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POLICY AND PRACTICE

Post occupancy evaluation of green residential buildings, in the Greater Kuala Lumpur, Malaysia

AbdulLateef A. Olanrewaju[1] · Yen Sim Chong[1]

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Abstract
Homebuyers are now demanding green buildings over conventional buildings due to better performance, higher operating savings, and the premium satisfaction that the green buildings offer. However, whilst the supply of green buildings is increasing, the satisfaction of the occupants requires evaluation. This research investigated the satisfaction of the occupants of certified residential green buildings in the Greater Kuala Lumpur. The research was based on a cross-sectional survey questionnaire comprising 15 performance factors and 118 green building occupants. The survey forms were administered through hand delivery. The satisfaction of the occupants with respect to the ability of the buildings to accommodate the elderly and the disabled was very high. The occupants were also satisfied with the acoustics, overall lighting, layout, and overall air quality of the buildings. The factor analysis structured the performance factors into four clusters, namely, lighting, indoor environmental quality, operating cost, and spatial. The findings will be useful for the design teams because developers and city planners and the green rating certifiers and facilitators make their decisions on the prioritisation of the performance criteria of the green buildings. Whilst the data were collected in Malaysia, the information is applicable to beyond Malaysia.

Keywords Occupant satisfaction · Green building index · Green certification · Design team · Operational savings · Sustainability

1 Introduction

The global market for green construction is estimated to reach US$425.4 Billion by 2027, growing at a CAGR of 8.6% (Research and Markets, 2020). This is an increase of 84.75% from 2020 to 2027. The demand for sustainable buildings will continues to grow exponentially. The impacts of buildings on sustainability goals are huge. For instance, building construction and operation consume energy, water, and raw materials and generate wastes and discharge potentially harmful atmospheric matter into the environment (Hwang & Kim,

✉ AbdulLateef A. Olanrewaju
olanrewjau20002000@gmail.com

[1] Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia

2011; Olanrewaju et al., 2018; Feige et al., 2013; Fowler et al., 2010; Gill et al., 2011; Geng et al., 2019 and Zalejska-Jonsson, 2012). Green buildings were introduced to lessen the negative impacts of buildings on the users, occupants, communities, and the environment. A green building is a building that complies with environmental ethics in planning, design, construction, and operation. Green building techniques allow buildings to use fewer resources (e.g., energy, materials, water, labour, gas), improve building indoor environmental quality and ventilation, reduce whole life costs, and increase users' satisfaction and productivity. Since the green building initiative started, there has been a significant increase in the number of certified green buildings. Green buildigs are buildings that use non-toxic materials and natural materials, generate less waste, and are energy and water efficient, and to a large extent use recycled materials; as well, they can be recycled when necessary (Spiegel & Meadows, 2010). A building is green because certain practices, strategies, and techniques are incorporated in the design, construction, and operations of the building so that the building has better performance for the users, contractors, developers, environment, and community. Therefore, a study on green buildings is an area research where a great reduction in energy costs, waste generation, material costs, pollution, maintenance costs, and water costs could be achieved, and it would enhance the integration, safety, security, and well-being of the households. The expectations of the occupants of green buildings are different from that of conventional buildings. In fact, according to Metz and Cheatham (2008), buyers/occupants of green buildings have higher expectations as compared to occupants of conventional buildings. Greeen buildings can reduce indoor air quality contaminants, and liability claims, as well as ensure compliance with regulatory requirements and respond to consumers' demands (Spiegel & Meadows, 2010). In addition, they increase users' confidence and satisfaction because most green materials are free from formaldehyde and contain low or no volatile organic compounds.

In Malaysia, a great deal of research on the satisfaction levels of green building occupants has been conducted (Abd Jalil et al., 2016a; Azizi et al., 2018; Esfandiari et al., 2017; Kamaruzzaman et al., 2011; Lim et al., 2017; Rao, 2012). Surprisingly, only a few of the previous studies have concentrated on residential buildings. However, even the research that involves the satisfaction level of the green building occupants focused primarily on the energy efficiency of the buildings (Ng & Akasah, 2013, Qahtan and Keumala, 2010, Abd Jalil et al., 2016a, b) excluding critical variables like usability, design layout, visual comforts, maintenance, and water efficiency. Close to 40% of new buildings in Malaysia are adopting green building initiatives (The Sundaily, 2018 and Clean Malaysia, 2018). Half of the 24.6 million sqft in building certified by GBI are residential buildings (GBI, 2020a). Although, there many rating tools in malaysia, GBI has certified must of the buildings. There are 560 green certified buildings by GBI, about 37.3% of which are residential new buildings. However, there is a lack of information on the satisfaction level of the occupants of the green residential buildings. In order to motivate homebuyers and to provide feedback and feed forward information to the design and construction teams, information on the performance of the existing green buildings is required. This research aims to fill this gap. In order to 'market' and encourage homebuyers/users to invest in the green buildings, it is critical to measure the satisfaction level of the occupants (compare predicted service with the actual service). Therefore, to contribute to knowledge in this space, this article reports a study that was conducted to assess the Post Occupancy Evaluation (POE) on certified green buildings to measure the satisfaction of the occupants of the buildings. The satisfaction index of each of the factors were conducted. However, just scoring the performance factors is not sufficient because the performance factors do not act individually but rather, they interact with other factors leading to multiple complex linkages. Analyses of the interaction among the performance factors is clustering problem because the data are not labelled. Clustering problem is a situation where machine is trained on unlabeled data without prior guidance. Some poplar algorithms for unsupervised learning include K-mean, C- mean and factor analysis (Jolliffe & Cadima, 2016). Factor analysis is used here because it consistent with the aim of this research.

2 Literature review and conceptual justification

Sustainable development or sustainability has many interpretations. It is often defined as "the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). The built environment industry has been cited as one of the major industries that have tremendous impacts on the sustainable development goals. To illustrate, it was estimated that buildings consumed more than 40% of the world's energy, use 25% of the harvested wood, release 50% of fluorocarbons, produce 40% landfill materials, use 45% of energy in operations, discharge 40% of the Green House Emissions, and use 15% of global fresh water (Wood, 2009, 2014 and Killip, 2006). The building sector uses 50% of the mined, harvested, and dredged raw materials annually in the US (Spiegel & Meadows, 2010). Additionally, when other $C0_2$ emissions attributable to buildings are considered- such as the emissions from the manufacturing and transportation of building construction and demolition materials and transportation associated with urban sprawl, are accounted for, the impacts of the buildings of sustainable development goals are tremendous. For example, the embodied energy in a single building's envelope is around 8–10 times the annual energy used to heat and cool the building (Spiegel & Meadows, 2010). Residential buildings account for a significant profile of the statistics presented above. For instance, globally, 67% of the energy consumed by buildings is accountable to residential buildings (Pérez-Lombard et al., 2008) and this energy is mainly used for space heating, space cooling, water heating, cooking, lighting, and refrigeration (Levine et al., 2007). Also, the energy use and CO_2 emission in the building during the operation and maintenance phases are larger than the energy consumed during the construction phase (Olanrewaju & Abdul-Aziz, 2015). Quoting the EPA's data, Spiegel and Meadows (2010) found that every square foot of a residential building generates 4 lb of waste during construction.

