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Article

Sustainable housing and quality of life in Shenzhen: The role of knowledge, technology and innovation

Qiang Xie, Muhammad Shahid Khan*

Innovation Management, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand
*** Corresponding author:** Muhammad Shahid Khan, shahid.kh@ssru.ac.th, s63484945136@ssru.ac.th

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Abstract: Housing is one of the most significant components of sustainable development; hence, the need to come up with sustainable housing solutions. Nevertheless, the sales of houses are steadily falling due to the unaffordability of houses to many people. Based on the expanded community acceptance model, this research examines the relationships between sustainable housing and quality of life with the moderating factors of knowledge, technology, and innovation in Shenzhen. Additionally, it aims to delineate the principal dimensions influencing quality of life. The study employs purposive sampling and gathers data from residents of Shenzhen via a Tencent-distributed survey. Analysis was conducted using Smart Partial Least Squares (PLS) 4.0. Results indicate a positive correlation between economic sustainability in housing and quality of life. Contrarily, the social and environmental aspects exhibited negligible impacts on quality of life. Knowledge, technology, and innovation were identified as significant moderators in the correlation among all three sustainable housing dimensions and quality of life. The findings are anticipated to enhance understanding of the perceived impacts of sustainable housing on quality of life in Shenzhen and elucidate the role of knowledge, technology, and innovation in fostering this development.

Keywords: sustainable housing; greenhouse; community acceptance model; knowledge; technology and innovation

1. Introduction

Housing, a fundamental human necessity, serves as a shelter and underpins individual health and societal functionality. It is integral to socio-economic development and significantly impacts China's GDP, fiscal revenue, and employment (Y. Zhang, 2023). Since 2018, the real estate sector has contributed approximately 26% to the GDP of China (Rogoff and Yang, 2022). Consequently, a downturn in the housing market presents a substantial risk to the broader socio-economic landscape. China currently confronts a housing crisis, characterized by a one-third reduction in sales from pre-pandemic levels (Gao and Woo, 2024) and a 60% decline in new construction rates (Hoyle and Jain-Chandra, 2024). This stagnation is attributed not only to the disruptions caused by COVID-19 but also to significant price misalignments and regional supply-demand discrepancies stemming from a decade-long housing boom (Rogoff and Yang, 2021). As Chinese households consider housing a safe asset, demand remains high, driving prices upward (Luo and Mei, 2023) and transforming a basic necessity into an unaffordable luxury. Consequently, some residents have relocated to suburban areas, resulting in lengthy daily commutes to urban centres (Duan and Duan, 2023). This urban sprawl exacerbates traffic congestion, environmental degradation, and fails to meet the diverse needs and expectations of urban populations (Bao et al., 2022). Moreover, housing development significantly influences environmental sustainability. The United Nations Environment Programme (2021) reported that buildings and construction accounted for 37% of energy-related CO_2 emissions in 2020, contributing to global warming, flooding, severe pollution, and associated health challenges. In light of these issues, there is a growing advocacy for sustainable housing development.

China, the world's largest CO_2 emitter (Larsen et al., 2021) and leading construction market, has committed to reducing its emission intensity by 18% from 2021 to 2025 as outlined in its 14th Five-Year Plan (FYP) (The State Council Information Office of the People's Republic of China, 2021). In terms of sustainable housing, the government has emphasized green buildings. Specific targets for building energy efficiency were set in the 11th and 12th FYPs, while the Ministry of Housing, Urban-Rural Development (MOHURD) in the 13th FYP aimed for 50% of all new urban buildings to be green, with a goal of 77% of urban buildings achieving green certification by the end of 2020. Despite these initiatives, only green commercial and public buildings have gained acceptance, with housing lagging behind due to policies that focus predominantly on the supply side rather than the demand side (Zhao and Chen, 2021). Market acceptance of sustainable housing remains low, attributed to high sales prices, inadequate awareness or knowledge, insufficient price discounts in sub-sales to offset the pre-sale premium, and a misalignment between government policies and market expectations (Jiang et al., 2021; Sang et al., 2020; Yuan et al., 2022; Zhao and Chen, 2021). Although the COVID-19 pandemic has shifted consumer needs and increased demand for properties with enhanced energy efficiency and other sustainability features (Deloitte Canada, 2022; Moreno et al., 2021), no significant improvement in China's housing market has been observed.

To effectively evaluate sustainable housing development in China, it is crucial to assess residents' satisfaction with their current living conditions, thereby enabling stakeholders to make informed adjustments and enhance planning for sustainable housing initiatives. Moreover, this study investigates the roles of knowledge, technology, and innovation in advancing the quality of life through sustainable housing. A comprehensive literature review was conducted to pinpoint existing research gaps and establish a theoretical framework. Hypotheses derived from previous studies were formulated for empirical testing. The methodology for data collection and analysis was meticulously outlined, including research design, sample selection, and data collection instruments. The findings captured encompass the link between sustainable housing and quality of life; and the effect of knowledge, technology, and innovation on this link. Lastly, the paper presents the findings, the implications that can be derived from the respondents' inputs, the limitations of the research, and the suggestions for future research.

This research is based on Shenzhen city which is situated in the southeastern part of China adjacent to Hong Kong. Shenzhen has been selected as the research context because it perfectly captures the spirit of the Reform and Opening-up period being recognized by the government as one of the advanced socialist regions with Chinese features (Central Committee of the Chinese Communist Party, 2019). Additionally, the United Nations Development Programme (2022) has recognized Shenzhen's leadership and exemplary role in advancing the Sustainable Development Goals (SDGs), both nationally and internationally. Therefore, Shenzhen is posited as an ideal location for conducting this research.

