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Smart Technologies for Socioeconomic Sustainability in Urban Housing: A Southeast Asian Perspective

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ABSTRACT

Rapid urbanisation across Southeast Asia intensifies the demand for housing that is simultaneously affordable, sustainable, and socially inclusive. This study investigates how smart technologies—Artificial Intelligence, Internet of Things devices (IoT), Building Information Modelling, and passive cooling innovations—can advance socioeconomic sustainability in urban housing. A three-phase methodology combined a scientometric analysis of 454 Scopus-indexed papers, a systematic literature review of eight rigorously screened studies, and a qualitative content analysis of practice-based sources. The scientometric mapping reveals growing scholarly attention to energy efficiency and climate resilience, yet affordability and social equity remain peripheral themes. Evidence from Malaysia, Indonesia, the Philippines, Singapore, and Thailand shows that smart sensors, digital simulations, and value-management frameworks can reduce cooling energy by up to 18,000 kWh annually, cut construction costs, and enhance thermal comfort in low-income settings. However, adoption is uneven owing to high capital costs, limited policy incentives, and skills gaps. The study proposes an integrated framework linking environmental performance, housing affordability, and social inclusion through appropriate digital tools. Policymakers and urban planners are urged to embed financing mechanisms, capacity-building, and participatory design into housing programmes to mainstream technology-enabled, equitable sustainability across the region within the next decade.

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Highlights:

- Proposes an Integrated Framework for Sustainable Affordable Housing in Southeast Asia combining digital technologies, affordability, and inclusion.
-Applies a triangulated methodology: scientometric analysis, systematic literature review (SLR), and content analysis to explore regional housing trends.
-Identifies BIM, IoT, passive cooling systems, and digital simulations as effective tools for enhancing housing sustainability and affordability.
-Reveals limited but promising implementation of smart housing solutions in Malaysia, Indonesia, the Philippines, Singapore, and Thailand.
-Highlights the gap between technological innovation and policy adoption in low- to middle-income urban housing contexts.

Contribution to the field statement:

This study proposes an original Integrated Framework for Sustainable Affordable Housing in Southeast Asia, grounded in scientometric, SLR, and content analysis. It fills a research gap by aligning digital technologies with affordability, inclusion, and urban resilience, offering actionable insights and a structured approach to future-proof, equitable housing policy in rapidly urbanising contexts.

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1. Introduction

1.1 Background and Context

Housing plays a pivotal role in the broader framework of sustainable development, where environmental stewardship, economic resilience, social equity, and cultural integrity intersect (Ebrahimigharehbaghi et al., 2022; Haruna et al., 2023). The sustainability of housing has evolved beyond physical structures to encompass the quality of one's living environment (Fatourehchi & Zarghami, 2020), equitable access to shelter (Ismail et al., 2024), and the promotion of inclusive and liveable communities (Ibrahim, 2020). This integrative understanding has been echoed by a range of scholars who stress that sustainable housing must address affordability, long-term energy performance, community well-being, and spatial justice (Jiahao et al., 2022). Earlier foundational work by Chiu (2004) laid the groundwork by arguing for the inclusion of social and cultural dimensions alongside environmental design in sustainable housing discourse. However, more recent studies have extended this by examining how housing acts as a vehicle for achieving broader sustainable development goals, particularly in the rapidly urbanising contexts across Southeast Asia and the Global South. These works position housing as not only a physical asset but also a dynamic system that responds to evolving demographics, including low-income earners (Wesonga et al., 2023), and technological integration (Atta et al., 2021). Accordingly, sustainable housing is now widely regarded as a multi-dimensional process that must align economic viability (Ahmed & Salam, 2022; Squires & Hutchison, 2021), technology integration (Atta et al., 2021; Guarini et al., 2019), climate resilience (Ruíz & Mack-Vergara, 2023), and social inclusion (Bresson & Labit, 2020) to foster long-term urban resilience and quality of life, especially for low-income earners.

The integration of digital technologies into sustainable housing has emerged as a transformative strategy for addressing the complex challenges of 21st-century housing provision (Moghayedi et al., 2021, 2023). Technologies such as BIM, the IoT, smart metering, and digital design simulation tools have shown significant potential in enhancing energy efficiency, reducing waste, and optimising the performance of residential buildings (Asif, Naeem, & Khalid, 2024). These tools enable real-time monitoring and predictive analysis, allowing for data-driven decision-making in building operations and maintenance. Importantly, smart technologies are increasingly seen as tools for not only reducing carbon footprints but also enhancing the livability and affordability of housing. They also have an economic role by allowing better resource management (Rock et al., 2024). However, their integration into affordable housing development remains largely underexplored across Southeast Asia. Existing studies have tended to focus on high-end or green-certified housing, with limited evidence presented to show how such technologies can be scaled and adapted to meet the needs of cost-constrained, densely populated urban communities, especially low-income earners.

Moreover, the rise of Industry 4.0 has begun to influence the housing construction and supply chain ecosystem. Tanko et al. (2024) highlighted the integration of automation, digital fabrication, and AI into housing design and delivery, which holds the dual promise of increasing productivity and reducing construction time and costs. These technological advancements offer scalable solutions for sustainable housing, particularly in contexts where demand for housing outpaces traditional construction capabilities.

In Southeast Asia, where much of the urban population falls within the lower- to middle-income brackets, the affordability of construction technologies and long-term cost savings are critical factors. While innovation is accelerating, the degree to which these advancements translate into real affordability for vulnerable populations remains uncertain, warranting further investigation.

Despite its promise, several challenges inhibit the widespread adoption of technology in sustainable housing. These include high upfront capital costs and limited financing options for lower-income buyers. Importantly, without financial schemes that explicitly consider long-term affordability, such as energy cost savings, we may risk widening existing socioeconomic gaps rather than narrowing them. For these innovations to be relevant and equitable, urban planning frameworks must integrate digital

tools alongside socioeconomic support mechanisms, inclusive policy design, and public awareness campaigns (Atta et al., 2021; Luo et al., 2020).

In regional case studies, particularly in Southeast Asia, there is growing evidence of initiatives aimed at embedding smart technologies into affordable and sustainable housing models. For instance, the use of BIM for energy-efficient retrofitting in Malaysia and the application of passive cooling systems with phase change materials in Indonesia showcase how local innovations can address context-specific environmental challenges (Motalebi et al., 2022). Moreover, sustainable housing development in Southeast Asia continues to face significant limitations, primarily because national efforts are heavily focused on addressing housing affordability for low- and moderate-income groups. In many urban and peri-urban areas, a considerable proportion of the population struggles with the basic issues of securing homeownership or even rental housing due to rising costs and stagnant wages. This persistent affordability crisis renders the pursuit of environmentally sustainable housing features a distant goal for many, with economic survival taking precedence over ecological considerations. Hence, while sustainability remains a critical aspiration, its integration into mass housing schemes in the region is still constrained by structural socioeconomic realities. These include income disparities, a lack of home financing instruments for informal workers, and rising urban land costs. Addressing these challenges will require not only technical innovation but also deeper alignment between housing policy, fiscal support mechanisms, and inclusive urban planning, with both affordability and liveability placed at the centre of sustainable housing models.

