

Sustainable residential building retrofit for improving energy efficiency: The owners' perspective in Malaysia

Emad Kasra Kermanshahi¹, Mahmood Bin Md Tahir¹, Nor Hasanah Abdul Shukor Lim¹, Ali Tighnavard Balasbaneh² and Shervin Roshanghalb²

¹Department of Structure and Materials, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310, Johor, Malaysia

²Faculty of Civil Engineering, Tabari University Babol, Mazandaran, Iran

Email: emadkasra@gmail.com

Abstract. Malaysia has made continuous efforts to tackle energy sustainability challenges in recent years. There are significant opportunities to cut energy consumption and greenhouse gas emission (GHG) through retrofitting of existing domestic stocks. Due to the extremely fragmented nature of retrofit practice in the construction industry, there are some challenges among project stakeholders, including home occupants and builders in retrofitting residential buildings. There is a lack of research regarding the client's requirements for housing retrofit priorities and preferences for retrofitting measures and materials. Therefore, the aim of this research is exploring the owner's point of view for housing retrofit and their decision-making factors for choosing retrofit measures. In this study, by using sampling techniques, 400 people staying in Kuala Lumpur and Johor Bahru were selected for the housing retrofit preference survey. Statistical Package for the Social Sciences software (SPSS Version 22) was used as a statistical software to analyze survey data. It was revealed from the questionnaire survey that window/door is the top priority for clients to improve energy efficiency. Furthermore, the most critical factors in improving energy efficiency are initial cost and thermal performance, respectively. Moreover, in decision-making factors for selecting construction materials, owners emphasized on initial cost and payback time as important factors. Therefore, all experts in the construction industry should take into account the interests of customers with technical matters at the same time. In conclusion, this research empowers professionals to know homeowner needs and preferences from the beginning of retrofit projects.

1. Introduction

The construction industry is one of the biggest industries in the world today [1]. In the construction industry, it is a significant concern for construction customers to maximize value, lower cost, and achieve sustainability [2]. Sustainable development has been the main topic of debate for years in some countries such as the United Kingdom, the United States of America, and Malaysia [3]. One of Malaysia's government goals is to reduce carbon intensiveness to 4% by 2020 compared with 2005 degrees and decrease energy usage to 40% by 2050. Other aims are to reach out to 22% household recycling rate and reduction of non-revenue water to 25% by 2020 [4]. In Malaysia, people's knowledge and concern are increased about the effects of building on the environment, labor efficiency, and public health. Thus, the public and private sectors start to request buildings with



optimal energy consumption, enhancing resource efficacy, and better internal environment quality. The advantages of sustainable building are more valued and concerned by house owners, organizers, promoters, insurers, and other people. Despite these supply and demand, the improvement in a sustainable building is comparatively decelerated [5].

Furthermore, the majority of the construction players in Malaysia are focusing on new developments, neglecting the existence of existing buildings in Malaysia. However, the main problem in this area takes place at existing buildings. The building in Malaysia is 4,928,883 thousand, with an annual growth rate of about 2.2%, and the demolition rate is less than 1% [6]. In the meantime, it must be said that most of the residential buildings (80%) will exist by 2050, and most of them (95%) are not designed or constructed based on sustainability standards [7, 8]. Apart from increasing the enormous number of retrofit projects in Malaysia recently, there are a few updating projects in existing homes with sustainable criteria. There is a huge unexploited potential for energy saving in most house stokes.

Sustainable retrofit could be beneficial in different aspects including environment [e.g., energy efficacy, reduction of emission, waste and water usage]; economical with regard to costs [e.g., increase building value, enhance rental gains, functional cost, expanded life span of building] and social in regard to building occupants [enhanced productiveness, greater health and wellness]. Compared to the demolition of existing buildings and rebuilding, building green retrofit, to some extent, is more beneficial [9].

Malaysian government and communities both brought to light and concerned about smart and sustainable plans in housing. Unfortunately, current regulation to residential is more concentrated on physical housing development, and cultural and social activities have not taken into consideration [5]. Therefore, it is required to encourage a broader idea and thought about sustainability in housing with the aim of improvement in environmental performance and making better the lives of society by the effect of sustainability plans.

