ASSESSMENT OF GREEN RETROFIT OF EXISTING MATURE RESIDENTIAL ESTATES IN SINGAPORE

Bon-Gang Hwang, Ming Shan* and Sijia Xie

Department of Building, National University of Singapore, 4 Architecture Drive, Singapore

ABSTRACT

While the authorities in many countries around the world launched green retrofit programs to upgrade the existing mature buildings during the past decade, limited was known about the residents' perceptions of those programs. As a result, this study aimed to investigate the residents' perceptions of the green retrofit programs in Singapore, which is one of the leading countries for green development, and to explore their willingness in extending green retrofit into their individual houses. A questionnaire was administered to 90 residents from a mature public residential estate in Singapore that just underwent a pilot green retrofit program. The results reported that 86 percent of the respondents were satisfied with the green retrofit program, and their most favourite green feature installed was the outdoor light emitting diode lighting. In addition, over 50 percent of the respondents were supportive of having their individual houses undergo green retrofit and were willing to bear an upfront cost up to SGD 5,000 (approximately USD 3,540). This study also found that achieving cost savings from lower utility bills in the long run was the top motivation that drives the residents to retrofit their houses. This study contributes to the body of knowledge by conducting a thorough investigation of residents' perceptions of green retrofit programs. Furthermore, the findings from this study provide the industry and the authorities running green retrofit programs with the opportunities to reveal respondents' preferences on different green features, and to upgrade their green retrofit programs accordingly, creating more sustainable benefits for the residents.

Keywords: *Green Retrofit; Questionnaire; Respondents' Perceptions; Singapore.*

1. INTRODUCTION

As defined by the Organization for Economic Co-operation and Development (OECD, 2002), residential buildings are a particular type of built environment that is constructed to satisfy peoples' dwelling needs. However, residential buildings have also been criticized as a major consumer for energy and a significant contributor to waste (Shen et al., 2016). According to Santamouris et al. (2007), residential buildings consumed 20 percent of the energy in OECD countries. Balaras et al. (2007) stated that residential buildings accounted for 63 percent of energy consumption and 77 percent of CO_2 emission in the building sectors of European Union member countries. Therefore, the authorities worldwide have launched a series of initiatives aiming to reduce the resource consumption and achieve a better energy efficiency in residential buildings (Liang et al., 2016). It is noteworthy that these initiatives not only emphasized the development of new eco-communities but also stressed the green retrofit in existing mature residential estates (Zuo and Zhao, 2014).

In a typical densely populated metropolis like Singapore, a large number of residential buildings have been built to address people's housing needs (Agarwal et al., 2016). According to the Housing and Development Board (HDB, 2016b), more than 88 percent of the existing residential buildings in Singapore were built before 2005, the first year when Singapore launched its green building campaign (BCA, 2014). This ratio implies that there will be considerable residential buildings facing green retrofit in the future. In 2012, the Singapore government launched a green retrofit program named HDB Greenprint in several existing mature residential estates, aiming to improve their energy efficiencies and provide their residents with a healthier indoor environment (HDB, 2016a). Although there have been considerable studies relating to green retrofit in the

*Corresponding Author: E-mail – bdgsm@nus.edu.sg

current literature, most of them concentrate mainly on the environmental benefits generated from the retrofitting (Liang et al., 2015, Wilkinson et al., 2015). Very few have investigated the residents' perceptions of the green retrofit programs. As a result, this study aims to bridge the knowledge gap. Among those pilot estates in Singapore, Yuhua is the first mature residential estate to undergo the green retrofit and its retrofit work already completed in November 2015. Thus, the objectives of this study are to investigate the residents' perceptions of the pilot green retrofit program, explore their willingness to expand the green retrofit program in their individual houses, and propose some practical recommendations to enhance the existing green retrofit program in Singapore.

This study contributes to the current body of knowledge by adding the literature of green retrofit. Furthermore, this study benefits the practice as well, because the achievements and lessons learned from the current practices were carefully summarized, which can be used to improve and upgrade the existing green retrofit programs effectively in the future.

2. BACKGROUND

2.1. GREEN RETROFIT

The existing research on green retrofit is mainly concentrated on three areas: benefits of, decision-making of, and implementation of green retrofits. For example, Wilkinson and Reed (2009) illustrated the benefits and potential for green roof retrofit to commercial buildings in a city centre to property managers and other property professionals. Berardi (2016) investigated the benefits on the local microclimate and the building energy saving resulting from green roof retrofits. Castiglia Feitosa and Wilkinson (2018) assessed the benefits of green wall retrofit in attenuating the urban heat island effect and internal temperatures in buildings. In addition to the benefits of green retrofit, decision-making of green retrofit also attracts attention from the researchers. For instance, Booth and Choudhary (2013) analysed how decisions can be made in the face of the uncertainties involved in the retrofit analysis of a housing stock. Liang et al. (2016) analysed the behaviours of the building owners and occupiers, who are the direct decision makers in initiating green retrofit at the initial intention phase, using game theory. Fan and Xia (2018) presented an optimization model that can help decision makers to identify the best combination of green retrofit options. Furthermore, many studies look into the implementation of green retrofit. Jin et al. (2014) explored the operation modes of the green retrofit supply chain. Hwang et al. (2015) addressed the risks in green retrofit projects and came up with a comprehensive set of mitigation strategies that can tackle those risks. Liang et al. (2015) examined the critical success factors for the implementation of green retrofit from a stakeholder perspective, using the approach of social network analysis. Bu et al. (2015) conducted a literature review of the existing building retrofitting process, especially examined the functional, technical and organizational issues of the green retrofit process. According to the literature review presented above, it can be observed that the existing research on green retrofit is abundant; but very little of them has investigated people's perceptions of green retrofit.

