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Receptiveness of Young Singaporeans Towards Smart Features in Public Residential Buildings (SPRBS): Drivers and Barriers

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Abstract: The development of smart and sustainable cities (SSCs) is a global focus to ensure cities remain resilient in a challenging environment. In Singapore, various initiatives have been introduced to maintain its competitiveness as an SSC. This study investigates the drivers and barriers affecting the receptiveness of young Singaporeans (aged 18 to 35) towards smart features in public residential buildings (SPRBs). Questionnaires were distributed to young Singaporeans, and 213 valid responses were collected over three months in 2023. It is worth noting over 40% of the respondents are 25 years old and below, classified as Generation Y. The results showed that among 80.3% of respondents who were familiar with SPRBs in Singapore, 68.1% of them either had a minimal or moderate understanding of SPRBs. The top five drivers were ease of access, safety-related factors, and psychological needs, while the top five barriers included cyberattacks, privacy and security concerns, overdependence, and task perception. Research findings have presented meaningful insights for relevant stakeholders to understand different perspectives of young Singaporeans arising from the implementation of SPRBs. It is hoped that public authorities will use this study to assess the feasibility of SPRBs and improve the concept to meet the evolving needs of future homebuyers in Singapore.

Keywords: smart features; public residential buildings; drivers; barriers; Singapore; receptiveness

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1. Introduction

A new wave of digital innovation, known as the Fourth Industrial Revolution (Industry 4.0), is evolving at an exponential pace and disrupting almost every industry globally. Rapid development of information and communication technologies (ICT) has enabled physical products and services to be enhanced with digital capabilities, thereby leading to the pervasive implementation of highly advanced technologies in the built environment and fundamentally changing our daily lives. Ref. [1] noted that Industry 4.0 and technological innovations are expected to cause significant changes to residential spaces. Over the years, smart features implemented in residential buildings have progressively evolved from wired and niche technologies to widely accessible and connected smart appliances that offer individualised services in diverse application areas [2]. In today's world, a home is no longer a place where appliances perform their intended functions independently. Rather, it consists of a distributed system where different applications, services and technologies function together to optimise service delivery and achieve enhanced performance [3]. The COVID-19 pandemic further highlighted the importance of and the need to integrate these technologies into the larger urban systems and with supportive plans and policies [4]. Research has been conducted to determine the feasibility and associated drivers and barriers for implementing smart home features [5,6]. Despite the practical importance of this market, there was relatively little academic research on the factors that influence smart home receptiveness in Singapore. Most studies conducted in other countries, with a few exceptions, examined the smart features in Singapore's condominiums [7] and urban living [8]. Knowing these gaps, this study seeks to determine the receptiveness of young Singaporeans (aged 18 to 35) towards the smart features in the context of public residential buildings (hereafter SPRBs) in Singapore, where the majority of Singaporeans reside. The main research aim is to identify and investigate various drivers and barriers influencing their receptiveness. The research objectives are as follows:

(a) To identify the drivers and barriers that affect an individual's receptiveness towards SPRBs.
(b) To propose recommendations for promoting the wider implementation of SPRBs in Singapore.

Singapore has actively pursued smart and sustainable urban development through initiatives such as the Smart Nation Initiative (SNI) and the Smart HDB Town Framework. Launched in 2014, SNI aims to digitise urban life by integrating smart technologies across various sectors, including public housing. The Smart HDB Town Framework, introduced by the Housing & Development Board (HDB) (HDB is the agency responsible for public housing), focuses on leveraging smart technologies to improve energy efficiency, security, and overall living experiences in public housing estates. This study focuses on public residential buildings because, unlike private developments, smart features are still emerging in public housing under the Smart HDB Town Framework. In Singapore, over 90% of private residential projects launched in 2019 included smart features [9], such as Jadescape, the first fully smart private development by Qingjian Realty, offering advanced technologies across six categories: security, efficiency, health, living, community, and care [10]. However, perceptions of these features among young people in public housing remain underexplored. The findings are expected to reflect current and future market demands, influencing the broader adoption of SPRBs. This, in turn, supports Singapore's continuous development as a smart and sustainable city.

2. Literature Review

2.1. Technolgical Advancement

The evolution and expansion of fifth-generation (5G) technologies, artificial intelligence (AI) and the Internet of Things (IoT) have enabled traditional consumer products to be wirelessly connected and equipped with intelligent characteristics. In turn, these technologies facilitate the development of smart and sustainable buildings which are more adaptive and responsive to the changing environmental conditions and individual needs [11]. Smart home features are commonly equipped with communication protocols such as 5G, Bluetooth and wireless fidelity (Wi-Fi). Fifth-generation networks are a comprehensive ecosystem that connects heterogeneous devices and allows data exchange through the Internet infrastructure, thereby facilitating a connected and mobile society [12]. Rapid deployment of IoT and AI technologies has resulted in the increasing use of smart features to enhance the efficiency of everyday lives, thereby leading to the concept of smart living. As one of the key enablers of the paradigm shift towards smart living in Singapore, the integration of hardware and software systems, sensors and cloud computing platforms has transformed traditional homes into homes that are more intelligent and responsive to the needs of individuals [13]. Thus, this facilitates an effective management of residential spaces while meeting the current and future needs of building occupants.

Hundreds of smart home products are currently available worldwide [14]. These products can be implemented throughout the building lifecycle to provide individuals with real-time insights, thereby maximising comfort and productivity at the lowest energy costs. These features are connected through an internal home network, with mobile devices communicating via a home gateway and telecommunications network [3]. Linked through the telecommunications network, the cloud servers collect and analyse data from the smart features and mobile devices to provide automated and interactive services [3]. The home gateway enables data to be shared and communicated within the smart home, as well as facilitates information exchange with the external network [15]. In this study, SPRBs comprise internet-enabled devices and appliances that can be automated, controlled and managed remotely in an interactive home environment. The infrastructure of SPRBs includes applications, communication protocols, network connectivity, and sensing devices [13].