2. Literature review

2.1. Sustainable housing

Sustainable housing can be defined as a form of development that meets the housing needs of the current generation without compromising the capacity of future generations to satisfy their housing requirements (United Nations, 1987). Although this definition highlights the functionality and resilience of housing, it has been critiqued for its vagueness and lack of clarity regarding the extent of sustainability and development (Hajian and Jangchi Kashani, 2021). Target 11.1 of the United Nations Sustainable Development Goals (SDGs), which aims for universal access to adequate, safe, and affordable housing by 2023, provides additional context for sustainable housing (United Nations, n.d.). Sustainable housing should be a secure, high-quality facility, adequately operated, maintained, and periodically refurbished and retrofitted to ensure optimal benefits in line with the three principal sustainability pillars: economic, social, and environmental (Adabre et al., 2022). The focus on sustainable housing varies across countries based on their developmental stages; for instance, most developing nations prioritize price or rental affordability, often overlooking other aspects of sustainable housing development (Adabre et al., 2022), whereas developed nations may place greater emphasis on environmental concerns. Furthermore, there has been a global shift in focus towards sustainable housing over the years. Increasing environmental consciousness among consumers has led to a focus on the environmental dimensions of sustainable housing. Developers prioritize spatial planning, design, and the use of sustainable materials to mitigate land occupation, increased transport volumes, and other adverse impacts. Post-COVID-19, changes in social behaviour have once again shifted the primary concerns of sustainable housing from environmental protection towards addressing people's housing needs, such as self-sufficiency and coworking spaces (Wajid et al., 2022). In the context of the pandemic and beyond, D'Alessandro et al. (2020) suggested that sustainable housing should incorporate key elements such as (i) visibility and accessibility to green spaces; (ii) flexibility, adaptability, sharing, and crowding of living spaces; (iii) re-appropriation of sustainable architecture principles and features; (iv) water consumption and wastewater management; (v) waste management; (vi) housing automation; (vii) indoor building and finishing materials. In summary, as depicted in **Figure 1**, the concept of sustainable housing integrates four interrelated dimensions—economic, environmental, institutional, and social—and strives to provide decent, affordable, and healthy housing for all, considering environmental protection, economic benefits, and social inclusion. Under this concept, the examples of sustainable housing include green housing, prefabricated homes, tiny homes, shipping container homes, etc. Within the scope of this study, in the context of Shenzhen, sustainable housing refers to green housing and eco-homes that has been transformed from traditional housing as other types of sustainable housing are not common in the city where land scarcity is concerning.

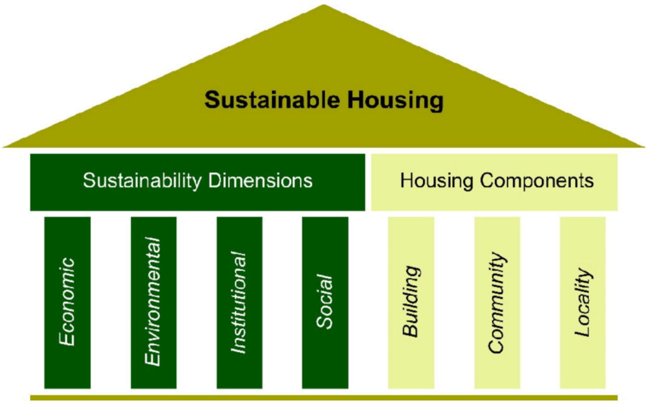

Figure 1. A general concept of sustainable housing (Adamec et al., 2021).

In this study, the institutional pillar is not addressed, as it is considered that this dimension is more abstract and qualitative, which does not align well with the quantifiable metrics typically used in sustainability assessments. Moreover, there is a tendency to regard institutions as a distinct category rather than as an integral component of the economic, environmental, and social dimensions of sustainability (Rosati and Faria, 2019).

2.1.1. Social aspect of sustainable housing development

Social sustainability within sustainable housing aims to create living environments that enhance well-being, inclusivity, and quality of life, while considering long-term societal impacts. It covers various aspects of community life and individual well-being (Moghayedi et al., 2023). The primary components of social sustainability in this context include user comfort, neighbourhood participation, safety, and proximity to essential services. This domain primarily focuses on the built environment's role in providing access to green spaces, recreational facilities, and promoting active lifestyles, particularly in Shenzhen where air quality and access to natural environments are critical (Yang et al., 2021). The integration of green roofs, urban gardens, and pedestrian-friendly streets in housing design can significantly enhance residents' physical and mental health, thus improving their quality of life. Additionally, the density of housing development plays a crucial role in determining user comfort and, by extension, life quality (Mouratidis and Yiannakou, 2022). Due to land scarcity, most Chinese cities feature extremely high-density developments (Zhou et al., 2021), which, while offering benefits such as enhanced access to public transport, increased walkability, and improved physical health, have been associated with reduced life satisfaction and happiness (Mouratidis, 2022). Common spaces such as parks, coworking spaces, community centres, and gardens serve as vital communal hubs that foster social interaction, community engagement, and a collective spirit (SGS Economics and Planning, 2020). When neighbourhoods function as supportive networks, assisting with daily tasks like childcare or grocery shopping, not only is neighbourhood attachment strengthened, but also residents' quality of life (Chan and Li, 2022). Moreover, involving residents in decision-making processes related to housing management, maintenance, and neighbourhood development can further enhance their sense of belonging and ownership (Mamokhere and Meyer, 2023), leading to increased satisfaction. Finally, ensuring the safety and security of residents is essential. The built environment significantly influences perceptions of neighbourhood safety (Velasquez et al., 2021). Dadong's case study provides evidence for this as safety features such as artificial light, security cameras, community policing in sustainable housing increased the safety perceptions of residents (Lea, 2023) which is an aspect that improves the quality of life (Peng et al., 2024).

