56.Hou, H., Lai, J.H.K. and Edwards, D. (2020), Gap theory based post-occupancy evaluation (GTbPOE) of dormitory building performance: a case study and a comparative analysis, Building and Environment (https://doi.org/10.1016/j.buildenv.2020.107312)

Gap theory based post-occupancy evaluation (GTbPOE) of dormitory building performance: a case study and a comparative analysis

Huiying (Cynthia) Hou [1], Joseph H.K. Lai [2], David Edwards [3]

[1] Faculty of Architecture, Delft University of Technology
(email: H.Hou@tudelft.nl)
[2] Department of Building Services Engineering, The Hong Kong Polytechnic University
(email: bejlai@polyu.edu.hk)
[3] School of Engineering and the Built Environment, Birmingham City University
(email: drdavidedwards@aol.com)

Abstract

Student housing significantly influences the quality and competitiveness of the university education environment. Whereas the traditional post-occupancy evaluations (POEs) of buildings have typically focussed on investigating users' satisfaction, an earlier study developed the gap theory based post-occupancy evaluation (GTbPOE) method, by which both the users' expectation and satisfaction (viz. performance gap) of a university dormitory were investigated. To validate the applicability of the GTbPOE method, further research was undertaken to evaluate the building performance of another dormitory. Using face-to-face interviews, responses of 104 dormitory users were collected, of which the relative importance ratings of six essential aspects (namely: visual comfort, thermal comfort, aural comfort, fire safety, hygiene, and communication via information technology) were analyzed via the Analytic Hierarchy Process (AHP). A series of gap analyses on the users' expectation and satisfaction levels corroborated the existence of the adaptation effect on the users' perception: that is, the longer the stay, the smaller the performance gap. A comparative analysis on the findings between the two dormitories - one from the earlier study and the other from the present study - further demonstrated the usefulness of the GTbPOE method in benchmarking building performance. Adoption of this method in future POE studies will enable reliable identification of any shortcoming in building performance and hence, can form the basis for improvement measures to augment the performance of buildings within the built environment.

Keywords: Adaptation; AHP; POE; perception; student; university; user

1. Introduction

Occupants' satisfaction with the performance of their buildings reflects the quality of design, construction, operation and management of the facilities serving the buildings. In the higher education sector, student housing provisions and operations have a significant influence on the competitiveness of the education environment (Calcara, 1999; Hassanain, 2008; Kärnä and Julin, 2015). Dormitory quality is an important factor that affects students' decisions when choosing which university to study at. University students often regard dormitories as their second home and thus, project a high level of expectation of this dwelling.

With campus assets becoming drivers of innovation (Magdaniel et al., 2018), research on campus development and management is bourgeoning. In most public universities, the student dormitory is a quintessentially important element of campus facilities that impacts upon (positively or negatively) the overall quality of campus environment. However, the design and service quality of student dormitories are enigmatically under-researched. As student accommodations have become increasingly global assets, and investment in the student housing market has substantially increased (Knight Frank, 2019), identifying user preferences will facilitate optimal building design and management, thereby contributing to future optimising of dormitory development.

In built environment studies, a satisfaction survey is commonly used to solicit users' perceptions of building performance. However, the application of this approach to general post-occupancy evaluation (POE) studies lacks precision in revealing the building's actual performance if factors such as background and type of the building's users are not considered (Hinks, 2004). Recognizing the limitation of this traditional approach, Lai (2013) developed a gap theory based post-occupancy evaluation (GTbPOE) method, by which the responses from individual building users are tested; only those drawn from consistent judgments of the users are taken for further analysis, thus ensuring the reliability of the result of analysis. In the study of Lai (2013), users' expectation and satisfaction levels of six building performance aspects of a dormitory were investigated (namely: visual comfort, thermal comfort, aural comfort, fire safety, hygiene, and communication via information technology). A major research finding was the existence of the adaptation effect (Rose et al., 1996), i.e., the longer users stayed in the dormitory, the narrower the gap between their expectation and satisfaction levels.

Validation of the applicability of the GTbPOE method to another building was not done before. Therefore, further research was pursued in this present work via a case study conducted on another dormitory. The findings were compared with the previous work of Lai (2013); in particular, whether the adaptation effect exists among dormitory users. Recounting the tasks and outcomes of this further research, this paper is structured as follows. First, it reviews the key pieces of relevant literature to contextualise the study within the wider body of knowledge. Second, it explains the data collection method used, the types and extent of data collected, and the steps taken to analyze the data. Third, the data analyses findings are reported upon. Fourth, the findings are discussed and the implications highlighted. Finally, the paper ends with conclusions drawn from the preceding sections, which include suggestions for future work.

2. Review of key issues

2.1 Post-occupancy evaluation in education environment

Service delivery is largely a human-centric activity and occupancy experience in buildings is service-driven (Lai and Yik, 2011). According to marketing and consumer behaviour theories, building users can be considered as consumers of the built environment (Zalejska-Jonsson and Wilhelmsson, 2013). While traditional building performance research has tended to have an engineering focus, contemporary studies have increasingly extended to cover human behaviour and perception of building performance, which are useful feedback information for facilities management (Amaratunga and Baldry, 2002; Lavy et al., 2010; Nimako and Bondinuba, 2013; Li, Proese and Brager, 2018).

Both objective and subjective evaluation criteria can be incorporated into POEs (Cho et al., 2011). Users' perception towards building performance reflects the quality of the interaction between human activities and the built environment (Shaw and Haynes, 2004; Jamaludin et al., 2014; Park et al., 2019; Pastore and Andersen, 2019; Roberts et al., 2019; Du, Zhang and Lv, 2020; Li and Liu, 2020); user satisfaction, which is subject to the influence of personal attributes (Lai, 2014), is regarded as an important factor in building performance evaluation (Zhang, 2019). Many studies have proved that a poor built environment negatively affects human health and work productivity, and vice versa (Frontczak and Wargocki, 2011; Agha-Hossein et al., 2013).

Focusing on the occupancy phase of a building's life cycle, POEs value the feedbacks from building users (Hassanain, 2008; Li et al., 2018). With the adoption of service quality measurement tools (Council and National Research Council, 2002), studies have shed light on users' perception of the performance of buildings or their facilities. Based on service users' perception, service quality measurement is revealed by the subjective response of people to objects; mechanistic quality of an object or feature of a thing is not the focus of service quality measurement (Parasuraman et al., 1985; Nelson and Nelson, 1995). With various approaches adopted in past POE studies (Roberts et al., 2019), the recent work of Zhang (2019) adopts an applied and integrated cross-field customer satisfaction index (CSI) theory with the post-occupancy evaluation theory to analyze library indoor environment in Chinese universities.

2.2 Gap theory perspective

Traditional user satisfaction surveys are designed to measure building users' perceived quality regarding the performance of building facilities, with the users typically asked to indicate their levels of satisfaction with specific building performance attributes listed in the surveys. This approach has been criticized as inaccurate in performance measurement because satisfaction is a subjective feeling and such an individual judgment is usually influenced by the subject's personal attributes, and axiological beliefs that are often formed by prior encounters, and so on.

To provide a more accurate approach to measuring users' perception of service quality, the gap theory was developed in the field of service marketing. According to this theory, perceived service quality is viewed as "the degree and direction of discrepancy between customers' perceptions and expectations." Recognizing the importance of understanding service users' perception of a service before and after the consumption (Zeithaml et al., 1990), the users' perception before the consumption is framed as user expectation and it serves as a reference point based upon which the actual service performance is judged.

Grounded on the gap theory, a model called "SERVQUAL" was developed for measuring service quality (Parasuraman et al., 1985). Over the past few decades, numerous studies have adopted this model to measure service quality in sectors such as banking (Avkiran, 1994;

Lassar et al., 2000; Newman, 2001; Karatepe et al., 2005; Kant and Jaiswal, 2017), education (Athiyaman, 1997; Hasan et al., 2008; Nadiri et al., 2009; Abidin, 2015), tourism (Juwaheer, 2004; Kouthouris and Alexandris, 2005; Chang, 2009; Chand, 2010; Lee et al., 2016) and retail (Carman, 1990; Finn and Lamb Jr, 1991; Dabholkar et al., 1996; Ekinci, 2001; Naik et al., 2010). The SERVQUAL model evaluates five attributes of service quality, namely: 1) tangibles, 2) reliability, 3) responsiveness, 4) assurance, and 5) empathy. Among the five attributes, tangibles refer to "physical facilities, equipment and appearance of personnel" while reliability, responsiveness, assurance and empathy are used to describe the quality of design, delivery process and service providers (Darren, 2008). The five attributes suggest that service provision is either human based or facilities based, and modern service is provided on a bundle basis. In other words, when customers or service users assess a service scenario, their service experience is reinforced by a bundle of services, not only relying on one specific type of service.

Likewise, building users' experience relies on more than one type of facilities service. Inspired by the gap theory, Lai (2013) developed the GTbPOE method for conducting a post-occupancy evaluation on a student hostel. By measuring the "gap" between students' expectation and satisfaction levels of six aspects, the performance of the hostel was investigated. This work serves as a keystone for using the gap theory approach to evaluate occupants' perception of building performance.

2.3 Building performance aspects of student dormitories

Student dormitories, as one type of student accommodation, are different from privately owned residential apartments. Student dormitories provide not merely space, but also a series of facilities and services that enable students to adapt to campus life (Adewunmi et al., 2011; Nurul Ulyani et al., 2011). While architects strive to integrate social elements in student dormitory design by creating more social space for students (Kim et al., 2018), scant research has delved into the technical efficiency of dormitory design and students' perception towards it.

