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Student residential apartment performance evaluation using integrated AHP-FCE method

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Abstract
Student residents' perception of the student residential apartment environment has gained greater prominence. Developing a performance evaluation framework from students' perspective is essential to post-occupancy management. In this study, an occupant-oriented performance evaluation framework was established based on a student residential apartment complex in the Netherlands through literature analysis, expert interviews and a focus group discussion with student resident representatives. The innovative framework, which comprises three levels of building performance attributes, divides the architectural design and building services performance attributes into two major categories. A questionnaire survey designed based on analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE) methods was used to evaluate the framework. Data on student residents' perceived importance of and satisfaction with the building performance attributes was collected by the survey. The analysis results show that building service performance attributes were considered less important to the student residents than architectural design attributes. Student residents' perceived priority weightings for various building performance attributes were compared by gender, educational level and length of stay. This study incorporates, in an innovative manner, student residents' perception into developing a performance evaluation framework for student residential apartments, and adopted the integrated AHP-FCE method to measure student residents' perception on the overall building performance. The findings have important ramifications for the post-occupancy management stage.

Keywords: Building performance evaluation, evaluation framework, student residential apartments, perception, AHP-FCE

1. Introduction
Student residential apartment, as a special type of building, serve as a haven environment for students to live, study and socialise. Research indicates that the performance of student residential apartmenthas a significant impact on students' well-being and productivity in learning, such as affecting their physical health, emotional state and academic achievements [1, 2]. Student residential apartment with superior building performance can enhance students' quality of life,

learning performance and general growth [3]. Student residential apartment performance shall be continuously evaluated for further enhancement in order to meet the needs of residents [4]. The findings of our study can be used to enhance the design, functionality, and suitability of student residences. In the post-occupancy management stage, students' perception of the building performance should be incorporated in the evaluation mechanism. Thus, a performance evaluation mechanism from the residents' perspective shall be developed for each student residential apartment / project.

The effectiveness of student residential apartment as a facility service affects students' decision regarding which higher education schools to attend [5]. In turn, by offering students multipurpose facility services, higher education institutions can boost their value-added and acquire a competitive edge in luring high-quality students [5]. In addition, due to rising student enrolment, there has been major growth in the student residential apartment , as well as a rise in demand for high-quality residential apartment with the necessary amenities [4, 6]. To accommodate the trend of rising student enrolment, modular construction has been commonly used in the Netherlands to build student residential apartments. Nevertheless, the quality of modular residences has not been examined. Therefore, it is debatable whether modular construction is appropriate for the development of student residential apartments.

This study developed an occupant-oriented student residential apartment performance evaluation framework using a case study based on a modular student residential apartment complex in the Netherlands. An integrated AHP-FCE method was applied to investigate student residents' perceived importance of and satisfaction with the building performance attributes of the selected student residential apartment complex. This paper is structured as follows: section 2 is a literature review on student residential apartment evaluation; section 3 describes the methodology, including selecting a student residential apartment complex as a case study, adjusting the SRAPEF using expert interviews and focus group discussions with the student residents from the selected student residential apartment complex, and elaborating data collection and analysis methods; section 4 elaborates the analysis results; section 5 is discusses the results; and section 6 concludes the study and indicates its limitations and future research direction.

2. Literature review

2.1 Student residential apartment performance evaluation attributes

Eight most commonly investigated performance attributes influencing student residents' living experience and their satisfaction with the residential apartment environment are identified. They are exterior appearance, interior design, building layout, thermal comfort, visual comfort, acoustic comfort, indoor air quality, and management services. Literature review results on each type of performance attribute are provided in the following sub-sections.

2.1.1 Exterior appearance

Exterior appearance is one of the most critical aspects of building performance. The exterior appearance of student residential apartments is generally considered to include the exterior design, materials and colors applied, surrounding landscape, and sidewalk quality [7]. According to Thomsen [8], the exterior appearance significantly influences students' level of satisfaction since it can gives them a sense of belonging, which raises satisfaction. Ning and Chen [9] stated that the outside color scheme and aesthetics of student residential apartments greatly impacted the students in their study. The students in the case study found the dark facade and overused rectangular entrances unsatisfactory; by contrast, bright colors, entrances, and lobbies with attractive designs may boost pleasure. Nazarpour and Norouzian-Maleki [10] observed that student residential satisfaction was positively related to the accessibility of green places, such as parks and natural regions.

2.1.2 Interior design

The interior design of student residential apartments is a predictor of satisfaction [11]. Mustafa [12] observed that interior design as a characteristic that affects the quality of architectural design and is identified a strongly correlation with student residents satisfaction scores. Since residential apartments must serve various purposes in a relatively limited space, the interior design of residential apartments typically considers the efficacy of interior lighting [13], design of sleeping areas, design of restrooms (bathrooms and toilets), quality of furniture, size of the dormitory, and ratio of public and private spaces [14, 15], and all building attibutes affect students' learning, living, and social experiences [16].

2.1.3 Building layout

Building layout has been regarded to impact the satisfaction of student residents significantly [17]. Researchers generally categorise building layout into effective circulation [7], room size [18], ceiling height [19], room layout [13], and accessibility of the many available areas [20] for examining the satisfaction of student residents, and the majority of the findings show that students are satisfied with these segmented attributes. Ajayi et al. [21] found that accessibility of buildings (e.g., distance between toilets and dorms) is a critical factor in student satisfaction. Students may be unhappy if essential facilities are difficult to access. Room size and furniture are also important considerations [19].