Many authors define and discuss different barriers and challenges of residential building retrofit in various ways but tend to agree on there being several main barriers facing homeowners. A significant barrier to apply whole house retrofit is recognized as imperfect homeowners' knowledge regarding retrofit measures and have difficulty to comprehend the retrofit solutions suggested by professionals [10, 11]. Therefore, this imperfection or defect causes problems for customers because they judge incorrectly, and they are not able to distinguish which kind of retrofit measures is the best in both financial and environmental aspects between all suggested and available choices.

Sustainable retrofit must furnish the satisfaction and fulfillment of homeowners' needs. Nevertheless, in actual fact, occupants are not satisfied with the results of sustainable retrofit because their expectations and preferences are not fully realized by experts [12]. Briefly, it is cleared that there is a vicious circle demonstrated between clients and construction experts in the housing setting. Presently, retrofit outcomes are suggested and recommended to occupants based on construction experts' preferences despite the fact that they have to more concentrate on customer's requirements. It is vital for construction experts to know the house owners' preferences and their decision taking elements for housing retrofit to provide a reasonable and satisfactory solution for them [13]. According to Lomas (2010), to choose the correct retrofit measures for the retrofit solution, it is essential for construction experts to investigate and combine both technical and socio-technical (inhabitants' intent and taste) factors [14].

Based on literature reviews, most of the studies focused on house owners' behavior [7, 15-19]. There is no study on house owners' desires and decision making to choose retrofit measures for housing retrofit, but several studies investigated the relationships between householder' psychological components and retrofit measures. The current study will purposely collect the householders' point of view about their house retrofitting decision factors.

2. Research methodology

This study aims to determine house-owners' priorities for retrofitting the residential building. The questionnaire survey was conducted to disclose the housing retrofit priorities for homeowners. The questionnaire included twelve questions arranged to investigate the importance of decision-making priorities factors among house-owners and professionals. These key factors comprise a) energy efficiency Preferences among construction components; b) Importance of home retrofit measures, and; c) Importance of decision-making factors for selecting construction materials. The questionnaires' structure includes multiple choices and rating questions. The respondents were asked to rank the questions in the Likert Scale from a range of 0 for "not considered" to 5 for "very important". This study used a 5-point Likert Scale in order to better communication and measure the answers. Statistical Package for the Social Sciences software (SPSS Version 22) is used as a statistical software to analyze survey data.

2.1. Statistical population

A group of people, units, or objects with common features is known as the statistical population concerned by researchers [20]. The statistical population of this research consists of homeowners staying in Kuala Lumpur and Johor Bahru, Malaysia. According to the report of statistics organization of Malaysia, populations of the Kula Lumpur and Johor Bahru in 2018 were approximately equal 1.79 and 3.76 million people, respectively [21]. A small part of the population is selected because it is impossible to access every participant. This selection is because of two main reasons (1) the study resources availability (financially, time, human resources); and (2) convenience access to residential areas. The population of the present research was huge, and around 5.5 million people. As a result, the researcher applied Cochran formula [22] for calculation of the sample size and a multistage sampling approach for selection of the sample units, as shown in equation 1:

$$n = \frac{t^2 pq}{d^2} \quad (1)$$

where n=sample size, t=the value for selected α of 0.05=1.96, p= proportion of the population =0.5 and d= degree of confidence=0.05 Consequently,

$$n = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} \approx 384 \quad (2)$$

Ultimately, the researcher has to consider at least 384 homeowners in Kula Lumpur and Johor Bahru, according to Cochran's formula. However, for this study, the sample size must be chosen 384, in order to reduce the error of non-responding questionnaires, a total of 400 homeowners were chosen. After collecting the data, 11 questionnaires were excluded from the analysis due to the high level of non-responding, and therefore, finally, 389 questionnaires were selected as a final sample.