Among the studies on student accommodations, Amole (2009) evaluated student housing satisfaction based on 12 student dormitory performance factors: bedroom social and place qualities, dormitory design, social densities in the dormitory, storage and room furnishing, floor levels, dormitory maintenance, conveniences, dormitory facilities, laundry, balcony, dormitory management and location. These factors focus on the function of specific space used to support certain type of human activities. Besides, Nimako and Bondinuba (2013) regarded student accommodation as one type of service product and defined student accommodation quality (SAQ) as "the extent to which accommodation services meets students' needs and expectation." They (*ibid*) raised the concept of core service in students' dormitory accommodation and argued that bedroom, toilet and bath facilities are basic facilities to provide core services while other facilities are categorised under facilitating services (e.g. utility facilities, security, rules and regulation) and supporting services (value added services, such as junior common room, entertainment hall/facility, reading room, library, ease of transportation to lectures and garage).

Hassanain (2008) categorised student housing facilities performance into two dichotomous groups namely: technical performance, and functional performance. Technical performance covers thermal comfort, acoustical comfort, visual comfort, indoor air quality and fire safety. Functional performance are reflected by interior and exterior finish systems, room layout and furniture quality, support service, efficiency of circulation and proximity to other facilities on campus. In this present study, a survey was conducted on university students to investigate their level of satisfaction with the performance attributes of student housing facilities. With the technical performance elements of Hassanian (2008) taken into account, Lai (2013) identified six key performance aspects of a student hostel through a walk-through visit and a focus group meeting with the users there. Indoor air quality was not included as a key performance aspect because of two reasons. First, most dormitories in Hong Kong, including the one studied in Lai (2013) and the current one, are equipped with window-type air-conditioners instead of central air-conditioning units, allowing the users to have individual control in their own rooms. Second, all the rooms are provided with openable windows; the users can open the windows for natural ventilation. Rather than indoor air quality, thermal comfort was considered by the focus group as a key performance aspect. Adopting the same set of key performance aspects as that of Lai (2013) also allows cross comparison to be made between the findings of the two studies. The six performance aspects (and associated facilities) are:

1) visual comfort (natural and artificial visual facilities);
2) thermal comfort (natural ventilation and mechanical ventilation/air-conditioning facilities);
3) aural comfort (exterior and interior noise control facilities);
4) fire safety (passive and active protection facilities);
5) hygiene (flush water supply and drainage discharge facilities); and
6) communication via information technology (hardware and user interface facilities).

3. Method and data

3.1 The selected dormitory

This study adopted the approach of Lai (2013), using the GTbPOE method to investigate the users' perception of a university dormitory's performance in Hong Kong. In this study, a dormitory building at a different university in Hong Kong was selected. The selected dormitory building, labelled as "Dormitory L", was built in 1993. It provides 293 dormitory places: 160 for male students and 133 for female students. The building is 7-storey high, with most of the areas (3-7/F) designated as student accommodations. The usages of the other areas include: warden suites (2/F), tutor rooms, study areas (3-7F), dining areas (3-7/F), shared bathrooms and toilets (3-7/F), and reception and lobbies (G/F).

Figure 1 shows a typical floor plan (3/F) of the dormitory building. There are three types of student rooms: double rooms for two persons, triple room for three persons and quadruple room for four persons.

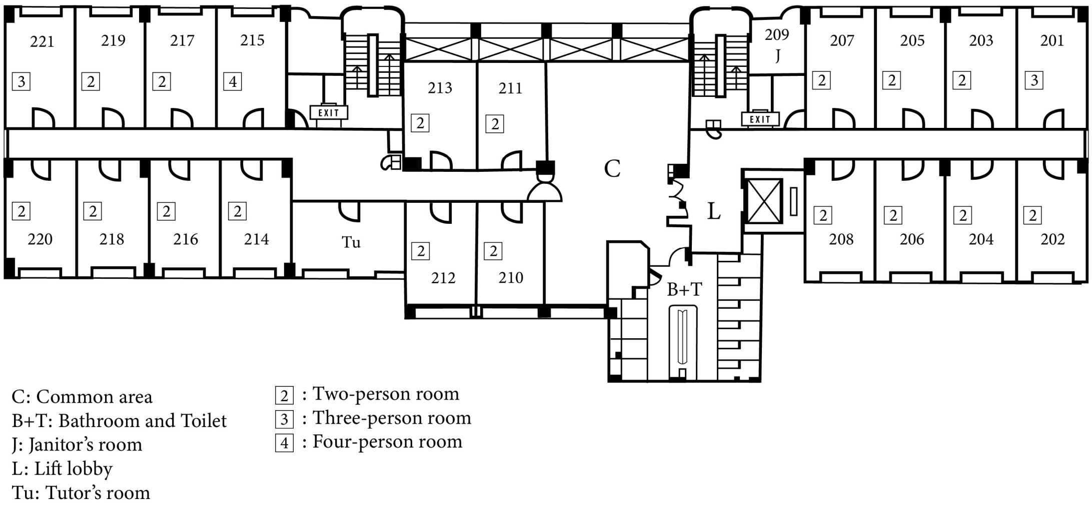


Figure 1: Typical floor plan of Dormitory L

3.2 The study process

Figure 2 represents a flowchart depicting the study process of this research project. After a review of relevant literature (as reported above), an appropriate POE approach and evaluation framework (grounded on the work of Lai (2013)) was identified. Subsequent to the selection of a student dormitory for the case study, a questionnaire was designed for an interview survey of the dormitory users. Data collected was processed in two stages: first, the users' perception of the importance levels of the six building performance aspects were determined by the Analytic Hierarchy Process (AHP) of Saaty (1990a); second, the difference between the users' perceived building performance levels (expectation and satisfaction) were analyzed. The research findings were then compared with the counterparts of Lai (2013), followed by drawing results and conclusions.

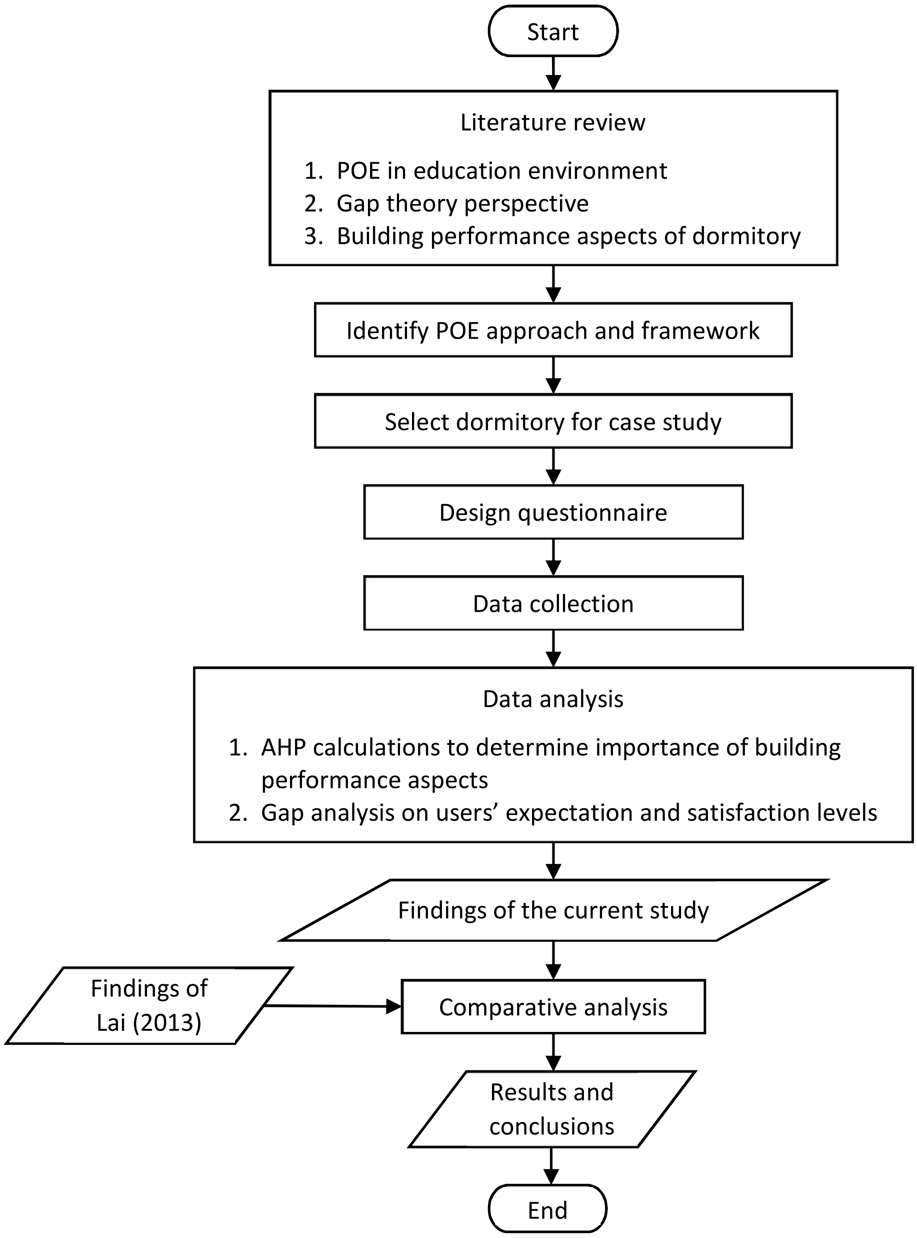


Figure 2: Flowchart of the study process

3.3 The questionnaire survey

A structured questionnaire was designed to collect responses from the dormitory users during the interview survey. In order to obtain reliable responses, face-to-face interviews were held. The research team approached the users on a random basis inside the dormitory building. The background and purpose of the study was explained to each of the interviewees and they were informed that their participation is entirely voluntary. The questionnaire begins with enquiries on the students' personal particulars and boarding information, including their gender, type of room that they reside in the dormitory, length of residence, typical period residing in the dormitory and fraction of time they stayed in their room. The second part of the questionnaire invites students to indicate their levels of expectation and satisfaction on each building performance aspect based on a 7-point scale (1: extremely low; 2: very low; 3: slightly low; 4: fair; 5: slightly high; 6: very high; and 7: extremely high). The third part asks them to indicate their perceived relative importance between pairs of the building performance aspects on a 9-point scale. The design of pairwise comparison is elaborated in section 3.4.