2.2. PUBLIC HOUSING IN SINGAPORE AND THE GREEN RETROFIT EFFORTS

Singapore is a small and compact island but with a large population, making public housing a critical issue to the local authority and society (Phang, 2015). In order to tackle this knotty problem, Singapore government established the Housing Development Board (HDB) in 1960, an authority entrusted with the responsibility of providing quality homes and living environments for Singapore people (Low et al., 2012). Over the past five decades, HDB has built 1,116,485 subsidized flats across the island for the 3,408,900 Singapore citizens (HDB, 2016b). Currently, 80.2 percent of Singapore's population are living in HDB flats and 90.8 percent of them own their flats (Department of Statistics, 2016). The high lodging and home ownership rates have suggested that the public housing system of HDB achieved unprecedented success in Singapore.

As a world class leader in the area of green buildings, Singapore has also intensified its green efforts in the sector of residential buildings. Particularly, the local authorities like BCA and HDB have launched a series of initiatives to retrofit those existing traditional residential buildings, considering that the majority of them are the traditional ones that were designed and built previously without sustainable considerations (HDB, 2016a). For instance, in 2011 the BCA launched the BCA Green Mark for Existing Residential Buildings, aiming to help the building owners and facility operators carry out green retrofits from the perspectives of energy efficiency, water efficiency, sustainable operation and management, and community and well-being (BCA, 2011). In 2012, HDB launched the HDB Greenprint scheme and piloted it in Yuhua Estate firstly (HDB, 2016a). More details of the green retrofit program at Yuhua Estate are introduced in the following section.

2.3. THE HDB GREENPRINT @ YUHUA ESTATE

The green retrofit of Yuhua Estate was coded as HDB Greenprint@Yuhua, and it was carried out between October 2012 and November 2015, costing SGD 23 million (approximately USD 16.6 million) (HDB, 2016a). The retrofit involved 38 blocks and affected 3194 households living in this community. Five specific green features, namely elevator energy regeneration systems, solar photo voltaic systems, outdoor light emitting diode (LED) street lighting, rainwater harvesting systems, and pneumatic waste conveyance systems, were installed under this retrofit program. Among these green features, the elevator energy regeneration system is an innovative type of elevator that can save power consumption by reusing the energy recovered from the elevator's descending travels with heavy loads and ascending travels with light loads. The solar photo voltaic system is installed to convert the natural sunlight into solar power that can be used to power lift and light common areas like corridors and staircases. The rainwater harvesting system is designed to collect rainwater for common area washing and landscape irrigation. The pneumatic waste conveyance system is an automated and enclosed waste collection system which uses high-speed air suction to transport household waste via an underground pipe network to the centralized bin centre. The outdoor LED street lighting refers to the replacement of conventional bulbs for the LED bulbs in the car parks and driveways to the car parks, which can not only reduce energy consumption but also increase residents' safety as parking areas and driveways are now brighter due to higher lumens. Moreover, to encourage the use of energy-efficient appliances in homes, the HDB Greenprint@Yuhua also introduced Green Home Package and offered the residents of Yuhua discount coupons (10 to 30 percent off) for their purchases of electrical appliances like refrigerators, air-conditioners, LED televisions, washing machines, lightning and fans.

3. METHODS AND DATA PRESENTATION

As a systematic method of collecting data based on a sample, questionnaire is widely used to gather professional views in sustainable construction research (Hwang et al., 2015). Thus, this study decided to administer a questionnaire to investigate the residents’ perceptions of the HDB Greenprint @Yuhua.

The developed questionnaire was structured into three sections. The first section sought respondents’ background information, including the types of their flat, the size of their households, their monthly household income, and their monthly household utility expenditure. The second section of the questionnaire solicited respondents' overall satisfactions with the HDB Greenprint@Yuhua, as well as their perceptions of the five essential components of HDB Greenprint@Yuhua. The third section of the questionnaire solicited respondents’ willingness and considerations of extending the green retrofit program into their individual houses. This section also sought the green features that the respondents would like to install most in their individual houses. A five-point scale was employed as the rating system in the second and third section. Furthermore, to ensure the readability, comprehensiveness, and accuracy of the questionnaire, pilot surveys were conducted with two HDB engineers that were involved in HDB Greenprint@Yuhua. Based on their comments, slight revisions were made to the statements in the questionnaire, and footnotes were added to explain the terminologies used. Table 1 shows the framework of the questionnaire.