2.1.2. Environmental aspects of sustainable housing development

The environmental dimensions of sustainable housing development can be evaluated from several perspectives: are resource sourcing, resource quality, energy efficiency, and design efficiency. Generally, construction works have been known to utilize large amounts of natural resources leading to production of large quantities of wastes and pollutants. The following are some of the sustainable building materials that should be used instead of the common building materials like Guo et al. (2022) recycled resources, reclaimed wood, and low-impact concrete. These materials not only minimize the environmental impact but also help in enhancing the Indoor Air Quality (IAQ) thus having a positive impact on the health condition of the residents (Vijayan et al., 2023). Furthermore, the quality of the resources used in the provision of the structures also assists in minimising environmental effects as well as increasing the comfort of the residents. For instance, the use of Low VOC paints and finishes is an essential factor in the promotion of health standards through the protection of the indoor environment, and reduction of the residents' exposure to dangerous chemicals (Kralikova et al., 2020). The life expectancy of the materials used in construction is a major concern in the construction of any structure. Since the use of durable and superior materials means that there is no frequent need to maintain or replace parts, the quality of life is improved and residents' satisfaction is maintained over the long-term (Jacoby and Alonso, 2022). In addition, energy efficiency specifically affects the quality of life of the residents through the conservation of energy and decrease in energy expenses (Wang et al., 2022). Energy conservation is a process that entails the use of efficient energy consuming appliances, use of renewable energy sources like solar panels, and architectural design that includes better insulation, double glazing, and efficient heating, ventilation, and air conditioning systems. Furthermore, design efficiency plays a crucial role in the environmental dimension of sustainable housing development, particularly concerning the resiliency and adaptability of housing usage. It is increasingly important that buildings demonstrate flexibility throughout their life cycles to accommodate evolving consumer needs (WEF, 2021). For example, a two-bedroom unit with dual living rooms may initially suit a newlywed couple; however, the additional living room can be converted into a third bedroom for a growing family or into a home office. Research indicates that factors influencing buildings' perceived usability and long-term value are critical during initial planning stages (Chen, 2022). Strategic housing design is a cost-effective strategy that yields significant financial advantages for both developers and residents by optimizing resource use, ultimately enhancing residents' quality of life (H. Zhang, 2023).

2.1.3. Economic aspect of sustainable housing development

The price has been reported to be a major factor that discourages consumers who think about sustainable housing in China; as a result, sustainable housing becomes an "unaffordable luxury" for many individuals (Yuan et al., 2022). Hence, the increased prices are due to the extra costs incurred in the construction of green materials and energy-efficient technologies that developers must put in place to meet green building policies and get certifications (Zhao and Chen, 2021). Additionally, the initial capital required for making green enhancements in older homes is also quite expensive, thus, does not encourage homeowners to go for more green enhancements within their homes. Consequently, financial accessibility becomes essential for homebuyers interested in acquiring sustainable housing or enhancing the environmental performance of an existing building. Financial incentives such as green mortgages, energy-efficient mortgages, and green home loans could significantly foster sustainable housing development by making it more accessible to a broader population (KMRC, 2022). Typically, the interest rates for green mortgages are lower than those for conventional mortgages, and some financial institutions offer loan amounts up to 100 percent with terms extending to 30 years, plus waive appraisal fees to promote sustainability (Kasikorn Bank, 2022). These facilities could substantially reduce the financial burden on sustainable homeowners, thereby enhancing their satisfaction and quality of life. Despite these measures, the affordability of sustainable housing remains a concern. While housing prices in Shenzhen have dropped by approximately 15% over the past three years due to financial distress and shifting housing demands (Bloomberg, 2023), housing remains unaffordable for vulnerable populations, including college graduates, migrant workers, and low-income families. Wei et al. (2023) observed that such populations are often marginalized under China's affordable housing policy regime, particularly rural migrants without local household registration (hukou). There exists a critical mismatch between the housing needs and preferences of migrant workers, with supply still inaccessible to them due to exclusionary policies. It is recommended that policy amendments are necessary to make sustainable housing affordable and available to all demographics. Return on investment (ROI) is a primary concern for Chinese real estate investors, as housing assets are considered safer than other investment types (Dong et al., 2021). Sustainable housing tends to attract high-quality tenants who value sustainability and are willing to pay a premium for such features, thereby yielding a higher ROI for the property. Additionally, sustainable housing provides economic stability, featuring elements such as solar panels and energy-efficient insulation, which shield residents from the financial burdens associated with fluctuating energy costs (Chan and Adabre, 2019), ultimately improving their overall quality of life by reducing financial stress.

2.2. Community acceptance model

Community acceptance constitutes one of the three interrelated dimensions of social acceptance, as depicted in **Figure 2**. It is manifested through the perspectives and actions of the local community concerning sustainable development initiatives within their region (Roddis et al., 2020). These actions vary widely, from active resistance to different levels of acceptance, which include attitudes toward sustainability, readiness to adopt sustainable measures, and intentions to participate in sustainable housing practices.

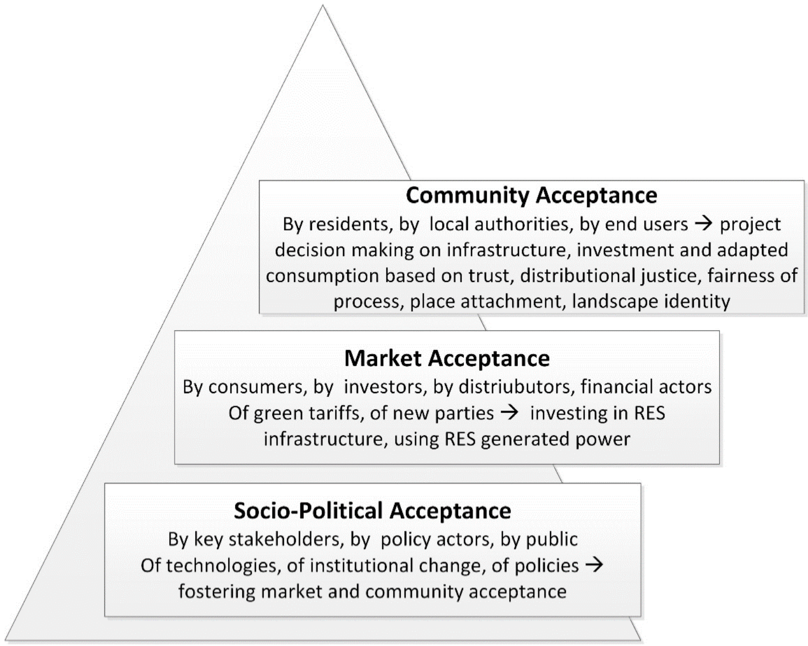

Figure 2. Three dimensions of social acceptance (Escobar-Avaria et al., 2022).