2.2. Singapore Government's Initatives on Technology Advancement

In line with the vision of becoming a global city, the first national information technology (IT) master plan was formulated in 1980 [16]. Thereafter, the vision of becoming a smart city was established in 2014. Over the past decades, Singapore has devised plans and policies and progressively pushed for different stages of digitalisation to increase its productivity and efficiency [17]. Moreover, urban planning and governance approaches are continuously revised to keep up with technological advancements and achieve the vision of becoming a smart city. In view of an increasingly digitised and knowledge-based economy, the Smart Nation Initiative (SNI) was launched in November 2014 to enhance living, strengthen communities, and create more opportunities for all. Building upon the previous major technology-enabled initiatives [17], SNI reflects a broader digital transformation that aims to digitise all aspects of urban life through the widespread deployment of smart technologies in different building types [18]. With the involvement of main stakeholders, technology-enabled solutions are co-created for and with ICTs, big data and networks [12]. Furthermore, by collecting and interpreting real-time data, parties can gain different insights and translate them into meaningful actions [19]. Thus, this generates new business opportunities and contributes to greater economic productivity. As a centralised public agency, the Smart Nation and Digital Government Group (SNDGG) was established to coordinate cross-government digitisation efforts [18]. Additionally, the InfoCom and Media Development Agency (IMDA) leads the holistic development of hard and soft infrastructures, including the development of the Smart Nation Sensor Platform (SNSP) and standardising the use of IoT [20]. SNSP is an integrated, nationwide platform that utilises sensors to gather essential data that can be analysed to create smart solutions. The Singaporean government has launched various initiatives on technology advancement, as mentioned earlier. Clearly, technology is an enabler of this progress. This study explores how smart public housing can support such initiatives, highlighting the importance of understanding barriers and benefits from young stakeholders' perspectives.

2.3. Smart Public Residential Buildings (SPRBs)

Sustainable development and smart technologies are key to improving the planning, development and management of public housing locally [21]. In 2011, the "Roadmap for Better Living in HDB Towns" was launched to develop well-designed, community-centric and sustainable towns [22]. This was followed by the "Smart HDB Town Framework" in 2014, facilitating the adoption of smart features in public housing throughout Singapore [8]. As part of an ongoing and iterative process to design the most optimal homes for Singaporeans, these initiatives have been refreshed to meet the new and evolving societal needs and emerging challenges. With a primary focus on the holistic well-being of individuals, the new "Designing for Life" roadmap was initiated in October 2020 to provide a better living environment for residents at different stages of their lives [22]. Through careful planning supported by science and data, the enhanced roadmap serves to guide the design and planning of existing HDB towns and new public housing developments for the next decade [23].

While the earliest HDB flats focused on simple and practical design, there is a recent shift towards the provision of smart and sustainable homes that are functional and adaptive to the aspirations of the next generation [24]. Before introducing new technologies in HDB estates, multiple stringent laboratory trials are conducted at the HDB Centre of Building Research to ensure their compliance with relevant building regulations, cost-effectiveness and technical feasibility [24]. These trials also allow HDB to review the design and provision of necessary digital infrastructure to support the use of smart features in public residential developments [25]. Additionally, prior to their implementation on a larger scale, collaborations are made between various government agencies and industry players to develop and test the feasibility of smart features in a real-world environment [21]. Subsequently, feedback provided by residents enables parties to determine factors that are deemed to be essential and evaluate the level of demand for smart features among individuals. These technologies are then further refined to fulfil respective individual needs. Two pioneering projects (see Figure 1) worth noting are as follows:

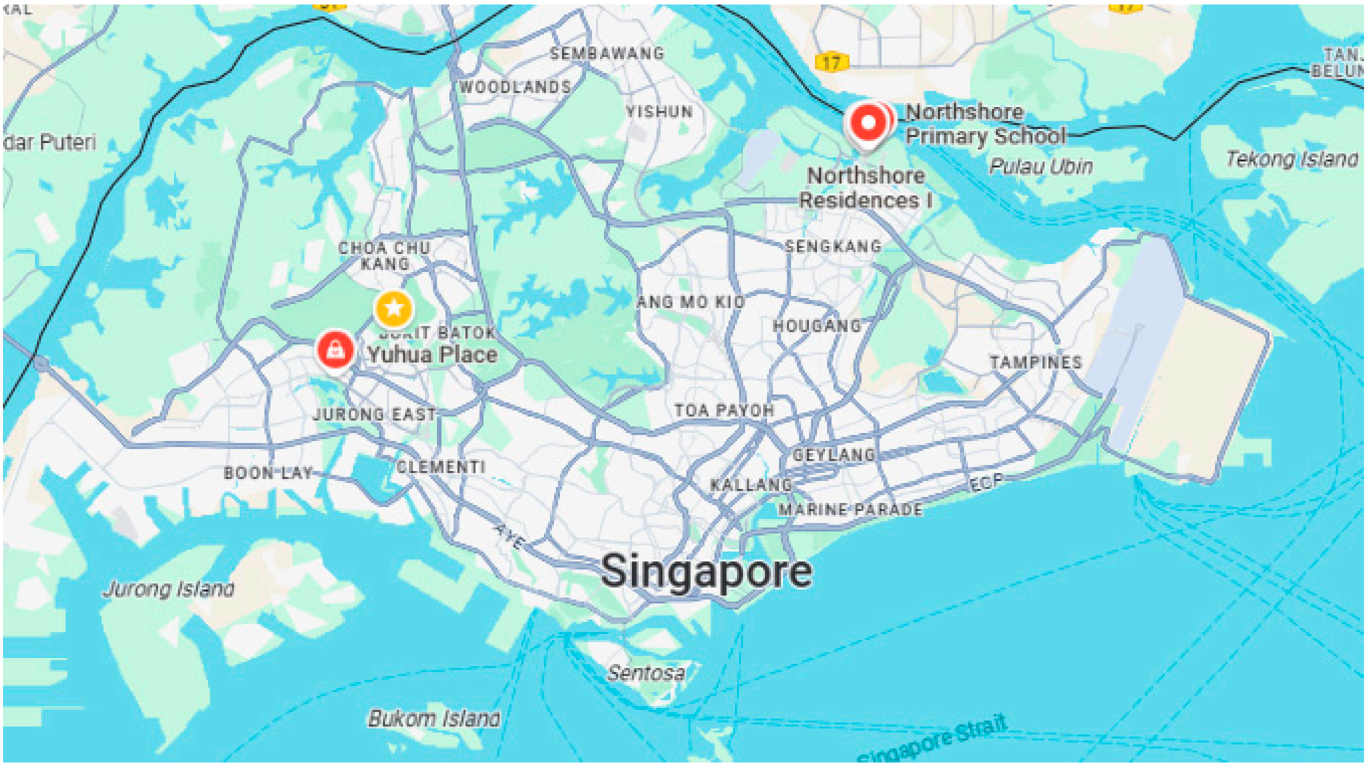

Figure 1. Locations of two pioneering projects. Note: Yuhua (west Singapore) and Punggol Northshore (northeast Singapore).

Yuhua. Yuhua was the first public housing estate to test out smart urbanism programmes that were jointly managed by various state authorities [8]. Smart features, namely the Elderly Monitoring System (EMS) and Home Energy Management System (HEMS), were progressively deployed in homes and neighbourhood spaces through several upgrading projects from 2015 to 2018 [8]. This allowed residents to gradually familiarise themselves and feel comfortable with the implementation of smart features in everyday spaces. Between October 2015 and April 2016, ten households of different demographics participated in an initial trial of smart homes [25]. Responses provided with regard to the ease of use and non-intrusive nature of smart features have helped HDB to determine how the smart features could be further improved to enhance the everyday lives of residents [25]. In April 2016, the trial was extended to another 3200 households in Yuhua estate, and residents could purchase smart home solution packages from commercial providers [26]. Lessons learnt from these trials were also considered when designing Punggol Northshore Residences [26]. For example, homes must be well-equipped with necessary infrastructures to reduce the need for additional hardware such as smart gateways and smart power plugs [26].

Punggol NorthShore Residences I and II. Punggol Northshore is the first smart and sustainable public housing district to testbed smart technologies from the design stage. Consisting of 1402 housing units, Northshore Residences I and II are the first two smart-enabling housing precincts within the district [27]. These housing units are equipped with high-tech distribution boards and smart power sockets to facilitate a seamless integration between smart features developed by different manufacturers [27]. Furthermore, individuals can control appliances that are connected to a power source through a mobile application. Within the estate, sensors are installed to monitor the performance and reliability of key estate services, such as lighting, lifts and waste collection. For instance, sensor-controlled smart lightings installed at common areas will adjust their illumination levels based on real-time human traffic patterns, thus potentially ensuring a 60% reduction in energy consumption [28]. In addition, predictive maintenance ensures that issues are promptly identified and resolved to minimise the disruption caused to the services and residents. Hence, these smart features will bring about a more efficient, liveable, safe and sustainable living environment.

2.4. The Research Gap

A closer examination of the smart home research shows that a great deal of studies either focused on their technical aspects [29] or the receptiveness of elderly users [30] towards implementing smart features in buildings. Reference [29] found older consumers are more likely to purchase smart homes but also noted the need for a strategy targeting younger buyers. This is understandable, as smart home technologies can address elderly users' needs, such as health monitoring [31]. However, as young adults are often considered to be more comfortable with and knowledgeable about new technologies [32], their receptiveness towards smart features in smart homes can affect their feasibility and market potential in the near future. Clearly, the gap lies in the limited research on factors influencing smart home receptiveness in Singapore. The next section identifies the key drivers and barriers.

2.5. Key Drivers and Barriers

As an individual's initial perceptions of the usefulness of SPRBs are formed at the earliest point of contact [33], this subsequently impacts their implementation in Singapore. For instance, when smart features are perceived to be more beneficial than comparable non-IoT devices, individuals will be more willing to pay for them [34]. Therefore, other than assessing the technological performance, it is also imperative to understand factors that individuals consider important and necessary when implementing SPRBs. The Technology Acceptance Model (TAM), proposed by [35], can help determine an individual's receptiveness towards SPRBs. TAM suggests that when technology is perceived as easy to use and useful, individuals are more likely to use it. However, the prediction accuracy of TAM may be limited as factors, such as external variables and technology-specific variables, are not taken into account [36]. Based on a review of existing studies, Tables 1 and 2 identify the drivers and barriers influencing their receptiveness towards SPRBs. Drivers are factors that increase an individual's receptiveness, while barriers decrease an individual's receptiveness. This study draws from the work of reference [5], who mapped out the benefits and challenges of smart homes as follows:

- Benefits: health, environmental, financial, psychological well-being and social inclusion.
- Challenges: technological, financial, ethical and legal, and knowledge gaps and psychological resistance.

Table 1. Drivers influencing an individual's receptiveness.