2.1.4 Thermal comfort

Thermal comfort is a mental state that expresses satisfaction with the thermal environment, and is assessed through subjective ratings [22]. Improving the quality of the thermal environment in residential apartments can improve students' satisfaction level [23], academic performance [24], and health [25]. As one of the most extensive aspects, studies usually focus on the relationship between thermal comfort and indoor thermal conditions (e.g., temperature, relative humidity, and wind speed) [26]. Two thermal comfort measurement models have been developed and used in related studies: a human thermal balancing model (predicted mean vote index PMV and anticipated percentage discontent index PPD) and an adaptive thermal comfort model [27], but PMV/PPD models could not predict how students in residential apartments with natural ventilation feel about the temperature.

2.1.5 Visual comfort

Visual comfort is defined as a subjective state of visual health caused by the visual surroundings [28]. Natural lighting is considered to be superior to artificial lighting in student residential apartments since it improves students' psychological and visual senses, academic performance, and educational process [29]. Student residents prefer rooms with windows to allow more daylight and improve visual comfort. However, increasing the amount of daylight in a space might increase the possibility of glare [30]. Moadab et al. [31] suggested that people regard daylight as of one of the utmost important elements for living and working in residential apartments, and residential apartments should give sufficient daylight. Therefore, appropriate regulation and distribution of natural and artificial lighting design can benefit students in the student residential environmen.

2.1.6 Acoustic comfort

Acoustic comfort refers to the perceived satisfaction with the acoustical conditions of the environment. It is defined as avoiding noise sources or the ability to conduct sound-emitting activities without disturbing others [32]. The majority of student residents are concerned about intrusive noise because they frequently experience noise issues [33]. Outside noise is the main source of student discomfort [12], particularly noise created by neighbors, residential life, and home building [34]. Also, noise created by students (e.g. conversation) can result in tremendous discontent. The control of noise depends on the level of filtration of the building envelope, and quiet accommodation can be provided through use of high performance walls, floors, windows and doors [20].

2.1.7 Indoor air quality

Indoor air quality refers to the quality of the air inside and surrounding buildings [35]. Over the last 30 years, research has revealed that indoor air quality considerably affects occupant comfort, health, and productivity [36]. Indoor air quality in student residential apartments is usually related to CO_2, formaldehyde and total volatile organic compounds (TVOC) concentrations. CO_2 levels exceed the standard level in 90% of long-term occupied non-ventilated rooms [37]. Studies show that poor indoor air quality in student residential apartments may cause a variety of ailments, such as sick building syndrome (SBS) [38], cold and flu [1], asthma and respiratory infections [39], and that boosting ventilation rates relieve these symptoms. Furthermore, the quality of sleep in residential apartments in affected by indoor air quality, with poor sleep quality negatively affecting performance [40].

2.1.8 Management services

Management services include water, power, housekeeping, security, fire safety and internet-related services provided to students [41]. Satisfaction and productivity levels can be enhanced by providing students with a safe and convenient dorm environment [42]. Kumar and Khan [43] stated that students' satisfaction with their residential apartments is entirely dependent on the quality of the various services. Among these studies, safety and fire safety are typically parts of management services because they can play a significant role in safeguarding lives and property from natural disasters [44]. Most students were disappointed with the availability and efficiency of security and fire safety measures in their residential apartments [45].

2.2 Occupant-oriented approach towards building performance evaluation

In the past decade, occupant-oriented approach has been commonly adopted in building performance evaluation. Occupants are an important aspect of building performance because they are a key driver of building system operations and the primary recipient of building services [46, 47]. The early stages of occupant-oriented research looked into the relationships between the built environment and human health [48]. This approach of investigation typically employs a questionnaire-survey as the primary measurement tool to obtain occupants' perceptions of the quality of the indoor environment and their own health conditions.

In recent years, an increasing number of studies have used the AHP method to investigate building experts' or occupants' perceptions of the overall performance of specific types of buildings. Questionnaires based on the AHP method are designed for experts and occupants to indicate their perceived importance of specific building performance attributes in order to obtain occupants' perceptions on building performance. Lai and Yik [49, 50] adopted the AHP method to investigate building occupants' perception. They conducted two similar studies using the AHP method to evaluate the IEQ performance of buildings, one for residential buildings and one for commercial buildings. Building occupants were asked to rate the importance of four IEQ parameters in each study: thermal comfort, air cleanliness, odour, and noise. Lai [51] and Hou et al. [5] developed a two-level AHP-based building performance framework for student residential apartments. Student were asked to rate the perceived importance of six performance attributes: visual, thermal, aural, fire, hygiene and communication. In these two studies, students were asked to indicate their expectation and satisfaction with each performance attribute as well as their perceived importance of building performance attributes. The data on expectations and satisfaction were compared in order to accurately reflect student residents' perceptions of the building's performance.

Yang and Mak [52] used an AHP-FCE method to investigate students' perceptions of classroom indoor environment, recognising that perceived importance and satisfaction are two dynamic factors that affect one's perception of building performance. In one of their studies, they created an assessment model of the classroom acoustical environment based on a multi-layer FCE method, with five main criteria and a few subsets of alternatives. The weightings of all the main criteria and alternatives were collected through questionnaires distributed to AHP students. Yang and Mak [53] created a four-layer IEQ assessment model for university classrooms based on the FCE method in another study. The assessment model was evaluated using an AHP-designed survey. University students enrolled in a specific class were invited to participate in the AHP-based survey.

Recognizing that building performance of residential apartments has a significant influence on student occupants' living experience, it is critical to use an occupant-oriented approach to examine building performance. An integrated AHP-FCE method was used to create a scientific and innovative framework for evaluating student residential apartment performance, as well as to facilitate systematic questionnaire design, data collection, and analysis.

3. Methodology

3.1 Student residential apartment performance evaluation – a case study

This study intended to conduct a case study based on one single student residential apartment or multiple student residential apartments in one university campus to verify the SRAPEF that was developed through literature review. The case study included three research activities: expert interviews, focus group discussions, and a survey of the student residents. The survey's goal was to investigate student residents' perceptions of the importance of and satisfaction with the performance of the building they live in.