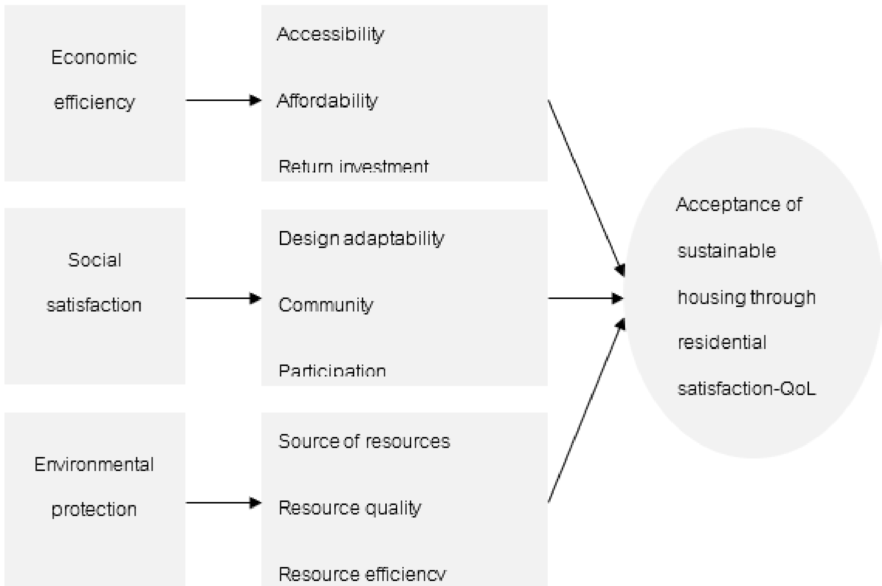

Figure 3. Community Acceptance Model of Sustainable Housing (Okitasari et al., 2022).

Community acceptance within the realm of sustainable housing encompasses the endorsement of both newly constructed green buildings and houses retrofitted with green enhancements by key local stakeholders, notably residents and local authorities. This study embraces the definition of community acceptance articulated by Okitasari et al. (2022), which links the notion of community acceptance to residential satisfaction and quality of life, specifically focusing on residential quality (**Figure 3**). This linkage is critical in sustainable housing contexts where residents prioritize the overall performance of the building, including its economic, environmental, and social advantages. Residents anticipate that sustainable buildings will surpass conventional structures in terms of indoor environment quality, energy efficiency, comfort, and overall satisfaction.

Other than this, this study also attempted to integrate the Community acceptance model above with the framework for future real estate by BCG (WEF, 2021), as shown in **Figure 4**.

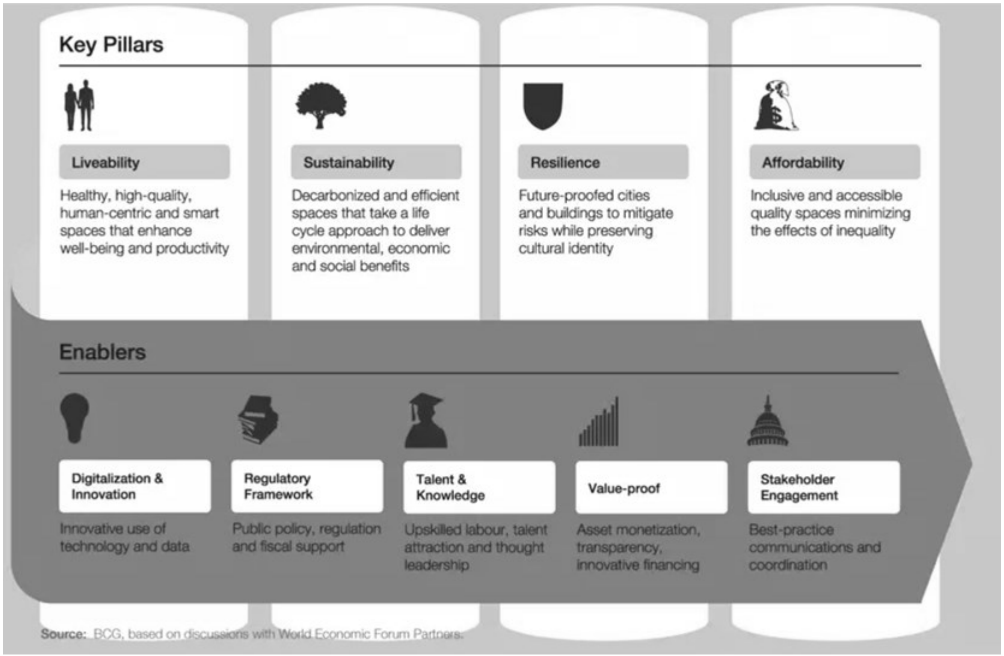

Figure 4. The framework for future real estate by BCG (WEF, 2021).

The vision for future real estate is anchored in four fundamental pillars: livability, sustainability, resilience, and affordability. The livability pillar emphasizes the creation of healthy, high-quality, human-centric, and intelligent spaces that boost well-being and productivity. In contrast, the resilience pillar advocates for constructing a city that is future-proof, preserving cultural identity and mitigating risks. These pillars are integral components of the broader social sustainability framework. The affordability pillar focuses on promoting inclusive and accessible spaces of quality, aiming to minimize the impact of economic inequality and is thus categorized under economic sustainability. According to the forum, realizing housing that integrates these four pillars necessitates several key enablers. The Boston Consulting Group identifies five primary enablers: digitalization and innovation, regulatory frameworks, talent and knowledge, value proof, and stakeholder engagement. This study specifically concentrates on the roles of knowledge, technology, and innovation. Consequently, the community acceptance model is expanded to facilitate sustainable housing, proposing a more comprehensive framework for analysis.

2.3. Sustainability enablers

Talent and knowledge are posited as foundational elements for driving sustainability, forming the basis upon which informed decisions, policies, and practices are established. Thus, it is imperative for real estate developers to leverage knowledge, technology, and innovation (KTI) to remain competitive in a market characterized by rapidly changing consumer needs. Professionals who understand the dynamics of cities, design of buildings, and the socio-economic characteristics of societies are more likely to design homes that address people's needs (WEF, 2021). These needs if met not only boost the resident's satisfaction but also the quality of life. In addition, human capital development in real estate firms enhances efficiency and creativity hence a better performance of the firm (Fedyk and Hodson, 2023; Hanifah et al., 2022). In addition to knowledge, technology and innovation have played a huge role in enhancing the provision of sustainable housing and thereby the quality of life of residents (Moghayedi et al., 2023). For instance, new technologies in construction like 3D printing and prefabrication have greatly minimized on cost of labour and materials. These methods increase the housing affordability through fast tracking of construction timeliness and minimizing resource usage. Another good example is the incorporation of Building Management Systems (BMS) with Internet of Things (IoT) sensors; this enables real-time control and monitoring of the building systems, this helps in enhancing the use of resources with regards to the occupancy rates and the environmental conditions of the building (Valinejadshoubi et al., 2021). Also, the smart home systems that are developed based on the IoT technology improve residents' quality of life through the provision of individual control of the lighting, security, and climate conditions through smartphone applications or voice commands, therefore providing residents with individual comfort and mood (W. Li et al., 2021).