Code	Drivers	Reference
	Convenience and efficiency	
D1	Provides convenience to user	(1–4); (6–9); (11–13)
D2	Ensures time savings	(2); (5); (7); (11); (13,14)
D3	Allows remote controlling of home functions	(1–5); (7–9); (11–13); (15)
D4	Provides multiple ways to perform a task	(2–3); (10)
D5	Provides ease of access for user	(8); (10,11); (14,15)
D6	Provides a conducive environment to carry out different activities at home	(7); (12); (14)
D7	Provides insights for home management	(1); (3,4); (7)
	Health and safety	
D8	Increases safety and security	(1–3); (5–14)
D9	Enables real-time surveillance of home environment	(5); (10); (12)
D10	Ensures appliance safety and automatic shutoffs where necessary	(5); (10); (14)
D11	Allows customised preferences and settings for user comfort	(3); (11,12)
D12	Provides comfort to user	(1); (3–6); (8–15)
D13	Allows for tracking of health and wellness	(1,2); (4–12); (14,15)
	Environmental	
D14	Ensures cost savings	(2–7); (9–15)
D15	Enables energy and utilities management	(2); (4–12); (14,15)
D16	Contributes to environmental sustainability	(4); (6,7); (9); (12,13); (15)
	Psychological well-being	
D17	Enhances quality of life	(1); (5–15)
D18	Provides a source of entertainment to user	(1–4); (7–10); (15)

Note: 1: [37], 2: [38], 3: [39], 4: [14], 5: [40], 6: [41], 7: [32], 8: [42], 9: [43], 10: [44], 11: [45], 12: [15],13: [46], 14: [37], and 15: [47].

Table 2. Barriers influencing individual's receptiveness.

Code	Barriers	References
	Users	
B1	Hard to integrate smart features into current lifestyle	(6–8); (11,12); (14)
B2	Basic control skills needed to use smart features	(5); (10); (12)
B3	Overly dependent on smart features in daily life	(1,2); (5–7); (9); (12–15)
B4	Lack of awareness and knowledge about smart features	(2,3); (5–8); (10–12); (14,15)
B5	No strong interest in smart features	(11); (15)
B6	Time needed to familiarise myself with smart features adopted	(4,5); (12)
B7	Uncertain about added value of adopting smart features	(3); (6); (9); (11); (13)
	Technology	
B8	Reliable internet connection needed to use smart features	(1–4); (6–11); (14,15)
B9	Possible connection issues between smart features produced by different manufacturers	(1,2); (4–7); (9); (13–15)
B10	Smart features can become outdated easily	(3); (9); (14)
B11	Complexity involved in using smart features	(3,4); (6–8); (12–15)

Table 2. *Cont.*

Code	Barriers	References
	Financial, ethical and legal	
B12	High costs involved, e.g., maintenance and repair costs	(1–3); (5–8); (10,11); (13–15)
B13	Lack of after-sales services by service providers	(3,4); (14)
B14	Privacy and security reasons	(1–3); (5–11); (13); (15)
B15	Possible misuse of personal data by other parties	(5,6); (9); (11,12)
B16	Trust issues with others, e.g., government, manufacturers and service providers	(1); (3–11); (14)
B17	Possible cyberattacks by hackers	(3); (5–7); (9); (11–12)
B18	Lack of relevant legislations to protect users	(4); (7); (12)

Note: 1: [37], 2: [38], 3: [48], 4: [33], 5: [41], 6: [49], 7: [43], 8: [45], 9: [50], 10: [51], 11: [15], 12: [30], 13: [46], 14: [37], and 15: [47].

We based our study on [5]'s work because its user-focused classification aligns with our aim to investigate the drivers and barriers influencing individual receptiveness to SPRBs. We made slight modifications to the categories, such as separating 'convenience and efficiency' from [5]'s health-related category (see Table 1) and renaming 'knowledge gaps and psychological resistance' to 'users' (see Table 2).

3. Method

3.1. Research Design

The research began with a preliminary literature review to identify potential drivers and barriers that could influence the receptiveness of young Singaporeans towards SPRBs. A questionnaire was developed based on these identified factors and distributed to the target group for data collection.

3.2. Questionnaire

As a versatile and low-cost research instrument, a questionnaire is used to obtain meaningful information on individual perspectives in a standardised manner [52]. To reach out to a diverse range of targeted respondents quickly and effectively, the questionnaire was adopted as the main mode of data collection in this study. The questionnaire was developed (Please refer to Appendix A for sample questionnaire) and managed using Google Forms. It first collected demographic information from respondents, including age, gender, education, and income. Next, the survey assessed respondents' awareness and knowledge of SPRBs in Singapore, including their familiarity with these technologies and opinions on the potential for broader implementation. A series of statements on drivers and barriers was then provided, with respondents rating their importance in affecting receptiveness to purchasing a smart public residential unit (hereafter SPRU). A 4-point Likert scale was used to eliminate neutrality and reduce misinterpretation, with each point corresponding to a specific value. Respondents were also asked to identify parties that could influence their decision to live in an SPRU and explain their rationale. Lastly, respondents were asked about their willingness to purchase (WTP) an SPRU, indicated by the percentage of price premium they would accept, ranging from 0% to 30%, with a 5% incremental interval.

3.3. Sampling and the Respondents

The targeted respondents were young Singaporeans aged 18 to 35, who represented 22.5% of the population in 2022 [53] and are defined as youths by the National Youth Council of Singapore. Data collection took place from April to June 2023, with potential respondents contacted via face-to-face conversations or messaging platforms. A total of 227 responses were collected over several months, with 14 invalid responses excluded for not meeting demographic requirements, leaving 213 valid responses for analysis. The respondents' profiles in terms of gender, age, education, and income are shown in Table 3. Of the 213 valid responses, 54.9% were male and 45.1% were female. With a median age of 27, about 41.8% of the respondents belong to Generation Z (the definition of Generation Z follows the work of Bresman and Rao (2017), which noted individuals who were born in and after 1997 are Generation Z) (age 25 and below) [54], while the remaining would be classified as Generation Y (58.2%). Table 3 indicates a generally well-educated sample, with around 90% of respondents having completed at least an A level, diploma, or degree (6.6%, 37.1%, and 45.1%, respectively). Approximately 21% of respondents reported no income, likely due to ongoing education, while 44% earn between SGD 4001 and SGD 6000.

Table 3. Profile of respondents.