Sampling is the procedure of selecting a subset of individuals (a group of people, events, behaviors, or elements) that are representative of the whole population being studied [23]. The sampling is a crucial factor in identifying the sample, which is an accurate representation of the homeowners. This study was carried out in Johor Bahru as an industrial city, and Kuala Lumpur as the capital city of Malaysia. Usually, the initial selection of the research area and the population is purposive [20]. In the next stage, the residential area was chosen based on multi-stage cluster sampling based on the residential zone and blocks. In the end, the researcher employed a random sampling method to select the homeowners' places. Following the data collections, editing of the data was conducted to ensure the error, comprehensiveness, and uniformity of the data. Editing is considered as a part of the data processing and analysis stage. Following the recommendation of Sekaran, this research includes all respondents in the analysis who completed at least 75 percent of questionnaire answers; while those

with an unanswered question, more than 25 percent are excluded. Any missing data has been considered as missing values [20].

3. Result and discussion

3.1. Housing retrofit preferences survey

3.1.1. *Respondents' profile.* In this study, by using sampling techniques, 400 resident people in Kuala Lumpur and Johor Bahru were selected for the housing retrofit preference survey with a 97% response rate. The statistical findings are shown that most of the respondents were within 30s years, the average age group. Regarding the house type, most of the respondents (34.2%) were living in a flat/apartment, and also the majority of them had a house with age within 16-20 years (44.2%). Therefore, as a result, homeowners living in old residential buildings are more interest in retrofitting their houses than comparatively the owners are living in the new and more energy-efficient homes.

3.1.2. *Reliability analysis.* [24] defines reliability as "the degree to which measures are free from random error and therefore yield consistent results". Thus, the primary purpose of reliability is to reduce the in research errors, and biases Cronbach's coefficient alpha is taken into consideration as one of the most general approaches to measuring reliability [25]. Hence, this research implemented this method of internal consistency to evaluate the reliability of the measures. In this research, the internal consistency technique has been approved to evaluate the reliability of the measures. The authors propose different levels of acceptance for evaluating Cronbach's alpha reliability. However, Nunnally, in his book, Psychometric Theory increased the acceptance level and considered that Cronbach's alpha must exceed higher than 0.70 for greater internal consistency [26]. Therefore, this study used this cut-off point (0.70) as the minimum for defining the internal consistency of scales.

Table 1. Reliability of the research variables among homeowners.

Items	Number of items	Cronbach's alpha
Reasons for retrofit	7	0.73
Reasons for non-retrofit	6	0.76
Homeowners priorities	12	0.87
Decision-making Factors for Measures	6	0.81
Decision-making Factors for Materials	9	0.83

This research determined Cronbach's alpha to ensure that the specified items are sufficient in their representation of the underlying constructs. The results related to these assessments are reported in Table 1. As can be seen from Table 1, all the research variables show Cronbach's alpha values greater than 0.70, which indicates a high level of internal consistency among the questionnaire items.

3.1.3. *Reasons for retrofit.* Respondents were asked to determine the reasons if they plan to retrofit the home. Among all the participants (n=250, 64%) responded that they are going to do a retrofit, but (n=139, 36%) of them commented they have no plan to retrofit their home.

The results for the respondents who plan to retrofit their homes are presented in Figure 1. The reasons for retrofitting the home were asked in the Likert Scale from 0 for "not considered" to 5 for "very important". As can be observed from Figure 1, respondents commented that aesthetics, payback cost period (ROI), and energy-efficient are the most important reasons for retrofitting their home with mean values equal to 3.96, 3.86, and 3.82, respectively. Moreover, the results reveal that the following two significant reasons are related to thermal comfort and indoor air quality with mean values equal to 3.75 and 3.51, respectively. Finally, Figure 1 reports that the least important reasons for retrofit are increasing market value and carbon reduction with mean values equal to 3.33 and 3.06, respectively.

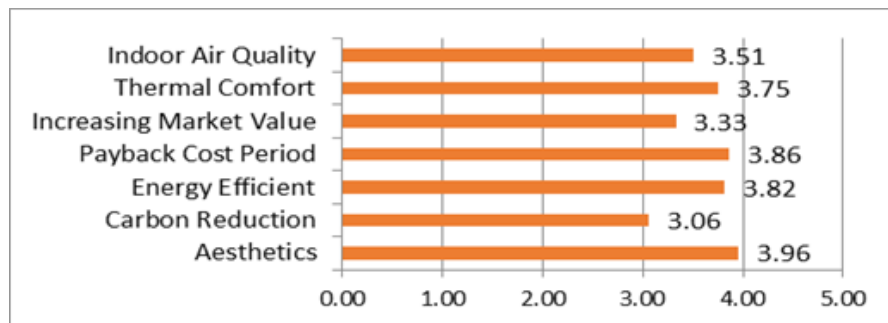


Figure 1. Mean chart of reasons to retrofit the home (X-axis: Likert Scale).