Therefore, if the residential building is designed, constructed, and operated to reduce energy and water consumption and curtail carbon emission, this will save a million metric tonnes of $CO_{2.}$ Studies revealed that green buildings provide more satisfaction to occupants as compared to conventional buildings (Aminuddin et al., 2012; Deuble & de Dear, 2012; Hwang & Kim, 2011; Li, Ng et al., 2018; Meyer, 2019; Symonds et al., 2019; Yeheyis et al., 2013; Zuo & Zhao, 2014). The benefits that green buildings provide include electricity and water efficiency, less waste generation, better lighting, acoustic control, thermal comfort, increased productivity, better indoor environmental quality, and the general well-being of the users. Research on green building has been discussed in various countries in the extant literature (Geng et al., 2019; Gou et al., 2012; Lim et al., 2017; Tharim et al., 2017; Wood et al., 2016; Zhang & Altan, 2011). Most of the studies focused on the occupants' satisfaction of commercial and office buildings, however. Research that examined the transaction of a residential buildings in the USA revealed that there was a significant premium associated with green residential buildings (Aroul & Hansz, 2012). Zalejska-Jonsson (2012) and Zalejska-Jonsson et al. (2012) investigated the performance of green residential buildings in Poland. However, the research was based on a comparison between conventional and low–energy buildings. These studies found that in general, low-energy buildings display high performance when compared with conventional buildings based on the criteria that were evaluated. Gill et al. (2012) examined the performance of energy and water in a low-energy affordable building in the UK; based on which, it was also established that the green building had better performance. Hong (2014) assessed the satisfaction of green homeowners in Malaysia with respect to the performance of 'objective' green housing features using the regression analysis technique. Tan's research was mainly concerned with the implementation of the green features in the buildings. However, this current research is related to the consequences of the green features or elements in the buildings, not the features per se. in other word, the research is about the impact of incorporating green features on the home occupants. Incorporating green features into a building is not enough, the consequences of the features after implementation need to be examined to ascertain if the building meets the design functions or not. This is very imperative in the context of the Malaysian green rating tools because users are not involved during the process of green certification.

2.1 Post occupancy evaluation (POE) of green buildings

To continue to justify the investment or uptake of the homebuyers in the green buildings, the performance of the existing certified green buildings requires evaluation by the occupants. The POE is a technique that has been used to compare the performance of buildings with the designed criteria based on the occupants' experiences and interactions with the buildings. This is very important because buildings do not often perform as designed and constructed. To illustrate, the energy performance of the green buildings is over-exaggerated during the proposal stage (Li, Ng et al., 2018a). Furthermore, Al Horr (2016) opined that the comfort and well-being of the occupants may contradict building performance. This can be revealed by making reference to energy-efficient buildings with tighter envelopes which often lead to poor ventilation (Meyer, 2019 and Symonds et al., 2019). In addition, energy performance may not be correlated with user satisfaction. Additionally, only a few rating tools involve users in assessing building performance or measuring certified buildings during the occupation (Li, Froese et al., 2018). Therefore, the POE of the green building is a strategic tool to evaluate the building performance. The occupant's evaluation can be carried out using different methods, including surveys, interviews, and case studies. Largely, it involves inciting a response from the occupants on the different aspects of the building, notably the energy consumption, indoor air quality, movement in the building, nature and extent of maintenance, acoustics, and lighting quality of the buildings. Whilst some POEs involve the building itself, other evaluations include the external facilities provided by the building like parking space, security, and general neighbourhood. What should be included on a POE form depends on the purpose of the evaluation. In particular, the POE for hospital buildings would include questions on the productivity of the employees and patients' wellness. For residential buildings, emphases would be made towards occupant well-being, energy-savings potential, quality of the indoor air, ventilation provided water-related matters, and total satisfaction of the building occupants. The POE has been used in many studies to evaluate the satisfaction of the users of green buildings (Fowler et al., 2010; Li, Froese et al., 2018 and Deuble & de Dear, 2012). In the marketing theory, customer satisfaction is a powerful technique to increase customer experience and provide feedback to stakeholders for future development. It measures the difference between experience and expectation. Home occupants' satisfaction is evaluated with reference to expectations. A critical aspect of the satisfaction assessment and POE, in general, is that the buildings' occupants need to have interactions with the buildings because, without adequate information on the requirements and expectations, satisfaction cannot be measured.

2.2 Green building index (GBI) Malaysia

The World Green Building Council (WorldGBC) was established to promote the supply and demand for green buildings at the international level. There are many green rating tools around the world. The tools are designed considering the country's particular characteristics, especially with environmental factors. The examples of the green rating tools are Al Sa'fat—Dubai Green Building Evaluation System, Leadership in Energy and Environmental Design, British Research Establishment Environmental Assessment Method, BEAM Plus, Green Mark (Singapore) and GreenBuilding Council of Australia Green Star (Australia However, the tools are generally optional rather than mandatory. However, in some places in the USA, the green building is mandatory (Aroul and Hantze, 2012). Furthermore, whilst some of the rating tools have been developed by government agencies, the majority of the rating tools were developed/established by professionals in the construction industry, notably the architects and engineers. Nearly all the tools are design and construction-related because of the general perception is that once the design and construction are in compliance with the sustainability requirements, the buildings will deliver the designed performance specifications. Research has since shown that the perception is unsubstantiated and misleading. Whilst some of the rating tools have certified buildings in three categories, some have 5 levels. For instance, the DGNB certiicate in Germany is granted in Platinum, Gold or Silver. Table 1 contained the 10 green or sustainable rating tools for construction projects in Malaysia. Table 2 contains the assessment criteria and Table 3 contains the rating scales. GBI certiication has a 3-year validity period.

About 40% of the total certified green buildings are residential buildings and 30% of the buildings that have platinum ratings are residential buildings (Table 4), and some 20% of the reduced carbon emission is from the residential buildings (Table 5), and in terms of the floor areas, about 50% are attributed to the residential buildings (Table 6). Whilst the GBI has certified many residential buildings, there is a lack of information on the effectiveness of the green rating tools in Malaysia. However, the primary purpose of this research has been to examine the performance of green certified residential buildings in Malaysia. Whilst the satisfaction levels of the commercial buildings have been conducted, research on green residential buildings has yet to receive any concerted investigations.

2.3 Performance satisfaction factors

Based on the extensive review of the literature on the green buildings, the common features found in most of the guidelines for green buildings in most countries are energy and water management; CO_2 reduction; efficient use of water resources; efficient waste management; minimising all forms of pollution, including noise; maximising the health and well-being of the users; fostering and caring for the local ecology; location; occupants' satisfaction levels and productivity; neighbourhood; and site management (Olanrewaju et al., 2019). In

Table 1 Summary of sustainability or green rating tools for construction projects in Malaysia

Tool and year established	Developer/ owner	Main Assessment Criteria	Coverage (Main emphases)
Green Building Index (GBI) 2009	Malaysian Institute of Architect and Association of Consulting Engineer Malaysia	•Energy efficiency • Sustainable site planning & management •Water efficiency •Indoor environmental quality •Material & resources •Innovation	•Design •Construction •Operation
CASBEE Iskandar 2016	lskandar Malaysia	•Energy efficient •Neighbourhoods efficiency •Carbon society efficient •Environmental efficiency	•Design •Construction
Green Performance Assessment System (Green PASS) 2012 now merged under the MYCREST	Construction Industry Development Board of Malaysia(CIDB)	•Carbon efficiency •Energy efficient •Water efficiency	•Construction •Operation
GreenRealEstate(GREENRE) 2013	RealEstate andHousingDevelopers'Association(REHDA)	•Energy efficiency •Water efficiency •Environmental protection •Indoor environmental quality •Carbon emissions •Other green features	•Construction •Operation
TheLowCarbonCitiesFrameworkandAssessment System 2011	The Ministry of Energy, Green Technology and Water	•Carbon efficiency •Energy efficiency •Water efficiency •Environmental protection	•Construction •Operation
Malaysian Carbon Reduction and Environmental Sustainability Tool (Mycrest) 2016	Kementerian Kerja Raya Malaysia(KKR),Jabatan Kerja Raya Malaysia(JKR)and Construction Industry Development Board Malaysia(CIDB)	•Gas emission •Energy consumption •Waste materials •Social and safety •Material efficiency	•Pre-design •Design •Construction •Operation

Table 1 (continued)

My Green Highway Index 2012	Jabatan Kerja Raya Malaysia or Public Works Department	•Energy efficiency • Environmental efficiency •Water (storm) management •Material efficiency •Safety efficiency	•Design •Construction
Melaka Green Seal 2014	The State of Melaka	•Energy efficiency •Internal environment quality •Sustainable management & planning •Material efficiency •Water efficiency	•Design •Construction
Skim Penilaian Penarafan Hijau JKR (PHJKR) 2012	Jabatan Kerja Raya Malaysia or Public Works Department	•Environment efficiency •Energy efficiency •Material efficiency	•Design stage
Sustainability Index (SUSDEX) 2010 Now Called SUSDEXPI us	The Sime Darby Property	•Resource efficient •Energy efficiency •Environmental efficiency •Social and security • Design efficiency •Material efficiency • Water efficiency •Labour efficiency	•Pre-design •Design •Construction •Operation