Demographics	Number	Percent
Gender		
Female	117	54.9%
Male	96	45.1%
Age		
25 and below (Gen Z)	89	41.8%
26–29	61	28.6%
30 and above	63	29.6%
Median age: 27		-
Education Level		
"O" level, "N" level or equivalent	0	0%
NITEC/higher NITEC	24	11.3%
"A" level or equivalent	14	6.6%
Polytechnic, diploma or equivalent	79	37.1%
Degree	96	45.1%
Postgraduate degree or higher	0	0%
Gross monthly income		
No income	45	21.1%
Below SGD 2000	20	9.4%
SGD 2000–4000	49	23.0%
SGD 4001–6000	95	44.0%
SGD 6001–8000	4	1.9%
SGD 8001–10,000	0	0%

Note: N = 213.

4. Results

4.1. Awareness and Perception of SPRBs

As shown in Table 4, 70.0% of respondents did not have smart features currently installed and used at home. This implies that the implementation of smart features is not common in public residential buildings. Respondents' awareness and perception of SPRBs is also shown in Table 4: most of the respondents had a minimal (37.6%) to moderate (30.5%) understanding of SPRBs. These suggest that there is a lack of mass publicity about such residential buildings locally. Among respondents who were aware of SPRBs, many got to know about SPRBs mainly through social media platforms. This indicates that social media (N = 58) plays an important role in disseminating information related to different initiatives. Online news articles (N = 33) and word of mouth (N = 27) were the second and third most mentioned ways to learn about SPRBs, respectively.

Table 4. Awareness of SPRBs.

	Number	Percent
Installation of smart features at home (N = 213)		
Yes	149	70.0%
No	64	30.0%
Awareness of SPRBs in Singapore? (N = 213)		
Yes	77	36.2%
No	136	63.8%
Familiarity with SPRBs? (N = 213)		
Low	42	19.8%
Minimal	80	37.6%
Moderate	65	30.5%
Relatively comprehensive	26	12.2%
Comprehensive	0	0
Source of information about SPRBs		
Social media platforms	58	-
Online news articles	33	-
Word of mouth	27	-
Online advertisements	26	-
Television or radio	18	-
Physical or online retailers	17	-
Printed media	9	-
Outdoor advertisements	4	-
None of the above	1	-

4.2. Drivers and Barriers

Respondents were required to rate the importance of various drivers and barriers in affecting their receptiveness towards purchasing an SPRU. With Cronbach's α of 0.908 for drivers and 0.777 for barriers, the results attained a desirable level of reliability. The chi-squared test and Cramer's V (φ_c) were applied to determine the significance of each driver. The results suggested that, except for D18 ($p > 0.05$), all identified drivers increased an individual's receptiveness towards SPRBs (see Table 5).

The top-ranked drivers were "Provides ease of access for users (D5)" (Mean = 2.765) and "Provides convenience to users (D1)" (Mean = 2.681), both falling under the convenience and efficiency category. SPRBs facilitate the daily lives of individuals and are especially useful to support the needs of households with children, elderly and/or persons with disabilities [42]. For example, individuals can use the built-in voice-enabled function to control various smart features, enhancing technology accessibility and promoting independent living [55]. Smart features offer convenience by enabling remote control via the Internet and adapting to individual preferences with minimal human intervention. Additionally, convenience is achieved when minimum performance standards are met [56].

Health and safety-related drivers were ranked next in terms of influencing receptiveness to purchasing an SPRU. These included "Increases safety and security (D8)" (Mean = 2.755) and "Enables real-time surveillance of home environment (D9)" (Mean = 2.701), ranked second and fourth, respectively. Safety-related smart features allow individuals to monitor activities inside and outside their homes, accessing real-time photos and videos from mobile devices. Additionally, real-time notifications are sent for timely interventions, such as alerts to emergency centres in the event of safety incidents. Hence, SPRBs assure the safety and security of individuals in terms of their personal lives, privacy and properties.

Psychological needs appeared to be another driver for the respondents. For example, "Provide comfort to user (D13)" (Mean = 2.725), which was ranked third. Comfort relates to an individual's demand for resources to reproduce a specific relationship between the body and its wider environment [56].

Table 5. Drivers influencing receptiveness towards SPRBs.

Code	Drivers	Mean	S.D.	Ranking	p-Value	Cramer's V (φ_c)
	Convenience and efficiency					
D1	Provides convenience to user	2.681	0.579	5	0.006	0.218
D2	Ensures time savings	2.642	0.537	7	0.025	0.209
D3	Allows remote controlling of home functions	2.632	0.512	8	<0.001	0.324
D4	Provides multiple ways to perform a task	2.441	0.506	15	0.002	0.242
D5	Provides ease of access for user	2.765	0.527	1	0.003	0.235
D6	Provides a conducive environment to carry out different activities at home	2.451	0.526	14	<0.001	0.381
D7	Provides insights for home management	2.392	0.508	16	<0.001	0.461
	Health and Safety					
D8	Increases safety and security	2.755	0.532	2	0.004	0.227
D9	Enables real-time surveillance of home environment	2.701	0.499	4	0.041	0.173 **
D10	Ensures appliance safety and automatic shutoffs where necessary	2.475	0.537	13	<0.001	0.337
D11	Allows customised preferences and settings for user comfort	2.495	0.538	12	<0.001	0.304
D12	Provides comfort to user	2.725	0.508	3	0.008	0.213
D13	Allows for tracking of health and wellness	2.368	0.512	18	<0.001	0.308
	Environment					
D14	Ensures cost savings	2.574	0.560	10	<0.001	0.365
D15	Enables energy and utilities management	2.505	0.519	11	<0.001	0.318
D16	Contributes to environmental sustainability	2.387	0.516	17	<0.001	0.493
	Psychological and well-being					
D17	Enhances quality of life	2.598	0.573	9	<0.001	0.308
D18	Provides a source of entertainment to user	2.672	0.500	6	0.062 *	0.162 **

Note 1: Respondents were asked to indicate their level of agreement with the statement: "How far do you agree with the following statements that would increase your receptiveness towards purchasing a public residential unit equipped with smart features?". Note 2: * not significant at p-value > 0.05. Note 3: For Cramer's V, a value of 0.2 or less indicates a weak association, while a value greater than 0.6 indicates a strong association. Therefore, except for ** D9 (φ_c = 0.173) and ** D18 (φ_c = 0.162), other drivers were moderately associated with an individual's receptiveness towards SPRBs.