3.1.4. *Reasons for no retrofit.* Figure 2 provides the statistical findings for the reasons of respondents who do not have any plan to retrofit the home in the Likert Scale type. As revealed in Figure 2, respondents said that not required to retrofit, high initial cost, and interruption caused by retrofit are the most important reasons for no interesting in retrofit with mean values equal to 4.09, 4.01 and 3.97, respectively.

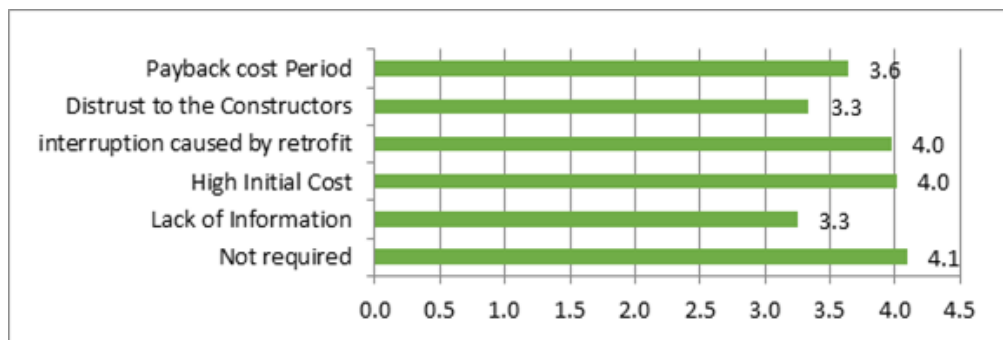


Figure 2. Mean chart of reasons for no plan to retrofit the home (X-axis: Likert Scale).

Moreover, the results reveal that the next important reason is associated with the payback cost period with a mean value equal to 3.63. Finally, Figure 2 demonstrates that the least important reasons for retrofit are distrust of the constructors and lack of knowledge and information regarding retrofit alternatives with mean values equal to 3.34 and 3.25, respectively.

3.1.5. *Retrofit preferences among construction components.* Homeowners were asked in terms of their priorities if they want to improve energy efficiency at home in the Likert Scale type. As can be observed from Figure 3, homeowners said that window/door, interior, and exterior wall insulation are the most important items for improvement of energy efficiency with mean values equal to 4.13, 3.94, and 3.92, respectively. Moreover, the findings show that the next three important elements are associated with painting outside the house, roof, and floor with mean values equal to 3.90, 3.84, and 3.81, respectively. Moreover, Figure 3 indicates that the least important items for energy efficiency improvement are moveable furniture, electrical equipment, and electrical wiring with mean values equal to 3.49, 3.43, and 3.28, respectively. Owners believed that windows and doors are the largest cool loss element in their houses. Homeowners desire to change windows/doors because it is affordable compared to other components. They also mentioned that the installation of windows is quick and easy, so it has less disruption for them while retrofitting their homes.

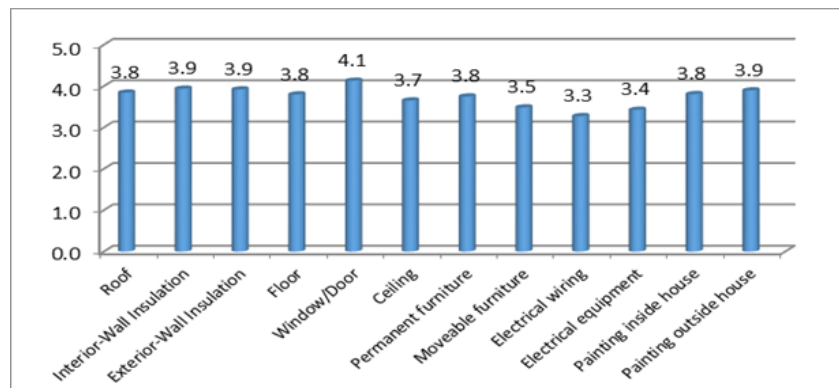


Figure 3. Homeowners' priorities for retrofitting among construction components (Y-axis: Likert Scale).