Construction Industry Development Board Malaysia (CIDB 2018a)

Table 2 Green building index assessment criteria for residential new building

Part	Item	Maximum Points
1	Energy Efficiency (EE)	23
2	Indoor Environmental Quality (EQ)	12
3	Sustainable Site Planning & Management (SM)	33
4	Material & Resources (MR)	12
5	Water Efficiency (WE)	12
6	Innovation (IN)	8

GBI, (2019)

fact, it has been suggested that to deliver sustainable housing, it has to be energy efficient, able to generate its own energy (Patterson, 2007) decarbonise itself, reduce waste, provide thermal comfort, and have good ventilation and a good layout. Based on the GBI (2013), the POE for residential buildings involves air quality, thermal comfort, day lighting comfort, visual comfort, and acoustic comfort in a building. Therefore, the design criteria for the green residential buildings are expected to cover all the above features, and a failure in the delivery of the performance requirements will have severe consequences on the satisfaction of the occupants. The performance satisfaction factors in buildings differ depending on the building's typology. Whilst there is no conclusive list of performance factors for green buildings, Table 7 contains the summary of the strategic performance factors common to green residential buildings.

3 Research methodology and analytics techniques

The survey data were collected by the second author, as part of a research that investigated the satisfaction of green building users in Malaysia. A social experiment involving a survey questionnaire was conducted to collect the primary data. The data were collected through hand delivery based on a convenience sampling. In convenience sampling, the survey is administered to available, accessible, and willing respondents. Convenience sampling is a very suitable procedure to collect primary data, especially where it is not easy to access the respondents and if the exact size of the population is not known. It can be used for both explanatory and exploratory research. Convenience sampling is appropriate for a research with a limited timeframe and cost (Bougie & Sekaran, 2016). However, the main shortcoming is that the findings may not be generalised. However, with a large sample size, the findings can be indicative of the population (Pituch & Stevens, 2016). This conclusion is in tandem with the principle of the central limit theorem (CLT). According to the theorem, the distribution of the sample mean approximates a normal distribution as the sample size increases and for the CLT principle to be valid, the sample size should not be less than 30. The respondents involved in this study were the occupants of three certified green residential buildings in the Greater Kuala Lumpur area. The survey was conducted between 27/07/2019 and 30/08/2019. The respondents were asked questions based on their personal 'experience' with the building, they had to measure their satisfaction with the

Table 3 Categories of green building index rating

Point	GBI Rating
86 to 100 points	Platinum
76 to 85 points	Gold
66 to 75 points	Silver
50 to 65 points	Certified

GBI (2020) The GBI rating system. Available at: https://www.greenbuildingindex.org/how-gbi-works/gbi-rating-system/ [Accessed on 21December 2020]

building performance factors on a five-point Likert scale, where 1 = Least satisfied, 2 = Less satisfied, 3 = Satisfied, 4 = Very satisfied, and 5 = Extremely satisfied. The extent of the satisfaction with the performance factors was measured by the Average Satisfaction Index (ASI) (Eq. 1) and standard deviation.

$$ARI = \frac{\sum_{i=0}^{5} a_i x_i}{5\sum_{i=0}^{5} x_i} \times 100 \quad (1)$$

where a_i was the index of a group; constant expressing the weight given to the group; x_i was the frequency of the responses, i = 1, 2, 3, 4, and 5 and was described as below: x_1, x_2, x_3, x_4, x_5 were the frequencies of the responses corresponding to $a_1 = 1, a_2 = 2, a_3 = 3, a_4 = 4, a_5 = 5$, respectively. For interpretation, an ASI score of 1.00–20.00 denoted the least satisfied, 21.00–40.00 denoted less satisfied, 41.00–60.00 denoted satisfied, 61.00–80.00 denoted very satisfied, and 81.00–100.00 denoted extremely satisfied. Thus, the performance factor with the highest ARI score was considered as the major factor. All the performance factors were positively worded.

Only occupants that have resided in buildings for more than six months were selected to allow the occupants to 'experience' the performance of the building. Due to restrictions and other logistic reasons, only three buildings were examined in this study. The 3 buildings were selected strictly based on convenience sampling technique. The three buildings named building A, B and C (due to the infringement rights) are located in the Greater Kuala Lumpur area. The total units in the three buildings are 2377. Building A has 413 units, Building B has 1601 units, whilst Building C has 363 units. However, at the time of the survey many of the units, especially in building A were unoccupied.

Apartment A is a Freehold development that is located at Ampang, Kuala Lumpur. The unit comprises of 41 floors. The prices range between RM 400,000 and RM 3 million.

Apartment C is a leasehold residential building that is located at Damansara in Selangor. Apartment B is a freehold development that consist of 33 stories with 4 types of units. It located in Kuala Lumpur. The apartment B is marketed for its uniqueness for occupants to 'take care of their elderly parents'. This apartment was developed by a reputable developer in Malaysia. The apartment is located in the mist of many commercial and residential buildings. The prices of the units are between RM 550,000 ~ RM 1,8 million The distance from building A to building B is 19.1KM and the distance from building B to building is 26.1KM, whilst the distance between building C and building A is 24.5KM. The distances were determined based on Google map. All data gathered adopted the IBM SPSS 25 for the data analytics. The test and analyses are one sample t-test, correlation, multiple linear

Table 4 GBI certified building by rating categories

Rating level	Total as of 31-Aug-2019	Non residential new construction	Residential new construction	Industrial new construction	Non residential existing building	Industrial existing building	Interior	Township
PLATINUM	21	13	6	–	1	–	–	1
GOLD	116	65	41	2	2	1	2	3
SILVER	67	39	19	2	2	–	–	5
CERTIFIED	356	174	143	15	15	3	1	5
Total	560	291	209	20	19	4	3	14

GBI (2020) Executive summary of GBI certified building Available at: https://www.greenbuildingindex.org/how-gbi-works/gbi-executive-summary/ [Accessed on 21December 2020]

Table 5 CO_2 Emission reduction of GBI rated buildings

CO2 Reduction Projection	Total As Of 31 Sept 2020	Non Residential New Construction	Residential New Construction	Non Residential Existing Building	Industrial New Construction	Industrial Existing Building	Interior
CO_2 Emission Reduction (ktCO2e/annum, based on electricity energy reduction	1,311	880	297	96	20	17	1

GBI (2020) CO_2 Emission Reduction Available at: https://www.greenbuildingindex.org/how-gbi-works/gbi-executive-summary/ [Accessed on 21December 2020]

Table 6 Gross floor area of GBI rated buildings

Gross Floor Area	Total as of 8/31/2019	Non Residential New Construction	Residential New Construction	Non Residential Existing Building	Industrial New Construction	Industrial Existing Building	Interior
Gross Floor Area, sqm(As Submitted)	24.6 million sqft)	10.7 million	12.1 million	1.0million	593,975.32	72,120.12	5.151.35

GBI (2020) Available at: https://www.greenbuildingindex.org/how-gbi-works/gbi-executive-summary/ [Accessed on 21December 2020]

Table 7 Summary of previous studies satisfaction of green residential buildings users