Table 1: The Framework of the Questionnaire

Questionnaire scope	Code	Item surveyed by the questionnaire
Satisfaction with the HDB Greenprint@Yuhua	A	Overall satisfaction
	B1	Greenprint program: solar photovoltaic system
	B2	Greenprint program: elevator energy regeneration system
	B3	Greenprint program: outdoor LED lights
	B4	Greenprint program: pneumatic waste conveyance system
	B5	Greenprint program: rain harvesting system
	C	Endorsement on the generalization of the HDB Greenprint program

Questionnaire scope	Code	Item surveyed by the questionnaire
Willingness to extend green retrofit into individual houses	D	Willingness to pay for retrofit
	E	The scale of the upfront cost would bear
	F1	Consideration: pride of owning
	F2	Consideration: cost saving
	F3	Consideration: better aesthetic
	F4	Consideration: higher resale value
	F5	Consideration: attractiveness for rental
	F6	Consideration: financial assistance
	F7	Consideration: saving environment
	G1	Green feature: energy monitoring system
	G2	Green feature: low e-film window
	G3	Green feature: LED lighting
	G4	Green feature: dimmer switch
	G5	Green feature: low-flow water

To disseminate the questionnaire, an online survey was created first. Then, a letter of intent was prepared, which explained the purposes and objectives of the survey and included the link to the questionnaire. Then, the letter of intent was delivered to the mailboxes of 385 households which were proportionally selected from the entire Yuhua Estate community. The 385 households selected were offered a period of six weeks to respond, and a door-to-door reminder was sent to obtain more feedback. Finally, a total of 100 responses were received, and ten of them were eliminated due to its low degree of completeness. Thus, the number of the valid responses was 90, representing a response rate of 23 percent, which was consistent with the norm of 20 to 30 percent with the most questionnaire surveys in the construction management research (Akintoye, 2000). Table 2 presents the profile of these 90 households.

Table 2: Profiles of the Respondents

Profile	Frequency	Percentage	Cumulative Percentage
Type of flat			
1- & 2- room flat	5	5	5
3-room flat	25	28	33
4-room flat	33	37	70
5-room & Executive flat	27	30	100
Size of household			
1-2 people	5	6	6
3-4 people	31	34	40
5-6 people	53	59	99
7 people or more	1	1	100
Monthly income of household			
Less than SGD 2K	6	6	6
SGD 2K - SGD 4K	17	19	25
SGD 4K - SGD 6K	32	36	61
SGD 6K - SGD 8K	24	27	88
SGD 8K - SGD 10K	9	10	98
Above SGD 10K	2	2	100
Household monthly utility bill			
Less than SGD 50	4	4	4
SGD 51 - SGD 100	36	40	44
SGD 101 - SGD 150	39	44	88
SGD 151 - SGD 200	9	10	98
Above SGD 201	2	2	100

Statistical tests were conducted to analyse the collected data. As many statistical tests require the normal distribution of the data (Kim, 2015), the data normality test was conducted first. Upon the recommendation of Gel et al. (2007), the commonly used Shapiro-Wilk test was conducted to check the normality, with the aid of SPSS Statistics 17.0. Considering the respondents for the questionnaire are households from different groups in terms of flat type, the size of household, household monthly income, and household monthly utility expenditure, it is necessary to conduct an inter-group comparison. Two widely used inter-group comparison tools, namely Kruskal-Wallis test and one-way analysis of variance, were considered. Kruskal-Wallis test is a non-parametric statistical test method suitable for processing non-normal data, while one-way analysis of variance is a parametric statistical test method suitable for processing normal data (Shan et al., 2017). Therefore, the results of the Shapiro-Wilk test determine which inter-group comparison tool shall be used for this study.

4. RESULTS AND DISCUSSIONS

Table 3 presented the results of data analysis. According to the results of Shapiro-Wilk test, the collected data were not normally distributed. Therefore, the Kruskal-Wallis test was used to conduct inter-group comparison.

4.1. RESIDENTS' PERCEPTIONS OF THE COMPLETED HDB GREENPRINT@YUHUA

4.1.1. RESIDENTS' SATISFACTIONS WITH HDB GREENPRINT@YUHUA

According to Table 3, the respondents' overall satisfactions with HDB Greenprint@Yuhua scored 4.10, suggesting the residents of Yuhua Estate were largely satisfied with the program. Table 3 also showed the five specific green features of this program received satisfaction assessments from 3.73 to 4.05, indicating all of them have satisfied the residents. The outdoor LED lighting obtained the highest assessment of 4.05 and was the most satisfied green feature, followed by pneumatic waste conveyance systems (4.01), rainwater harvesting systems (4.01), solar photo voltaic systems (3.95), and elevator energy regeneration systems (3.73).