Each of the interviews took approximately 10 minutes to complete and the interviewees' responses were recorded on printed survey forms. The survey period was from June 2018 to February 2019. A total of 104 dormitory users voluntarily participated in the questionnaire survey. 79 of them were residents each with a registered dormitory place and the remainder were visitors.

3.4 Stated preference method and AHP calculations

A stated preference method was adopted in this study and required participants to rank or judge attributes or to choose from hypothetical choice sets (Adamowicz et al., 1994). This method allows for the development of choice sets of the six building performance aspects for the dormitory users to rank. Instead of ranking the individual importance of each of the performance aspects, the users were asked to make pairwise comparisons of the six aspects.

The AHP method of Saaty (1990a; b), which provides a fundamental scale of relative magnitudes expressed in a dominance unit to represent judgments in the form of paired comparisons, allows understanding of individual respondent's explicit preference for the importance of the items under consideration. Typically, the method involves three steps: 1) construction of hierarchy; 2) pairwise comparisons and weight calculations; and 3) verification of consistency (Wong and Li, 2008; Darko et al., 2019).

Step 1: Construction of hierarchy

The AHP method was used to solicit the dormitory users' stated preference between pairs of the aspects of building performance aspects; the hierarchy of the aspects is as shown in Figure 3.

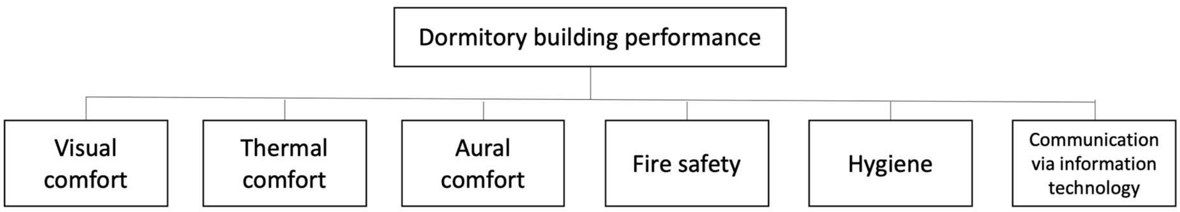


Figure 3. Hierarchy of the building performance aspects

Step 2: Pairwise comparisons and weight calculations

Similar to the interview process in earlier studies of this kind (Lai and Yik, 2009; Lai and Choi, 2015; Liu et al., 2018; Leccese et al., 2020), the participants were asked to rate the relative importance of each pair of the aspects. The relative importance of the six building performance aspects was rated using the nine-point scale proposed by Saaty (1980): the levels of the perceived importance include: equal (1), moderate (3), strong (5), very strong (7), and most (9); the intermediate values between two adjacent performance aspects are represented by 2, 4, 6, and 8 (see Figure 4).

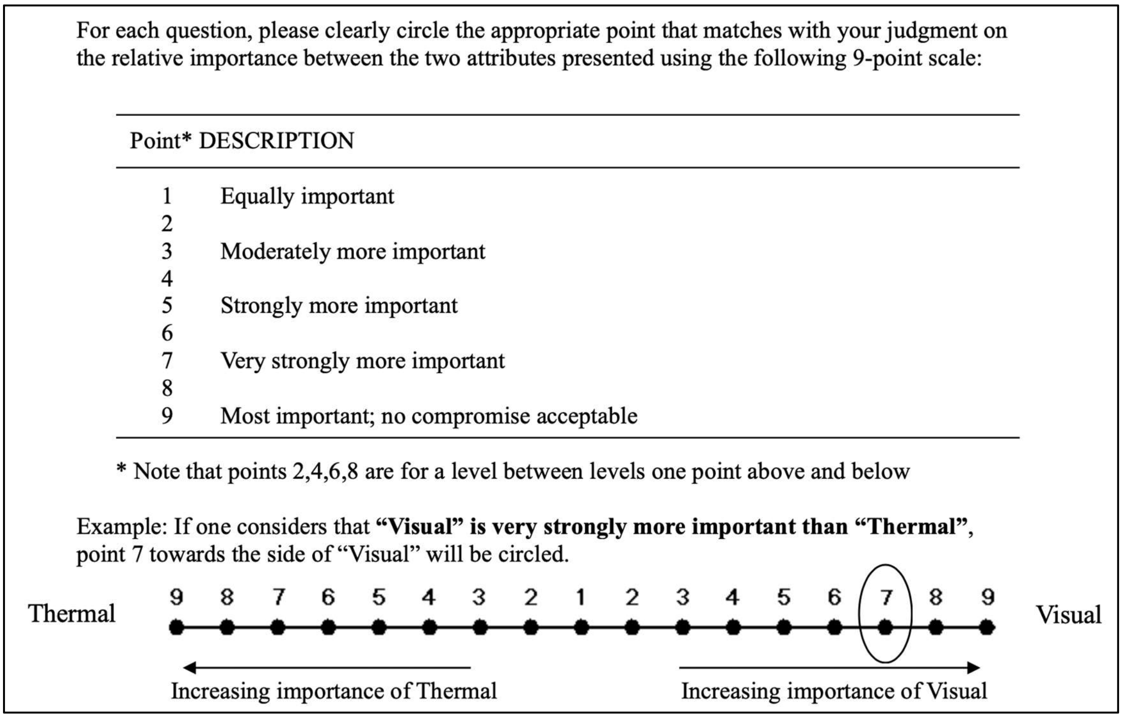


Figure 4: Example of response on the 9-point relative importance scale

With six aspects under investigation, 15 pairwise comparisons were made by each student resident. The result of the 15 comparisons of each user were transformed into a paired comparison matrix (Eq.1 and 2). A normalisation procedure was applied to obtain the normalised matrices for each set of pairwise comparison results. The priorities obtained from the comparison was used to weigh the priorities of the rated performance aspects. The weight of each aspect was calculated using Eq. (3).

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & a_{23} & \dots & a_{2n} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \frac{1}{a_{3n}} & \dots & a_{4n} \end{bmatrix}; \quad (1)$$

$$a^{*}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}; \quad (2)$$

$$w_i = \frac{\sum_{j=1}^{n} a^{*}_{ij}}{n}; \quad (3)$$

where
a_{ij} = matrix elements (i,j = 1, 2, 3, … n);
n = number of aspects (in this study, n = 6)

Step 3: Verification of consistency

In order to eliminate the possible inconsistency revealed in the criterial weights through the computation of consistency level of each matrix, verifications were made on the consistency of the responses. The computation of consistency ratio (CR) requires determination of the eigenvalue (λ_{max}) (Eq. 4, 5, and 6) and the consistency index (CI) (Eq.7). The CR of each set of responses was computed using Eq.8, where the random index (RI) is 1.24 for a 6 x 6 matrix (Saaty, 1990a; b). The CR value was then checked against the CR limit, which is 0.1 (Saaty, 2000). Appendix 1 shows an example of how the consistency check was conducted.

$$D = [a_{ij}]_{nxn}\ [W_i]_{nx1} = [d_i]_{nx1}\ ; \qquad (4)$$

$$E = \frac{d_i}{w_i}\ ; \qquad (5)$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} E_i}{n}\ ; \qquad (6)$$

$$CI = \frac{\lambda_{max} - n}{n-1}\ ; \qquad (7)$$

$$CR = \frac{CI}{RI}\ ; \qquad (8)$$

3.5 Gap theory based analysis

Analysis of user perception of building performance needs to consider the fact that variation of user service perception may exist and change for the same individual on pre- and post-occupancy views. Following the analysis method of Lai (2013), a user expectation-satisfaction gap (viz. E-S gap) was determined using the interview data. First, the E-S gap of each user was measured based on the user's expectation and satisfaction levels given for each aspect, as represented by Eq. (9), where a (1, 2, 3, 4, 5 or 6) is assigned to the a^{th} aspect of building performance being rated. Eq. (10) was used to calculate the mean E-S gap of each of the six aspects.

Second, based on the adaptation theory (Rose et al., 1996; Lai, 2013), the E-S gap will narrow as the time of stay in the dormitory increases. This theory is based on the assumption that a user tends to feel more accustomed to the condition of the built environment as the user spends a longer time in it. This assumption was tested in this study as the respondents, who were randomly sampled for the interview survey, were with different residence periods: the users could be different in their moving in/out time, frequency of stay, duration of stay per week/month etc. Considering this important residential characteristic, the assumption that the E-S gap narrows with the users' occupancy period was tested. For this purpose, a residence index, which is the ratio of a user's residence period to the maximum residence period, was calculated (Eq. (12)); the residence period of each user was computed by Eq. (11), which takes into account number of months, weeks per month, days per week, hours per day, and fraction of time staying in the dormitory during a typical day.

Third, Lai (2013) constructed a conceptual model that integrated the building performance gap and adaptation effect. The model is composed of two dimensions: E-S gap (y axis) against residence index (x axis). Given that the minimum and maximum levels of expectation/satisfaction are 1 and 7 respectively, the E-S gap values range from -6 to 6. With the maximum value of residence index being 1 and two lines (upper bound and lower bound) created by Eq. (13) and Eq. (14), a triangular envelope is formed with x-y coordinates (0, 6), (0, -6) and (1,0).