Factor	Author
How satisfied are you with the overall air quality of this building?	GBI (2013), Spiegel & Meadows (2010), CIDB (2018a)
How satisfied are you with the ventilation in this building?	Byrd (2012); Kamaruzzaman, et al. (2015)
How satisfied are you with the overall lighting comfort in this building?	Spiegel & Meadows (2010), CIDB (2018a)
How satisfied are you with the natural lighting of this building?	Olanrewaju et al. (2017), GBI (2013)
How satisfied are you with the artificial lighting of green building?	Byrd (2012); Spiegel & Meadows (2010)
How satisfied are you with the overall acoustic quality in this building?	GBI (2013), Spiegel & Meadows (2010)
How satisfied are you with the noise level from outside to the building?	GBI (2013)
How satisfied are you with the electricity consumption of this building?	Zalejska-Jonsson (2012); Li, Ng et al. (2018); Li, Froese et al. (2018), Pastore and Andersen, 2019; Li Ng, & Skitmore (2018); Li, Froese et al. (2018)
How satisfied are you with the water consumption of this building?	Olanrewaju et al. (2017), Olanrewaju et al. (2018), GBI, 2013, Spiegel & Meadows (2010)
How satisfied are you with the cost of the building maintenance?	Olanrewaju et al. (2018), Spiegel & Meadows (2010)
How satisfied are you with the water harvesting system?	Olanrewaju et al. (2017), GBI (2013), Spiegel & Meadows (2010)
How satisfied are you with the general layout of this building?	Olanrewaju et al. (2018), GBI (2013)

regression, satisfaction index, standard deviation,. The t-test was conducted to examine whether each of the performance factors contributed to the satisfaction of the performance of the buildings by the occupants or not. Factor analysis was performed to cluster the performance factors to facilitate the decision-making on the greenness of the buildings. The factor analysis is a form of an unsupervised machine learning algorithm that is used in grouping constructs that are not clearly obvious or are labelled prior to the computations. The categorisation can be computed based on the correlation or co-variance amongst the variables.

4 Data analysis and findings

Altogether, 389 sets of survey questionnaires were administered through hand delivery and out of which 118 valid responses were received by the cut-off date. The responses from Building A were 32, for Building B there were 47, and for Building C there were 50. The analysis of the data results is presented in the tables and figure and discussed in the following sections.

4.1 Demographic profiles of the home occupants

The data revealed that more than 70% of the respondents had occupied the buildings for more than one year and some 30% of them had lived in the buildings for more than 3 years with a mean occupation period of 2 years and the standard deviation was 8 months. The mean of the occupants in a unit was 3. More than 90% of the units were occupied by more than 2 people and about 11% had more than 6 occupants. The data revealed that 70% of the home occupants spent more than RM500[1] for maintenance yearly, and many spent more than RM1500 for maintenance annually (Table 8). It was also revealed that 60% of the homes were more than 1000 square feet and only 3% of the units were more than 2000 square feet. The average square feet for a unit was 1,750 square feet and the average annual maintenance cost was RM750. The Spearman correlation indicated that there was a significant positive association between maintenance cost and unit size ($r=0.45$, $n=129$ $p<0$ 0.001). In particular, the size of the building accounted for about 20% of the maintenance cost.

The data revealed that more than 80% of the respondents spent more than RM500 annually for electricity consumption (Table 9). The mean cost was approximately RM1100 and the standard deviation was about RM500. Table 10 contains the distribution of the annual water bills for the units from where it can be seen that most of the respondents spent about RM225 annually and quite a number spent more than RM500 for the same period. The average bill paid per unit for water consumption was RM325 and this can vary by up to RM150 (i.e. between 275 and RM475). Significant positive relationships were found between unit size and cost of electricity and water bills (Table 11).

4.2 Analysing the taxonomy of the occupants' satisfaction levels in the green buildings

The reliability test indicated that the consistency for the factors was very high (Table 12). The results of Spearman Correlation, conducted to determine the validity, suggested that the correlation values (r) were generally within 0.20 and 0.80. Whilst a correlation of more than 0.80 implies collinearity, correlation less than 0.2 implies that the constructs are not related. The results of the one sample t-test statistics, conducted to examine the measurement of the population with respect to each of the factors, are contained in Table 13. The null hypothesis was that the performance factor does not contribute to the greenness of the building (H_0: $U=U_0$) and the research hypothesis was that the performance factors contribute to the greenness of the building (H_r: $U>U_0$). U_0 was the population mean. The significance of the performance factors was statistically significant. The smaller standard errors suggested that the measurements of the respondents were indicative of the measurements of the population with respect to each of the factors. To interpret these, all the factors would contribute to the greenness of the buildings. The results of the KMO (0.892) and Bartlett's test (x^2 (91) $=732.347$, $p=0.000$) also implied that the respondents had similar experiences with respect to the performance of the green buildings.

The descriptive statistics on the performance factors are contained in Table 14. The ARI for all the performance factors was 77.10 and the average standard deviation was 16.13. Specifically, 4% of the buildings' occupants were less or least satisfied with the green

[1] Exchange rate: USD 1 = RM4.2.

Table 8 Cross-tabulation between Maintenance cost and unit size

Cost Unit size	< RM500	RM500-RM1K	RM1K-RM1.5 K	RM1.5 K-RM2K	> RM2K	Total
500-1000sf	21	20	3	0	0	44
1000sf-1500sf	12	20	10	8	2	52
1500sf-2000sf	1	6	5	4	2	18
> 2000sf	1	1	2	0	0	4
Total	35	47	20	12	4	118

buildings. 25.38% were 'satisfied' with the buildings. However, 70.81% of the occupants were very satisfied or extremely satisfied with the performance of the buildings. Taking into account the distribution of the Performance Index under the Analytics Techniques section, it is obvious that the buildings met the general expectations of the occupants.

4.3 Results of the exploratory factor analysis

The adequacy of the data was high and significant (Table 15) and the performance factors were grouped into 4 components which explained 66% of the total variance (Table 16). This was also evident in Fig. 1. The factor loading for each of the factors was more than 0.5. The details of the components are contained in Table 17.

5 Discussion

A plethora of studies indicated that green buildings perform better than conventional buildings. Research on the satisfaction of residential green buildings has received little consideration in the extant literature.

5.1 Discussion of the findings on the taxonomy of the performance factors

The data revealed that the occupants were most satisfied with the function of the buildings in terms of being able to accommodate the elderly and those with mobility impairments. Although this factor has not received prominence in the existing literature and majority of the green ratings have not included credit for this factor, in practice, some of the green buildings observed were not 'usable' by the elderly, children or those with disabilities. Green buildings involve the simplification and standardisation of design and construction to avoid the unnecessary waste and high costs associated with cutting and installations of materials and components. However, this practice often affects the buildings' usability by the elderly and those with mobility impairments. Mass housing production, though it can reduce the cost of production and increase productivity, the buildings may not be able to meet the requirements of certain users and may limit adaptability and refurbishment. The second most satisfying performance factor is the acoustic feature in the buildings. It is

Table 9 What is the electricity cost used in your unit each year?

Cost	Frequency	Percent
< RM500	17	14.4
RM500-RM750	18	15.3
RM750-RM1000	15	12.7
RM1000-RM1250	16	13.6
RM1250-RM1500	11	9.3
RM1500-RM1750	13	11.0
RM1750-RM2000	14	11.9
> RM2000	14	11.9

impressive that this factor is highly related. Green rating tools often include credit for the acoustic property of the building (Geng et al., 2019 and GBI, 2013). However, it has been argued that green materials and designs compromise the acoustic features of the buildings (Al-horr, 2016) because green buildings tend to have more openings. Because green buildings are designed to make use of natural air and sunshine, this may tend to increase the openings in the green buildings, as a result, it may tend to increase the noise quality in the building which may often create discomfort for the occupants (Frontczak et al., 2012) Some of the green materials may also create acoustic problems in the buildings.

Illumination is required in a building more than 60% of the time. The amount of light in the building should be enough to allow the appropriate tasks to be conducted by the occupants at any given time. Lighting in the building can be provided through a natural or mechanical source. Like ventilation, it also is provided using the mixed method. However, whilst natural lighting is desirable for green buildings (Spiegel & Meadows, 2010 and Al-horr, 2016) the local condition has a great influence on the amount of lighting that can be provided. For instance, a place with a longer night time will not benefit much from natural lighting. The shape of the building would also dictate the amount of natural lighting that can be provided in the buildings. The intensity of the natural lighting is also another critical factor; with poor penetration due to certain factors including the geometrics, openings, and orientation of the buildings would also affect the amount of natural lighting available. In green buildings, consideration for natural lighting is critical because it is cost-effective and will emit less carbon emissions. Ratings for the green buildings allow a significant amount of credit for the use of natural lighting in the buildings.