Despite the unanimous satisfactions, differences were found among the households, particularly in terms of their monthly household income and monthly household utility expenditure. The Kruskal-Wallis test results in Table 3 showed that the households receiving monthly incomes less than SGD 2K (USD 1.4K) and above SGD 10K (USD 7.2K) gave relatively lower assessments than the rest households. In Singapore, the families who received monthly incomes less than SGD 2K were low-income families. Individuals from these families are normally pessimistic about their lives owing to their limited income, and this might be the reason why they gave relatively low assessments to the HDB Greenprint@Yuhua. Conversely, the families whose monthly incomes exceed SGD 10K are high-income families in Singapore. Individuals from these families always have high standards and expectations for their lives, and this might be the reason why they gave low assessments. Furthermore, Table 3 showed that the households paying a high monthly utility bill (i.e., above SGD 201) gave significantly lower assessments of satisfaction than the rest households. This might be because these families normally use considerable household appliances and the savings generated by the installed green features are limited which cannot satisfy these families.

4.1.2. ISSUES ENCOUNTERED DURING HDB GREENPRINT@YUHUA

The questionnaire also investigated the issues that were raised by HDB Greenprint@Yuhua. Although 74 percent of respondents replied in the survey that their life was undisturbed by the green retrofit program, the rest complained several issues. Particularly, noise disruption was the most critical issue as mentioned by 22 percent of respondents. This result echoed Zuo and Zhao (2014) who stated that noise was one of the negative experience with the construction of green buildings. Furthermore, some respondents complained the power supply to the estate was cut off at times due to the implementation of the retrofit works. A few respondents also complained that the green retrofit has affected their lift use as the bulky materials required by the retrofit were transported via lifts sometimes. These feedback from the respondents reminded the authorities and industry that some measures should be taken to minimize the negative impacts of the green retrofit.

Table 3: Respondents' Perceptions of HDB Greenprint@Yuhua and their Preferences for Individual Green Retrofit Programs

Code	Mean	*P*-value	Flat type (no. of rooms)					Size of household					Monthly household income (SGD)							Monthly household utility expenditure (SGD)					
			1&2	3	4	5 & Executive	*P*-value	1-2	3-4	5-6	≥7	*P*-value	<2K	2K-4K	4K-6K	6K-8K	8K-10K	>10K	*P*-value	<50	51-100	101-150	151-200	>201	*P*-value
A	4.10	0.000*	3.5	4.18	4.11	4.12	0.259	3.75	4.00	4.20	4.00	0.406	3.33	4.00	4.24	4.14	4.25	3.00	0.027#	3.67	4.10	4.25	3.83	3.00	0.035#
B1	3.95	0.000*	3.75	3.86	3.96	4.04	0.464	4.00	3.70	4.09	4.00	0.209	3.33	3.80	4.07	4.19	3.88	2.00	0.006#	3.33	3.97	4.14	3.67	2.00	0.005#
B2	3.73	0.000*	3.25	3.73	3.67	3.88	0.184	3.25	3.63	3.85	3.00	0.091	3.33	3.67	3.69	4.00	3.75	2.50	0.058	3.33	3.65	3.94	3.50	2.50	0.015#
B3	4.05	0.000*	3.25	4.09	4.15	4.04	0.031#	3.50	3.93	4.20	3.00	0.011#	3.33	4.07	4.07	4.29	4.00	2.50	0.005#	3.67	4.03	4.22	3.83	2.50	0.008#
B4	4.01	0.000*	3.00	4.14	4.04	4.04	0.005#	3.25	4.00	4.09	4.00	0.062	3.33	4.00	4.07	4.19	4.00	2.50	0.022#	3.67	4.03	4.11	4.00	2.50	0.061
B5	4.01	0.000*	4.00	3.95	4.04	4.04	0.911	3.75	3.89	4.09	5.00	0.143	3.33	4.07	4.07	4.05	4.25	2.50	0.019#	3.67	4.00	4.17	3.83	2.50	0.019#
C	4.09	0.000*	3.75	4.05	4.19	4.08	0.248	3.75	4.04	4.15	4.00	0.274	3.33	4.13	4.17	4.14	4.00	3.50	0.008#	3.67	4.10	4.17	4.00	3.50	0.072
D	3.30	0.000*	2.40	2.76	3.55	3.67	0.001#	2.80	3.03	3.51	3.00	0.071	2.17	2.59	3.38	3.75	4.00	3.00	0.000#	2.25	2.86	3.77	3.56	3.00	0.000#
E	1.52	0.000*	1.00	1.27	1.58	1.62	0.353	1.33	1.35	1.61	1.00	0.447	1.00	1.00	1.24	1.77	2.00	3.00	0.001#	1.00	1.32	1.58	1.63	3.00	0.245
F1	2.92	0.000*	2.50	2.55	3.15	2.88	0.368	3.00	2.47	3.14	1.00	0.022#	1.00	3.00	2.84	3.18	2.78	2.00	0.338	1.00	2.74	3.11	2.88	2.00	0.200
F2	4.48	0.000*	5.00	4.45	4.42	4.5	0.426	5.00	4.41	4.45	5.00	0.377	5.00	4.43	4.56	4.55	4.33	2.00	0.471	5.00	4.58	4.58	4.00	2.00	0.136
F3	3.25	0.000*	2.00	3.00	3.31	3.38	0.247	2.33	2.88	3.48	2.00	0.022#	1.00	3.29	3.04	3.64	3.22	2.00	0.031#	1.00	3.11	3.44	3.13	2.00	0.137
F4	3.89	0.000*	3.00	4.00	3.88	3.92	0.986	3.67	3.76	3.95	4.00	0.598	1.00	3.86	3.92	4.14	3.78	2.00	0.108	1.00	4.11	3.92	3.88	2.00	0.082
F5	3.42	0.000*	1.50	3.55	3.46	3.46	0.166	2.67	3.06	3.64	2.00	0.107	1.00	2.71	3.48	3.82	3.22	2.00	0.041#	1.00	3.47	3.5	3.38	2.00	0.289
F6	4.20	0.000*	5.00	4.09	4.31	4.08	0.269	5.00	3.94	4.23	5.00	0.043#	5.00	4.00	4.40	4.23	3.89	2.00	0.145	5.00	4.42	4.28	3.50	2.00	0.037#
F7	3.98	0.000*	4.00	3.91	4.12	3.88	0.585	4.00	3.88	4.00	5.00	0.204	3.00	4.14	4.04	4.05	3.89	2.00	0.078	3.00	4.11	4.08	3.63	2.00	0.012#
G1	4.08	0.000*	4.00	4.00	4.15	4.04	0.841	4.00	3.88	4.16	4.00	0.496	3.00	4.00	4.12	4.05	4.44	2.00	0.013#	3.00	4.11	4.14	4.13	2.00	0.046#
G2	3.37	0.000*	3.50	3.36	3.19	3.54	0.306	3.33	3.41	3.34	4.00	0.824	3.00	3.43	3.32	3.36	3.56	3.00	0.857	3.00	3.37	3.36	3.50	3.00	0.842
G3	4.05	0.000*	3.50	3.91	4.27	3.92	0.035#	3.67	4.00	4.09	4.00	0.537	3.00	3.86	4.12	4.00	4.44	2.00	0.007#	3.00	4.11	4.17	3.75	2.00	0.017#
G4	3.78	0.000*	3.00	3.55	3.88	3.85	0.045#	3.00	3.71	3.86	4.00	0.037#	3.00	3.43	3.68	4.00	4.00	3.00	0.038#	3.00	3.63	3.97	3.50	3.00	0.030#
G5	3.85	0.000*	3.50	3.55	3.88	3.96	0.059	3.67	3.59	3.95	4.00	0.210	3.00	3.71	3.84	3.91	4.11	2.00	0.030#	3.00	3.79	3.94	3.88	2.00	0.022#