1.2 Problem Statement and Research Gap

Sustainable housing has emerged as a vital component of urban development, given the increasing environmental, social, and economic challenges confronting cities worldwide. Broadly defined, sustainable housing refers to the planning, design, construction, operation, and maintenance of residential environments that minimise ecological footprints, promote resource efficiency, and enhance the well-being of both occupants and communities (Olubi & Aseyan, 2022). As a multidimensional concept, sustainable housing extends beyond energy efficiency and carbon reduction to include the responsible use of materials, waste minimisation, climate resilience, and long-term affordability (Adabre et al., 2023; Adabre & Chan, 2021). It also embodies principles of liveability by incorporating elements such as comfort, safety, accessibility, and social integration to enhance quality of life (Koçak Güngör & Terzi, 2024). Furthermore, it reflects the evolving aspirations of urban populations, particularly younger demographics, by addressing lifestyle preferences, economic capacities, and the demand for socially and environmentally responsible living environments (Winston, 2022).

According to recent studies, although sustainability is commonly mentioned in discussions about housing, its actual implementation is usually dispersed, especially in metropolitan areas where many residents have low or intermediate incomes. Instead of being viewed holistically, important issues like affordability, energy consumption, and liveability are usually addressed separately (Hartono et al., 2020; Larson & Zhao, 2020). Although new digital technologies like smart sensors, building information modelling (BIM), and the Internet of Things (IoT) have considerable potential to improve building performance, lower energy costs, and boost resilience to climate hazards (Elnour et al., 2024), their incorporation into affordable housing in Southeast Asia is still not widely studied in either academic research or real-world applications. Regarding the successful integration of smart technologies into affordable housing solutions in these low- to middle-income urban contexts, there is a crucial knowledge gap. A large percentage of the literature is disjointed, technologically isolated, or overly centred on high-income environments. Addressing this gap is especially urgent for the urban planning profession, which is increasingly struggling to strike a balance between affordable housing, environmental resilience, and fast urbanisation. Planners must incorporate social justice, technological innovation, population growth, and spatial efficiency into their decisions as Southeast Asia cities continue to rise. By providing a comprehensive, evidence-based examination of how digital

technologies, when strategically aligned with affordability and policy frameworks, can support resilient housing delivery, this study addresses a significant disciplinary need. The findings, including regional case studies, offer actionable insights that urban planners can leverage to develop more inclusive, efficient, and sustainable urban housing models. As such, the study contributes to closing a major conceptual and empirical gap in planning practice, housing policy, and urban studies. The core research gap lies in the lack of empirical and integrative studies examining how digital technologies can be embedded into affordable housing strategies without compromising economic feasibility, especially in the Southeast Asia context. In particular, there is limited understanding of how smart innovations intersect with local affordability challenges, implementation constraints, and sociocultural factors. Moreover, prior research often fails to synthesise the existing technological landscape through a systematic or scientometric lens. Therefore, this study aimed to investigate the evolving landscape of sustainable housing in Southeast Asia by mapping key research trends, analysing the role of digital technologies in enhancing sustainability and examining alternative housing approaches that have been implemented across the region.

1.3 Objectives and Hypotheses

A comprehensive methodological framework was employed, integrating scientometric analysis, SLR, and content analysis. To address Research Objective 1, a scientometric approach was utilised to explore recent trends in sustainable housing research in the Southeast Asia context. In relation to Research Objective 2, the SLR method was applied to critically examine the existing body of literature, focusing particularly on the impact of digital technologies on sustainable housing. Meanwhile, Research Question 3 was addressed using qualitative content analysis to examine alternative sustainable housing approaches across Southeast Asia countries. This method enables the systematic review and interpretation of diverse textual sources, including policies, reports, and grey literature. It helps identify key themes, innovations, and contextual practices that reflect each country's unique strategies for sustainable housing development. Therefore, this detailed review aims to deepen the understanding of the current research landscape and identify gaps that require further investigation. This study presents three clear objectives, each requiring a specific method for comprehensive analysis, as detailed in Table 1.

Table 1: Outline of Research Objectives and Analytical Approaches.

Research Objectives	*Type of Analysis*
● To explore sustainable housing trends in Southeast Asia	● Scientometric analysis
● To analyse the impact of digital technologies on sustainable housing in Southeast Asia	● Systematic literature review analysis
● To examine alternative sustainable housing approaches adopted across other Southeast Asia countries	● Scoping technique and content analysis

1.4 Significance and Structure of the Paper

In the context of a rapidly urbanising Southeast Asia, this paper bridges a critical knowledge gap by analysing how digital technologies can be successfully incorporated into affordable and sustainable housing. This integration is still under-represented in both the academic and practical domains. Through the use of a triangulated methodology—scientometric analysis, content analysis, and systematic literature review (SLR)—the study provides an interdisciplinary viewpoint that connects

the fields of urban planning, housing affordability, and technology innovation. For scholars, housing professionals, and urban policymakers looking to improve socioeconomic inclusion and climate resilience in housing policy, this multi-layered approach produces useful insights.

The paper is structured as follows: the methodological framework and analytical techniques applied in all three phases are described in Section 2. The results are shown in Section 3 in accordance with the three research goals. The findings' theoretical contributions, ramifications, and contextual relevance are covered in Section 4. A summary of the main findings and suggestions for future study directions are presented in Section 5.

2. Materials and Methods

2.1 Study Design and Setting

The research process, as outlined in Figure 1, began with the identification of the research problem, followed by the formulation of research aims, which were divided into three distinct research objectives. Each objective guided a corresponding analytical approach: scientometric analysis for mapping sustainable housing research trends (Objective 1), SLR for assessing the impact of digital technologies (Objective 2), and content analysis for examining alternative housing practices across Southeast Asia (Objective 3). After setting the objectives, the process continued with data collection and data cleaning to ensure quality and consistency. Each method was then applied to its respective objective, and the combined insights were synthesised into the findings, offering a comprehensive and multi-layered understanding of sustainable housing in the context of urban Southeast Asia.