Because student residential apartments in the Netherlands are uniform in terms of design and management services, it is not necessary to investigate student residential apartments in different geographical locations. A number of five selection criteria were determined in order to identify suitable student residential apartment(s) for investigation: The student residential apartment(s) shall 1) provide at least 100 of the same type of occupancy units; 2) allow student residents to stay for long-term stays (at least one year); 3) be located on campus; 4) be equipped with the necessary building service systems (e.g., lighting, ventilation, and heating systems); and 5) provide adequate management services (e.g., cleaning, maintenance, fire safety, bicycle parking, etc.). The criteria are met by two student residential apartments, A and B, as well as a student residential apartment complex. Appendix 1 shows where they locate on the university campus.

Student residential apartments A and B were excluded from the case study because 1) very few students volunteered to participate in the focus group discussion, and 2) the surveys were distributed via an online mass-media platform, but only about ten student residents completed the online surveys. As 1) six student residents participated in the focus group discussion and 2) a sufficient number of student residents completed the survey, the student residential apartment complex was chosen.

The student complex has 186 total residential units spread among three buildings, each of which has 62 units spread among six storeys. On the ground floor of each building are communal amenities such the entryway, bicycle parking, and garbage disposal room. State-of-the-art management services are offered, and are administered by the largest student housing management organisation in the Netherlands. The student complex was erected in 2009 using a modular construction technique, which allows prefabricated housing components to slot into a steel frame like cabinet drawers.

Figure 1 shows images of the student complex. The student residential apartment complex comprises three student residential apartments with comparable exterior and interior designs. Figures 2a and 2b depict two separate student dorm buildings from the student dorm complex. Figure 2c depicts a typical residential apartment for students, which includes a single bed, a study desk, a chair, a TV, and some basic kitchen facilities (e.g., a kitchen sink, an oven, a microwave, etc.). Figure 2 shows a single student room and the sampled floor design for the second floor.

Figure 1. Photos of the student residential apartment complex (Source: authors)

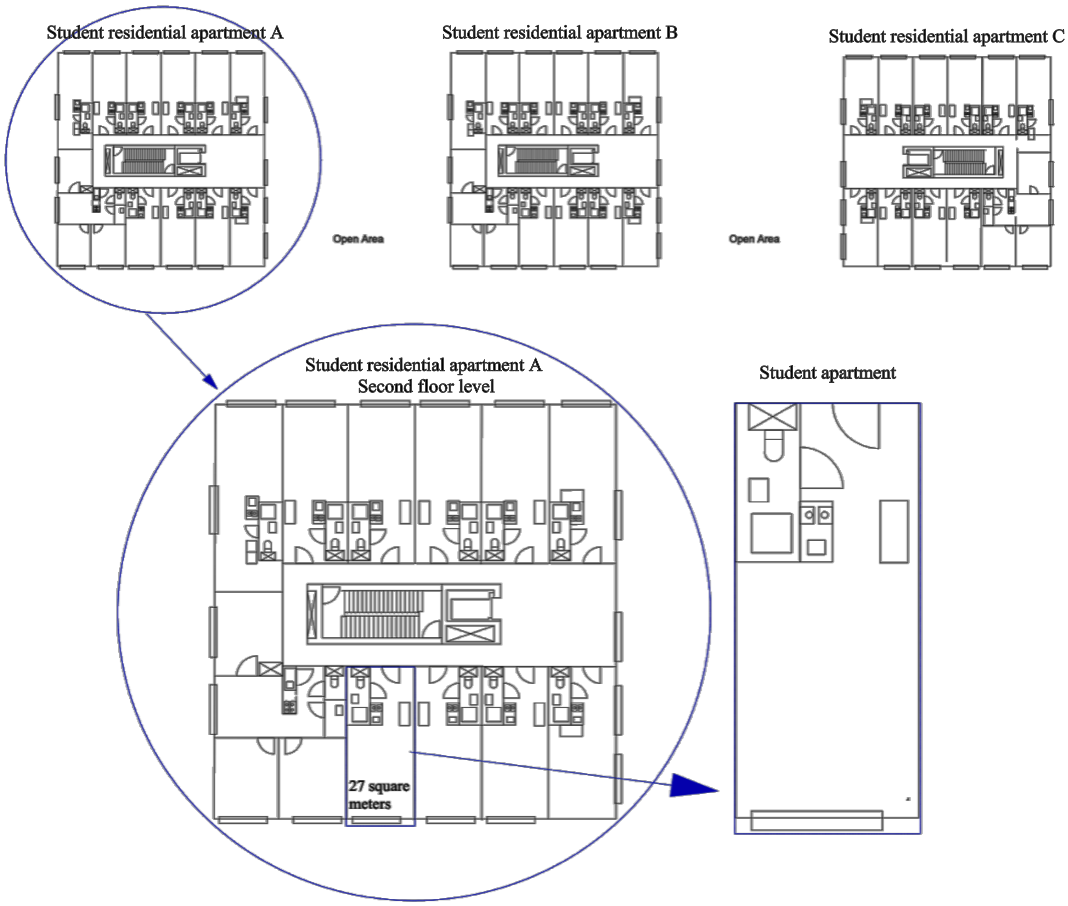

Figure 2. Sample floor plans of the student residential apartment and a single apartment (Source: authors)

3.2 Proposing a student apartment performance evaluation framework

The eight performance attributes are divided into two categories based on the extensive literature review (see Section 2.1): architectural design attributes and building services attributes. This dichotomy was incorporated into the building performance evaluation method and was commonly used in the post-occupancy evaluation (POE) of student residential apartments [9, 13, 34, 45, 54]. Instead of categorising student residential apartment performance as functional or technical, this study categorises student residential apartment performance attributes as architectural design or building services. The former refers to performance characteristics that meet the needs of student activities, whereas the latter refers to those that ensure residents have a comfortable environment to support their daily lives. To outline the relationships between the eight performance attributes, a hierarchical framework has been proposed (Figure 3).