Note: * The Shapiro-Wilk test was significant at the significance level of 0.05, suggesting that the data were not normally distributed.
The Kruskal-Wallis test result was significant at the significance level of 0.05, suggesting a significant difference among the households.

4.2. RESIDENTS' WILLINGNESS TO EXTEND THE GREEN RETROFIT PROGRAM INTO INDIVIDUAL HOUSES

The results of questionnaire showed that 4 percent of respondent were very willing to pay for the green retrofit in their individual houses, 52 percent were willing, 16 percent chose neutral, 25 percent were unwilling, and 3 percent were very unwilling to pay. This result indicated that, at least, the majority of the respondents had no objections to investing in the green retrofit in their individual households.

Despite the support from the majority, the Kruskal-Wallis test results in Table 3 showed that respondents' willingness differs significantly regarding their types of flats, monthly household income, and monthly household utility expenditure. Comparing to those living in big flats (i.e., 4-room, 5-room, and executive flats), those living in small flats (i.e., 1-room, 2-room, and 3-room flats) were less willing to pay for the green retrofit in their households. This was because residents living in small HDB flats were normally from the low-income group and thus they had no extra money to let their home undergo green retrofit. By contrast, the respondents with higher monthly household income were found more willing to undergo green retrofit as they were expecting to achieve a better living experience through the green retrofit in their homes. These results further echoed Swan et al. (2013) who had stated that the income levels would impact people's wills to engage with the sustainable retrofit agenda. Additionally, comparing to the respondents paying utility bills less than SGD 100 (USD 72), those paying SGD 100 or above were found more willing to undergo green retrofit. This was mainly because these respondents hoped to reduce their utility expenditures after the green retrofit.