Many studies on green buildings have focused on the indoor air quality (Levine et al., 2007, Al-horr, 2016 and Frontczak et al., 2012). The toxic fumes in the buildings may be evaluated by the indoor air quality. The quality of the air in green buildings, according to the overwhelming findings from the POE studies, is that green building perform better off as compared to the conventional buildings, notably due to the design (Gill et al., 2012). The orientation and ventilation of green buildings are arranged to effectively use natural air. Poor indoor air quality could contribute to sick building syndrome (Spiegel & Meadows, 2010) and may lead to sickness. Good indoor air quality is achievable by selecting materials with very low volatile organic compounds/persistent bio-accumulative toxins. Some chemicals used in the buildings, especially for finishes can be a source of volatile organic compounds. However, because green buildings materials are often free from formaldehyde and contain a low volatile organic compound, the indoor air quality is nourishing. In the US, this has been able to help reduce liability claims against developers (Spiegel

Table 10 How much do you paid on the average for water bills annual?

	Frequency	Percent
<RM200	16	13.6
RM200-RM250	25	21.2
RM250-RM300	16	13.6
RM300-RM350	10	8.5
RM350-RM400	14	11.9
RM400-RM450	12	10.2
RM450-RM500	10	8.5
>RM500	15	12.7

& Meadows, 2010). However, because green buildings use recycled materials it is important that the recycled materials are carefully tested.

Building layout is a vital aspect of the green building design. The requirements imposed on green building designs affect the layout. A green building is expected to adopt the 'universal' design approach to accommodate various types of occupants, especially the elderly and disabled and to use natural lighting. Therefore, it was interesting to find that the occupants were very satisfied with the buildings' layouts. In fact, none of the buildings' occupants were least or less satisfied with the layouts which accommodated senior citizens (and the like). Previous POEs of residential buildings did not include the performance factor in the evaluations, although the building layout provides tremendous influential benefits for the building. Green building rating tools place tremendous emphasis on the design of the green buildings. The importance of this is supported by a number of studies (Spiegel & Meadows, 2010, GBI, 2013 and Akadiri et. al., 2012). The design layout for a green building is different from that of a conventional building. During the design of a green building, particular emphasis is accorded to an arrangement of the functional requirements of each space in order to maximise energy use, water use, and ventilation and to provide a view of the outside. However, whilst the design of the layout aims to increase efficient utilisation of resources, especially during operation, sometimes this has a negative influence on the users, especially when the design dictates that a particular room should be located in a particular location with a specific orientation.

The design of the green building dictates that it should conserve energy as far as practicable by making use of the natural lighting. Therefore, it was fascinating to find that the occupants were very satisfied with the artificial lighting offered by the green buildings. The artificial lighting was provided to compliment the natural lighting and, especially used at night and earlier. The annual relative humidity value ranges from 74 to 86%. The annual average rainfall is 2,420 mm for Peninsular Malaysia, 2,630 mm for Sabah and 3,830 mm for Sarawak Malaysian Meteorological Department (2017). Malaysia enjoys tropical weather temperatures ranges from 20 to 33 °C on the average Malaysian Meteorological Department (2019). The nature of Malaysia's weather and climate means that it experiences a monsoon season and enjoy. The sunshine and rainfall should be tapped into the building design. Furthermore, it does not come as a surprise that the natural lighting fortuitously offered by the buildings was also highly rated. In fact, about 80% of the occupants of the building were very or extremely satisfied with this feature. Ventilation is an important function of buildings for adequate air movement in order to remove foul air and bring in fresh air (Spiegel & Meadows, 2010). Ventilation in the building can be achieved

Table 11 Spearman's rho correlation between unit size and electricity cost and water cost

	Unit size	Energy cost	Water bill	Maintenance cost
Unit size				
Coefficient	1.000	0.475**	0.521**	0.445**
Sig. (2-tailed)	0.00	0.00	0.000	0.000
Energy cost				
Coefficient	0.475**	1.000	0.825**	0.283**
Sig. (2-tailed)	0.000	0.00	0.000	0.002
Water bill				
Coefficient	0.521**	0.825**	1.000	0.393**
Sig. (2-tailed)	0.000	0.00	0.00	0.000
Maintenance cost				
Coefficient	0.445**	0.283**	0.393**	1.000
Sig. (2-tailed)	0.000	0.002	0.000	0.00

**Correlation is significant at the 0.01 level (2-tailed)

in two distinctive ways, the natural ventilation and mechanical ventilation. There is also the mixed-method: a combination of the natural and mechanical methods. Each of these has its pros and cons. In the design of the green building, unique consideration is accorded to natural ventilation because it is cheap to operate and use and poses less health hazards. Only when natural ventilation is expensive or impractical to achieve should mechanical or the mixed-method be preferred. Mechanically, buildings can be ventilated with equipment like air-conditioning and fans. Natural designs, however, depend on the orientation, siting, size, and geometrics of the buildings. However, a recent survey on Danish homes revealed that home occupants have a preference for natural ventilation (Frontczak et al., 2012).

This research revealed that the occupants are satisfied with the thermal comfort the buildings. This is interesting because previous research revealed the thermal discomfort environment in residential buildings in Malaysia (Jamaludin et al., 2015). The thermal comfort of the green building has been researched and the results varied with some point to the factors that it depended on when the evaluations were conducted. Green rating allocates significant credit for the thermal comfort of the buildings (GBI, 2019). In particular, some studies revealed that the thermal comfort of the green building may be better in the summer whilst poor in the winter. The overwhelming results showed that in most of the cases, the thermal comfort of a green building is better as compared to the conventional building (Al-horr et a., 2016, Frontczak et al., 2012 and Zainordin et al., 2018). The thermal comfort of the building's occupants relates with the temperature in the building and is a measure of how cold (very cold or extremely) or hot (very hot or extremely hot) the occupant is feeling in the buildings. It is relative and varies from individual to individual; and even for an individual, it depends on the time of day and the individual's other condition in time. The thermal comfort in a building may be affected by air velocity, air temperature, relatively humidity, nature of clothing, and medical condition of the occupants. For a building, it usually considered that if most (more than 75%) of the occupants claimed that they were thermally comfortable, the building was considered to have good thermal comfort The BREEAM Thermal comfort provides a guideline on how to achieve optimum comfort in buildings.

Table 12 Reliability statistics

Cronbach's Alpha	Part 1	Value	0.870
		N of items	8.000a
	Part 2	Value	0.765
		N of items	7.000b
	Total N of items		15.000
Correlation between forms			0.831
Spearman-Brown coefficient	Equal length		0.908
	Unequal length		0.908
Guttman Split-Half coefficient			0.892

Water consumption is one of the basic requirements in the green building that is considered during the design stage. In Malaysia, 8 points of the total point for green building is attributed to water consumption. Our research found that the buildings performed well for water consumption. Gill et al. (2012) found that water consumption in green affordable housing in the UK was better. The amount of water consumed by a building is quite large during operation. A green building design has a host of water-saving features. The significance of the water-savings building in Malaysia cannot be over-emphasised, especially in the Greater Kuala Lumpur. The phenomena of water disruptions in the Greater Kuala Lumpur are high. However, the water bill is relatively cheaper in Malaysia. But as this research revealed, most of the occupants' spent RM35 monthly for water.

The occupants also expressed high satisfaction with the visual comfort of the buildings. an Australian study occupants of sustainable buildings are very interested in their personal comfort levels (Reed & Jailani, 2014) Unlike conventional buildings, the green buildings offer better visual comfort. In conventional buildings, emphases are given to the quantity of lighting in the buildings with less emphases on its impact on the users' behaviours. Visual comfort is very important because just providing adequate illumination in a space is not enough (Lemon, 2015). The quantity and quality of the light in the building, if not well regulated, would cause discomfort to the eyes because of the eyes' adaptation to the light. Because green buildings provide quality electric lighting, natural lighting, and views to outside, they tend to improve good visual comfort. Visual comforts have the impact of emotion, mood, and satisfaction of the users. The occupants were also questioned about the level of satisfaction with the noise level from outside the buildings. The design layout on the requirement to converse energy from natural lighting often results in a number of openings as compared to the conventional buildings. The home occupants were also satisfied with the noise level entering the buildings from the outside. In other words, the intensity of the noise was not high enough to disturb the tasks in the buildings. Because green buildings are designed with openings, noise from the outside, especially from moving vehicles, may pose a risk to the occupants. However, as our research revealed, the occupants were very satisfied with the quality of the buildings with respect to noise prevention from the external sources. Most often, noise from outside the buildings disturb the occupants of green buildings. The occupants of these buildings, were, however, very satisfied with the buildings ability to control the external noise.