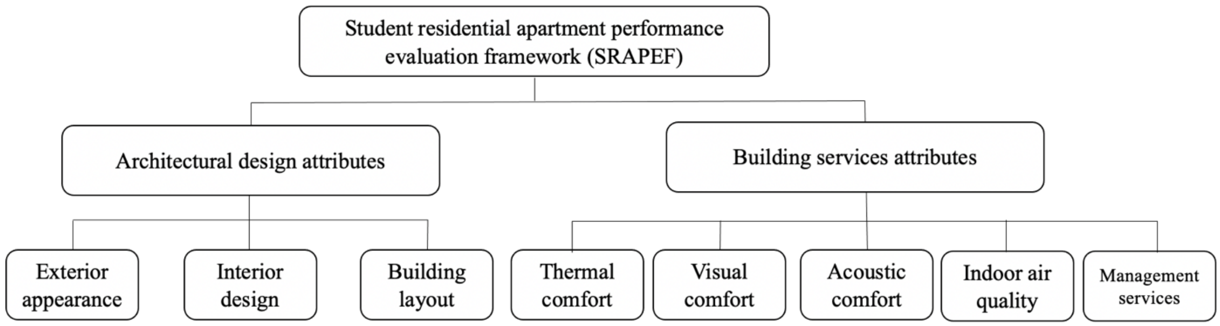

Figure 3. Student residential apartment performance evaluation framework (proposed SRAPEF)

3.3 Expert interviews and focus group discussion with student residents to verify the proposed SRAPEF

To validate the proposed SRAPEF, interviews with seven experts and a focus group discussion with student residents from the investigated student residential apartment were conducted (Figure 1).

Table 1 provides a summary of the seven expert interviewees. Interviewee A is a real estate advisor with expertise in student residential apartment development, whereas interviewee B is a branch director in charge of a number of student residential apartments in a few Dutch cities. Interviewees C and D are two technical administrators who manage the student residential apartment operation on a daily basis. Interviewee E works as a policy officer, and one of his responsibilities is to conduct a student satisfaction survey. Interviewee F is a university professor in the Netherlands with 30 years of research experience in building management, and interviewee G is a consultant from one of the Netherlands' housing associations. The interviewees were asked to discuss the critical building performance attributes that influence student residents' living experiences, as well as their thoughts on the proposed SRAPEF.

Table 1. Brief profile of the expert interviewees and the interview details

Interviewee	**Position**	**Experience in student residential apartment management (SRAM) / housing management (HM)**
A	Real estate advisor	22.3 years in SRAM[1]
B	Branch director	5.9 years in SRAM[1]
C	Technical administrator	2.5 years in SRAM[1]
D	Technical administrator	N/A
E	Policy officer	1.1 year in SRAM[1]
F	University professor in the	Over 30 years in HM
G	Consultant from one housing association	Over 10 years in HM

[1] information obtained from LinkedIn; [2] Interview conducted online; [3] Interview conducted at campus

Following the expert interviews, a focus group discussion with students living in the student residential apartment complex was held to validate the proposed SRAPEF (Figure 3). Six students from the student residential apartment complex volunteered to take part in the focus group discussion. In the focus group discussion with student residents, two questions were raised: 1) whether the proposed SRAPEF's identified performance attributes enable a thorough evaluation of student residential apartment performance from the perspective of student residents; and 2) whether the SRAPEF's overall structure and categorisation of the factors are appropriate for supporting evaluation.