4.2.1. RESIDENTS' WILLINGNESS TO PAY FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

The questionnaire also examined the upfront cost the respondents were willing to bear for the green retrofit in their individual houses. The results showed that 58 percent of respondents were willing to pay no more than SGD 5K to have their houses undergo green retrofit, 31 percent of the respondents were willing to pay SGD 5K to 10K, 11 percent were willing to pay SGD 10K to 15K, and no respondents were willing to pay more than SGD 15K. Meanwhile, the Kruskal-Wallis test results showed that the upfront cost was statistically uncorrelated with the respondents' flat types, the size of household and monthly household utility expenditure, except for the monthly household income. It showed that the respondents with higher income were likely to spend more on green retrofit compared to the lower income group, which was consistent with the earlier finding that the higher income group was more willing to pay for the green retrofit in their individual houses.

4.2.2. RESIDENTS' KEY CONSIDERATIONS FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

The questionnaire provided a list of seven considerations that may affect residents' involvement of green retrofit and requested the respondents to rate. Results in Table 3 showed that, the top four motivations for respondents to have their individual houses go green are: to achieve cost savings from lower utility bills in the long run (mean assessment = 4.48), the availability of financial assistance and green loans (4.60), saving the environment (3.98), and higher resale value (3.89). It is noteworthy that, among the top four motivations, three were associated with economic benefits the residents might gain, which suggested that economic considerations were still the top priority for most households to take into account when the decision of going green is assessed. Such findings echoed Darko and Chan (2016) who claimed that achieving economic benefits was one of the important goals for the authority, industry, and public to boost green buildings. By contrast, the bottom three motivations were the pride of owning a green home (mean assessment = 2.92), better aesthetic for home (3.24) and enhanced attractiveness for rental (3.41). Pride of owning a green home gained the lowest assessment, suggesting that residents were more interested in the substantial benefits brought by the green retrofit program. Better aesthetic for home received the second lowest assessment. This might be because green appliances bear a very similar resemblance to traditional household electronic appliances, and thus respondents may feel little or no change to the aesthetic of their homes. Enhanced attractiveness for rental is also not a significant motivation, referring to its third lowest assessment. This was because normally residents would not retrofit their houses just for the sake of increasing its rental attractiveness; instead, getting a better living experience and achieving some economic gains are the major impetus for residents to carry out the retrofit.

4.2.3. THE MOST PREFERRED GREEN FEATURES FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

This study gathered five green features that were most commonly used in current green retrofit programs and requested the respondents to rate for their preferences. The Kruskal-Wallis test results in Table 3 showed that the respondents' assessments varied significantly regarding monthly household income and monthly household utility expenditure. These results are reasonable as the residents' preferences for the green features are highly associated with their financial situations (Swan et al., 2013). According to Table 3, the most popular feature was energy monitoring system with an assessment of 4.08, followed by LED lighting (4.05), low-flow water fixture (3.85), a dimmer switch (3.78), and low e-film window (3.37). Energy monitoring system was preferred because it allows homeowners to monitor the flow of energy throughout the entire home in real-time (Abubakar et al., 2017). LED lighting was preferred because it consumes up to 90 percent less power than those incandescent bulbs (Pelka and Patel, 2003). The third most preferred green feature was low-flow water fixture such as sink faucets, toilets, and shower heads that use less water per minute than those traditional and older models. It was favoured as it was a relatively low-cost and quick way for the individual household to conserve water and save money (Beal et al., 2013). Dimmer switch was the fourth most preferred green feature welcomed by the Yuhua's residents. Using a dimmer switch can prolong the life of the lighting appliances effectively and thus saving expenditures for the residents (Leslie, 2003). A low e-film window can reduce solar heat gain and radiant heat loss, creating year-round heating and cooling savings of up to three times as much as conventional window film with the comparable light transmission (Ismail and Henríquez, 2005). Nevertheless, it received the lowest preference. This might be because the benefits of e-film window could not reflect in the form of number economically so the residents refused to give a higher preference.

5. RECOMMENDATIONS TO REINFORCE THE EXISTING GREEN RETROFIT PROGRAM

Based on the findings of the questionnaire, three practical recommendations were put forward to reinforce the existing green retrofit program, as presented below.

5.1. ESTABLISHING A GREEN RETROFIT GUIDE FOR INDIVIDUAL HOUSES

The results of the questionnaire showed that more than fifty percent of respondents were interested in having their individual houses undergo green retrofit. Thus, a Green Retrofit Guide for Individual Houses might need to be established, to help those interested families carry out their retrofit works more easily and effectively. This guide should concentrate on those key elements that have high potentials for increasing the energy efficiency. Also, it should be able to function as a handy tool for building owners, facility managers, and consultants, which can guide these parties for retrofitting step by step, from building evaluation, target-setting, to the selection of suitable retrofit works, just like the Existing Building Retrofit Guide introduced by BCA (2010). Most importantly, this guide should involve the residents proactively before the commencement of the green retrofit work, so that the intents and requirements from the homeowners can be clear specified and understood, which can help achieve the success of the green retrofit program.