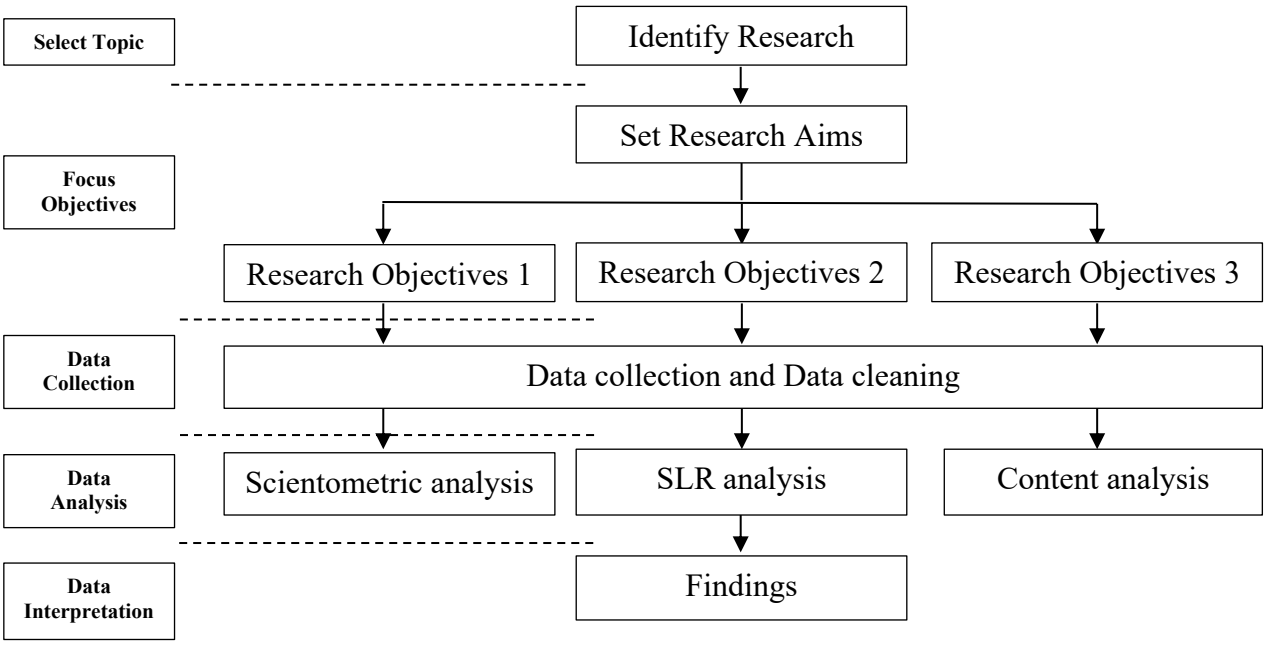

Figure 1. Diagram outlining the research process.

2.2 Scientometric approach

A screening process was applied to determine suitable search terms for retrieving relevant articles. An initial search conducted through the Scopus database produced a total of 487 articles. The search was subsequently refined to concentrate on the terms "sustainable housing" or "green home" or eco-home" or "eco-smart homes" in conjunction with "housing affordability", aligning with the study aims. As a result, the number of articles was reduced to 454. Further filtering was carried out to retain only those papers written in English. The overall search strategy is illustrated in the flow diagram shown in Figure 2.

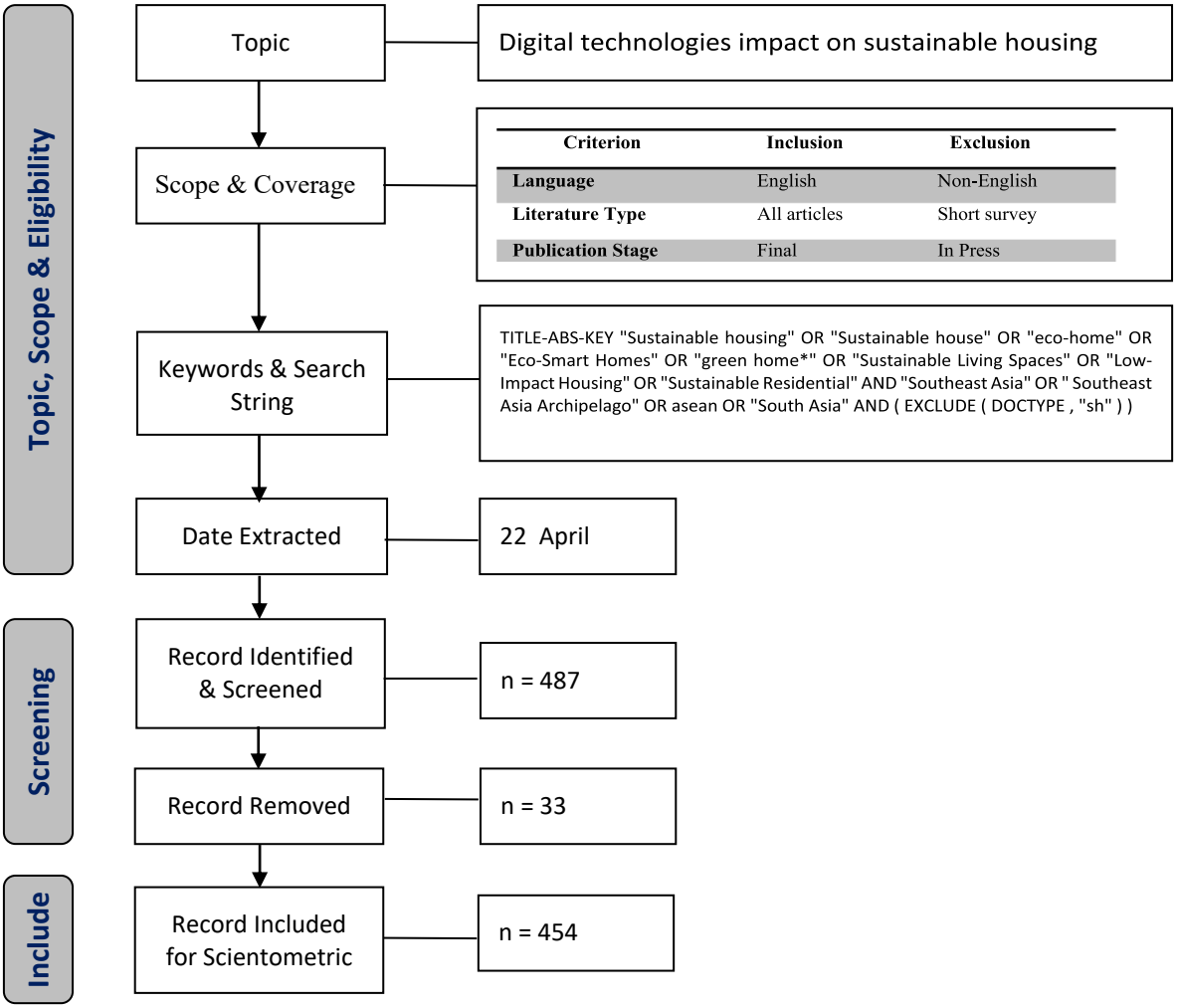

Figure 2. Diagram outlining the search process used for the scientometric analysis.

2.3 SLR approach

The SLR utilised two major databases, Scopus and Mendeley. This section outlines four key phases of the review process: identification, screening, eligibility, and data extraction. Furthermore, only articles published in reputable, peer-reviewed academic journals were included in the analysis, while books and lecture notes were excluded to ensure a high standard of publication quality.

2.3.1 Identification

Following the identification of all pertinent keywords (as outlined in Table 2), search queries were constructed for use in both the Scopus and Mendeley databases. During the preliminary phase of the systematic review, a total of 3,378 scholarly records were successfully retrieved from these two sources.

Table 2: Search String Using Scopus and Mendeley Databases.