Based on all the discussion above, this study proposed six hypotheses and presented in the **Table 1**.

Table 1. Proposed hypothesis of this study.

No.	Proposed Hypotheses
H1	Social aspects of sustainable housing development have a positive impact on the quality of life of residents.
H2	Environmental aspects of sustainable housing development have a positive impact on the quality of life of residents.
H3	Economic aspects of sustainable housing development have a positive impact on the quality of life of residents.
H4	KTI enhance the positive relationship between social aspects of sustainable housing development and quality of life.
H5	KTI enhance the positive relationship between environmental aspects of sustainable housing development and quality of life.
H6	KTI enhance the positive relationship between economic aspects of sustainable housing development and quality of life.

A research framework based on the hypotheses above is illustrated in **Figure 5**. The framework is extended from the Community Acceptance Model of Sustainable Housing proposed by Okitasari et al. (2022), integrating the BCG framework of sustainable real estate.

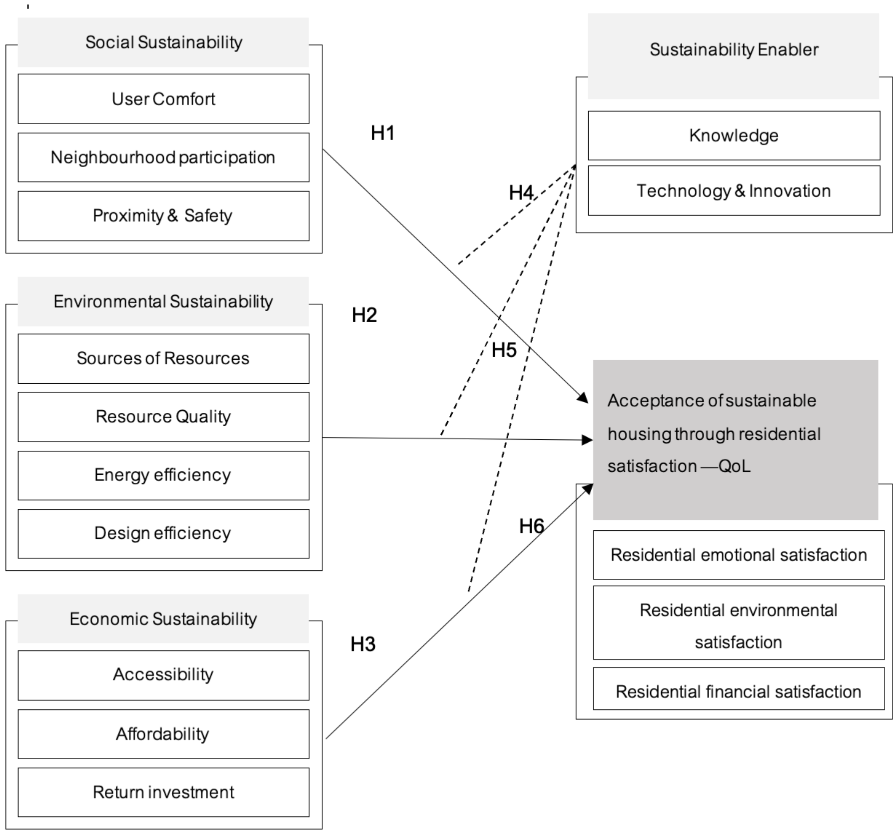

Figure 5. Amended community acceptance model of sustainable housing.

3. Methodology

Drawing upon existing studies such as those by Ezennia (2022) and Okitasari et al. (2022), this paper employs a mixed-method approach with a cross-sectional survey research design to fulfill the research objective. This design facilitated data collection from residents of Shenzhen over a two-month period. Data were collected using a self-administered survey designed to test the hypotheses within the research framework, utilizing Tencent forms for data gathering. The questionnaire is divided into three sections: Part A gathers demographic information about the respondents, including gender, monthly income, highest qualification, and residential district; Part B comprises questions that operationalize the study's variables; Part C includes semi-structured questions aimed at eliciting rich and nuanced insights from the respondents. The design of the survey questions was meticulously refined with reference to the existing literature. Prior to conducting the full-scale survey, a pilot test involving 10% of the intended sample size was carried out to refine the survey instrument, ensuring the clarity, reliability, and validity of data collection. The demographic information collected enables this study to identify factors that may influence respondents' interests and opinions. This information could provide valuable insights for stakeholders such as real estate firms or policymakers, helping them to develop targeted policies, services, and products that more effectively address the needs of diverse population groups.

The respondents of this study are Shenzhen residents who, within the sustainability framework, are ideally able to afford a house. To ensure the sample is representative of the target population and yields quality data, a non-probability purposive sampling method was utilized. To mitigate potential researcher bias associated with this sampling approach, clear sampling criteria were established. Respondents were required to specify the districts where their homes are located and confirm their ability to afford a house before participating in the survey. Although convenience sampling is more commonly employed and easier to implement, it often fails to accurately capture the diversity of the target population; therefore, it was not considered suitable for this study. The sample size was set at 666 residents, calculated using the sample size formula with a population of 17.55 million in Shenzhen, a confidence level (z) of 0.95, a sample proportion (p) of 0.5, and a margin of error (e) of 0.05. As the survey was conducted on a voluntary basis, there are no missing values in the data, ensuring robustness in data analysis and hypothesis testing. This study employed Smart PLS 4.0 for data analysis due to its user-friendly interface and ease of use compared to other software such as SPSS Amos. Confirmatory factor analysis (CFA) was conducted to assess the hypotheses regarding significant relationships between independent and dependent constructs (Hair et al., 2022).