5.2. DEVELOPING A GREEN RETROFIT INCENTIVE PLAN FOR INDIVIDUAL HOUSEHOLDS

This study revealed that residents' willingness to install green features in their individual houses were affected by their financial capabilities. The respondents from the low-income families are reluctant to adopt green retrofit, while those from the high-income families showed greater interests. This result suggests that a green retrofit incentive plan for individual houses should be developed, to let households of all income groups have the equal chance to enjoy green and sustainable homes. Under this plan, the government should offer some incentives to low-income households. Furthermore, this plan should also urge financial institutions like banks to provide low-interest loans to individual households to facilitate them in retrofitting their individual houses.

5.3. UPGRADING THE GREEN HOME PACKAGE

As mentioned earlier in the Background section, the HDB Greenprint@Yuhua introduced a Green Home Package that allowed residents to purchase discounted appliances to lower their utility bills. Currently, the Green Home Package merely covers a large number of electrical appliances such as refrigerators, air-conditioners, LED televisions, washing machines, bulbs, and fans. However, the results of the questionnaire showed that the residents were also interested in some nonelectrical green features like low-flow water fixtures and low e-film window. Thus, the existing Green Home Package might need to be upgraded to include some non-electric stuff, such as eco-friendly windows, paints, papers, as well as the low-flow water fixtures installed in the kitchen or toilet. Also, the upgraded Green Home Package may consider developing an online portal, which will function as a convenient purchase platform to provide prompt and direct shipment for individual households and to recommend them qualified contractors for the in-house installations.

6. CONCLUSIONS AND RECOMMENDATIONS

Green retrofit has been proven to be a high-volume and low-cost strategy that can effectively improve the energy efficiency in those existing traditional buildings. Nowadays, it has become one of the most significant development activities ongoing in the existing building and construction industry. However, current literature shows that few studies have investigated the residents' perceptions of green retrofit programs. Thus, this study administered a questionnaire with the residents of a mature public residential estate of Singapore that just completed a pilot green retrofit program, to capture their perceptions of the program. Results showed that, despite minor problems like noise, power supply and lift disruptions, the majority of respondents were satisfied with the green retrofit program. In particular, outdoor LED lighting was assessed as the most preferred green feature, followed by pneumatic waste conveyance systems, rainwater harvesting systems, solar photo voltaic systems, and elevator energy regeneration systems. The questionnaire also explored residents' willingness to expand the green retrofit program into their individual houses. Results showed that more than 50 percent of respondents were supportive of having their individual houses undergo green retrofit and were willing to bear an upfront cost up to SGD 5K. It also disclosed the top four motivations that drive respondents to have their houses go green, which were achieving cost savings from lower utility bills in the long run, the availability of financial assistance and green loans, saving the environment, and higher resale value. Furthermore, results revealed that energy monitoring system was the most preferred green feature that the respondents would like to install in their houses, followed by LED lighting, low-flow water fixture, dimmer switch, and low e-film window. Lastly, this study came up with three practical recommendations to enhance the current green retrofit program. These recommendations were establishing a green retrofit guide for individual houses, developing a green retrofit incentive plan for individual households, and upgrading the Green Home Package.

Although the objectives of this study were achieved, some limitations were still present. First, this study collected opinion based data from respondents, which might be biased due to respondents' different perception patterns. Second, the findings from this study applied to Singapore exclusively, which may vary in other countries. In spite of these limitations, the findings from this study are still valuable, because they are the first-hand information concerning the residents' perceptions and expectations for the green retrofit program. Based on this fresh information, the authorities and industry can improve upon the current green retrofit program effectively. For the future research actions, an assessment model that gauges the energy efficiency of the green retrofit program could be developed. Also, it would be very interesting to explore the interrelationships between the residents' personal behaviours and the energy efficiency performances of their houses.

7. REFERENCES

Abubakar, I., Khalid, S. N., Mustafa, M. W., Shareef, H. and Mustapha, M., 2017. Application of load monitoring in appliances' energy management – A review. *Renewable and Sustainable Energy Reviews, 67,* 235-245.

Agarwal, S., Satyanarain, R., Sing, T. F. and Vollmer, D., 2016. Effects of construction activities on residential electricity consumption: Evidence from Singapore's public housing estates. *Energy Economics, 55*, 101-111.

Akintoye, A., 2000. Analysis of factors influencing project cost estimating practice. *Construction Management and Economics, 18(1),* 77-89.

Balaras, C. A., Gaglia, A. G., Georgopoulou, E., Mirasgedis, S., Sarafidis, Y. and Lalas, D. P., 2007. European residential buildings and empirical assessment of the Hellenic building stock, energy consumption, emissions and potential energy savings. *Building and Environment, 42(3)*, 1298-1314.

BCA, S., 2010. *Existing Building Retrofit.* Singapore: Building and Construction Authority.

BCA, S., 2011. *BCA Green Mark for Existing Residential Buildings*. Singapore: Building and Construction Authority.

BCA, S., 2014. *3rd Green Building Masterplan*. Singapore: Building and Construction Authority.

Beal, C. D., Stewart, R. A. and Fielding, K., 2013. A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption. *Journal of Cleaner Production, 60,* 116-128.