Fourth, the calculated results of the present study, including E-S gaps and residence indices of individual respondents, were plotted against the above-mentioned envelope. This was done for each of the six building performance aspects in order to reveal any time-related perception changes of the dormitory users.

$$G_{i,a} = S_{i,a} - E_{i,a} \quad (9)$$

$$\overline{G_{a,g}} = \frac{\sum_{i-1}^{n_g}(S_{i,a} - E_{i,a})}{n_g} \quad (10)$$

$$P_i = M_i \times W_m \times D_i \times H_i \times R_i \quad (11)$$

$$RI_i = \frac{P_i}{P_{max}} \quad (12)$$

$$G_{a,L} = 6RI - 6 \quad (13)$$

$$G_{a,U} = -6RI + 6 \quad (14)$$

where
D_i = number of days per week of the i^{th} user staying in the dormitory
$E_{i,a}$ = expectation rating (1, 2, ... , 7) given by the i^{th} user for the a^{th} aspect
G_a = E-S gap of the a^{th} aspect
$G_{a,g}$ = E-S gap of the a^{th} aspect associated with group g
$G_{i,a}$ = E-S gap pertaining to the i^{th} user for the a^{th} aspect
H_i = number of hours per day of the i^{th} user staying in the dormitory
M_i = number of months of the i^{th} user staying in the dormitory
n_g = number of samples of group g (g: A, B and C for room types A, B and C respectively; F: female; M: male)
P_i = residence period of the i^{th} user
P_{max} = maximum residence period
R_i = fraction of time of the i^{th} user staying in his/her room during a typical day
RI_i = residence index of the i^{th} user
$S_{i,a}$ = satisfaction rating (1, 2, ... , 7) given by the i^{th} user for the a^{th} aspect
W_m = number of weeks per month (average = 4.33)

3.6 Comparison between two cases

To understand whether, and to what degree, there exists any difference between the performances of the dormitory of the present case study and the one of Lai (2013), comparisons were made between the levels of expectation and satisfaction, and the E-S gaps of the two dormitories. Such a series of comparisons were made for all the six performance aspects.

4. Findings

4.1 Importance weights and ranks of the rated aspects

The relative importance ratings given by the interviewees on the six performance aspects were processed by the AHP method. Of all the 104 samples, 49 passed the consistency check (CR ≤

0.1). This sample size is not small when compared to those in other studies using the AHP method, e.g. Ho et al. (2008) conducted two AHP surveys focusing on building health and building safety with 35 and 23 participants respectively; Wong and Li (2008) evaluated the comparability of the perceived selection criteria based on 10 construction experts; Alshamrani and Alshibani (2020) developed an automated decision system to assist school districts in selecting the best envelope and structural systems based on the responses of 15 experts. Note also that the AHP method does not always require a statistically significant sample size (Baby, 2013). The CR value is not determined by the sample size but the items being compared (hence the comparison matrix size): the more pairwise comparisons are made, the more difficult to achieve a CR < 0.1 (Wong and Li, 2008)

The usable sample comprises 40 dormitory residents and 9 visitors. The overall usable rate (consistency rate) is 47%, with the residents and visitors proportions being 51% and 36% respectively (Table 1). Although the consistency check process removed a significant amount of the collected samples (53%), it can ensure the quality of the data used in the subsequent analysis.

Table 1. Classifications of the samples

	Overall	**Resident**	**Visitor**
Total sample	104	79	25
Usable sample (CR ≤ 0.1)	49	40	9
Non-usable sample (CR > 0.1)	55	39	16
% Usable sample	47	51	36

The AHP weights of the six building performance aspects of the usable samples were averaged to yield the mean importance weights of the aspects, and the margin of error (Er) of each importance weight was calculated based on a 95% level of confidence under the Student's *t*-distribution. The results indicate that the *hygiene* aspect (0.3195) was weighed by the residents as the most important, followed by *thermal*: 0.1661, *aural*: 0.1633, *visual*: 0.1474, *communication*: 0.1048, and *fire*: 0.0988 (Table 2). Visitors of the dormitory also weighed *hygiene* to be the most important (highest score: 0.3095), while *fire* was regarded as the least important (lowest score: 0.0688). The importance rankings between female and male users (including both residents and visitors) show similar results (Table 3). Both the female and male users weighed *hygiene* as the most important building performance aspect (female: 0.3055; male: 0.3427) and *fire* as the least important (female: 0.0864; male: 0.0993).

Table 2: AHP weights and ranks between residents and visitors

Aspect	**Resident (n=40)**			**Visitor (n=9)**		
	Weight	**Er**	**Rank**	**Weight**	**Er**	**Rank**
Visual	0.1474	0.0214	4	0.1732	0.0316	3
Thermal	0.1661	0.0294	2	0.1593	0.0433	4
Aural	0.1633	0.0225	3	0.1885	0.0446	2
Fire	0.0988	0.0276	6	0.0688	0.0127	6
Hygiene	0.3195	0.0385	1	0.3095	0.0941	1
Communication	0.1048	0.0148	5	0.1008	0.0185	5

Table 3: AHP weights and ranks between female and male users

Aspect	Female (n=28)			Male (n=21)		
	Weight	Er	Rank	Weight	Er	Rank
Visual	0.1549	0.0267	4	0.1467	0.0008	3
Thermal	0.1656	0.0357	3	0.1565	0.0015	2
Aural	0.1875	0.0295	2	0.1431	0.0008	4
Fire	0.0864	0.0299	6	0.0993	0.0016	6
Hygiene	0.3055	0.0530	1	0.3427	0.0027	1
Communication	0.1001	0.0172	5	0.1117	0.0004	5

An intriguing finding is that although fire safety is of priority in building design, *fire* was rated as the least important aspect. A plausible reason for this is that the dormitory was recently renovated; the users regarded the new installations as reliable, especially in terms of fire safety. Another plausible explanation may be that *fire* is only perceived as important in an emergency situation – such situations are thankfully rare.

Another noteworthy finding is that the users rated *hygiene* as the most important aspect. In fact, people in Hong Kong, including the younger generation (typically Generation Z) sampled in this study, have developed a strong sense on hygiene in the built environment since the SARS epidemic outbreak in 2003 (let alone the recent global corona virus pandemic). The fact that the Hong Kong government has devoted considerable resources to enhancing public awareness of hygiene could be a factor added to the high importance rating of the *hygiene* aspect.

4.2 Expectation and satisfaction levels

Tables 4 and 5 show the overall and sub-group results, including the minimum, maximum and mean values of user expectation and satisfaction levels, of the six building performance aspects. Table 4 shows that *visual* and *hygiene* received relatively high scores in expectation and satisfaction, whereas the counterparts of the *fire* aspect were rated relatively low.

Table 4: Overall levels of expectation and satisfaction

Aspect	Expectation			Satisfaction		
	Min.	Max.	Mean	Min.	Max.	Mean
Visual	4	7	6.04	4	7	6.10
Thermal	4	7	5.84	4	7	5.76
Aural	4	7	6.13	3	7	5.53
Fire	4	7	5.64	3	7	4.98
Hygiene	4	7	6.19	3	7	6.13
Communication	4	7	5.93	4	7	5.06

Table 5: Expectation and satisfaction levels of the female and male groups

Aspect	Expectation		Satisfaction	
	Male	Female	Male	Female
Visual	6.039 (3)	6.038 (3)	6.098 (2)	6.096 (2)
Thermal	5.843 (5)	5.837 (5)	5.775 (3)	5.760 (3)
Aural	6.147 (2)	6.135 (2)	5.549 (4)	5.529 (4)
Fire	5.657 (6)	5.644 (6)	5.000 (6)	4.981 (6)
Hygiene	6.186 (1)	6.192 (1)	6.118 (1)	6.125 (1)
Communication	5.931 (4)	5.933 (4)	5.049 (5)	5.058 (5)

Note: ranks are parenthesized

Table 5 further reports the user expectation and satisfaction by dividing the samples into the male and female groups. The results exhibit a high consistency in the ranking order between the two groups. For example, *hygiene* was highly and consistently rated by the male and female users in terms of expectation and satisfaction. *Aural* was a highly rated aspect in terms of expectation (6.135; rank 2) but was given a low score in satisfaction (5.549; rank 4).

Table 6 summarizes the sub-grouped satisfaction levels and ranks pertaining to users of different room types. The rating variations of the double room group are more diverse than those of the other room types. The ranking orders of the rated aspects, from the perspectives of the triple room and quadruple room users, are identical, although triple room is generally an option preferable to the quadruple room – as the ratings given by the triple room users for all the rated aspects, except *hygiene*, are comparatively higher.

Table 6: Satisfaction levels and ranks by room type

Aspect	Double Room		Triple Room		Quadruple Room	
	Rating	Rank	Rating	Rank	Rating	Rank
Visual	5.9259	2 [3]	6.6154	1 [1]	6.1667	1 [2]
Thermal	5.6111	3 [2]	6.2308	3 [1]	5.8333	3 [2]
Aural	4.8519	6 [3]	5.3846	5 [1]	5.1667	5 [2]
Fire	5.4444	4 [3]	5.8462	4 [1]	5.7500	4 [2]
Hygiene	5.1111	5 [1]	5.0000	6 [3]	5.0833	6 [2]
Communication	6.1481	1 [2]	6.4615	2 [1]	6.0000	2 [3]

Note: ranks across room types are in square brackets

Figure 5 shows the distribution of the overall respondents' expectation and satisfaction levels of the rated building performance aspects. Across the six aspects, the interviewees had a relatively high expectation. According to the chart on the left in Figure 5, over 45% of the interviewees indicated their expectation of all the six aspects as very high (rating = 6). For instance, over 65% of the respondents expected the performance of the *hygiene* aspect to reach the very high level or above (rating ≥ 6). The *communication* aspect was also given very high expectations: 45% of the interviewees rated it at level 6; another 45% rated it at level 7.