This framework has a total of 20 constructs arranged in two different levels of hierarchy. The second order constructs are Social Sustainability, Environmental Sustainability, Economic Sustainability, Sustainability Enablers and Quality of Life (QoL). The social sustainability can be defined as User Comfort (UC), Neighborhood Participation (NP), and Proximity and Safety (PS). On the other hand, the Environmental Sustainability consists of the Source of Resources (SQ), Resource Quality (RQ), Energy Efficiency (EE) and Design Efficiency (DE). The economic sustainability aspects include the Financial Accessibility (ACC), Affordability (AFF) and Return on Investment (ROI). Quality of Life (QoL) is further delineated into three dimensions: This study identified three factors namely Social Satisfaction (SS), Environmental Satisfaction (ES), and Financial Satisfaction (FS). The two sustainability enablers that have been incorporated into this research are Knowledge (K) and Technology and Innovation (TI). All the items that were used in the assessment of these constructs were carefully chosen and fine-tuned from previous research.

4. Results and findings

The demographic profile of the respondents is presented in **Table 2**. The data reveal that the majority of respondents are male, aged 35 and above, married, and possess a Master's degree as their highest academic qualification. The table indicates that only 33% of the respondents own their homes in Shenzhen, while 31% rent, and 36% reside in their parents' homes. Regarding income, approximately one-third of the sample earns below CNY 20,000 monthly, and 10% earn more than CNY 60,000. This distribution highlights the income disparity within Shenzhen's society. Although 70% of the respondents are married, the homeownership rate stands at only 33%; this suggests that many families either have not yet acquired their own home or choose to live with parents, a practice relatively common in China. Approximately 26.4% of the Chinese population reportedly lives with parents or in-laws post-marriage, reflecting cultural housing norms (Blazyte, 2022).

Table 2. Responder's profile.

Demographic characteristic	Category	Frequency	Percentage
Gender	Male	370	56%
	Female	296	44%
Age Group	18–25	98	15%
	26–34	82	12%
	35–49	238	36%
	50 and above	248	37%
Homeownership status	Own	219	33%
	Rent	206	31%
	Parent home	241	36%
Districts	Luohu	45	7%
	Futian	57	9%
	Nanshan	67	10%
	Yantian	79	12%
	Bao'an	72	11%
	Longgang	62	9%
	Longhua	67	10%
	Dapeng	78	12%
	Pingshan	76	11%
	Guangming	63	9%
Monthly income	Below CNY 10,000	121	18%
	CNY 10,001–CNY 20,000	117	18%
	CNY 20,001–CNY 30,000	114	17%
	CNY 30,001–CNY 40,000	88	13%
	CNY 40,001–CNY 50,000	74	11%
	CNY 50,001–CNY 60,000	87	13%
	above CNY 60,000	65	10%
Marital status	Single	199	30%
	Married	467	70%
Education Level	High school	62	9%
	Diploma	112	17%
	Trade/technical/vocational training	107	16%
	Bachelor's degree	81	12%
	Master's degree	124	19%
	Professional degree	92	14%
	Doctorate	88	13%

This study utilized Smart PLS version 4.1.0.0 to test the hypotheses. Validity and reliability assessments were conducted to confirm the appropriateness of the relationships between items and constructs within the research framework. Within the measurement model, both convergent validity and discriminant validity were evaluated to ensure that the constructs accurately reflect the measured variables and are distinct from each other, respectively.

As presented in **Table 3**, all the first-order constructs demonstrate outer loading values exceeding 0.70, Cronbach's alpha (CA) above 0.70, and average variance extracted (AVE) greater than 0.50 (Hair et al., 2022). These findings securely establish the convergent validity of the study, indicating that the multiple items used to measure each construct are indeed effectively capturing the intended constructs.

Table 3. Convergent validity of first order constructs.

Constructs	Item	Outer Loading	Cronbach's alpha	Average variance extracted (AVE)
UC	UC1	0.775	0.910	0.628
	UC2	0.820		
	UC3	0.785		
	UC4	0.779		
	UC5	0.795		
	UC6	0.802		
NP	NP1	0.759	0.907	0.617
	NP2	0.790		
	NP3	0.802		
	NP4	0.802		
	NP5	0.797		
	NP6	0.765		
PS	PS1	0.759	0.912	0.631
	PS2	0.818		
	PS3	0.783		
	PS4	0.837		
	PS5	0.797		
	PS6	0.771		
SR	SR1	0.723	0.904	0.609
	SR2	0.784		
	SR3	0.799		
	SR4	0.775		
	SR5	0.799		
	SR6	0.798		
RQ	RQ1	0.679	0.906	0.576
	RQ2	0.791		
	RQ3	0.753		
	RQ4	0.798		
	RQ5	0.758		
	RQ6	0.793		
	RQ7	0.732		

Table 3. (*Continued*).

Constructs	Item	Outer Loading	Cronbach's alpha	Average variance extracted (AVE)
EE	EE1	0.746	0.896	0.632
	EE2	0.794		
	EE3	0.830		
	EE4	0.798		
	EE5	0.806		
DE	DE1	0.724	0.884	0.602
	DE2	0.795		
	DE3	0.805		
	DE4	0.787		
	DE5	0.768		
ACC	ACC1	0.764	0.871	0.627
	ACC2	0.791		
	ACC3	0.806		
	ACC4	0.805		
AFF	AFF1	0.797	0.863	0.677
	AFF2	0.833		
	AFF3	0.838		
ROI	ROI1	0.800	0.873	0.633
	ROI2	0.813		
	ROI3	0.780		
	ROI4	0.789		
K	K1	0.778	0.902	0.605
	K2	0.786		
	K3	0.760		
	K4	0.770		
	K5	0.777		
	K6	0.796		
TI	TI1	0.803	0.905	0.614
	TI2	0.811		
	TI3	0.753		
	TI4	0.774		
	TI5	0.787		
	TI6	0.772		
SS	SS1	0.771	0.849	0.652
	SS2	0.818		
	SS3	0.831		
ES	ES1	0.758	0.833	0.623
	ES2	0.807		
	ES3	0.802		
FS	FS1	0.789	0.854	0.660
	FS2	0.837		
	FS3	0.810		

The convergent validity of the second-order constructs is detailed in **Table 4**.