The water harvesting system in the buildings also received a high recommendation as more than 70% of the occupants were very pleased with the feature in the buildings. Green building rating systems include credit for water harvesting systems. Except for near the

Table 13 Results of one—sample t-test

Factor	Test value = 3.5					SE mean
	t	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference		
				Lower	Upper	
How satisfied are you with the overall thermal comfort of this building?	4.147	0.00	0.322034	0.168234	0.475833	0.077659
How satisfied are you with the overall air quality of this building?	6.104	0.00	0.440171	0.297339	0.583003	0.072114
How satisfied are you with the ventilation in this building?	4.780	0.00	0.355932	0.208462	0.503402	0.074463
How satisfied are you with the natural lighting of this building?	6.765	0.00	0.440678	0.311668	0.569687	0.065142
How satisfied are you with the artificial lighting of green building?	5.277	0.00	0.364407	0.227652	0.501162	0.069053
How satisfied are you with the visual comfort of the lighting of this building (e.g. glare, reflections, and contrast)?	4.254	0.00	0.29661	0.158524	0.434697	0.069725
How satisfied are you with the overall acoustic quality in this building?	6.552	0.00	0.466102	0.325219	0.606984	0.071137
How satisfied are you with the noise from outside the building?	3.823	0.00	0.29661	0.142944	0.450276	0.077592
How satisfied are you with the energy consumption of this building?	4.347	0.00	0.355932	0.193781	0.518083	0.081876
How satisfied are you with the water consumption of this building?	4.473	0.00	0.381356	0.21252	0.550192	0.085251
How satisfied are you with the cost of the building maintenance?	2.176	0.00	0.186441	0.016716	0.356165	0.0857
How satisfied are you with the water harvesting system?	2.945	0.00	0.228814	0.074959	0.382668	0.077687
How satisfied are you with the general layout of this building?	6.786	0.00	0.457627	0.32407	0.591185	0.067438
How satisfied are you to accommodate elderly and disabled in this building?	9.317	0.00	0.542373	0.427081	0.657664	0.058215
How satisfied are you with the overall lighting comfort in this building?	6.897	0.00	0.457627	0.326214	0.58904	0.066355

industrial sites, which may be acidic and some contain contaminants (like bacteria, algae, and protozoa), rainwater is better than well and municipal water (Spiegel and Meadows, 2010). Rainwater harvesting involves collecting, storing, and distributing the rainwater from the roof to use in the buildings. To reduce using municipal and groundwater and the associated bills, as well as the disruptions to the water supply, green buildings use the harvesting system. The system helps to control water run-off, flooding, and erosion, especially around the downspouts. A water harvesting system provides excellent and cheap water. In Malaysia, with the abundant rainfall of 2400 mm annually and high cost of water consumption, the system is not popular because of poor acceptability amongst the households (Hafizi et al., 2018) high cost and poor installation. However, the harvested water is cheap and can be used for washing of clothes, cars, dishes, as well as flushing, and gardening; and if treated with UV light, it is safe to drink.

Relatively, the home occupants believed that the buildings were expensive to maintain. However, this was unexpected because, because one of the main benefits of green buildings, according to Wood (2006 and 2009) and Olanrewaju et al. (2019) was the lower maintenance cost. Maintenance contributes to sustainability in a number of ways, including holding noxious odours to the barest minimum level, and reduction of emissions by ensuring the durability and availability of the building parts (Sherwin, 2000). Comparing the buildings' operational lives with the design/ construction lives, the operation lives of the buildings make up more than 95% of the total buildings' life spans. To understand the importance of maintenance towards building performance and to the sustainability targets, all internationally recognised systems for certifying green buildings include maintenance issues in their assessment criteria. In Malaysia, the Green Building Index (GBI) articulates maintenance as a component towards meeting the sustainable development goal. As a matter of fact, in the GBI assessment, maintenance issue contributes to about 5% of the total building performance criteria. Although the green rating tool allocates credit for maintenance, the allocation is low and not given specific consideration. There are strategic requirements to match buildings' maintenance with sustainable requirements. More than 90% of the lifetimes of building projects require maintenance works.

5.2 Discussion of the results of the factor analysis

The factor analysis structured the 15 performance factors into four components. The derivation of the components' names was based on the similarity amongst all the factors under a particular component. A second-order factor analysis that combined each of the factors into their individual components loaded all the factors into one component separately, confirming the consistency of the components.

5.2.1 Component 1: lighting

This component has six related factors that collectively explained 44% of the total variance in the model. A second order factor analysis computed combined that factor into one component. The validity ranges from 0.43 to 0.622. The KMO and Chi-square of 0.828 $\chi 2$ $(15) = 227.537$ is statistically significant ($p < 0.05$). The Cronbach's Alpha for the 6 satisfactions was 83%. One of the primary performance requirements of the green building is the premium indoor environmental quality (IEQ) it offers. Research on the indoor environmental quality is huge due to the impacts of the indoor environment on the occupants' well-being, comfort, productivity, and satisfaction. Considering, that many occupants are

Table 14 Descriptive statistics of the occupants

Performance factor	Least satisfied	Less satisfied	Satisfied	Very satisfied	Extremely satisfied	Performance Index	Standard deviation
How satisfied are you to accommodate elderly and disabled in this building?	0	0	21	71	26	80.86	12.7
How satisfied are you with the overall acoustic quality in this building?	0	4	25	60	29	79.32	15.52
How satisfied are you with the overall lighting comfort in this building?	0	1	30	60	27	79.14	14.48
How satisfied are you with the general layout of this building?	0	1	31	58	28	78.98	14.58
How satisfied are you with the overall air quality of this building?	0	7	18	67	25	78.8	15.6
How satisfied are you with the natural lighting of this building?	0	2	27	65	24	78.64	14.08
How satisfied are you with the water consumption of this building?	2	6	28	50	32	77.44	18.48
How satisfied are you with the artificial lighting of green building?	0	4	30	62	22	77.1	14.92
How satisfied are you with the energy consumption of this building?	1	9	23	58	27	77.1	17.86
How satisfied are you with the ventilation in this building?	1	2	36	53	26	76.92	16.1
How satisfied are you with the overall thermal comfort of this building?	1	5	33	54	25	76.24	16.8
How satisfied are you with the visual comfort of the lighting of this building (e.g. glare, reflections, and contrast)?	0	3	39	55	21	75.9	15.2
# How satisfied are you with the noise from outside the building?	1	7	29	59	22	75.9	16.92
How satisfied are you with the water harvesting system?	1	5	41	49	22	74.36	16.78
How satisfied are you with the cost of the building maintenance?	1	11	36	46	24	73.5	18.54

indoors for more than 90% of the time, the quality of the indoor environment becomes a very important consideration for most families. The IEQ of the building is influenced by ranges of variables like thermal, acoustic, visual, airborne contaminants, air movement, and humidity in the buildings. A survey on Danish homes revealed that air quality, visual, acoustic, and thermal comforts were the main parameters of indoor environmental issues. The impacts of the Indoor Environmental Quality (IEQ) of the building on the occupants are very important. Therefore, it was not surprising that that the occupants of the certified green buildings in Malaysia, who were pleased with the air quality, were also satisfied with the lighting and ventilation of the buildings. This outcome was remarkable because natural lighting has been complimented with the artificial lighting and the results can be interpreted to imply that the ventilation was used to maintain the air quality of the buildings. The building design should ensure that the buildings permeate air movement for the air indoors to be dry and fresh. A significant cost can be saved if it is made with a good blending of natural and artificial lighting together with good ventilation. According to Jamaludin et al. (2015), as a solution to the thermal discomfort in conventional buildings in Malaysia a great of investment are made by the building users to install of air conditioning systems. Collectively, this will reduce pollution and at the same time increase the occupants' satisfaction because lighting lamps increase room temperature. Fluorescent and incandescent lights are also common in green buildings, however, they are hazardous.