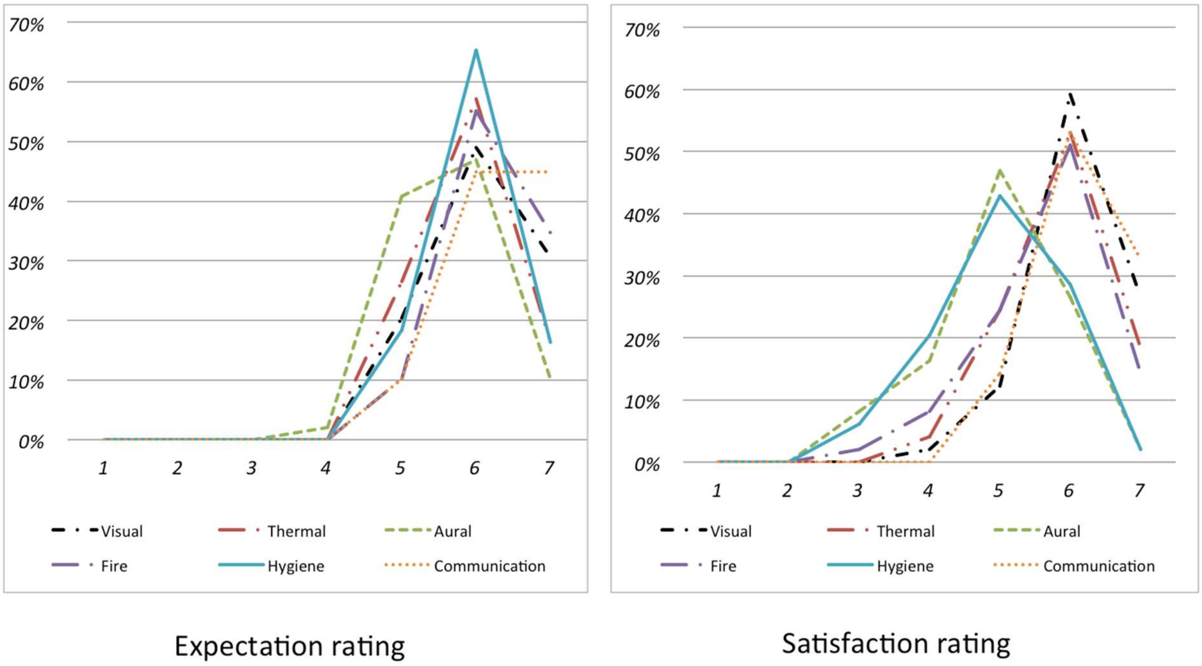


Figure 5: Distributions of expectation and *satisfaction ratings*

The right part of Figure 5 shows that the respondents were generally satisfied with the building performance of the dormitory. Among the six aspects, *visual*, *thermal*, *fire* and *communication* were the more satisfied aspects. Over half of the student residents rated these four aspects at level 6 and this satisfaction level was indicated by even 60% of the interviewees for the *visual* aspect. Besides, the peak proportions of response of *hygiene* and *aural* are lower than those of *visual*, *thermal*, *fire* and *communication*. The satisfaction level at which the peak response proportions of *hygiene* and *aural* occur is apparently lower than that of the other four aspects.

Considering both the findings of expectation and satisfaction in Figure 5, in particular, the majority (65%) of the users had a very high (rating = 6) expectation of *hygiene* while only 42% rated the satisfaction level of this aspect as slightly high (rating = 5). For the remaining aspects, the differences between the proportions of responses for the various expectation and satisfaction levels vary. Therefore, further analysis is needed to ascertain their performance gaps.

4.3 Gap analysis

4.3.1 Distribution of gap values

As mentioned earlier, the levels of expectation and satisfaction of a user may not align with each other. If the E-S gap on building performance reduces with the period that a user stays in the building, the adaptation effect exists (cf. Lai, 2013). To test whether this effect also exists in the current study, a series of gap analyses were conducted.

For the first step of the gap analyses, the gap value for each aspect, pertaining to each respondent, was calculated using Eq. 1. Then, the frequency of each gap value was determined. The frequency distributions of the gap values, as plotted in Figure 6, show that a relatively high proportion (40-50%) of the users indicated the existence of a negative performance gap (-1) in the *fire*, *hygiene* and *aural* aspects. For the other three aspects - *visual*, *thermal* and *communication*, 45%-50% of the users considered the levels of expectation and satisfaction as indifferent (i.e. zero performance gap). On the basis of these two observations, the latter three aspects outperformed the *fire*, *hygiene* and *aural* aspects.

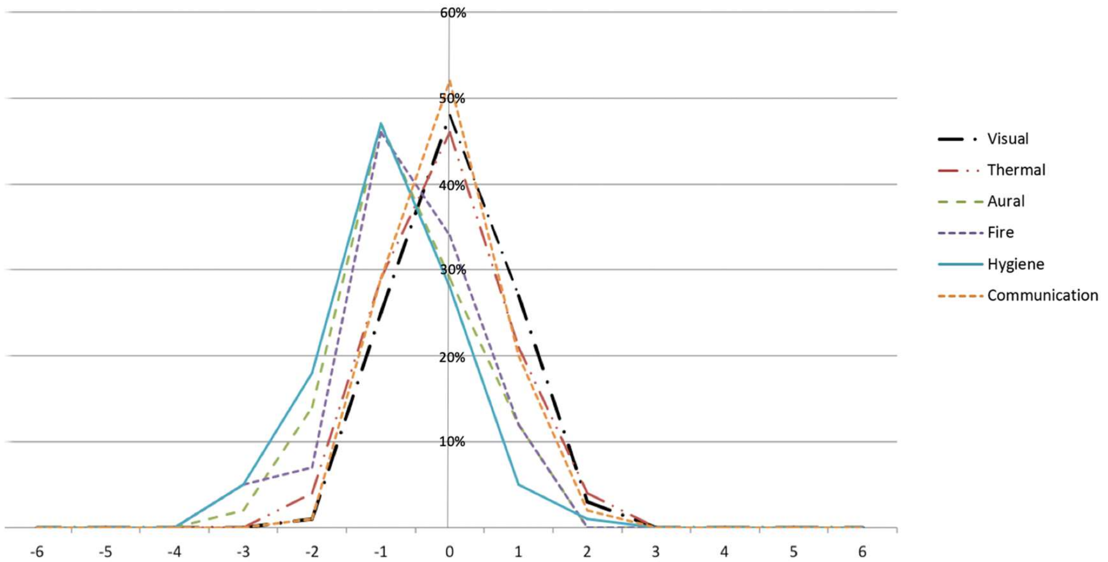


Figure 6. Distribution of expectation-satisfaction gaps

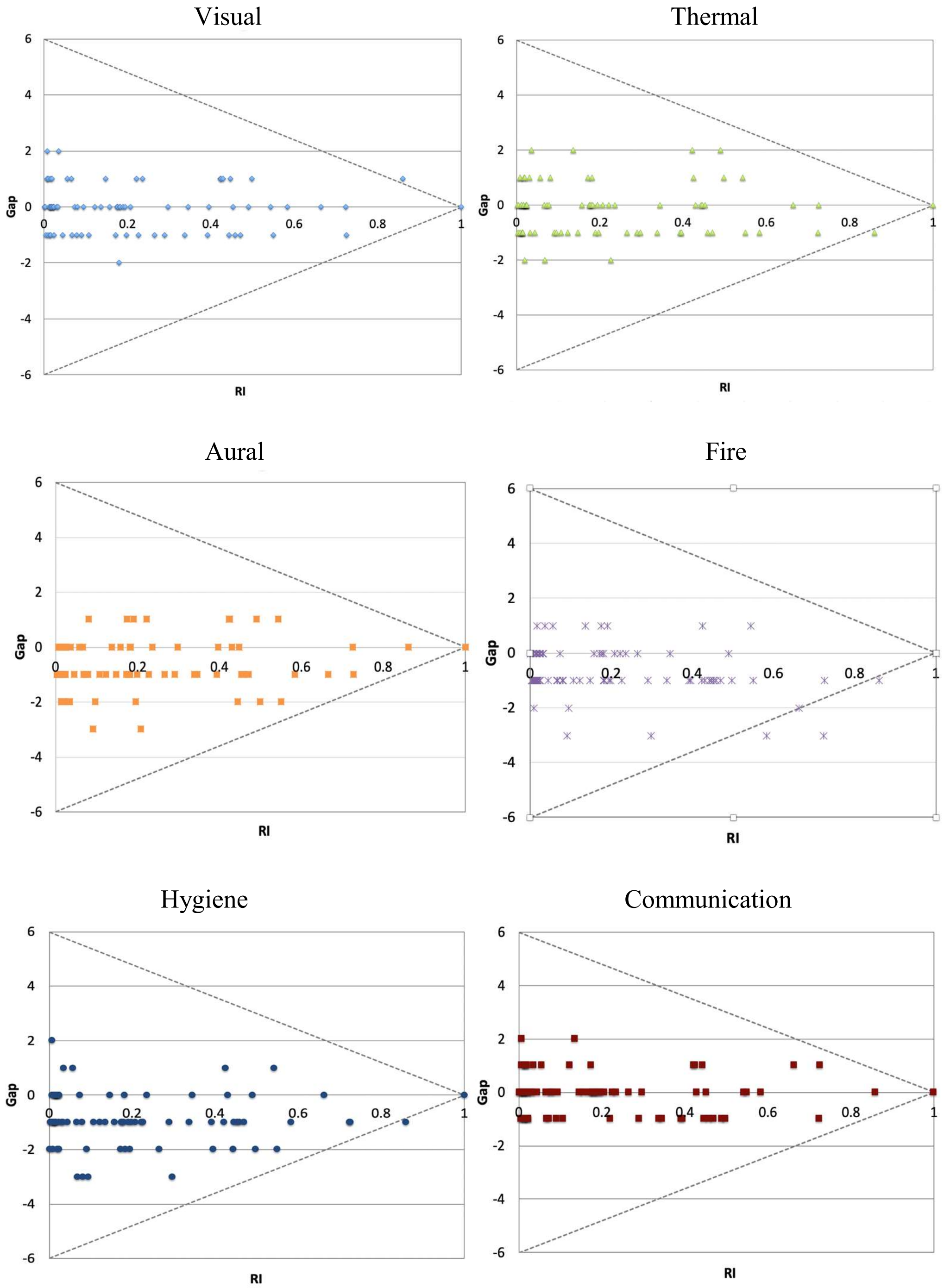
4.3.2 Residence index

The observation of certain fluctuations in the user expectation-satisfaction gaps suggests the need for further analysis of cross-sectional variations and convergence tendencies of the gaps over time. In other words, the E-S gaps of individual performance aspects need to be dissected in the time domain to show whether, or how, the adaptation effect influenced the users' responses. To this end, the second step of the gap analyses scrutinized the variation of the E-S gaps against the residence indices calculated in the foregoing section.