4.3. Barriers

The tests indicated that most barriers decreased an individual's receptiveness towards SPRBs, as their significance level was less than 0.05. However, there was insufficient evidence to support that a few barriers decreased receptiveness, as their p-values were greater than 0.05. These barriers included reliability of internet connection (B8), connection issues between smart features (B9), high costs (B12), and lack of after-sales services (B13). In terms of the degree of association, all barriers showed either a weak ($\varphi_c < 0.2$) or moderate ($0.2 < \varphi_c < 0.6$) association with receptiveness towards SPRBs.

According to Table 6, the top-ranked barrier was "Possible cyberattacks by hackers (B17)" (Mean = 2.750). A cybersecurity incident is an illegitimate activity conducted on or through a computer system that adversely affects its cybersecurity or the cybersecurity of another computer system [57]. In recent years, pervasive connectivity of smart features to the Internet and other IoT devices has provided a new platform for cyberattacks to occur [58]. For example, a data breach which occurs due to a vulnerable smart feature can result in shared exploitation across interdependent systems [58]. In turn, this leads to an unsafe physical and digital environment that can have immediate or possible long-term consequences on an individual's life, safety and well-being.

Table 6. Barriers influencing receptiveness towards SPRBs.

Code	Barriers	Mean	S.D	Ranking	*p*-Value	Cramer's V (φ_c)
	Users					
B1	Hard to integrate smart features into current lifestyle	2.637	0.529	11	0.006	0.241
B2	Basic control skills needed to use smart features	2.672	0.547	6	0.007	0.239
B3	Overly dependent on smart features in daily life	2.721	0.480	3	<0.001	0.286
B4	Lack of awareness and knowledge about smart features	2.667	0.492	8	<0.001	0.342
B5	No strong interest in smart features	2.701	0.479	4	<0.001	0.351
B6	Time needed to familiarise myself with smart features adopted	2.667	0.471	8	<0.001	0.358
	Technology					
B7	Uncertain about added value of adopting smart features	2.632	0.502	12	<0.001	0.444
B8	Reliable internet connection needed to use smart features	2.373	0.522	16	0.303 *	0.131
B9	Possible connection issues between smart features produced by different manufacturers	2.324	0.478	18	0.236 *	0.141
B10	Smart features can become outdated easily	2.436	0.496	14	0.012	0.172
B11	Complexity involved in using smart features	2.686	0.464	5	<0.001	0.344
	Financial, ethical and legal					
B12	High costs involved, e.g., maintenance and repair costs	2.387	0.604	15	0.061 *	0.186
B13	Lack of after-sales services by service providers	2.627	0.503	13	0.065 *	0.160
B14	Privacy and security reasons	2.735	0.503	2	0.006	0.241
B15	Possible misuse of personal data by other parties	2.672	0.519	6	0.003	0.259
B16	Trust issues with others, e.g., government, manufacturers and service providers	2.343	0.485	17	0.044	0.172
B17	Possible cyberattacks by hackers	2.750	0.506	1	<0.001	0.280
B18	Lack of relevant legislations to protect users	2.662	0.473	10	<0.001	0.348

Note 1: Respondents were asked to indicate their level of agreement with the statement: "How far do you agree with the following statements that would decrease your receptiveness towards purchasing a public residential unit equipped with smart features?". Note 2: * not significant at *p*-value > 0.05.

The second-ranked barrier was "Privacy and security reasons (B14)" (Mean = 2.735). Privacy relates to an individual's right to control their personal information, while security refers to the protection of personal information [59]. In order for smart features to perform their intended functions, the collection, utilisation and circulation of personal information tend to be managed by external third parties worldwide [15]. As such, concerns regarding the preservation of confidential information are raised. To illustrate, despite acknowledging the inevitability of smart features gathering and storing personal information, some are concerned about the possible disclosure of personal information without their consent [48]. For instance, in 2020, there were local reports about the hacking of IP cameras installed in HDB flats, and leaked footage was uploaded online [60]. As safety and security were valued as key drivers, it is therefore understandable to see that the lack of them will be perceived as a barrier.

The third-ranked barrier was "Overly dependent on smart features in daily life (B3)" (Mean = 2.721). As the responsibility of daily tasks is transferred to the smart features, SPRBs create a fundamental shift towards an interdependent human-technology relationship in residential spaces [30]. For example, SPRBs can cause households to heavily depend on smart features due to the automation of home-related processes. Moreover, decisions made by the smart features are often less visible and more ambiguous, as they are always running in the background [61]. Hence, individuals tend to lose control over their daily tasks and require external assistance when problems arise [30].

Task perception appeared to be another barrier for the respondents. These included "No strong interest in smart features (B5)" (Mean = 2.701) and "Complexity involved in using smart features (B11)" (Mean = 2.686), which were ranked fourth and fifth, respectively. Smart features and their related user interfaces shall contain minimal options and easy-to-use controls, as many individuals are not interested in understanding the full set of functionalities provided [33]. Additionally, negative perceptions towards SPRBs can have a resulting effect on its implementation. For instance, when smart features are perceived to be complex, individuals may uninstall them completely or give up on using the available advanced functions [62]. Instead, basic functions that are relatively similar to the conventional home appliances will be utilised [63].