Although the Average Variance Extracted (AVE) values fall below the acceptable threshold of 0.5, they are considered satisfactory as the Composite Reliability (CR) for all these constructs exceeds 0.6, indicating that the convergent validity is still adequate (Ab Hamid et al., 2017; Fornell and Larcker, 1981). With the establishment of convergent validity, discriminant validity is subsequently tested to confirm that each construct is distinctly separate from the others.

Table 4. Convergent validity of second-order constructs.

Constructs	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
Social	0.934	0.929	0.431
Environmental	0.935	0.932	0.38
Economic	0.902	0.899	0.452
Sustainability Enabler	0.915	0.912	0.467
QoL	0.863	0.862	0.412

Table 5. Discriminant validity: HTMT.

	Economic	Environmental	QoL	Social	Sustainability Enabler	Sustainability Enabler × Environmental	Sustainability Enabler × Social	Sustainability Enabler × Economic
Economic								
Environmental	0.345							
QoL	0.349	0.339						
Social	0.351	0.375	0.32					
Sustainability Enabler	0.365	0.377	0.38	0.343				
Sustainability Enabler × Environmental	0.236	0.049	0.212	0.243	0.045			
Sustainability Enabler × Social	0.162	0.246	0.21	0.045	0.046	0.203		
Sustainability Enabler × Economic	0.037	0.243	0.254	0.17	0.061	0.244	0.282	

Table 5 demonstrates that all constructs possess Heterotrait-Monotrait (HTMT) ratios below 0.85, confirming discriminant validity for the study as outlined by Henseler et al. (2015). Additionally, an inner collinearity test was conducted to assess multicollinearity among constructs. The results, presented in **Table 6**, indicate no concerns, with all Variance Inflation Factor (VIF) values remaining below 3.3, as suggested by Kock (2015).

Table 6. Inner multicollinearity values (VIF).

	VIF
Economic → ACC	1.000
Economic → AFF	1.000
Economic → QoL	1.427
Economic → ROI	1.000

Table 6. (*Continued*).

	VIF
Environment → DE	1.000
Environment → EE	1.000
Environment → QoL	1.594
Environment → RQ	1.000
Environment → SR	1.000
QoL → Economic Satisfaction	1.000
QoL → Financial Satisfaction	1.000
QoL → Social Satisfaction	1.000
Social → NP	1.000
Social → PS	1.000
Social → QoL	1.436
Social → UC	1.000
Sustainability enabler → Knowledge	1.000
Sustainability Enabler → QoL	1.383
Sustainability Enabler → Tech & Innovation	1.000
Sustainability Enabler × Environment → QoL	1.322
Sustainability Enabler × Social → QoL	1.259
Sustainability Enabler × Economic → QoL	1.298

The bootstrapping technique is used with a re-sampling of 5000 for the hypothesis testing, set at 0.05 confidence level. Whether a hypothesis is supported is determined when the *ß*-value is positive, the t-value is greater than 1.96, and the *p*-value is less than 0.50 (Hair et al., 2022). The findings of hypothesis testing are tabulated in **Table 7**.

Table 7. Finding of hypothesis testing.

Hypothesis	Relationship	Standard deviation (STDEV)	Beta (*ß*)	*T* value	*P* value	Findings
H1	Social > QoL	0.0490	0.091	1.8350	0.0670	Not Supported
H2	Environment > QoL	0.0500	0.129	1.5180	0.1290	Not Supported
H3	Economic > QoL	0.0500	0.138	2.7480	0.0060	Supported
H4	Sustainability Enabler × Social > QoL	0.0480	0.117	2.4620	0.0140	Supported
H5	Sustainability Enabler × Environmental > QoL	0.0490	0.108	2.1770	0.0300	Supported
H6	Sustainability Enabler × Economic > QoL	0.0520	0.209	3.9960	0.0000	Supported

From the analysis, only four hypotheses out of six hypotheses developed were supported. The study found that the economic aspect of sustainable housing is positively related to the quality of life of Shenzhen's residents ($ß = 0.138$, $t = 2.7480$, $P < 0.05$). Hence, H3 is supported. Meanwhile, the study found that the social aspect ($ß = 0.091$, $t = 1.8350$, $P > 0.05$) and environmental aspect ($ß = 0.129$, $t = 1.5180$, $P > 0.05$) while having a positive impact on QoL, the relationship is not statistically significant, thus H1 and H2 are not supported. Besides, this study also proves the moderating effect of sustainability enablers on the relationship between quality of life and all sustainability aspects. The results revealed that knowledge technology and innovation (KTI) enhance the positive relationship between social ($ß$ = 0.117, t = 2.4620, $P < 0.05$), environment ($ß$ = 0.108, t = 2.177, $P < 0.05$) and economic ($ß$ = 0.209, t = 3.9960, $P < 0.05$) aspects of sustainable housing development and quality of life respectively. With this, H4, H5 and H6 are supported.

Table 8 shows the assessment of the coefficient of determination (R^2), the effect size (f^2), and the predictive relevance (Q^2) of independent variables on dependent variables of QoL.

Table 8. Coefficient of determination (R^2) and effect size (f^2).

Construct	R^2	Q^2	f^2	**Decision**
QoL	0.326	0.116		
Social			0.008	No effect
Environment			0.005	No effect
Economic			0.02	Small
Sustainability Enabler			0.096	Small
Sustainability Enabler × Social			0.015	Small
Sustainability Enabler × Environmental			0.013	Small
Sustainability Enabler × Economic			0.043	Small

Based on the rule of thumb, R^2 values of 0.75, 0.5 and 0.25 can be interpreted as substantial, moderate and weak effects respectively (Hair et al., 2022). The R^2 of QoL is 0.326, indicating that social, economic and environmental aspects of sustainable housing explain 32.6% of the overall variance in the quality of life of Shenzhen's residents, and the effect size is relatively weak. The blindfolding procedure is also employed to assess the predictive relevance. The Q^2 of 0.116 for QoL in this study, which is higher than 0, indicates that the model has predictive relevance for the construct of QoL. In addition, to determine which constructs have the largest effect on the dependent variable, effect size (f^2) analysis is also conducted. According to Cohen (1988), f^2 of 0.02 indicates a small effect, 0.15 a medium effect, and 0.35 a large effect. This study found that the social and environmental aspects have no direct effect on QoL, while the economic effect has a small effect. Interestingly, with the intervention of a moderator of sustainability enabler, the three aspects of housing sustainability have a small effect on the QoL.