3.1.6. *Importance of house retrofit measures.* In this section, a comparison analysis was carried out to examine any differences among homeowners' priorities in terms of factors that they consider in energy efficiency improvement in the Likert scale type. The decision-making factors have been adopted from previous studies [16, 27].

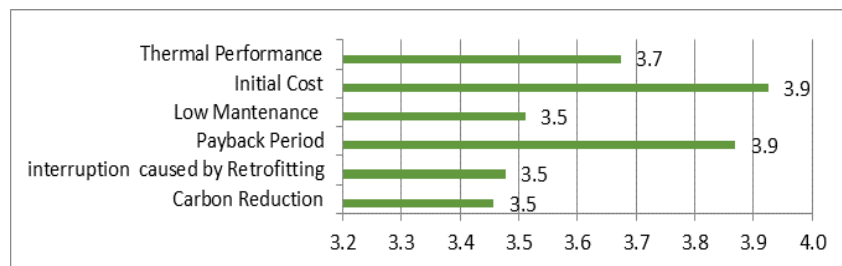


Figure 4. Decision making factors for retrofit measure for energy efficiency improvement (X-axis: Likert Scale).

As shown in Figure 4, homeowners commented that initial cost, payback period (energy cost-saving), and thermal performance are the most important factors in the improvement of energy efficiency with mean values equal to 3.93, 3.87, and 3.67, respectively. Further, the finding reveals that the least important factors considering energy efficiency improvement are low maintenance (durability), interruption caused by retrofit, and carbon reduction with mean values equal to 3.51, 3.48, and 3.46, respectively.

3.1.7. *Importance of decision-making factors for selecting construction materials.* In this section, a comparison analysis was carried out to examine homeowners' importance of decision-making factors for selecting construction materials in the Likert Scale type. The decision-making factors have been adopted from previous studies [16, 27]. The results are provided in Figure 5. Homeowners responded that aesthetic, initial cost, low maintenance (durability), thermal performance, health and safety (non-toxic materials) and life-cycle cost are the most important factors in decision making for selecting construction materials with mean values equal to 3.95, 3.87, 3.86, 3.86, 3.76 and 3.65, respectively. Furthermore, the finding demonstrates that the least important factors in decision making for selecting construction materials by homeowners are, manufactures reputation, certified/green, material, and recycle materials (CO₂ reduction) with mean values equal to 3.60, 3.33 and 3.30, respectively.

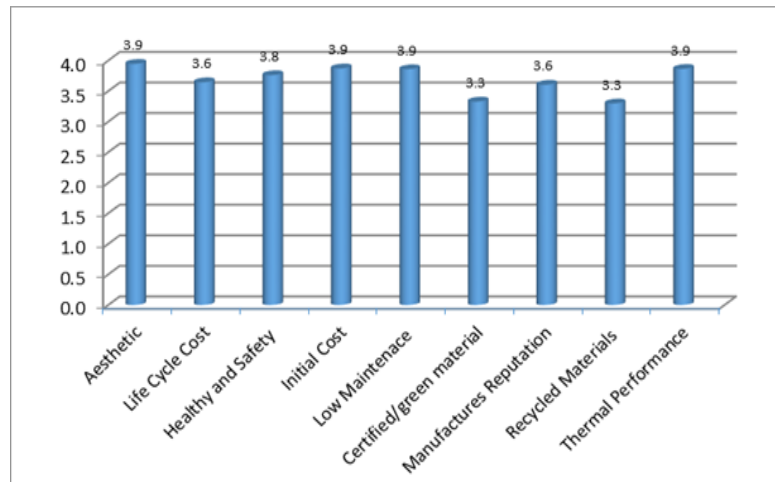


Figure 5. Decision-making factors for retrofit materials for energy efficiency improvement (Y-axis: Likert Scale).