Data Based	Query String
Scopus	TITLE-ABS-KEY (("Sustainable housing" OR "Sustainable house" OR "eco-home" OR "Eco-Smart Homes" OR "green home*" OR "Sustainable Living Spaces" OR "Low-Impact Housing" OR "Sustainable Residential") AND ("Southeast Asia" OR " Southeast Asia Archipelago" OR asean OR "South Asia") AND ("Technologies impact*" OR "Technology impact*" OR "Digital impact*" OR "Digital benefit*" OR "Technology benefits" OR technology OR technologies OR digital))
Mendeley	Sustainable Housing AND Technologies

2.3.2 Screening

During the screening phase, the pool of potentially relevant research materials was assessed for content aligned with the established research questions. A commonly applied content-related criterion at this stage involved the selection of studies based on themes pertaining to sustainable housing. At this point, the dataset was also refined by removing duplicate records. Following the exclusion of 3,323 articles after the initial screening, a total of 55 documents proceeded to a second round of evaluation, during which various inclusion and exclusion criteria were applied (refer to Figure 3). The primary inclusion criterion focused on peer-reviewed research articles, regarded as key sources of scholarly insight. Conversely, reviews, meta-syntheses, meta-analyses, books, book series, book chapters, and conference proceedings previously omitted in related studies were excluded. Moreover, only articles published in English were considered, with the review limited to literature produced between 2020 and 2025.

2.2.3 Eligibility

A total of fifty-five (55) articles advanced to the third stage of the eligibility assessment. At this level, all the article titles and key content were meticulously reviewed to confirm their alignment with the inclusion criteria and overarching objectives. As a result, 47 articles were excluded due to their lack of relevance to the research topic; inconsistencies between titles and abstracts; or the unavailability of full-text versions supported by empirical evidence. Consequently, eight articles were deemed suitable and retained for detailed analysis.

2.2.4 Data Abstraction and Analysis

The objective of this expert-driven analysis was to identify relevant themes and subthemes related to the research focus. The thematic development began during the data collection phase, wherein the authors closely examined a selected eight publications (as illustrated in Figure 3) to extract content pertinent to the study objectives. In the subsequent stage, major thematic categories were identified and refined, with particular attention given to the impact of digital technologies on sustainable housing in Southeast Asia. This process resulted in the formulation of four overarching themes: cooling performance, energy efficiency, cost efficiency, and climate and geological adaption.

The development of themes was undertaken collaboratively by the lead author and co-authors, drawing upon evidence within the literature. The authors regularly compared findings to identify any inconsistencies in the thematic development. Any conceptual differences encountered were addressed through collaborative discussion and resolved through consensus. Over time, the emergent themes were refined to ensure coherence and consistency across the dataset. To validate the thematic structure, the study incorporates an expert review involving two specialists, one with expertise in engineering and the built environment. This expert evaluation was conducted to ensure domain validity, thereby confirming the clarity, relevance, and applicability of each subtheme. The authors subsequently revised their findings in accordance with the feedback and recommendations from the expert reviewers.

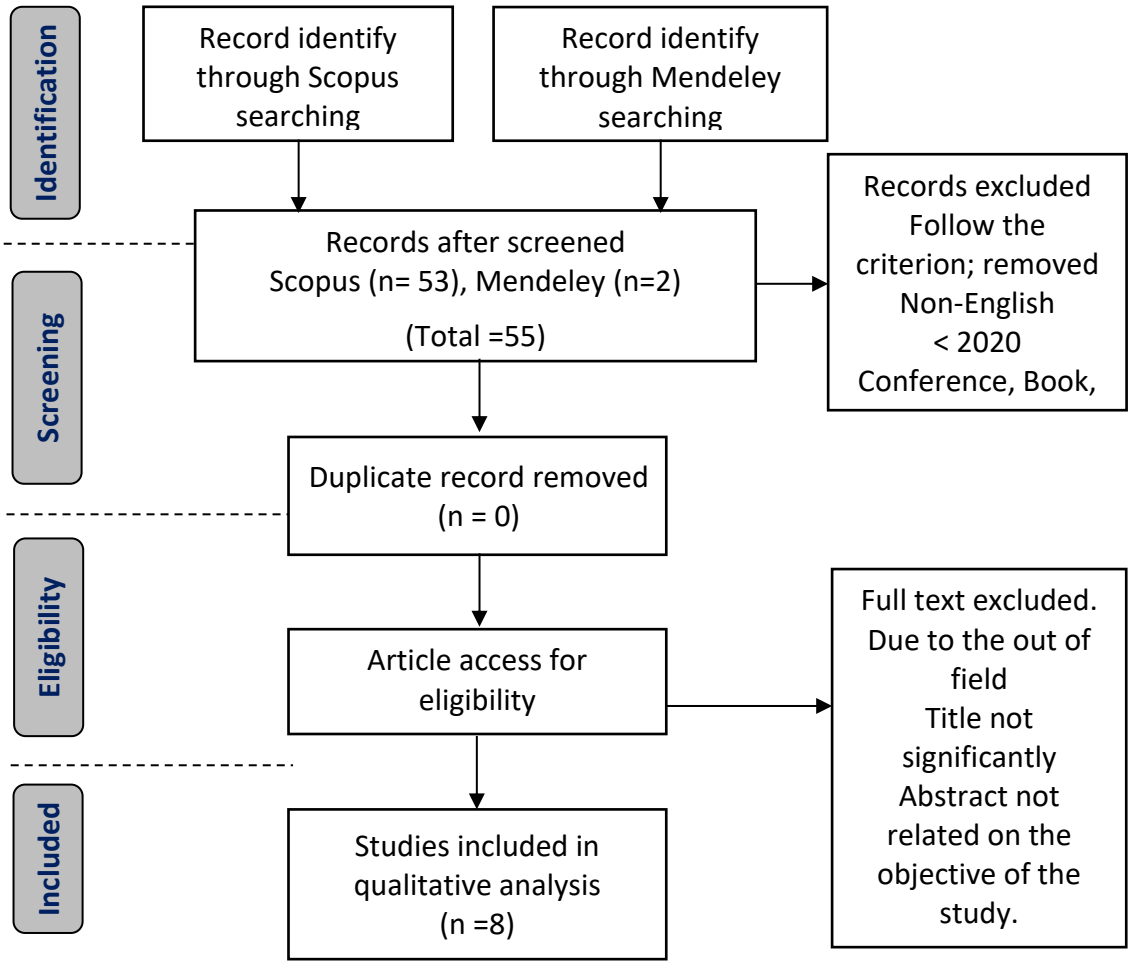

Figure 3. Diagram outlining the search process used for the SLR analysis

2.3 Content analysis approach

Content analysis is a qualitative research method used to systematically interpret textual data by identifying patterns, themes, meanings, or trends within documents, reports, policies, or other written or visual materials (Kleinheksel et al., 2020). In this study, content analysis was employed to examine alternative sustainable housing approaches adopted across Southeast Asia countries. This method was appropriate given the diverse and largely non-standardised nature of the data. By analysing this variety of sources, content analysis enabled the identification of key strategies, innovations, and context-specific practices that reflect each country's unique response to sustainable housing challenges.

3. Results

3.1 Sustainable housing trends in urban Southeast Asia

This scientometric section presents the thematic structure of sustainable housing research, as illustrated in Figure 4. Each cluster is colour-coded to represent a distinct thematic focus within the broader sustainability discourse in Southeast Asia housing research. The energy-focused sustainability cluster, represented by the red grouping, highlights the strong interconnection between sustainability, energy, innovation, circular economy, and the environment. This cluster underscores the critical role of energy systems and resource-efficient practices in shaping sustainable housing narratives in Southeast Asia. The emphasis on innovation and environmental considerations points to a growing recognition of the need for integrated solutions that go beyond conventional housing design. Notably, the prominence of circular economy principles suggests an emerging shift towards waste reduction, material reuse, and lifecycle thinking in the built environment. This trend also

reflects the region's increasing interest in smart technologies, low-carbon alternatives, and renewable energy integration within housing developments. As Southeast Asia nations strive to meet climate commitments and urban sustainability goals, this cluster indicates a broader movement towards embedding green energy systems and technological advancement into the fabric of housing policy and practice.