Figure 7 presents the patterns of the expectation and satisfaction gap points, which converge with increase in the residence index. The value of each data point was obtained by calculating the difference between the satisfaction value and the expectation value indicated by each respondent for each performance aspect (Eq. 9 and 10). In other words, each data point represents the gap value between the satisfaction and expectation levels. If the satisfaction level is larger than the expectation level, the gap value is positive (*positive gap*), and vice versa. If the satisfaction level equals the expectation level, the gap value is 0 (*zero gap*). The value of each data point can be identified by interpreting its value against the y-axis. The value of data point *i* on the x-axis reflects the value of respondent *i*'s residential index (RI_i) (Eq. 11 and 12). The larger the RI_i means the more time the *i* respondent spent in the dormitory building. The two dotted lines created for each performance aspect (using Eq. 13 and 14) form a bounded region (*gap region*) which is a mathematical manifestation of the adaptation effect (Rose et al., 1996). The shape of the bounded region depicts that users' satisfaction-expectation gaps tend to be smaller when the users spend more time in the building (Figure 7). The percentage of data points lying inside the bounded region reveals the degree of the samples influenced by the adaptation effect.

For three of the rated aspects (Table 7), more than 60% of respondents' satisfaction ratings were lower than their expectation ratings: *aural (60.8%)*, *fire (60.8%)*, and *hygiene (69.6%)*;

comparatively more of the data points fall within the negative-gap region (Figure 7). For *visual (zero gap: 48.1%)* and *communication (zero gap: 49.4%)*, nearly half of the respondents' satisfaction ratings coincide with their expectation ratings, which means that they found the performances of the two aspects optimal.



Note: Based on Eq. 13 and 14, when RI equals 0, $G_{a,L} = 6RI - 6 = -6$ while $G_{a,U} = -6RI + 6 = 6$. When RI equals 1, $G_{a,L} = 6RI - 6 = 0$ and $G_{a,U} = -6RI + 6 = 0$. Thus, three data points are generated: (0, 6), (0, -6) and (1,0). The two dotted lines for each performance aspect are created by connecting the three data points.

Figure 7. Residence indices of the six performance aspects

Table 7. Proportions of samples with different gap types

Aspect	***Bounded***	***Zero gap***	***Positive gap***	***Negative gap***
Visual	*98.7%*	*48.1%*	*22.8%*	*29.1%*
Thermal	*98.7%*	*40.5%*	*39.2%*	*20.3%*
Aural	*100%*	*29.1%*	*10.1%*	*60.8%*
Fire	*96.2%*	*29.1%*	*10.1%*	*60.8%*
Hygiene	*98.7%*	*24.1%*	*6.3%*	*69.6%*
Communication	*100%*	*49.4%*	*20.3%*	*30.3%*

4.4 Comparison between two dormitories

The E-S gap results of this study, conducted on Dormitory L, are compared to those of Lai (2013) for Dormitory P. Table 8 shows the mean values of expectation, satisfaction and performance gap for each of the six aspects between the studies. The expectation and satisfaction values of Dormitory L are 1 to 2 points higher than those of Dormitory P. This simple comparison on the satisfaction values may lead to a conclusion that the building performance of Dormitory L is better than that of Dormitory P. Although the satisfaction levels are relatively high - most of the aspects of Dormitory L were scored 5 or higher, the E-S gaps found from the two studies reveal other conclusions. Overall, most of the gap values of the two dormitories are negative. This indicates that the users were not satisfied with most of the rated aspects. Only the *visual* aspect was found with a positive gap across the two studies. This means that both of the dormitories provided sufficient lighting facilities, with the service quality of the *visual* aspect satisfying the users there. Note, however, that the positive gap values of this aspect are in fact small (0.06 for Dormitory L and 0.66 for Dormitory P). Therefore, effort to maintain the lighting facilities should continue.

The *aural* aspect recorded extreme expectation and satisfaction ratings in the two studies. It was rated as the worst performance aspect of Dormitory L (gap: -1.40) while in Dormitory P it (gap: 1.01) outperformed the other aspects. Of the remaining aspects, three in Dormitory L (*thermal:* -0.08, *fire*: -0.66, hygiene*:* -0.06) performed comparatively better than those in Dormitory P. However, the performance of the *communication* aspect of Dormitory L (gap: -0.87) was inferior to Dormitory P (gap: -0.09). The expectation, satisfaction and gap values of the six performance aspects are charted in Figure 8.

Table 8. Expectation, satisfaction and gap values of the two dormitories

	Dormitory L			**Dormitory P**		
Aspect	**Expectation**	**Satisfaction**	**Gap**	**Expectation**	**Satisfaction**	**Gap**
Visual	6.04	6.10	0.06	4.47	5.13	0.66
Thermal	5.84	5.76	-0.08	4.99	3.56	-1.43
Aural	6.13	5.53	-1.40	3.79	4.80	1.01
Fire	5.64	4.98	-0.66	4.17	3.30	-0.87
Hygiene	6.19	6.13	-0.06	4.65	3.04	-1.61
Communication	5.93	5.06	-0.87	3.95	3.86	-0.09

Figure 8. Graphical performance comparisons between the two dormitories

5. Discussion

The discussion is threefold: on the importance, expectation, satisfaction and gap values found from the current case study (Dormitory L); on the significance of the adaptation effect; and on the application of the GTbPOE method.

First, *hygiene* and *fire* are two building performance aspects consistently ranked the highest and the lowest in terms of importance, expectation and satisfaction. It is reasonable to believe that their importance is highly correlated with the expectation level of the users. In other words, the more important an aspect is perceived by a user, the higher is its performance the user expects. Based on the satisfaction rating and the gap value, *hygiene* performed the best in Dormitory L. One interesting observation is that although *fire* was rated the least important aspect, and users' expectation of, and satisfaction with, this aspect were the lowest. Its gap value is the third highest among the six aspects. These findings imply that while the *fire* aspect performed the worst when judged by the satisfaction rating, it is not the most urgent aspect to be improved, because the performance gap is only moderate among the rated aspects. Put differently, the satisfaction rating serves as an indicator of the perceived performance of the concerned aspect while the gap value aids the strategic planning for building maintenance and management. Furthermore, as the users are not building experts, their perceived importance is influenced by the actual building performance and their experience with the building. When a certain building performance aspect remains at a fair performance level over an extended period, the users may not regard it to be significantly important, while an observation of a poor performance level of a certain aspect may alert the users' attention and urge them to consider its importance.

Second, another finding from this case study indicates that the users' expectation and satisfaction levels, and hence, the performance gaps of the rated aspects were influenced by the adaptation effect. Across the board, the performance gaps of all the six aspects diminished with increase in the residence index. Put simply, the longer the period a user stays in the dormitory, the higher is the tendency the user accepts the level of building performance. This also demonstrates that the gap analysis can be a useful tool for facilities managers to formulate plans for maintenance and management of the dormitory facilities. For example, by grouping the gap values by gender and room type of the survey responses, facilities managers will be able to allocate resources and schedule maintenance works in a rational manner.

Third, the GTbPOE method was developed on a human-environment interaction basis. By collecting data of building users' characteristics (e.g. period of stay in the building) and their expectation and satisfaction levels of the essential building performance aspects, the method can produce rich information with management implications. Whereas traditional POE studies emphasize the collection of feedback on building performance, user satisfaction is often the main parameter investigated. As the preceding findings of the current study illustrate, traditional POE studies are deficient in that the users' characteristics (e.g. period of stay) are typically neglected. The GTbPOE method, on the other hand, plugs this deficiency by analyzing analytically the relationships between building performance and human factors. For example, certain building performance aspects with a moderate satisfaction level may be found with a large number of negative gap values. This reflects that the expectation levels of a large number of the users are higher than the satisfaction levels they perceived about those aspects. After identifying this group of users, their demographic information (e.g. year of study, period of stay) can be the starting point for the building's facilities manager to identify any specific reasons behind the users' expectation-satisfaction gaps. Focus group discussion, for instance, can be organized with this group of users. Their detailed feedback can help the facilities manager realize what improvements are needed, e.g. increasing the frequency of facilities inspection, reducing the downtime of facilities, etc. Feedback such as changing the location of lighting fixtures and providing more toilet facilities, etc. is useful information for designers to improve building design in the future. By taking this approach on a regular basis, the goal of total quality management can be achieved for similar building types such as serviced apartments, hotels, guesthouses, and so on.

Using the GTbPOE method, a standard or reference point for judging the building performance (expectation), users' perceived performance of the building (satisfaction) and their acceptance level of the building performance (E-S gap) can be examined. The gap value of each user's response indicates the user's zone of tolerance, which is "the extent to which customers (or service users) recognize and are willing to accept variation in service performance" (Zeithaml et al., 1990). When the gap value is positive, it means that the building delivers service that a user feels delighted to receive; when the gap value falls on zero, it means that the building performance achieves a service level that the user accepts. A negative gap value indicates that the building performance level is not acceptable to the user. These three sets of values are useful indicators from the facilities management perspective. The above comparison between the findings of the two dormitories in addition, demonstrates the usefulness of the GTbPOE method.