4. Conclusion

This study aims to investigate the importance of decision-making priorities factors among homeowners. These key factors include a) energy efficiency Preferences among construction components; b) Importance of home retrofit measures, and; c) Importance of decision-making factors for selecting construction materials. From the questionnaire survey, it was shown that the top priority of homeowners in energy efficiency improvement is window/door. Moreover, according to the findings, the initial cost is the most important factor for decision-making among the homeowners. Furthermore, in decision-making factors for selecting construction materials, homeowners also emphasized on initial cost and aesthetic as the most important factor. In contrast, homeowners believed that Carbon emissions reduction has the lowest priority for selecting the material. This research empowers professionals to know owner needs and preferences from the beginning of retrofit projects. As results reveal, the initial cost and payback time is significant for clients. Consequently, all experts in the construction industry should take into account the interests of customers with technical matters at the same time.

Acknowledgments

The authors are grateful to the Ministry of Higher Education, Malaysia (MOHE) and Research Management Centre (RMC), Universiti Teknologi Malaysia (UTM) for financial support under grant Q. J130000.2451.04G66 and Q. J130000.2451.04G58

References

- [1] Ofori G 2015 *Constr J. Dev. Ctries* **20** 115
- [2] Tighnavard Balasbaneh A Marsono A. K and Kasra Kermanshahi E 2018 *J. Constr. Inn.* **18** 274-300
- [3] Khairi M Jaapar A Yahya Z 2017 *IOP Conf. on Materials Science and Engineering* **271** 012030
- [4] Unit E P 2012 *Tenth Malaysia Plan 2011-2015* (Putrajaya: Malaysia)
- [5] Shafii F and Othman M.Z 2007 *Conf. on Sustainable Building South-East Asia SB07* (Kuala Lumpur: Malaysia) 5-7
- [6] Centre N P I 2018 *Residential Property Stock Report* (Malaysia)
- [7] Olanrewaju A Tan S Y Tat L L and Mine N 2017 *Procedia Engineering* **180** 1622-1632
- [8] Olanrewaju A L and Abdul-Aziz A R 2014 *Building maintenance processes and practices: The*

case of a fast developing country (Springer)

- [9] Tan Y, Liu G, Zhang Y, Shuai C and Shen G.Q 2018 *J. Build. Environ.* **143** 89-98
- [10] Owens S and Driffill L 2008 *Energy Policy* **36** 4412-4418
- [11] Juan Y K Perng Y H Castro-Lacouture D and K.S. Lu 2009 *Automat. Constr.* **18** 139-144
- [12] Burton S 2012 *Handbook of sustainable refurbishment: housing* 1st ed (Routledge) p 180
- [13] Banfill P Simpson S Haines V and Mallaband B 2012 *J. Struct. Surv.* **30** 267-279
- [14] Lomas K J 2010 *J. Build. Res. Inf.* **38** 1-11
- [15] Zhou K and Yang S 2016 *Renew. Sus. Energ. Rev.* **56** 810-819
- [16] Nair G Gustavsson L and Mahapatra K 2010 *J. Appl. Energy.* **87** 2411-2419
- [17] Lancaster R Moezzi M Widder S H Chandra S Baechler M C 2012 *Post-Retrofit Residential Assessment report* (U.S: Department of Energy)
- [18] Judson E P and Maller C 2014 *J. Build. Res. Inf.* **42** 501-511
- [19] Achtnicht M and Madlener R 2014 *J. Energy Policy* **68** 254-263
- [20] Sekaran U and Bougie R 2016 *Research methods for business: A skill building approach* 448
- [21] Department of Statistics Malaysia 2018 *Population distribution and basic demographic characteristics report* (Malaysia: Department of Statistics Malaysia)
- [22] Cochran W.G 2007 *Sampling techniques* (New Jersey: John Wiley & Sons)
- [23] Groves R M Fowler F J Couper M P Lepkowski J M Singer E and Tourangeau R 2011 *Survey Methodology* (New Jersey: John Wiley & Sons)
- [24] Zikmund W G Babin B J Carr J C and Griffin M 2013 *Business research methods* (Electronic Materials) 9th ed (Mason, OH: South-Western)
- [25] Cronbach L J 1951 *Psychometrika* **16** 297-334
- [26] Nunnally J C 1975 *Educ. Res* **4** 7-21
- [27] Jafari A and Valentin V 2018 *Build. Environ* **130** 94-103

Reproduced with permission of copyright owner. Further reproduction prohibited without permission.