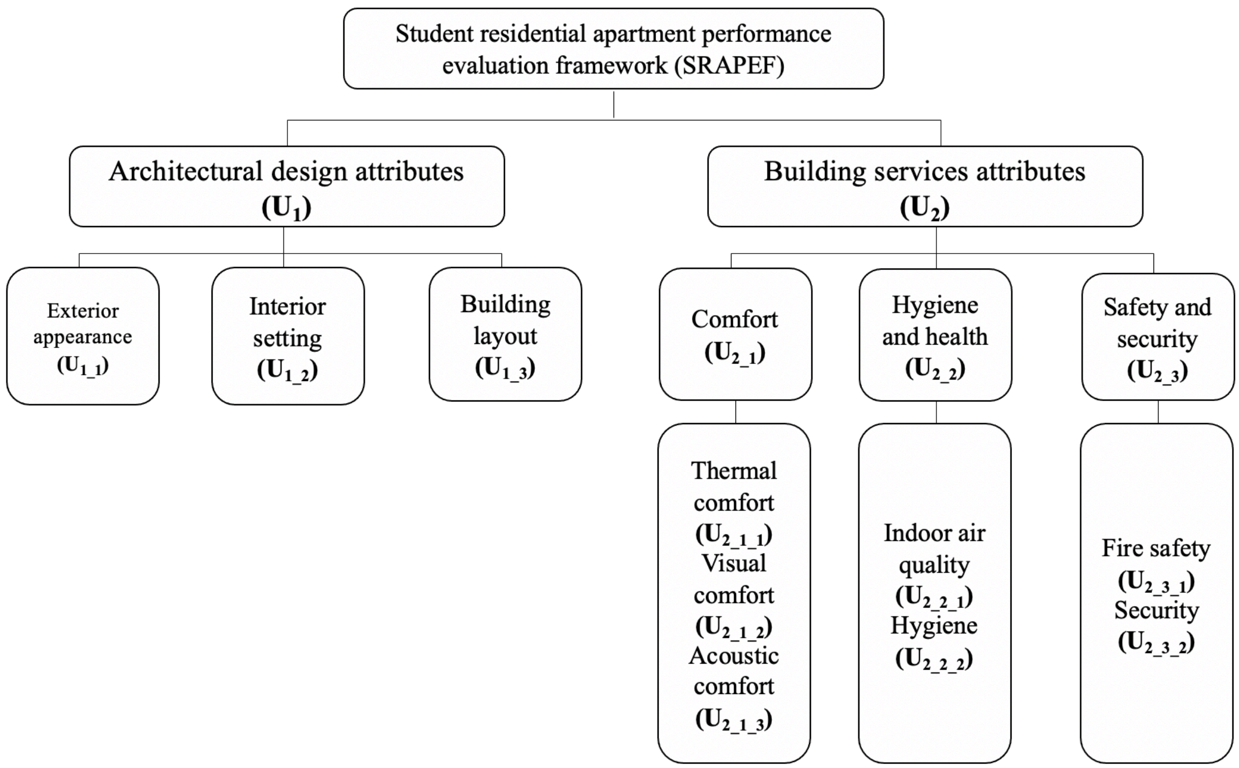

Figure 4. Revised student residential apartment performance evaluation framework (revised SRAPEF)

Note: Figure 1 is the proposed SRAPEF

A revised SRAPEF was devised based on the expert interviews and focus group discussion (Figure 4). The framework's first category level, which divides the performance attributes into "architectural design attributes" (U_1) and "building services attributes" (U_2), was chosen based on the consensus of the interviews and the focus group discussion.

Interviewees A, B, C, D, and F elaborated on how certain types of building service attributes affect the living experience of student residents, whereas interviewees E and G focused on the architectural aspect of building performance. The proposed SRAPEF was well received by all interviewees. The experts were eager to comment on the management services, claiming that they are critical for enabling long-term student housing operations. According to interviewees A, B, D, and F, student residential apartments are designed to meet the needs of general residents so that they can be leased to non-student residents when the student population decreases in the future.

All experts agreed that developing a building performance evaluation framework from the perspective of occupants will increase occupant motivation to participate in the satisfaction survey and facilitate evaluation effectiveness.

In contrast to the expert interviews, the student residents proposed a few changes to the proposed SRAPEF. The focus group discussion obtained consensus on the categorization of the performance attributes under U_1, but "interior design" was suggested to be changed to "interior setting" (U_{1_2}) because the individual student room does not contain many design elements and tends to be simple and of similar design. Based on the findings of the focus group discussions, the performance attributes under "building services attributes" (U_2) were reorganised into three categories and presented in two hierarchical levels. It was proposed that "comfort" (U_{2_1}), "thermal comfort" ($U_{2\_1\_1}$), "visual comfort" ($U_{2\_1\_2}$), and "acoustic comfort" ($U_{2\_1\_3}$) be grouped under one category because these three traits are more sense-based and students can decide based on their sensations. Even though "indoor air quality" ($U_{2\_2\_1}$) affects one's comfort, it also has an impact on one's health. Student residents who participated in the focus group discussion were generally aware that pollutants such as CO_2, CO, VOC, $PM_{2.5}$, and PM_{10} exist, and this believe that "indoor air quality" ($U_{2\_2\_1}$) should be placed under "hygiene and health" (U_{2_2}) in the framework.

Additionally, student residents in the focus group discussion noted that certain management services, such cleaning, fire safety, and security, should be emphasised. In the context of a student residential apartment, those are crucial management services that should be assessed on an individual basis because the term "management services" is inaccurate. Also, the term "cleaning" should be changed to "hygiene" to refer to the work of maintaining a clean environment. Under "hygiene and health" (U_{2_2}), it was suggested that "hygiene" ($U_{2\_2\_2}$) be paired with "indoor air quality" ($U_{2\_2\_1}$). "Fire safety" ($U_{2\_3\_1}$) and "security" ($U_{2\_3\_2}$) were grouped under "safety and security" (U_{2_3}).

Section 3.4 will first explain how the integrated AHP-FCE method was used in this study to translate the verified SRAPEF into a questionnaire, and then introduce the AHP and FCE methods.

3.4 Integrated AHP-FCE method for data collection and analysis

In order to collect residents' feedback on their perceived importance of and satisfaction with the identified performance attributes, the SRAPEF was translated into a questionnaire. The design of the questionnaire and data analysis were supported by the use of analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE) methods. The questionnaire (Appendix 2) contains three parts: general information, importance weightings of student residential apartment performance, satisfaction rating of the student residential apartment performance. The second part was designed based on AHP method.

AHP method is a quantitative and qualitative decision analysis technique that has been widely used in studies to facilitate decision-making. Fuzzy comprehensive evaluation (FCE) method is a multilayer comprehensive evaluation index system that converts qualitative evaluation into quantitative evaluation based on the membership degree theory of fuzzy mathematics [65]. The FCE approach can be weighted using the AHP method. These two methods have been frequently employed to solve ambiguous and difficult-to-quantify situations. Figure 5 illustrates the step-by-step approach of the AHP-FCE method. The following are the specific steps for the AHP-FCE method:

- *Step 1*: Using the results of the focus group discussions that were agreed upon for each category of the framework (SDFEF) as the basis for integrated AHP-FCE method;
- *Step 2*: Collecting perceived importance data of the performance attributes identified (using Saaty's 1-9 point scale), and collecting feedback data on student residents' satisfaction levels (using a 1-7-point scale);
- *Step 3*: Generating pairwise comparison matrix and calculating the weightings of indicators in each level W according to the survey data measured by Saaty's 1-9 scale, and generating membership matrix R according to the satisfaction data measured by a 7-point scale;
- *Step 4*: Calculating the fuzzy hierarchical assessment vector B by multiplying the weightings of indicators W and the membership matrix of indicators R;
- *Step 5*: Assessing the students' residential apartment performance by evaluating score N.

