing quality of life and advancing urban governance.

Author Contributions

The authors contributed equally to all parts of this research.

Conflict of Interest

The authors declare that there is no conflict of interest in this research.

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