The green cluster, centred around climate change, renewable energy, and energy efficiency, reflects a strong emphasis on the intersection between climate resilience and sustainable energy use in Southeast Asia. This cluster illustrates how researchers are increasingly linking climate change mitigation strategies with the integration of renewable technologies in housing development. The adoption of solar panels, passive cooling systems, and energy-saving appliances is regarded as vital in reducing the environmental footprint of residential buildings. Moreover, the cluster reveals an underlying narrative that sustainable housing must not only address shelter needs but also contribute to national and regional climate goals. However, the connections suggest that while the technological potential is acknowledged, there remains a significant policy gap in embedding these solutions into mainstream housing frameworks. This indicates a timely opportunity for governments and urban planners to incorporate climate-adaptive design standards and renewable energy incentives into housing policies to build future-proof and environmentally responsive communities across the region.

The yellow cluster, defined by the keywords 'sustainable development' and 'affordable housing', reflects a development-oriented perspective that positions sustainable housing within the broader goals of social inclusivity, economic equity, and long-term urban planning. This cluster suggests that researchers in Southeast Asia are beginning to acknowledge the importance of aligning sustainability objectives with the housing needs of low- and middle-income communities. However, the limited spread and lower density of this cluster in comparison to energy- or climate-related themes indicates that affordability, while recognised, remains relatively underexplored in the sustainable housing discourse. This gap indicates an urgent need for further research into practical, cost-effective housing models that do not compromise environmental goals. Specifically, future studies should explore financing mechanisms, material innovations, and community-led approaches that can enable sustainable development to reach vulnerable populations. Integrating affordability more deeply into sustainability frameworks would not only enhance housing accessibility but also support inclusive urbanisation and social resilience across the region. As Southeast Asia continues to urbanise rapidly, placing affordability at the core of sustainable housing strategies will be essential in ensuring that the benefits of green development are equitably distributed.

The blue cluster, represented by the core keyword 'energy consumption', signifies a niche but increasingly relevant area of research within the sustainable housing landscape in Southeast Asia. This cluster highlights a growing awareness of the energy demands associated with urban housing, particularly as cities in the region expand and modernise. While the focus on energy consumption is not as prominent as broader themes like climate change or renewable energy, its emergence signals a shift towards understanding the real-time implications of energy use within households. However, the current body of research appears limited in scope, often lacking disaggregated data that captures variations across different cultural, climatic, and socioeconomic contexts. This underscores the need for more granular, location-specific studies that examine energy behaviour and consumption patterns at the household level. Such insights are crucial for informing policy decisions and designing targeted interventions that can improve energy efficiency, reduce utility costs for residents, and support sustainable urban living tailored to the diverse realities of Southeast Asia communities.

The purple node, centred on the core keyword 'sustainable housing', stands out as a peripheral topic with relatively fewer direct connections to other dominant themes in the network. This is particularly notable given that sustainable housing is the overarching context of the research field. Its isolation suggests that while many studies refer to sustainable housing, they often do so as a broad backdrop or intended outcome, rather than treating it as the main subject of investigation. This indicates a conceptual gap, with the term used frequently but not sufficiently unpacked or critically analysed in its own right. There is, therefore, a strategic opportunity for scholars to re-centre sustainable housing

as a primary focus by investigating its specific components, such as the use of local and low-impact building materials, culturally responsive design approaches, the enforcement of sustainability-related housing policies, and the lived experiences and behaviours of residents. Strengthening this core would not only help clarify what constitutes sustainable housing in the Southeast Asia context but also ensure that future policies and practices are informed by grounded, holistic research. Addressing this gap could contribute to a more integrated and actionable body of knowledge that bridges the technical, social, and regulatory dimensions of sustainable housing development.

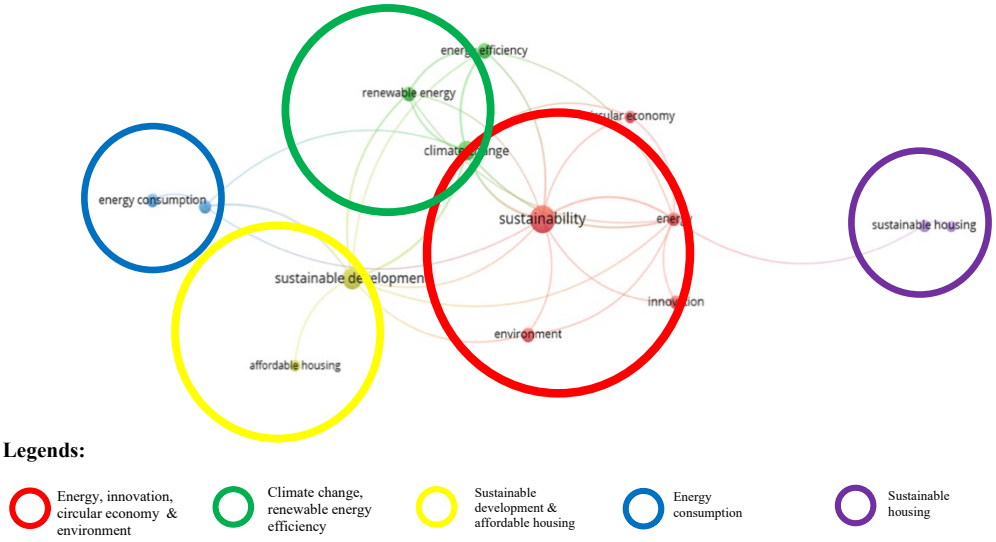

Figure 4. Thematic linkages in Sustainable housing research.

3.2 The impact of digital technologies on sustainable housing in Southeast Asia

Digital technologies are pivotal in advancing sustainable housing initiatives across Southeast Asia by addressing the region's distinct climatic, economic, and environmental challenges (see Table 3). Tools such as BIM, smart sensors, Geographic Information Systems (GIS), and the IoT have enabled significant improvements in housing design, construction, and performance. These technologies enhance cooling performance through passive design simulations, automated shading systems, and advanced ventilation strategies crucial for ensuring thermal comfort in tropical climates. Energy efficiency is promoted via real-time monitoring, smart metering, and renewable energy integration, contributing to lower consumption and compliance with green building standards. Cost efficiency is achieved through digitalised construction processes, prefabrication, and resource optimisation, which reduce project costs and support affordable housing delivery. Furthermore, digital tools aid in climatic and geological adaptation by allowing planners to assess environmental risks and develop resilient housing that can withstand floods, heat, and seismic events. Despite their growing relevance, the implementation of these innovations remains fragmented; they are mostly confined to pilot projects or academic research in countries like Malaysia and Indonesia. Therefore, broader adoption requires policy support, capacity-building, and inclusive planning to ensure that sustainable housing technologies benefit all segments of society.