4.4. Receptiveness and Willingness to Purchase (WTP)

Prior to adopting new technology, individuals often assess whether it is worth the investment or if cheaper alternatives are available [49]. If the perceived benefits are less than the monetary cost, their intention to adopt the technology decreases [64]. As shown in Table 7, 39.9% of respondents expressed willingness to pay for an SPRU in the near future, indicating that young Singaporeans are generally not very receptive to SPRBs. External parties, such as the government (N = 93), manufacturers/service providers (N = 85), and society (N = 76), have a significant influence on an individual's decision to live in an SPRU. Among respondents who were willing to purchase an SPRU, close to 45% of them were willing to pay a price premium of between 6% and 10% (see Table 7). They were of the view that SPRU was worth investing in to obtain the long-term benefits. Respondents who were willing to pay a price premium of between 0% and 5% felt that SPRU should remain affordable, given the rising cost of living in recent years. Respondents willing to pay a premium of 11% to 15% felt the price difference between an SPRU and a conventional unit would be minimal.

Table 7. Willingness to purchase.

	Number	Percent
Willingness to purchase (N = 213)		
No	128	60.1%
Yes	85	39.9%
[1] **Parties who can influence decision**		
Government	93	-
Manufacturers and/or service providers	85	-
Society	76	-
Yourself	60	-
Family and/or friends	51	-
None of the above	24	-
All of the above	12	-
[2] **How much more are you willing to pay for SPRU (N = 85)**		
0–5%	14	16.47%
6–10%	39	45.88%
11–15%	30	35.31%
16–20%	1	1.17%
21–25%	1	1.17%
26–30%	0	0.00%
30% above	0	0.00%

Note 1: [1] The response to 'parties who can influence decision' allows multiple inputs. Note 2: [2] Respondents were asked to explain why they were willing to pay a certain premium in an open-ended question.

For those unwilling to purchase an SPRU, common concerns included cost-related issues, poor previous experiences, and the view that smart features were unnecessary. Many respondents perceived SPRUs as more expensive than conventional residential units. Table 8 compares the housing prices of two similar-sized Build-To-Order (BTO) projects in non-mature estates, showing that an SPRU of different housing types is slightly more expensive than a conventional residential unit.

Table 8. Comparison between BTO projects launched in May 2015.

Details	EastLink I and II @ Canberra	Northshore Residences I and II
Estate	Sembawang	Punggol
Number of Housing Units	1041	1402
Considered as SPRU	No	Yes
	BTO Housing Price (Excluding Grants)	
2-Room	From SGD 75,000	From SGD 88,000
3-Room	From SGD 152,000	From SGD 182,000
4-Room	From SGD 238,000	From SGD 284,000
5-Room	NA	From SGD 364,000

Source: [65].

5. Discussion

5.1. Overall

The key research findings were as follows:

(1) Specifically, 70.0% of respondents did not have smart features currently installed and used at home.
(2) Among 80.3% of respondents who were familiar with SPRBs in Singapore, 68.1% of them either had a minimal or moderate understanding of SPRBs.
(3) External parties tend to exert higher influence on an individual's decision in terms of whether to live in an SPRU.
(4) Among 39.9% of respondents who were willing to purchase an SPRU, 45.88% of them were willing to pay a price premium of between 6% and 10%.
(5) The top five drivers were ease of access, safety-related factors, and psychological needs, while the top five barriers included cyberattacks, privacy and security concerns, overdependence, and task perception.

We provide our recommendations in the following sections.

5.2. Awareness and Knowledge

According to reference [38], prior knowledge about smart features is crucial for increasing an individual's willingness to integrate them into their daily lives. The research found that most respondents had only a minimal or moderate understanding of SPRBs, as they were unfamiliar with the full functionality. To address this, knowledge should be consolidated and clearly communicated to improve perceptions of SPRBs. Firstly, increasing awareness through regular campaigns across Singapore can help reach a broader audience and promote SPRBs. Offering opportunities to try smart features and address queries at such events can reduce uncertainty about their performance. Additionally, augmented or virtual reality tours in mobile showrooms can generate interest and keep individuals updated on the latest smart feature developments [61]. Secondly, the research found that most respondents learnt about SPRBs through social media, highlighting the importance of using various media to raise awareness. Many share their experiences on social platforms, enabling others to make informed decisions. Lastly, basic control skills are essential to ensure informed and safe usage of smart features in various contexts. Furthermore, familiarity with different aspects of smart features allows individuals to gain better home insights and decision-making capabilities, as they are better able to comprehend the type of data collected [30]. Existing legal infrastructure may have limited effectiveness due to unfamiliarity with relevant legislation [30]. Thus, introducing security awareness programmes can educate individuals on the impacts of security incidents and how existing laws protect privacy in cyberspace.

5.3. Privacy and Security

In the study, the top two barriers pertained to the possible cyberattacks and privacy and security concerns, hence emphasising the need to ensure that these issues are properly addressed. Due to the high interconnectivity of smart features, existing security mechanisms applied for non-IoT-based systems may be insufficient to protect an individual's privacy in cyberspace [66]. Currently, privacy and security measures are implemented on a case-by-case basis, depending on the types of smart features installed and the applications used [30]. A flexible and strong technical infrastructure is needed to mitigate privacy and security issues in a dynamic environment [67]. As comprehensive data security is difficult to achieve in this digital age [67], it is apparent to develop a digital mindset among individuals. However, individuals tend to be less aware of how information is collected and shared by the smart features, as their connections and data flow are typically not visible. Furthermore, the perceived level of security differs significantly, as some are confident in the existing security measures provided, while others may raise privacy-related concerns [48]. For instance, individuals who acknowledge the associated risks of third-party data collection are more likely to use the smart features continuously if they are deemed to be useful [68]. To gain an individual's trust in using smart features, policymakers should establish and maintain legislative frameworks, standards and security mechanisms to ensure that the collection of personal data is transparent and limited to its intended purposes. Factors, such as an individual's level of education and security awareness, have to be considered when implementing such security countermeasures [69].