The study finds that out of the three dimensions of sustainability, only economic aspects of sustainable housing development have a direct positive effect on residents' quality of life in the context of Shenzhen despite the rating for each dimension of sustainability does not have a significant difference as shown in **Table 9**. This may reflect resident's sentiment towards the housing price of Shenzhen, whereby they perceive that their quality of life can be enhanced if the economic aspect of sustainability is improved.

Table 9. Mean of constructs.

Sustainability dimension	Sub dimensions	Mean of Sub-dimension	Mean of Dimension
Social	NP	3.53	3.53
	PS	3.54	
	UC	3.51	
Environmental	DE	3.58	3.58
	EE	3.56	
	RQ	3.61	
	SR	3.57	
Economic	Acc	3.59	3.56
	Aff	3.54	
	ROI	3.55	

5. Discussion

The research conducted in Shenzhen indicates that while residents do not perceive the social and environmental dimensions of sustainable housing development as directly enhancing their quality of life, they recognize that the incorporation of advanced knowledge, technology, and innovations could potentially improve their living conditions. This perception suggests a possible information asymmetry between real estate developers and residents, either due to unmet resident needs within the current housing supply (Rogoff and Yang, 2021; Wei et al., 2023) or a lack of resident awareness regarding the advantages of sustainability features in these homes (L. Li and Chau, 2024). Consequently, it is recommended that developers undertake market surveys and engage a more varied workforce to better understand and address market demands. Additionally, implementing educational initiatives for consumers both before and after sales could enhance understanding of the benefits and costs associated with green housing. It is posited that as residents begin to embrace green living and sustainability concepts, their quality of life will improve.

Local culture may be a significant factor in why social sustainability does not notably enhance the Quality of Life (QoL) in the context of sustainable housing in Shenzhen. This can be exemplified by the Chinese idiom, "a relative afar is less use than a close neighbor," which reflects a collectivist orientation contrary to the more individualistic tendencies of Western cultures. In Chinese society, community orientation is prevalent; people derive enjoyment from societal interactions by fostering relationships within their community, and by offering mutual help and care. Respondents reported "no major difference" in neighborhood participation between conventional and sustainable housing under the umbrella of social sustainability. It appears that the sense of community and high levels of satisfaction may have pre-existed the concept of sustainability in housing, rendering the social sustainability features of sustainable housing—such as shared spaces, community events, or community organizations—no longer significantly contributory to residents' QoL. Additionally, Shenzhen, being home to major technology companies like BYD, Tencent, Huawei Technologies, and DJI, offers unique communal housing situations. Some of these companies provide free housing to their employees, fostering higher interactions among residents who share similar professions and interests. However, residents who have previously lived in company housing noted a "reduced interaction among residents due to gaps in topics of interest and daily routines," although they "appreciate the diversity" found in sustainable housing. Furthermore, the extensive public surveillance in Shenzhen (P. Zhang, 2019) has enhanced the city's overall safety perception, with most residents feeling "very safe wherever they are in the city." This increased sense of security makes the safety features of social sustainability in residential areas less significant in influencing QoL.

The mindset of the residents may be the primary reason for the lack of a significant relationship between the environmental aspects of sustainable housing and quality of life. Residents prioritize the long-term financial value of sustainable housing over immediate environmental benefits due to a low level of green awareness. According to some of the respondents, people tend to be less concerned with the materials used if the housing is green certified and increases the worth of their property with the intention of gaining more profit when selling the property. This orientation towards the economic bottom-line instead of the environmental outcome may reduce the significance of environmental factors in improving the quality of life. This is problematic because if the financial worth of the sustainable housing is considered in the long run as the primary factor of consideration, then the overall benefits that the society is likely to get from the sustainable housing development may be negated. A similar situation could create a market failure: market signals would be erroneously skewed towards overly valuing green certification while under-valuing genuine environmental improvements. This could lead to greenwashing and may not support the creation of truly sustainable housing. Therefore, it is suggested that state government and other key industry players should embark on public awareness and enlightenment programs to create the consciousness on the environmental gains that come with sustainable housing. Such initiatives could significantly increase green awareness among residents and encourage a more environmentally conscious approach to sustainable living.

6. Conclusion

In conclusion, this study investigated sustainable housing development and its impact on the quality of life in Shenzhen, revealing that only the economic aspect of sustainability positively affects the quality of life of Shenzhen residents; conversely, the social and environmental aspects were found to have no significant impact. Stakeholders, including policymakers and real estate developers, are advised to review existing policies and practices to determine if reforms or process improvements are necessary to further enhance residents' satisfaction with their housing conditions. Furthermore, this research has validated the expanded acceptance model of sustainable housing development as a robust and applicable framework that can be explored in various geographical contexts. Additionally, the study has underscored the moderating roles of knowledge, technology, and innovation as enablers of sustainability, which strengthen the relationship between sustainable housing development and the quality of life of residents. These findings highlight the necessity for a more balanced approach that prioritizes economic sustainability when pursuing sustainable development strategies. This approach should effectively utilize knowledge and talent, along with technology and innovation, to optimize outcomes.

7. Limitations and recommendations

This paper employs a purposive sampling method, which may limit the generalizability of the results to other contexts. Future studies are encouraged to integrate this sampling technique with others, such as snowball sampling, to enhance the diversity of the sample. Additionally, this study utilizes a cross-sectional approach, which could be susceptible to selection bias if the sample does not accurately represent the target population. It is advisable for future research to consider longitudinal designs and broader cultural contexts to improve the generalizability of findings. Given that cultural factors may influence the relationship between the social aspects of sustainable housing and quality of life, future research should include additional variables, particularly cultural elements, in the analysis. A thorough exploration of cultural nuances, values, and behaviors could yield valuable insights into how sustainable housing impacts diverse populations differently. Furthermore, it is recommended to conduct comparative studies across different geographical areas to discern the effects of varying cultural values and policy frameworks on the relationship between sustainable housing and quality of life.

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