Overall, the research approach adopted has significant practical value and impact particularly for facilities management teams who assess and maintain the quality of buildings and facilities. Such results provide useful benchmark indicators that could be used to strategically target areas for improvement when refurbishing existing buildings and facilities. Moreover, architects and designers could also benefit by retrospectively examining the actual performance of a building and its facilities in-use *vis-à-vis* as-designed. All too often, architects and designers do not have such information at their disposal and so lessons learnt are rarely carried forward onto future projects – as a consequence, the same mistakes or omissions may be carried forward and unwittingly repeated.

6. Conclusions

This study made use of the novel GTbPOE method to probe the post-occupancy building performance of a student dormitory. The innovation of the study lies in the methodology supported by three analysis methods (AHP, gap analysis and cross comparison) that complement each other to generate reliable results. First, the AHP method was applied to investigate the building users' perceived importance of the rated building performance aspects and ensured that only consistent responses of the users were taken for analysis. Second, a more accurate approach was used to identify the gap between the expectation and satisfaction levels the users perceived. Third, this study compared the user expectation and satisfaction levels of the same set of building performance aspects of two dormitories.

The findings of the six building performance aspects (visual comfort, thermal comfort, aural comfort, fire safety, hygiene and communication) of this study were scrutinized and compared with the counterparts of the seminal study of Lai (2013). Whereas the typical focus of traditional POE studies is on the satisfaction of the users of buildings, the foregoing analysed findings illustrated that the users' expectation should also be investigated. Instead of considering only the satisfaction level, its deviation from the expectation level, viz. performance gap, can better reflect how well the building has performed to users' needs. Rather than following a traditional POE approach, this work recommends using the GTbPOE method in future post-occupancy studies. This is because the results transpiring (form analysis conducted) provide greater depth, knowledge and understanding of users' needs. Such appreciation is critical for the future repair, maintenance, refurbishment and design of future buildings as well as the concomitant social and economic impact. That is, satisfied users (social impact) are more inclined to pay a higher premium (economic impact) for buildings and facilities that met their expectations.

The longer the users stayed in the dormitory, the smaller is the building performance gap they perceived. The existence of this observation across the six aspects evaluated manifests the significance of the adaptation effect. This is a crucial finding that should be taken into account when sampling users for POE studies. When the results of different POE studies are compared, the demographic characteristics of the users, especially their period of stay (or residence index), is a critical factor to be considered.

The above findings of the case study, which clearly unveil the levels to which the users are content with the six building performance aspects, validated the applicability of the GTbPOE method. The comparative analysis of the findings between the two dormitories further demonstrated the usefulness of the GTbPOE method in benchmarking the performance between peer buildings. This external benchmarking approach, likewise, can be taken for internal benchmarking purposes; for example, for a building having its performance evaluated annually by the GTbPOE method, the evaluation results can be benchmarked year-on-year. In doing so, any shortcoming in the performance will be identified, based upon which appropriate improvement measures can be formulated. Now that the scientific method and approach has been validated through this present study, future work is required to input the manual data collection system and analysis conducted into an automated hand-held system with graphical user inter-face (GUI) to simplify the use of the GTbPOE method in practice. By automated data input and via the use of technologies such as the internet of things (IoT) and cloud based servers, a comprehensive database could be developed to allow a comparative analysis between a wider population of buildings and facilities within these. Such a tool could provide an important knowledge learning opportunities for facility management practices, designers and architects alike.

References

Abidin, M., 2015. Higher education quality: Perception differences among internal and external stakeholders. *International Education Studies*, *8*(12), pp.185-192.

Adamowicz, W., Jordan, L. and Michael, W., 1994. Combining revealed and stated preference methods for valuing environmental amenities. *Journal of environmental economics and management*, 26(3), pp.271-292.

Adewunmi, Y., Omirin, M., Famuyiwa, F. and Farinloye, O., 2011. Post-occupancy evaluation of postgraduate dormitory facilities. *Facilities*, *29*(3/4), pp.149-168.

Agha-Hossein MM, El-Jouzi, S., Elmualim, A.A., Ellis, J. and Williams, M., 2013. Post-occupancy studies of an office environment: energy performance and occupants' satisfaction. *Building and Environment*, 69, pp.121-130.

Alshamrani, O.S. and Alshibani, A., 2020. Automated decision support system for selecting the envelope and structural systems for educational facilities. *Building and Environment*, p.106993.

Amaratunga, D. and Baldry, D., 2002. Moving from performance measurement to performance management. *Facilities*, 20(5/6), pp.217-223.

Amole, D., 2009. Residential satisfaction in students' housing. *Journal of Environmental Psychology*, 29, pp.76-85.

Athiyaman, A., 1997. Linking student satisfaction and service quality perceptions: the case of university education. *European Journal of Marketing*, 31(7), pp. 528-40.

Avkiran, N.K., 1994. Developing an instrument to measure customer service quality in branch banking. *International Journal of Bank Marketing*, 12(6), pp.10-18.

Baby, S., 2013. AHP modeling for multicriteria decision-making and to optimise strategies for protecting coastal landscape resources. *International Journal of Innovation, Management and Technology*, *4*(2), p.218.

Chand, M., 2010. Measuring the service quality of Indian tourism destinations: an application of SERVQUAL model. *International Journal of Services Technology and Management*, *13*(3-4), pp.218-233.

Chang, J.C., 2009. Taiwanese tourists' perceptions of service quality on outbound guided package tours: A qualitative examination of the SERVQUAL dimensions. *Journal of vacation marketing*, *15*(2), pp.165-178.

Calcara, J.R., 1999. Shaping Campus Facilities. *American School & University*, 71(8), pp.34f-34h.

Carman, J. M., 1990. Consumer perceptions of service quality: An assessment of the SERVQUAL dimensions. *Journal of Retailing*, 66 (1),pp.33-55.

Cho, S.H., Lee, T.K. and Kim, J.T., 2011. Residents' satisfaction of indoor environmental quality in their old apartment homes. *Indoor and Built Environment*, *20*(1), pp.16-25.

Council FF, and National Research Council., 2002. *Learning from our buildings: A state-of-the-practice summary of post-occupancy evaluation*. National Academies Press.

Dabholkar, P.A., Thorpe, D.I. and Rentz, J.O., 1996. A measure of service quality for retail stores: scale development and validation. *Journal of the Academy of marketing Science*, *24*(1), p.3.

Darko, A., Chan, A.P., Ameyaw, E.E., Owusu, E.K., Pärn, E. and Edwards, D.J., 2019. Review of application of analytic hierarchy process (AHP) in construction. *International journal of construction management*, 19(5), pp.436-52.

Du, X., Zhang, Y. and Lv, Z., 2020. Investigations and analysis of indoor environment quality of green and conventional shopping mall buildings based on customers' perception. *Building and Environment*, 177, pp. 106851.

Ekinci, Y., 2001. The validation of the generic service quality dimensions: an alternative approach. *Journal of Retailing and Consumer Services*, *8*(6), pp.311-324.

Finn, D. W. & Lamb Jr, C. W., 1991. An Evaluation of the SERVQUAL Scales in a Retailing Setting. *Advances in consumer research*, 18 (1), pp.483-490

Frontczak, M. and Wargocki, P., 2011. Literature survey on how different factors influence human comfort in indoor environments. *Building and Environment*, 46(4), pp.922-37.

Hasan, H.F.A., Ilias, A., Rahman, R.A. and Razak, M.Z.A., 2008. Service quality and student satisfaction: A case study at private higher education institutions. *International Business Research*, *1*(3), pp.163-175.

Hassanain, M.A., 2008. On the performance evaluation of sustainable student housing facilities. *Journal of Facilities Management*, 6(3), pp.212-225.

Hinks J., 2004. Business-related performance measures for facilities management. *Facilities Management: Innovation and Performance*, SPON Press, New York, NY, pp.97-107.

Ho, D.C.W., Chau, K.W., Cheung, A.K.C., Yau, Y., Wong, S.K., Leung, H.F., Lau, S.S.Y. and Wong, W.S., 2008. A survey of the health and safety conditions of apartment buildings in Hong Kong. *Building and Environment*, *43*(5), pp.764-775.

Jamaludin, A.A., Keumala, N., Ariffin, A.R. and Hussein, H., 2014. Satisfaction and perception of residents towards bioclimatic design strategies: Residential college buildings. *Indoor and built environment*, 23(7), pp.933-45.

Juwaheer, T.D., 2004. Exploring international tourists' perceptions of hotel operations by using a modified SERVQUAL approach–a case study of Mauritius. *Managing Service Quality: An International Journal*, 14(5), pp.350-364

Kant, R. and Jaiswal, D., 2017. The impact of perceived service quality dimensions on customer satisfaction. *International Journal of Bank Marketing*, 35(3), pp.411-430.

Karatepe, O. M., Yavas, U. & Babakus, E., 2005. Measuring service quality of banks: scale development and validation. *Journal of Retailing and Consumer Services*, 12 (5), pp.373-383.

Kärnä, S. and Julin, P., 2015. A framework for measuring student and staff satisfaction with university campus facilities. *Quality Assurance in Education*. 23(1), pp.47-66.

Kim, T.W., Cha, S. and Kim Y., 2018. Space choice, rejection and satisfaction in university campus. *Indoor and Built Environment*, 27(2), pp.233-43.

Knight Frank, 2020. Global student property 2019. [online] Available at:< https://content.knightfrank.com/research/1775/documents/en/global-student-property-report-2019-may-2019-6426.pdf> [Accessed June 22nd, 2020].

Kouthouris, C. and Alexandris, K., 2005. Can service quality predict customer satisfaction and behavioral intentions in the sport tourism industry? An application of the SERVQUAL model in an outdoors setting. *Journal of Sport & Tourism*, *10*(2), pp.101-111.

Lai, J.H. and Yik, F.W., 2009. Perception of importance and performance of the indoor environmental quality of high-rise residential buildings. *Building and Environment*, 44(2), pp.352-60.