Berardi, U., 2016. The outdoor microclimate benefits and energy saving resulting from green roofs retrofits. *Energy and Buildings, 121,* 217-229.

Booth, A. T. and Choudhary, R., 2013. Decision making under uncertainty in the retrofit analysis of the UK housing stock: Implications for the Green Deal. *Energy and Buildings, 64*, 292-308.

Bu, S., Shen, G., Anumba, C. J., Wong, A. K. D. and Liang, X., 2015. Literature review of green retrofit design for commercial buildings with BIM implication. *Smart and Sustainable Built Environment, 4(2)***,** 188-214.

Castiglia Feitosa, R. and Wilkinson, S. J., 2018. Attenuating heat stress through green roof and green wall retrofit. *Building and Environment, 140,* 11-22.

Darko, A. and Chan, A. P. C., 2016. Critical analysis of green building research trend in construction journals. *Habitat International, 57,* 53-63.

Department of Statistics, S., 2016. Key Household Income Trends, 2015. *In:* Statistics, D. O. (ed.). Singapore.

Fan, Y. and Xia, X., 2018. Energy-efficiency building retrofit planning for green building compliance. *Building and Environment, 136,* 312-321.

Gel, Y. R., Miao, W. and Gastwirth, J. L., 2007. Robust directed tests of normality against heavy-tailed alternatives. *Computational Statistics and Data Analysis, 51(5),* 2734-2746.

HDB, S., 2016a. *HDB Greenprint* [Online]. Available from: http://www.hdb.gov.sg/cs/infoweb/about-us/our-role/smart-and-sustainable-living/hdb-greenprint [Accessed August 27 2016].

HDB, S., 2016b. Key Statistics: HDB Annual Report 2015/2016. *In* Housing and Development Board, S. (ed.). Singapore.

Hwang, B. G., Zhao, X., See, Y. L. and Zhong, Y., 2015. Addressing Risks in Green Retrofit Projects: The Case of Singapore. *Project Management Journal, 46(4),* 76-89.

Ismail, K. a. R. and Henríquez, J. R., 2005. Two-dimensional model for the double glass naturally ventilated window. *International Journal of Heat and Mass Transfer, 48(3-4),* 461-475.

Jin, X., Meng, C., Wang, Q., Wei, J. and Zhang, L., 2014. A study of the green retrofit industry chain. *Sustainable Cities and Society, 13,* 143-147.

Kim, T. K., 2015. T test as a parametric statistic. *Korean Journal of Anesthesiology, 68(6),* 540-546.

Leslie, R., 2003. Capturing the daylight dividend in buildings: why and how? *Building and Environment, 38(2),* 381-385.

Liang, X., Peng, Y. and Shen, G. Q., 2016. A game theory based analysis of decision making for green retrofit under different occupancy types. *Journal of Cleaner Production, 137,* 1300-1312.

Liang, X., Shen, G. Q. and Guo, L., 2015. Improving Management of Green Retrofits from a Stakeholder Perspective: A Case Study in China. *International journal of environmental research and public health, 12(11),* 13823-13842.

Low, S. P., Deng, X. and Laura, L., 2012. Communications management for upgrading public housing projects in Singapore. *Structural Survey, 30(1),* 6-23.

OECD, 2002. *Glossary of Statistical Terms - Residential Building* [Online]. Available from: https://stats.oecd.org/glossary/detail.asp?ID=2326 [Accessed November 13 2016].

Pelka, D. G. and Patel, K., 2003. An overview of LED applications for general illumination. 15-26.

Phang, S. Y., 2015. Singapore's housing policies: Responding to the challenges of economic transitions. *Singapore Economic Review, 60(3),* 1550036.

Santamouris, M., Kapsis, K., Korres, D., Livada, I., Pavlou, C. and Assimakopoulos, M., 2007. On the relation between the energy and social characteristics of the residential sector. *Energy and Buildings, 39(8),* 893-905.

Shan, M., Hwang, B.-G. and Wong, K. S. N., 2017. A preliminary investigation of underground residential buildings: Advantages, disadvantages, and critical risks. *Tunnelling and Underground Space Technology, 70(Supplement C),* 19-29.

Shen, L., He, B., Jiao, L., Song, X. and Zhang, X., 2016. Research on the development of main policy instruments for improving building energy-efficiency. *Journal of Cleaner Production, 112(2),* 1789-1803.

Swan, W., Ruddock, L. and Smith, L., 2013. Low carbon retrofit: Attitudes and readiness within the social housing sector. *Engineering, Construction and Architectural Management, 20(5),* 522-535.

Wilkinson, S. J., Lamond, J., Proverbs, D., Sharman, L., Heller, A. and Manion, J., 2015. Technical considerations in green roof retrofit for stormwater attenuation in the central business district. *Structural Survey, 33(1),* 36-51.

Wilkinson, S. J. and Reed, R., 2009. Green roof retrofit potential in the central business district. *Property Management, 27(5)*, 284-301.

Zuo, J. and Zhao, Z.-Y., 2014. Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30,* 271-281.