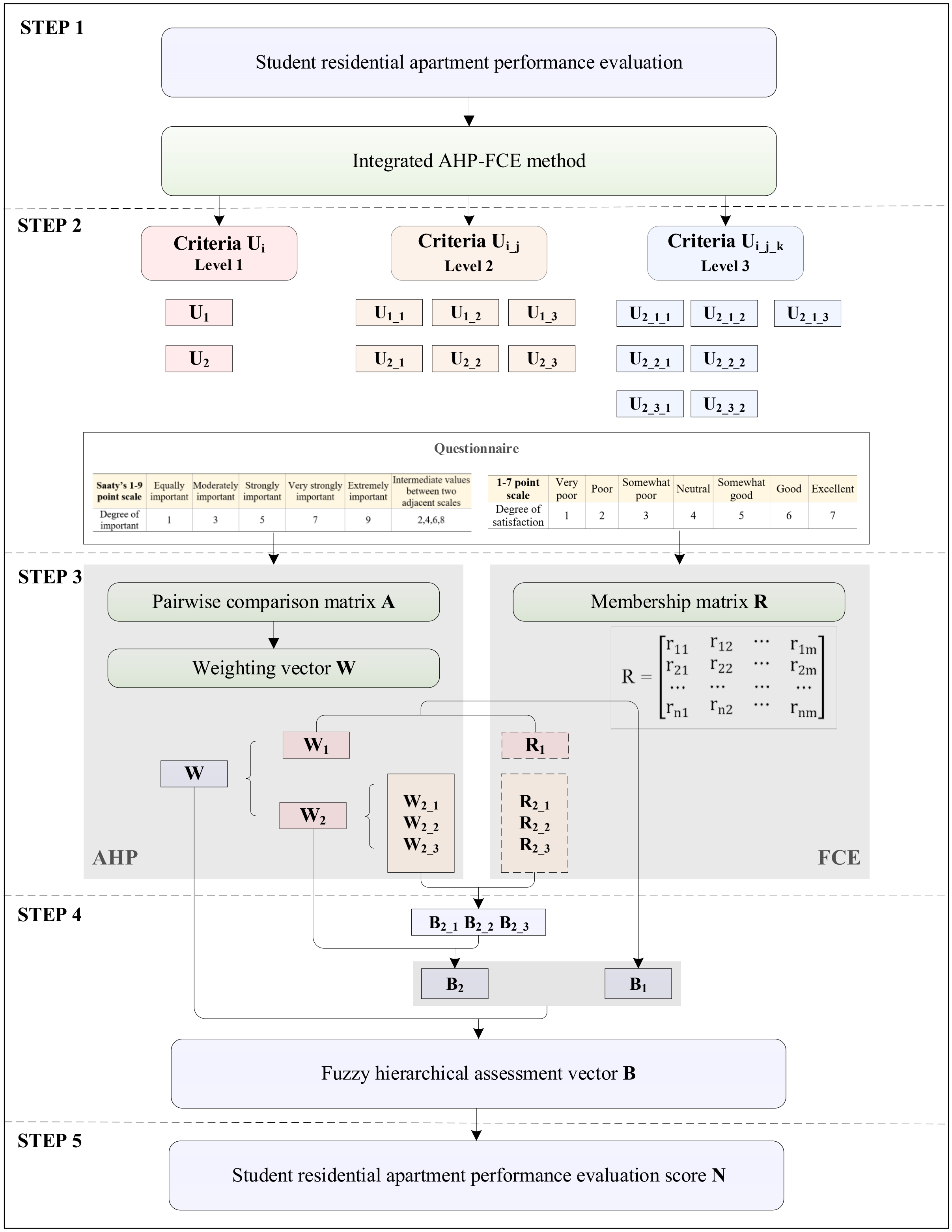

Figure 5. Step-by-step approach of the AHP-FCE method for student residential apartment performance evaluation

3.1.1 AHP method

The AHP, which was first proposed by Saaty [54], is used to obtain the weighting vectors of the three-level multi-criteria evaluation model. The first step of AHP is to construct the hierarchical structure. In this study, evaluation indicators have been identified and categorized into three hierarchical levels (Figure 4). The second step is to establish the pairwise comparison matrix A. Under the hierarchical structure, a pairwise comparison matrix A can be generated by *Equation (1)*. The next step is to calculate the weighting vectors of each level W using *Equation (2)*, w_i represents the weighting of each factor. The last step is to test the consistency. The consistency index (CI) and the consistency ratio (CR) are utilized to determine the consistency of pairwise comparisons and the matrix, respectively, as shown in *Equation (3)*. λ_{max} is the eigenvalue; and n represents the number of factors in the pairwise comparison matrix. Generally, $CR \leq 0.1$ indicates that the consistency of the pairwise comparison matrix is acceptable.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix}, a_{ij} = 1/a_{ji} \ (i = 1,2,3, \ldots n, \text{and } j = 1,2,3, \ldots m) \tag{1}$$

$$W=[w_1, w_2, \ldots, w_n], w_i = \frac{\sum_{j=1}^{n} \bar{a}_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} \bar{a}_{ij}}, \tag{2}$$

$$CI = \frac{\lambda_{max} - n}{n-1}, CR = \frac{CI}{RI} \tag{3}$$

3.1.2 FCE method

The FCE method is conducted based on the fuzzy set theory first proposed by Zadeh [55]. For complex objects which are subjected to multi-factors, quantitative evaluation can be obtained by applying membership functions of the FCE method. The steps for implementation of FCE method include:

- Firstly, to determine the evaluation indicator set. The evaluation indicators are the three levels of identified factors (Figure 4).
- Then, to build the judgement set V. The judgment set is considered $V = [V_1, V_2, V_3, V_4, V_5, V_6, V_7]$ as [excellent, good, somewhat good, natural, somewhat poor, poor, very poor], which can be expressed quantitatively as V = [7, 6, 5, 4, 3, 2, 1].
- Next, to establish the membership matrix R as shown in *Equation (4)*, in which n and k represent the quantities of sub-criteria and judgment indicator, respectively. The r_{nk} of R matrix reflects the normalized result.
- After that, to calculate the comprehensive evaluation vector B as shown in *Equation (5)*. The weighting vector W is calculated using AHP method.
- Lastly, to calculate the overall assessment score of the student residential apartment N by using *Equation (6)*.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1k} \\ r_{21} & r_{22} & \cdots & r_{2k} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nk} \end{bmatrix}, r_{nk} = \frac{V_{nk}}{\sum V_{nk}} \ (k = 1,2,3, \ldots 7) \quad (4)$$

$$B = WR = [b_1, b_2, \ldots, b_m] \quad (5)$$

$$N = BV^T \quad (6)$$

3.5 Data collection

An evaluation model was created using SRAPEF as a foundation. Based on the model, an integrated AHP-FCE method was employed to design the questionnaire and conduct the analysis. The criteria (performance attributes) at each level were paired up for the residents to indicate their weighting level. In other words, each student was given a set of pairwise comparisons composed of the criteria in the evaluation model and was required to indicate the weighting value for each pair of criteria. Saaty's 1-9 point scale used for pairwise comparison and the pairwise comparison questions are illustrated under Section 2 in Appendix 2.

Empirical data was collected through a questionnaire survey. A project assistant was appointed to distribute the questionnaire. Two rounds of data collection were conducted: for the first round, an online questionnaire was created based on which a QR code was generated; information sheets with the QR code were then distributed to the mailboxes of each student residence apartment in the student residential apartment complex; for the second round, the project assistant approached the residents door-to-door to distribute the QR code. A total number of 142 completed questionnaires (with all the information was filled in) were obtained and only 47 were valid questionnaires ($CR \leq 0.1$), as shown in Table 2. It is worth nothing that the AHP method does not always require a statistically significant sample size [68]. The CR value is not determined by the sample size but rather by the items being compared (hence the comparison matrix size); the more pairwise comparisons are made, the more difficult to achieve a $CR < 0.1$.

In this study, for each survey questionnaire received, three consistency ratios were calculated to ensure that the respondent passed all the consistency tests. Only the questionnaires that passed all the consistency tests were retained and used to calculate the weightings. In other words, only those residents who were able to present an acceptable level of consistency in indicating their perceived importance of student residential apartment performance attributes were considered as "experts" on student residential apartments. Thus, their responses were used for analysis.

Table 2. Background of the consulted student.

Type	Information	Number	Percentage
Gender	Male	29	62%
	Female	18	38%
Local or non-local student	Local (Dutch students)	13	28%
	Non-local (Non-Dutch students)	34	72%
Educational background	Undergraduate	15	32%
	Postgraduate	32	68%
	≤4	30	64%

Length of stay in the student residential apartment (months)	4-8	15	32%
	>8	2	4%
	≤2	3	6%
Typical days per week staying (days)	2-4	15	32%
	>4	29	62%

4. Results

4.1 AHP-FCE results

Student residents evaluated the residential apartment performance according to the judgment set V, V = [excellent, good, somewhat good, natural, somewhat poor, poor, very poor], and the results of the 47 valid questionnaires are shown in Table 3.

Table 3. Judgement results by student residents

Hierarchy level	Code	Performance attributes	V_1	V_2	V_3	V_4	V_5	V_6	V_7	Total
Level 1	U_1	Architectural design	6	22	12	5	1	1	0	47
	U_2	Building services	7	16	16	6	0	1	1	47
Level 2	U_{1_1}	Exterior appearance	6	23	8	8	2	0	0	47
	U_{1_2}	Interior setting	7	17	11	8	4	0	0	47
	U_{1_3}	Building layout	10	22	7	5	3	0	0	47
	U_{2_1}	Comfort	12	18	11	4	2	0	0	47
	U_{2_2}	Hygiene and health	4	11	18	9	3	2	0	47
	U_{2_3}	Safety and security	11	16	15	4	0	1	0	47
Level 3	$U_{2\_1\_1}$	Thermal comfort	5	18	14	2	6	2	0	47
	$U_{2\_1\_2}$	Visual comfort	9	10	20	5	2	1	0	47
	$U_{2\_1\_3}$	Acoustic comfort	11	14	13	6	2	0	1	47
	$U_{2\_2\_1}$	Indoor air quality	7	16	17	5	2	0	0	47
	$U_{2\_2\_2}$	Hygiene	8	13	21	3	1	1	0	47
	$U_{2\_3\_1}$	Fire safety	1	22	19	3	1	1	0	47
	$U_{2\_3\_2}$	Security	3	22	19	2	0	1	0	47

V_1: Excellent; V_2: good; V_3: Somewhat good; V_4: neutral; V_5: somewhat poor; V_6: Poor; V_7: Very poor.

According to Table 3, the judgment results were normalized to develop membership matrix R. The normalized membership matrixes of the level 1 and level 2 indicators can be expressed as follows:

$$R_1 = \begin{bmatrix} 0.128 & 0.489 & 0.170 & 0.170 & 0.043 & 0.000 & 0.000 \\ 0.149 & 0.362 & 0.234 & 0.170 & 0.085 & 0.000 & 0.000 \\ 0.213 & 0.468 & 0.149 & 0.106 & 0.064 & 0.000 & 0.000 \end{bmatrix}$$

$$R_{2\_1} = \begin{bmatrix} 0.106 & 0.383 & 0.298 & 0.043 & 0.128 & 0.043 & 0.000 \\ 0.191 & 0.213 & 0.426 & 0.106 & 0.043 & 0.021 & 0.000 \\ 0.234 & 0.298 & 0.277 & 0.128 & 0.043 & 0.000 & 0.021 \end{bmatrix}$$

$$R_{2\_2} = \begin{bmatrix} 0.149 & 0.340 & 0.362 & 0.106 & 0.043 & 0.000 & 0.000 \\ 0.170 & 0.277 & 0.447 & 0.064 & 0.021 & 0.021 & 0.000 \end{bmatrix}$$

$$R_{2\_3} = \begin{bmatrix} 0.021 & 0.468 & 0.404 & 0.064 & 0.021 & 0.021 & 0.000 \\ 0.064 & 0.468 & 0.404 & 0.043 & 0.000 & 0.021 & 0.000 \end{bmatrix}$$