In terms of cooling performance, Indonesia has emerged as a testbed for innovative thermal regulation solutions. Kitagawa et al. (2021, 2022) introduced radiant floor cooling systems combined with phase change materials (PCMs) and night ventilation techniques. These technologies have proven effective in reducing indoor temperatures, improving thermal comfort, and enhancing energy efficiency without overreliance on mechanical air conditioning. For example, their studies achieved a floor surface temperature reduction of up to 1.5 °C and 95% PCM thermal storage efficiency. These results are promising for regions with hot-humid climates, although scaling such solutions to low-income housing developments remains a challenge.

Malaysia, on the other hand, has focused on energy efficiency through digital design tools and retrofitting strategies. Mohsenzadeh et al. (2021) applied DesignBuilder simulations to determine optimal building forms for tropical climates, identifying circular structures and specific window configurations as the most energy-efficient. Complementing this, Ali et al. (2022) demonstrated how BIM (via ArchiCAD) could be used to guide retrofitting decisions in high-rise buildings, resulting in energy savings of over 18,000 kWh annually, reduced carbon emissions, and financial cost savings. These studies affirm the role of digital simulation tools in guiding sustainable architectural practices, particularly in high-density urban settings.

Cost efficiency is another area where digital tools are making an impact. Rostiyanti et al. (2023) developed a Value Management (VM) framework for design-and-build (DB) projects in Indonesia, identifying stage-specific success factors and the importance of stakeholder collaboration. This framework enhances cost-effectiveness and implementation efficiency, which are critical for public housing programmes with tight budget constraints. However, the incorporation of such tools into actual housing policy and construction workflows remains limited, often due to a lack of technical capacity or regulatory support.

Climatic and geological adaptation also plays a crucial role in housing resilience in Southeast Asia. Traditional architectural methods, when assessed using digital tools, show strong alignment with sustainability principles. For instance, in North Maluku, Indonesia, passive designs based on local wisdom have proven adaptable to extreme weather and geological risks. Ecotect simulations by Guntur et al. (2023) also revealed that stilted wooden homes offer significant thermal comfort and flood resilience. This integration of indigenous knowledge with digital simulations underscores the potential for hybrid approaches that are both sustainable and culturally grounded.

Finally, Manzoor et al. (2021) outlined strategic clusters for promoting BIM in Malaysia's construction sector, including economic, environmental, and awareness-based strategies. Public engagement and cost-benefit analysis of green materials are key to ensuring the wider adoption of sustainable practices. However, despite these promising developments, the region faces a fundamental constraint: the overarching focus of housing policies is still on affordability rather than sustainability. With many low- and moderate-income households struggling to rent or own homes, the integration of sustainability features into housing remains a secondary concern.

In brief, digital technologies are playing an increasingly significant role in advancing sustainable housing in Southeast Asia, although progress is uneven in certain countries. Technological innovation must be coupled with systemic policy reform, capacity-building, and inclusive financing mechanisms to ensure that sustainable housing is not a luxury but a norm accessible to all, particularly the most vulnerable populations.

Table 3: Technological Innovations in Sustainable Housing from Southeast Asia.

Benefit	Authors	Country	Type of technology	Impact
Cooling Performance	(Kitagawa et al., 2021)	Indonesia	Radiant floor cooling system with phase change material (PCM) and horizontal pivot windows for ventilative cooling	Improved thermal comfort with SET* reduced by ~0.79 °C and floor heat transfer coefficient reduced by ~1.52 W/m²K.
	(Kitagawa et al., 2022)	Indonesia	Radiant floor cooling system using phase change materials (PCMs) with night ventilation and forced airflow.	Improved floor temperature control and thermal comfort; achieved floor surface temperature reduction of up to 1.5 °C and 95% PCM thermal storage efficiency, even in climates with a narrow diurnal temperature range.
Energy Efficiency	Mohsenzadeh et al. (2021)	Malaysia	Building form optimisation using DesignBuilder	Identified circular building form and specific window extension (Case 3) as the most energy-efficient and

			simulation (circular and extended forms)	daylight-optimised design for tropical climates.
	Ali et al. (2022)	Malaysia	BIM via ArchiCAD for retrofitting analysis in high-rise buildings	Achieved 0.8% annual energy savings, reduced cooling load by 3%, saved 18,133.9 kWh, RM 6,618.88, and 1,265.16 kg CO_2 emissions through optimal window system retrofitting.
Cost Efficiency	Rostiyanti et al. (2023)	Indonesia	Value Management (VM) framework for design-and-build (DB) infrastructure projects	Identified stage-specific critical success factors (CSFs) and a supporting stakeholder cooperation factor, enhancing cost-effectiveness, design constructability, and implementation efficiency in DB projects.
Climatic and geological adaption	Rostiyanti et al. (2023)	Indonesia	Traditional sustainable architecture using passive design strategies (e.g., button system, natural materials, and spiritual-human-nature design philosophy)	Demonstrated that traditional architecture in North Maluku adapts effectively to extreme environments (earthquakes and volcanic activity), providing sustainable and comfortable housing through local techniques and ecological harmony.
	Guntur et al. (2023)	Indonesia	Climate-adaptive traditional housing using wood materials and stilt-based design (Ecotect simulation)	Identified optimal stilt house design (Type 2) for thermal comfort in riverine climate; emphasised the role of floor height (>1.2 m) in improving natural ventilation and climate resilience
	Manzoor et al. (2021)	Malaysia	BIM adoption strategies for sustainable buildings	Identified four strategic clusters (standardisation, economic, awareness, and environmental); key strategies include public awareness campaigns, sustainable material cost-benefit analysis, and strengthening sustainable development to promote BIM integration in green projects.

3.3 Sustainable Housing Practices in Other Southeast Asia Countries

As presented in Section 3.2, the analysis of technological innovations in sustainable housing based on literature retrieved from the Scopus and Mendeley databases demonstrates a predominance of research contributions from Malaysia and Indonesia. While this trend suggests a strong scholarly presence in these two countries, it should not be misconstrued as an indication that sustainable housing practices are absent from other Southeast Asia nations. Rather, it highlights the asymmetry in academic visibility within indexed databases. A complementary scoping review employing broader search strategies, including grey literature and open-source platforms (e.g., Google search using the phrase "sustainable housing in Southeast Asia"), revealed that other countries in the region, such as the Philippines, Singapore, and Thailand, have also been actively engaged in sustainable housing efforts. These findings indicate the need for a more inclusive and diversified evidence base that accounts for both peer-reviewed research and practice-based initiatives, thereby offering a more holistic understanding of sustainable housing developments across Southeast Asia.

Primavera Residences in Cagayan de Oro City, Philippines, exemplifies sustainable housing through its innovative design inspired by biomimicry. Developed by Italpinas Development Corporation (IDC), this mixed-use condominium integrates passive cooling strategies and renewable energy

technologies to enhance environmental performance and affordability (Salzer et al., 2016). The building's architecture draws inspiration from termite mounds, featuring a central atrium that facilitates natural ventilation. This design allows warm air to rise and exit through the roof, while cooler air is drawn in at lower levels, reducing reliance on mechanical cooling systems. Additionally, the façade incorporates brise soleil elements that provide shade, minimising solar heat gain and further decreasing indoor temperatures. These features collectively contribute to an estimated 32% reduction in energy consumption for residents (Salzer et al., 2016). Primavera Residences has achieved Excellence in Design for Greater Efficiencies (EDGE) certification from the International Finance Corporation, recognising its commitment to resource efficiency. Compared to conventional buildings, the development demonstrates predicted savings of approximately 33% in energy, 37% in water usage, and 32% in embodied energy of materials (Salzer et al., 2016).