5.2.2 Component 2: indoor environmental quality (IEQ)

This component comprised of 4 satisfactions collectively explained 8.95% of the variance in the model. The loading was 59% and 72%. A second order factor analysis combined the 4 satisfaction factor into a single component of IEQ. The KMO = 0. 774, $\chi 2$ (6) = 117.030, $p < 0.00$) with Cronbach's alpha of 0.772. The correlation matrix ranges from 0.376 0.502. The finding of this research revealed that the building occupants who were satisfied with the acoustic properties of the buildings were also satisfied with the noise that had been generated from the outside of the building into the building. Deductively, the buildings did not compromise the noise or sound control functions. It was fascinating to find that those who were satisfied with the acoustic properties of the green buildings also measured that they were insulated from noise from the neighbourhood as well as from being disturbed by the noise generated from the cities, which is a huge amount of noise. One of the expectations of the occupants of green buildings is for the building to be able to protect the occupants from noise entering the building from outside and for the building to able to protect occupants in the adjacent buildings from being disturbed with noise from that building. In fact, the LEED includes acoustic credit as an option in the certification of green buildings. The Global Sustainability Assessment System also includes the acoustic comfort of the occupant as a critical certification criterion. Sound insulation (EQ6) accounts for 1% of the total rating for green residential building assessment under the GBI's certification (GBI, 2013). However, research revealed that the acoustic comfort of the green buildings is less compared to the conventional buildings (Altomonte & Schiavon, 2013) because some green building materials have poor acoustic properties. For instance, hard materials that are commonly used for walls and floors in green buildings have poor acoustic properties (Al-horr et al., 2016). It is interesting that this component includes the thermal comfort of the buildings and satisfaction with respect to degree to which the water harvesting the system of the buildings perform. This reason could be explained considering the fact that sound waves generates heat as it travels in the space (Taban et al., 2020).

Table 15 KMO and Bartlett's test

Kaiser–Meyer–Olkin measure of sampling Adequacy		0.893
Bartlett's Test of Sphericity	Approx. Chi-Square	769.726
	df	105.000
	Sig.	0.000

5.2.3 Component 3: operating cost

This component has three factors that comprises of satisfaction with water and energy consumption as well as the building maintenance costs. The factors are positively correlated. This component comprised of 3 satisfactions collectively explained 6.778% of the variance in the model. The loading was 79% and 82%. A second order factor analysis combined the 3 satisfaction factor into a single component of operating cost. The KMO = 0. 683, $\chi 2$ (3) = 72.176, $p < 0.00$) with Cronbach's alpha of 0.772. The correlation matrix ranges from 0.453 to 0.502. What this component means is that occupants who were satisfied with the water consumption are were pleased with the energy consumption of the building and that the maintenance cost was in tandem with their expectations. One of the major benefits of the green buildings to the occupants is the lower operating costs as compared to the conventional buildings. Under the GBI, certification of the installation of water efficiency fittings (WE4) accounts for 4% (GBI, 2013). Green building should require less maintenance and should be flexible to refurbish and allow easy disposal of the demolished materials (Meyer, 2019 and Olanrewaju and Abdul-Aziz 2015). Malaysians spend a substantial portion of their incomes on energy, water, and housing maintenance. Collectively, on the average, the occupants spent about RM1000 to operate the buildings in KL (Tables 8, 9, and 10). The energy cost was for electricity and gas, and some 90% of the Malaysian energy cost is attributed to electricity consumption (Zainordin, 2018). Electricity is mainly used for cooling and lighting homes and for cooking. To make rooms thermally comfortable, a great deal of energy may be required. In KL, owners of a unit with 2500–3500 sq ft spent between RM600—1200 per month for energy costs. The monthly electricity cost on the average is about 5% of the household expenditure (Department of Statistics Malaysia, 2020). Though electricity and water prices in Malaysia are considered as some of the lowest in the region, however, they constitute a big portion of the operating costs and the recent price spike has been a major concern to the home users. Hence, the benefits that the green buildings offer due to energy savings present great incentives.

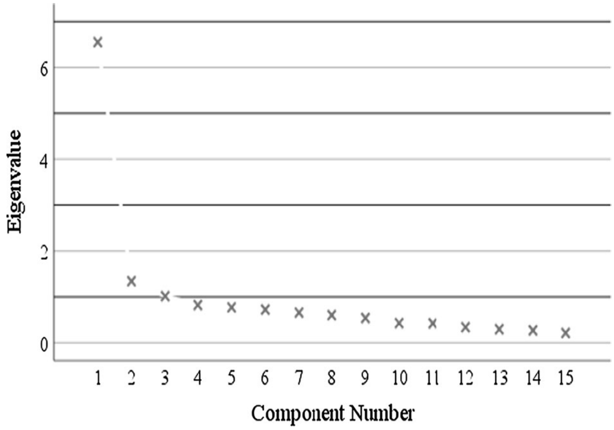
5.2.4 Component 4: spatial design

The layout of the building is a critical consideration of building users. Therefore, it was interesting to find that the occupants who were satisfied with the capability of the building to accommodate those with special needs were also satisfied with the general layout of the buildings. The building usability concept is well connected to the sustainability goal in the building environment (Yiing et al., 2013) which is also compatible with the green building design. In particular, green building should minimise maintenance and alteration to the barest minimum in the effort to accommodate varied users. Whilst the internal layout of the building is very important, most conventional buildings are not suitable for the elderly, children, wheelchair-bound, and those with other disabilities. If the design of

Table 16 Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	6.553	43.685	43.685	6.553	43.685	43.685	2.881	19.208	19.208
2	1.343	8.953	52.639	1.343	8.953	52.639	2.724	18.161	37.369
3	1.017	6.778	59.417	1.017	6.778	59.417	2.457	16.377	53.746
4	0.822	5.482	64.899	0.822	5.482	64.899	1.673	11.152	64.899
5	0.772	5.144	70.043						
6	0.723	4.820	74.863						
7	0.657	4.380	79.243						
8	0.603	4.021	83.263						
9	0.539	3.596	86.859						
10	0.428	2.854	89.713						
11	0.423	2.818	92.531						
12	0.340	2.270	94.801						
13	0.296	1.970	96.771						
14	0.271	1.803	98.574						
15	0.214	1.426	100.000						

Fig. 1 Scree plot performance factors



the buildings does not allow the elderly and those with vision and mobility impairments to operate freely, it may lead to a lot of modifications and refurbishments being needed which are usually expensive and stressful to carry out. A building that discourages physical movement would curtail interactions amongst the occupants, with potential implications on frustration and segregation. One of the basic requirements of the buildings, and in green buildings, in particular, is to support the needs of all the occupants. Green buildings, though cheaper over the whole life appraisal, should have little or zero negative impacts on the environment and occupants, ensure integration, and have positive impacts on all the occupants, users, operators, and the community. To accommodate the elderly, children, and those with disabilities (i.e., wheelchair-bound), the sockets and switches, especially in the rooms and kitchen, and the taps in the toilets and the kitchen must be fixed at a suitable height. In conventional buildings, electrical fittings and fixtures are fixed at a regular /standard height which is difficult to be used by those with disabilities. For instance, the wheelchair-bound may not be able to use the switches or taps fixed to the walls at about 1.5 m high. Similarly, the doors should be able to allow free movement of the wheelchairs. Steps if really necessary in the buildings should be carefully planned and ramps should be provided. Recent studies on green commercial and office buildings in Malaysia, however, revealed that those with vision/mobility impairments have difficulties in using the green buildings (Yiing et al., 2013).