Prior to their market launch, manufacturers shall ensure that smart features are developed, tested and evaluated carefully. For example, smart features and their user interfaces can be equipped with enhanced security capabilities to minimise the privacy risks related to the implementation of SPRBs. It is also essential to understand individuals' opinions about the privacy implications of SPRBs and situations where they prefer to have control of their privacy. To illustrate, as individuals may base their privacy in terms of who is collecting their data [68], they should be informed of how the collected data will be handled and protected. Therefore, these security countermeasures will serve to increase the receptiveness towards SPRBs.

5.4. User Centredness

According to the study, there was a relatively low receptiveness towards SPRBs, as 39.9% of respondents were willing to purchase an SPRU. This can be partly attributed to the gap between the existing functions of smart features and the actual needs of individuals [70]. Hence, this emphasises the need for individuals to feel able and comfortable in using smart features to complete their daily activities. Moreover, smart features should fit into the technological architecture of the home and continuously develop over time to suit and adapt to future needs [48]. To facilitate the implementation of SPRBs, stakeholders should understand the activity patterns, considerations, needs and preferences of individuals in diverse contexts of homes. For instance, individuals with special needs may require more time to familiarise themselves with using smart features, as their implementation will affect critical home functions [71]. Additionally, stakeholders need to acknowledge that individuals have different levels of technical competency. Thus, the development of smart features through a user-based approach ensures that they can be easily controlled and managed, thereby increasing the user-friendliness and efficiency of their associated services. For example, plug-and-play smart features can be provided for individuals who are less well-versed in technologies to enhance their user experience [14]. Individuals can also participate actively in the design and development process to improve the accessibility and ease of use of smart features [33].

5.5. Contributions

This study complemented various research studies on smart features and filled the research gap by unveiling the receptiveness of young Singaporeans towards SPRBs in Singapore. Through quantitative analyses, factors that could affect an individual's receptiveness towards SPRBs were also investigated. Therefore, the study has provided the foundation of knowledge to aid researchers in conducting future research related to the development and implementation of SPRBs in Singapore. Research findings have presented meaningful insights for relevant stakeholders to understand different perspectives of young Singaporeans arising from the implementation of SPRBs. In turn, it enables the authorities to evaluate the feasibility and potential of SPRBs in the near future. It is hoped that the recommendations can guide the government, manufacturers and/or service providers in improving the concept of SPRBs in tandem with the changing environmental conditions and needs of future homebuyers. This can be achieved through the introduction of relevant plans, policies and procedures to support its implementation. In the long run, this will facilitate a wider provision of smart and sustainable homes for individuals and enable Singapore to achieve continuous development as a smart and sustainable city.

6. Conclusions

Around the world, the development of smart and sustainable cities is emphasised to ensure that cities remain inclusive, resilient, safe and sustainable in an increasingly challenging environment. In Singapore, SGP 2030 and SNI were launched to facilitate the transformation of the built environment and ensure Singapore's continuous development as a smart and sustainable city. To realise its vision of a Smart Nation, stakeholders are actively co-creating and implementing smart features in various building types. The recent shift toward smart living has increased demand for homes that are more intelligent and responsive to individuals' needs. However, despite the market potential of SPRBs in Singapore, several challenges are encountered in its current stage of implementation. For example, as the living environment and an individual's way of life in homes are dynamic, it is imperative to account for diverse needs and address these challenges from various viewpoints [44]. To facilitate a wider implementation of SPRBs in Singapore, it is of essence to apply the concept in the context of everyday lives. Hence, long-term involvement and commitment are necessary for stakeholders to engage in proactive and smart planning, thereby creating a comfortable and secure living environment for individuals.

The study proposes a valid framework for SPRBs and identifies key drivers and barriers that could influence young Singaporeans' receptiveness to SPRBs. The findings show that young Singaporeans were generally not very receptive due to various concerns that need to be progressively addressed in the future. Therefore, it is hoped that public authorities can leverage this study to further examine the feasibility of SPRBs and introduce relevant strategies to enhance its implementation. Over time, SPRBs may become a future norm in Singapore and contribute to the transformation of its built environment. On a broader scale, this would help Singapore maintain its global competitiveness and relevance as a smart, sustainable city in the digital age. Although the research achieved its aims, several limitations exist. First, receptiveness to SPRBs may be influenced by factors such as sociocultural values, technology use, and opinions on government enforcement [43]. Demographic data like household composition, housing type, race, and religion were not gathered, which could affect the findings. Second, the cross-sectional study design may not fully capture evolving opinions due to the fast-paced development of new technologies [15], making the results less representative over time. Given these limitations, the following recommendations are made. A longitudinal study is suggested to capture how individuals' experiences and opinions about smart features evolve over time, influenced by factors like policy changes or increased public awareness. We also recognise the need for methodological triangulation in future research. Future research could take a case study approach, focusing on a specific smart feature and its drivers and barriers, providing more accurate insights into factors affecting SPRB implementation. This would help develop smart features that meet individual needs, address market limitations, and improve accessibility and usability.

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Appendix A

Sample questionnaire

Demographics

Q1. What is your gender?

Q2. What is your age as of 1 January 2023?

Q3. What is your highest educational qualification attained or currently pursuing?

Q4. What is your average individual gross monthly income?

Awareness of SPRBs

Q5. Are there any smart features (e.g., Google Home, Amazon Echo) currently installed and used at home?

Q6. Are you aware of SPRBs in Singapore (such as those located in Tengah and Punggol)?

Q7. How familiar are you with SPRBs?

Q8. Please indicate where you have heard of SPRBs. (Multiple answers are allowed).

Drivers and Barriers of Smart Features in Public Residential Buildings

Q9. How far do you agree with the following statements that will increase your receptiveness towards purchasing a public residential unit that is equipped with smart features (SPRU)?

Q10. How far do you agree with the following statements that would decrease your receptiveness towards purchasing a public residential unit equipped with smart features?

Willingness to pay

Q11. Are you willing to purchase a SPRU in the future?

Q12. Who can influence your decision in terms of whether to live in a SPRU? (Multiple answers are allowed)

Q13. How much more are you willing to pay to purchase a SPRU?

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