Sustainable housing practices across Southeast Asia reflect a diverse array of strategies tailored to local climates, cultures, and socioeconomic contexts. These initiatives encompass green building certifications, passive design techniques, community-driven developments, and the integration of renewable energy technologies. Singapore has established itself as a regional leader in sustainable housing through its Green Mark Scheme, launched by the Building and Construction Authority (BCA) in 2005 (Joy, 2023). This certification promotes energy efficiency, water conservation, and sustainable construction practices. Notably, the Keppel Bay Tower, shown in Figure 5, became Singapore's first zero-energy commercial building after a retrofit that included smart lighting systems, efficient cooling, and photovoltaic installations, resulting in a 30% reduction in energy usage (Joy, 2023).

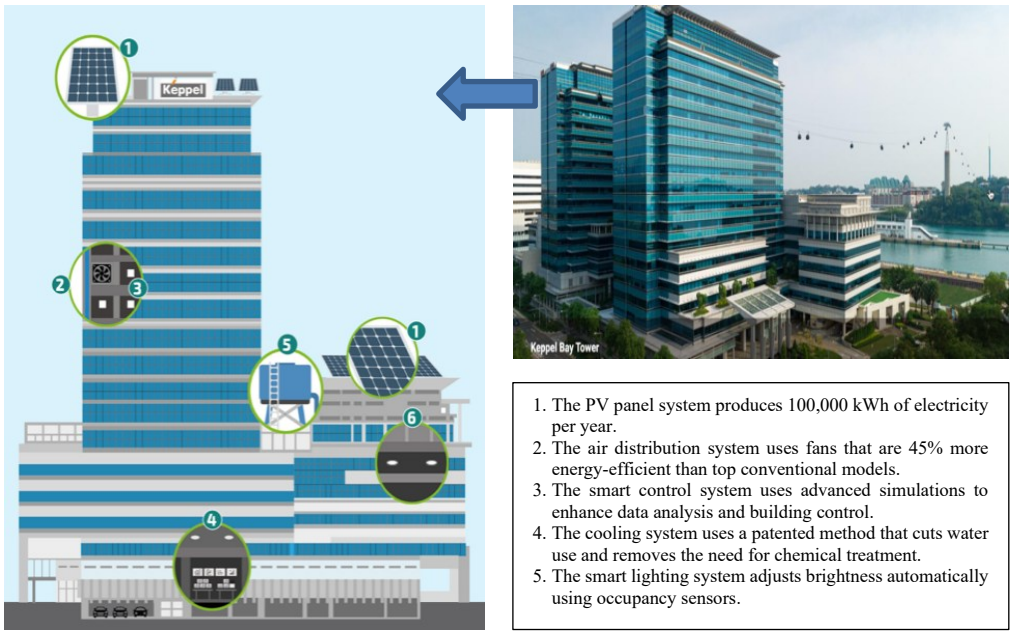

Figure 5. Keppel Bay Tower, Singapore's first Green Mark Platinum.

Meanwhile, Thailand has been at the forefront of integrating technologies into sustainable housing practices, with a strong emphasis on community participation, traditional knowledge, and innovative design. One significant initiative has been led by the Community Architects for Shelter and Environment (CASE), which has adopted participatory design processes to ensure that residents are actively involved in both the planning and construction of their homes. A notable example is the Ten House Project in Bangkok, which demonstrates the effective integration of traditional construction techniques with modern sustainability principles. The project employed locally sourced materials and passive design strategies such as natural ventilation and shading to create thermally comfortable living environments while reducing environmental impact (Jareemit & Canyookt, 2021; Yimprayoon

et al., 2022) . The success of this project highlights the value of combining indigenous knowledge with contemporary sustainable design approaches.

4. Discussion

4.1 Interpretation of Key Findings

This triangulated methodology of scientometric analysis, SLR, and content analysis offers a holistic understanding of sustainable housing in Southeast Asia. The scientometric analysis revealed that while themes like energy efficiency and climate resilience dominate scholarly discourse, the concept of sustainable housing remains underexplored as a central subject. The term is often cited peripherally, suggesting a need to re-centre it in academic inquiry, particularly within affordability frameworks.

The SLR uncovered the fragmented yet promising application of digital technologies such as BIM, passive cooling systems, and IoT tools in Malaysia and Indonesia. These innovations have demonstrated measurable impacts on energy savings, thermal comfort, and cost efficiency. However, their implementation has been largely confined to experimental or small-scale contexts, highlighting a significant gap between technological potential and mainstream application.

The insights from the content analysis extended to other Southeast Asia countries like the Philippines, Singapore, and Thailand. It revealed the successful integration of traditional wisdom and modern technologies in projects such as Primavera Residences, Keppel Bay Tower, and the Ten House Project. These examples underscore the potential of hybrid models that fuse local context with technological innovation.

The findings underscore the necessity of bridging the gap between digital innovation and housing affordability. While sustainable technologies are available, they are rarely incorporated into mass housing schemes due to economic, institutional, and technical constraints. Integrating digital technologies into sustainable housing not only enhances environmental performance but also delivers tangible socioeconomic benefits for urban populations in Southeast Asia. Smart design features such as passive cooling, real-time energy monitoring, and efficient building envelopes can significantly reduce household energy costs, freeing up income for other essential needs.

Meanwhile, the rise of digital construction methods, including BIM and prefabrication, is creating new employment opportunities in urban areas, particularly for digitally skilled workers aligned with Industry 4.0 demands. These advancements contribute to improved quality of life by offering more comfortable, resilient, and cost-efficient living environments. Over the long term, residents benefit from lower operational and maintenance costs, reinforcing housing affordability beyond the point of purchase. In response to escalating urban housing demands, national economic strategies are beginning to shift, as evident in policies that promote green building standards, smart city frameworks, and sustainable urban planning as tools for inclusive economic growth. Thus, sustainable housing is not only an environmental imperative but also a socioeconomic catalyst for equitable urbanisation.

4.2 Comparison with Previous Studies

Prior research demonstrating the revolutionary potential of digital technology in sustainable housing, especially through tools like BIM, IoT, and passive cooling systems, is supported and expanded upon by this study. However, in contrast to previous research, which mostly focuses on high-income or experimental housing conditions, this study offers a unique regional viewpoint by investigating their relevance in Southeast Asia-wide urban contexts characterised by low and intermediate incomes. This study also builds on previous research by using a triangulated approach that combines text analysis, SLR, and scientometric mapping to provide a thorough investigation of both scholarly discourse and practical applications.