5.2.5 Correlation test

In order to examine the relationships between the overall satisfaction of the sustainability of the building or greenness of the building and each of the performance factors, the correlation test was conducted and the results are presented in Table 18. The results show that the entirety of the factors were positively correlated with the 'greenness of the buildings and the relationships were statistically significant. To interpret this, the existence of these factors in the buildings, were indicative of the greenness of the buildings. Furthermore, quantitative inferential statistics using regression analysis was conducted to identify significant satisfaction in the green buildings. In particular, the multiple regression analysis was used to test the degree of the sustainability of the building with respect to the four components based on factor analysis. The results of the regression indicated that the four predictors explained 40% of the variance ($R^2=0.379$, $F(4,112)=18.703$, $p<0.05$). It was

Table 17 Rotated component matrix

Factor	Lighting	Indoor environmental quality	Operating cost	Spatial
How satisfied is you with the visual comfort of the lighting of this building (e.g. glare, reflections, and contrast)?	0.66535			
How satisfied are you with the overall lighting comfort in this building?	0.65863			
How satisfied are you with the artificial lighting of this building?	0.64824			
How satisfied are you with the overall air quality of this building?	0.59302			
How satisfied are you with the ventilation in this building?	0.58912			
How satisfied are you with the natural lighting of this building?	0.57766			
How satisfied are you with the overall acoustic quality in this building?		0.7173		
How satisfied are you with the water harvesting system?		0.6493		
How satisfied are you with the overall thermal comfort of this building?		0.6167		
How satisfied are you with the noise from outside the building?		0.5861		
How satisfied are you with the water consumption of this building?			0.7335	
How satisfied are you with the energy consumption of this building?			0.7130	
How satisfied are you with the cost of the building maintenance?			0.6966	
How satisfied are you with the general layout of this building?				0.7460
How satisfied are you to accommodate senior citizen in this building?				0.6975

Table 18 Correlation between sustainability of the building and the performance factors

Performance factor	Coefficient (r)	R^2	Sig. (2-tailed)
How satisfied are you to accommodate senior citizen in this building	0.139**	0.019	0.133
How satisfied are you with the overall air quality of this building	0.364**	0.132	0.00
How satisfied are you with the ventilation in this building	0.414**	0.171	0.00
How satisfied are you with the natural lighting of this building	0.212*	0.045	0.021
How satisfied are you with the artificial lighting of green building	0.339**	0.115	0.00
How satisfied are you with the noise from outside the building	0.387**	0.150	0.00
How satisfied are you with the cost of the building maintenance	0.236*	0.056	0.01
How satisfied are you with the overall acoustic quality in this building	0.403**	0.162	0.00
How satisfied are you with the energy consumption of this building	0.459**	0.211	0.00
How satisfied are you with the water consumption of this building	0.446**	0.199	0.00
How satisfied are you with the water harvesting system	0.438**	0.192	0.00
How satisfied are you with the general layout of this building	0.357**	0.127	0.00
How satisfied are you with the overall lighting comfort in this building	0.229*	0.052	0.013
How satisfied are you with the overall thermal comfort of this building	0.398**	0.158	0.00
How satisfied are you with the visual comfort of the lighting of this building (e.g. glare, reflections, and contrast)	0.293**	0.086	0.001

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed)

Dependent Variable: # How satisfied are you with the sustainability of this building?

found that all the 4 components will significantly explain the sustainability on the buildings. How satisfied are you with the sustainability of the building = 3.991 + 0.129 (Lighting) + 0.220(Indoor environmental quality) + 0.243 (Cost) + 0.270 (Spatial) The four components are moderate predictors of the sustainability of the buildings. The occupants are more satisfied with the spatial of the buildings but less with the lighting. The results suggest that additional satisfaction factors are required (Tables 19, 20, 21).

5.3 Conclusion and recommendations to the housing industry and government

This research has explored and investigated the satisfaction of certified residential green buildings. Whilst there is a plethora of research on green buildings, only scanty research has been conducted on the performance of the green residential buildings. Whilst the green rating tools are very necessary to improve building performance for the design and construction to implement green buildings, it is crucial to substantiate the effectiveness of the green rating tools to provide inputs to the construction of the green buildings. It is impressive that the buildings are meeting up with the sustainability functions. The government needs to play multiple roles through the various ministries, agencies, and departments, regulating the housing policies and providing an enabling environment for private developers. This is because the housing market has not matured to the extent that the government can shift its roles totally to that of an enabler only.

While this research provide insight on the occupants' satisfaction green building, the research has some limitation. For instance this study did not cover all the various 6 phases in the GBI's Assessment Criteria for the residential buildings. Thus, future research may extend this research by covering other criteria, notably the Sustainable Site Planning & Management (SM) and Material and Resources (MR) that impact on the site and construction phases of the buildings. This research did not focus on the design aspect of the building process, but rather on the operational aspect. In other words, the research was operational oriented. The aim of this research was to address the almost total lack of research evidence on quantitative satisfaction factors for certified green residential buildings especially in a country like Malaysia. However, it is recommended to consider neighbourhoods factors in framing green residential buildings. Neighbourhoods or community is essential part of a sustainable city. Indeed, a sustainable way of living should effortlessly derive from the way we design our neighbourhoods. Therefore, understanding the design of community scale developments is important in moving towards more sustainable cities. To be inclusive, there may be the need to move towards neighbourhood scale assessments.

The first practical implication of this research is that it serves as a reference to the designers and developers of green buildings. This is very imperative, considering that other comparative study focused on non-residential buildings. A second strategic practical implication of the research is derived from the finding on the conspicuous lack of homeowners' involvement in the certification process. A certain percentage of the scores should be allocated to the 'experience' of the users in the building. An 'eco- audit' of the findings would expose possible areas for improvements for the buildings. However, it is imperative that homeowners are involved in the certification for ontological reasons. This will imply delaying the final certifications until during occupancy, however. A third implication of this research is that the maintenance management of the green building requires systemic consideration. This is evidence stems from the research's findings. Although conducting the POE is allocated credit under the GBI assessment, it only accounts for 1%. Furthermore,

Table 19 Model summary

Model	R	R Square	Adjusted R square	SE of the estimate
1	0.633	0.400	0.379	0.552

Table 20 ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	22.823	4	5.706	18.703	0.000
	Residual	34.169	112	0.305		
	Total	56.991	116			

Table 21 Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
1	(Constant)	3.991	0.051		78.166	0.000
	Lighting	0.129	0.051	0.183	2.506	0.014
	Indoor environmental quality	0.220	0.051	0.314	4.294	0.000
	Cost	0.243	0.051	0.346	4.730	0.000
	Spatial	0.270	0.051	0.385	5.266	0.000

it only requires the developer to show commitment to conduct the POE within 12 months after the issuance of the Certificate of Completion and Compliance (GBI, 2013). For ontological and epistemology reasons, this is greatly inadequate. 1% is too small for the POE considering the importance of the occupants' satisfaction with the building performance (Al horr et al., 2016). For ontological reasons, 10% or more may be required. This is because, about 10% of household income are spent s for maintenance annually (Department of Statistics Malaysia, 2020). Furthermore, showing commitment to conduct the POE is flawed. Final certification should not be awarded until after the POE, and the POE should be conducted by the GBI evaluators. In the 'value-based[2]'rating tool certification, home occupants play active roles in building performance. Certifications should not be awarded until the building is 'experienced' by the occupants for a period of 12 months or more. The maintenance cost is high relative to maintenance of the conventional buildings. It has been argued that green buildings should demand less maintenance. Overtly, the findings create an opportunity to improve the energy efficiency of the buildings, the indoor air quality, and the acoustic properties in the building and provide feed-forward information to propose new residential green buildings. The procedure adopted to cluster the satisfaction factors offers a valid approach to effective decision making. The findings create an opportunity to improve the energy efficiency of the buildings, the indoor air quality, and the acoustic

[2] User and environmental centred rating tool.

properties in the building and provide feed forward information to propose new residential green buildings. Tangentially, it shows that the maintenance cost of green buildings is still high. This is a strategic aspect in the green building because both the green concept and maintenance have a similar purpose (Wood, 2006 and Sherwin, 2000).

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