Lai J.H. and Yik, F.W., 2011, An analytical method to evaluate facility management services for residential buildings. *Building and Environment*, 46(1), pp.165-175.

Lai, J.H., 2013. Gap theory based analysis of user expectation and satisfaction: The case of a hostel building. *Building and environment*, 69, pp.183-93.

Lai, J.H., 2014. Influence of personal attributes on perception of residential facilities management services. *Facilities*, 32(9/10), pp.509-521.

Lai J.H. and Choi, E.C., 2015. Performance measurement for teaching hotels: A hierarchical system incorporating facilities management. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 16, pp.48-58.

Lassar, W.M., Manolis, C. and Winsor, R.D., 2000. Service quality perspectives and satisfaction in private banking. *Journal of services marketing*, 14(3), pp.244-271.

Lavy, S., Garcia J.A. and Dixit, M.K., 2010. Establishment of KPIs for facility performance measurement: review of literature. *Facilities*, 28(9/10), pp.440-464.

Leccese, F., Salvadori, G., Rocca, M., Buratti, C. and Belloni, E., 2020. A method to assess lighting quality in educational rooms using analytic hierarchy process. *Building and Environment*, 168, p.106501.

Lee, Y.C., Wang, Y.C., Chien, C.H., Wu, C.H., Lu, S.C., Tsai, S.B. and Dong, W., 2016. Applying revised gap analysis model in measuring hotel service quality. *SpringerPlus*, *5*(1), p.1191.

Li, P., Froese T.M. and Brager G., 2018. Post-occupancy evaluation: State-of-the-art analysis and state-of-the-practice review. *Building and Environment*, 133, pp.187-202.

Li, J. and Liu, N. 2020. The perception, optimization strategies and prospects of outdoor thermal comfort in China: A review. *Building and Environment*, 170, pp. 106614.

Liu, L., Lin, Y., Xiao, Y., Xue, P., Shi, L., Chen, X. and Liu, J., 2018. Quantitative effects of urban spatial characteristics on outdoor thermal comfort based on the LCZ scheme. *Building and Environment*, 143, pp. 443-460.

Magdaniel, F.C., De Jonge, H. and Den Heijer, A., 2018. Campus development as catalyst for innovation. *Journal of Corporate Real Estate*, 20(2), pp.84-102.

Nadiri, H., Kandampully, J. and Hussain, K., 2009. Students' perceptions of service quality in higher education. *Total Quality Management*, *20*(5), pp.523-535.

Naik, C.K., Gantasala, S.B. and Prabhakar, G.V., 2010. Service quality (SERVQUAL) and its effect on customer satisfaction in retailing. *European journal of social sciences*, *16*(2), pp.231-243.

Nelson S. and Nelson T., 1995. RESERV: an instrument for measuring real estate brokerage service quality. *Journal of Real Estate Research*, 10(1), pp.99-113.

Newman, K., 2001. Interrogating SERVQUAL: a critical assessment of service quality measurement in a high street retail bank. *International Journal of Bank Marketing*, 19(3), pp. 126-39.

Nurul Ulyani M.N., Nor Aini Y. and Zulkifli O., 2011. Measuring satisfaction with student housing facilities. *American Journal of Engineering and Applied Sciences*, 4(1), pp.52-60.

Parasuraman A., Zeithaml V.A. and Berry L.L., 1985. A conceptual model of service quality and its implications for future research. *Journal of marketing*, 49(4), pp.41-50.

Park, J., Loftness, V., Aziz, A. and Wang, T., 2019. Critical factors and thresholds for user satisfaction on air quality in office environments. *Building and Environment*, 164, pp.106453.

Pastore, L. and Andersen, M., 2019. Building energy certification versus user satisfaction with the indoor environment: Findings from a multi-site post-occupancy evaluation (POE) in Switzerland. *Building and Environment*, 150, pp. 60-74.

Roberts C.J., Edwards D.J. and Hosseini M.R., 2019. Mateo-Garcia M, and Owusu-Manu DG. Post-occupancy evaluation: a review of literature. *Engineering, Construction and Architectural Management*, 26(9), pp.2084-2106.

Rose M.R., Nusbaum T.J. and Chippindale A.K., 1996. Laboratory evolution: the experimental wonderland and the Cheshire Cat syndrome. *Adaptation. Academic Press, San Diego, CA*, pp.221-241.

Saaty T.L., 1980. The analytic hierarchy process: planning, priority setting, resource allocation. US: McGraw-Hill.

Saaty T.L., 1990a. How to make a decision: the analytic hierarchy process. *European journal of operational research*, 48(1), pp.9-26.

Saaty T.L., 1990b. An exposition of the AHP in reply to the paper "remarks on the analytic hierarchy process". *Management science*, 36(3), pp.259-68.

Saaty T.L., 2000. *Fundamentals of decision making and priority theory with the analytic hierarchy process*. RWS publications.

Shaw D. and Haynes B., 2004. An evaluation of customer perception of FM service delivery. *Facilities*, 22(7/8), pp.170-177.

Wong, J.K.W. and Li, H., 2008. Application of the analytic hierarchy process (AHP) in multi-criteria analysis of the selection of intelligent building system. *Building and Environment*, 43, pp.108-125.

Zalejska-Jonsson A. and Wilhelmsson M., 2013. Impact of perceived indoor environment quality on overall satisfaction in Swedish dwellings. *Building and Environment*, 63, pp.134-44.

Zeithaml V.A., Parasuraman A., Berry L.L., and Berry L.L., 1990. *Delivering quality service: Balancing customer perceptions and expectations*. Simon and Schuster.

Zhang Z., 2019. The effect of library indoor environments on occupant satisfaction and performance in Chinese universities using SEMs. *Building and Environment*, 150, pp.322-9.

Appendix 1. An example of AHP weighting and consistency check computation

After a respondent completed the 15 pairwise comparisons, the results were input to Table 9.

Table 9. An example of pairwise comparisons of the six performance aspects

Pairwise comparison		Scale
Visual Vs. Thermal	C1:C2	-2
Visual Vs. Aural	C1:C3	2
Visual Vs. Fire safety	C1:C4	2
Visual Vs. Hygiene	C1:C5	3
Visual Vs. Communication	C1:C6	-3
Thermal Vs. Aural	C2:C3	2
Thermal Vs. Fire safety	C2:C4	3
Thermal Vs. Hygiene	C2:C5	1
Thermal Vs. Communication	C2:C6	2
Aural Vs. Fire safety	C3:C4	2
Aural Vs. Hygiene	C3:C5	-2
Aural Vs. Communication	C3:C6	5
Fire safety Vs. Hygiene	C4:C5	-3
Fire safety Vs. Communication	C4:C6	3
Hygiene Vs. Communication	C5:C6	5

Note: C1:C2 = - 2 means that the visual aspect was rated as less important than the thermal aspect and the respondent indicated the relative importance level as 2.

The results of the 15 comparisons of the respondent were transformed into a pairwise comparison matrix (Eq. 1 and 2), as shown in Table 10.

Table 10. Matrix of ratings based on the pairwise comparisons

Aspect	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
C1 = Visual	1.0000	0.5000	0.5000	2.0000	3.0000	2.0000
C2 = Thermal	2.0000	1.0000	2.0000	3.0000	1.0000	2.0000
C3 = Aural	0.5000	0.5000	1.0000	2.0000	0.5000	5.0000
C4 = Fire safety	0.5000	0.3333	0.5000	1.0000	0.3333	3.0000
C5 = Hygiene	0.3333	1.0000	2.0000	3.0000	1.0000	5.0000
C6 = Communication	0.5000	0.5000	0.2000	0.3333	0.2000	1.0000
Total	4.8333	3.8333	6.2000	11.3333	6.0333	18.0000

A normalization procedure was conducted for each matrix of ratings. The averages of the columns of each normalised matrix was calculated and an array of priorities for each level of hierarchy (in this study, the hierarchy only contains one level) is obtained. The priority vector values are the criteria weights (Eq. 3). Table 11 shows the normalised matrix and the calculated weights.

Table 11. A normalised matrix with results of criteria weights

Criteria	C1	C2	C3	C4	C5	C6	Average	Row sum	Priority vector	Rank
C1	0.2069	0.1304	0.0806	0.1765	0.4972	0.1111	0.2005	1.2028	0.2005	3
C2	0.4138	0.2609	0.3226	0.2647	0.1657	0.1111	0.2565	1.5388	0.2565	1
C3	0.1034	0.1304	0.1613	0.1765	0.0829	0.2778	0.1554	0.9323	0.1554	4
C4	0.1034	0.0870	0.0806	0.0882	0.0552	0.1667	0.0969	0.5812	`0.0969	5
C5	0.0690	0.2609	0.3226	0.2647	0.1657	0.2778	0.2268	1.3606	0.2268	2
C6	0.1034	0.1304	0.0323	0.0294	0.0331	0.0556	0.0640	0.3843	0.0640	6
TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	6.0000	1.00	

The consistency measure (E) of each aspect was obtained using Eq. 4 and 5. Table 12 shows the results of the consistency measure of each aspect. Table 13 shows the random index values (Saaty, 1990a; b).

Table 12. Consistency measure for each building performance aspect

Criteria	Consistency measure (E)
C1= Visual	7.0263
C2=Thermal	6.2917
C3=Aural	6.5077
C4=Fire safety	6.4831
C5=Hygiene	6.4895
C6=Communication	6.2650
Total	39.0634

Table 13. Random index values (Saaty, 1990a; b)

Matrix size	1	2	3	4	5	6	7	8	9	10	11	1
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1

λ_{max} = (7.0263 + 6.2917 + 6.5077 + 6.4831 + 6.4895 + 6.2650) / 6 = 6.51

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{6.51 - 6}{6-1} = 0.102$$

$$CR = \frac{CI}{RI} = \frac{0.102}{1.24} = 0.08$$

CR < 0.1