4.3 Strengths and Limitations

One of this study's main strengths is the methodological triangulation blending scientometric analysis, SLR, and content analysis. This offers a multi-layered knowledge of Southeast Asia's contextual practices, digital technology adoption, and sustainable housing trends. This integrated approach permits theoretical and practical contributions that are both globally transferable and regionally relevant, enhancing the credibility and depth of the findings. The interdisciplinary approach, which connects socioeconomic inclusion, urban planning, and technology, is another asset. Nevertheless, limitations exist. The scientometric and SLR relied heavily on indexed literature from Scopus and Mendeley, excluding valuable grey literature. Furthermore, the absence of empirical fieldwork means that the lived experiences of end-users remain unexamined. These limitations suggest the need for future research incorporating primary data and policy evaluation. Stakeholder interviews, questionnaires, and case-based field evaluations should be used in future research to overcome these constraints.

4.4 Implications and Future Directions

By expanding the knowledge of how digital technologies might be incorporated into affordable housing frameworks in Southeast Asia towns that are quickly urbanising, this study makes important theoretical and practical contributions. By emphasising the necessity of inclusive policies that encourage the adoption of technology in low- and middle-income housing complexes, the findings help shape policy. In practical terms, the study offers solutions to include smart technologies like BIM, IoT, and passive design systems to improve resilience, cost, and energy efficiency. In theory, it bridges the gaps between the literature on urban planning, technology innovation, and sustainable housing. With an emphasis on user experience, community involvement, and post-occupancy performance, future researchers should undertake empirical evaluations through field investigations. Furthermore, cost-benefit assessments and lifecycle analyses could confirm long-term scalability and affordability. Transforming creative design into fair housing solutions requires interdisciplinary cooperation. Ultimately, this study advocates more research to promote scholarship and practical solutions while laying the foundations for a more socially inclusive, digitally connected housing policy.

Figure 6 presents the comprehensive framework developed in this study, illustrating how theoretical foundations, digital technologies, and performance indicators converge to support sustainable affordable housing in Southeast Asia. The framework begins with core theoretical indicators—environmental sustainability, housing affordability, and social inclusion—which form the guiding principles for resilient housing strategies. These are operationalised through enabling digital technologies such as BIM, IoT, passive cooling systems, simulation tools, and AI-driven design applications. These tools contribute to measurable outcomes classified under four key performance indicators: cooling performance, energy efficiency, cost efficiency, and climatic or geological adaptability. By aligning these dimensions, the framework provides a structured, interdisciplinary approach for planning and assessing context-sensitive, future-proof housing solutions in rapidly urbanising environments, especially within low- and middle-income settings across the Southeast Asia region.

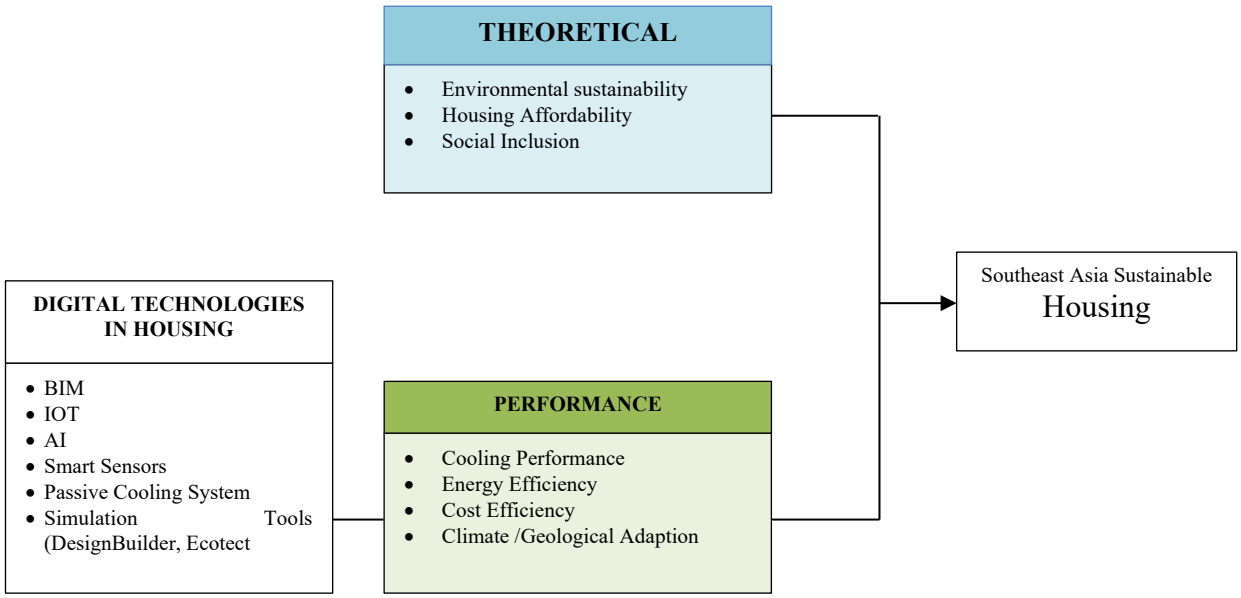

Figure 6. Proposed Integrated Framework for Sustainable Affordable Housing in Southeast Asia.

5. Conclusion

This study employed a triangulated methodology—a scientometric analysis of 454 Scopus-indexed papers, a systematic literature review (SLR) of eight rigorously screened studies, and practice-based content analysis—to clarify how smart technologies can underpin an integrated framework for sustainable, affordable, and socially inclusive housing in Southeast Asia. Publication trends reveal a 240 % rise in digital-housing research since 2020, yet only 22 % of papers explicitly address socioeconomic equity. Quantitatively, BIM-guided retrofits in Kuala Lumpur save 18 133 kWh and 1 265 kg CO_2 per block each year; phase-change cooling in Indonesia lowers operative temperatures by 1.5 °C; and biomimetic housing in the Philippines reduces whole-building energy, water, and embodied-carbon use by 32 %, 37 %, and 32 % respectively.

These findings confirm that BIM, IoT sensors, passive-cooling innovations, and digital simulations can shrink life-cycle costs while advancing SDG 11 targets for resilient, inclusive cities. Nevertheless, smart-housing adoption remains patchy: upfront capital premiums average 12–18 %, policy incentives are fragmented, and digital-skills shortages constrain diffusion beyond pilot schemes in Malaysia, Indonesia, the Philippines, Singapore, and Thailand. The persistent gap between technological innovation and policy uptake risks limiting benefits to higher-income developments unless systemic barriers are removed.

To bridge this divide, we propose an integrated policy framework that couples mandatory digital design standards with concessional green finance, multi-stakeholder value-management processes, and participatory planning. National housing authorities should embed BIM and IoT requirements in building codes, link them to micro-credit or rent-to-own schemes for low-income households, and fund vocational programmes that cultivate a digitally competent construction workforce. Municipal governments can accelerate market demand by enforcing post-occupancy performance disclosure, thereby incentivising developers to deliver energy-positive, climate-adaptive typologies.

The study is limited by its reliance on secondary data and a small pool of empirically validated projects; longitudinal post-occupancy evaluations and mixed-method stakeholder surveys are needed to test scalability across diverse climatic zones. Comparative research with other rapidly urbanising regions in the Global South would refine transferability. By prioritising field evidence, co-design with residents, and robust cost-benefit modelling, scholars and practitioners can transform smart-housing innovations into durable socioeconomic and environmental gains—normalising technology-enabled, equitable sustainability throughout Southeast Asia within the next decade.

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