The comprehensive evaluation vector B is obtained by multiplying the weight vector W (as shown in Table 4) by R. The following are the results:

$$B_{2\_1} = W_{2\_1}R_{2\_1} = [0.1817, 0.2911, 0.3374, 0.0954, 0.0670, 0.0200, 0.0073]$$

$$B_{2\_2} = W_{2\_2}R_{2\_2} = [0.1602, 0.3068, 0.4066, 0.0840, 0.0313, 0.0112, 0.0000]$$

$$B_{2\_3} = W_{2\_3}R_{2\_3} = [0.0431, 0.4681, 0.4043, 0.0529, 0.0104, 0.0213, 0.0000]$$

$$B_1 = W_1 R_1 = [0.1587, 0.4493, 0.1807, 0.1511, 0.0602, 0.0000, 0.0000]$$

$$B_2 = W_2 \begin{bmatrix} B_{2\_1} \\ B_{2\_2} \\ B_{2\_3} \end{bmatrix} = [0.1345, 0.3481, 0.3763, 0.0796, 0.0403, 0.0180, 0.0031]$$

$$B = W \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} = [0.1479, 0.4042, 0.2679, 0.1193, 0.0513, 0.0080, 0.0014]$$

After calculating the comprehensive evaluation vector B and the quantified evaluation set V = [7, 6, 5, 4, 3, 2, 1], the evaluation result score of the student residential apartment is:

$$N = BV^T$$

$$[0.1479, 0.4042, 0.2679, 0.1193, 0.0513, 0.0080, 0.0014]\,[7,6,5,4,3,2,1]^T = 5.449$$

The results revealed that residents rated the overall performance of the student residential apartment complex as "***Somewhat good.***" The findings indicated that the student residential apartment performance was considered to be at an above average level, implying that the needs of the majority students were met.

4.2 Student residents' perceived importance ranking

According to the method introduced and the 47 valid survey responses, Table 4 shows the AHP weighting and ranking of student residential apartment performance attributes. The results reveal that residents emphasised architectural design (U_1) more than (difference = 0.1088) building services (U_2). At level 2, under architectural design (U_1), exterior appearance (U_{1_1}) was weighted almost 1.5 times more than interior setting (U_{1_2}) and building layout (U_{1_3}). Under the building services aspect (U_2), comfort (U_{2_1}) was ranked the highest among the three performance attributes. Safety and security (U_{2_3}) and hygiene and health (U_{2_2}) received relatively equal weightings, meaning that residents considered them equally important. At level 3, under comfort (U_{2_1}), residents ranked visual comfort ($U_{2\_1\_2}$) the highest, followed by acoustic comfort ($U_{2\_1\_3}$) and thermal comfort ($U_{2\_1\_1}$). Under hygiene and health (U_{2_2}), hygiene ($U_{2\_2\_2}$) was ranked higher than indoor air quality ($U_{2\_2\_1}$). Under safety and security (U_{2_3}), residents ranked security ($U_{2\_3\_2}$) slightly higher (difference = 0.0264) than fire safety ($U_{2\_3\_1}$).

Table 4. AHP weightings and ranking of student residential apartment performance attributes

Hierarchy level	Code	Performance attributes	AHP weighting	Ranking
Level 1	**U_1**	Architectural design	0.5544	1
	U_2	Building services	0.4456	2

Level 2	U_{1_1}	Exterior appearance	0.4370	1
	U_{1_2}	Interior setting	0.2642	3
	U_{1_3}	Building layout	0.2988	2
	U_{2_1}	Comfort	0.4277	1
	U_{2_2}	Hygiene and health	0.2743	3
	U_{2_3}	Safety and security	0.2980	2
Level 3	$U_{2\_1\_1}$	Thermal comfort	0.2874	3
	$U_{2\_1\_2}$	Visual comfort	0.3673	1
	$U_{2\_1\_3}$	Acoustic comfort	0.3453	2
	$U_{2\_2\_1}$	Indoor air quality	0.4729	2
	$U_{2\_2\_2}$	Hygiene	0.5271	1
	$U_{2\_3\_1}$	Fire safety	0.4868	2
	$U_{2\_3\_2}$	Security	0.5132	1

4.3 Comparison of the perceived importance of the building performance aspects among sub-groups

The survey enquired about the students' background information to provide different insights into the respondents' evaluation of the performance of the built environment, and to reveal the preferences of particular sub-groups (e.g., gender, nationality, educational background, length of stay in the student residential apartment). In order to reveal the perception gaps among residents of different backgrounds, intra-group factor weighting comparison was conducted based on three groups of background information: gender, educational background, and length of stay (months).

4.3.1 Comparison by gender

Figure 6 shows the AHP weightings between female and male residents. According to the comparison results at level 1, female residents regarded architectural design (U_1) and building services (U_2) to be equally important, but male residents ranked architectural design (U_1) almost 0.2 higher than the building services (U_2).

At level 2, under architectural design (U_1), both female and male residents placed a higher level of importance on exterior appearance (U_{1_1}), followed by building layout (U_{1_3}) and interior setting (U_{1_2}). Under building services (U_2), both female and male students regarded comfort (U_{2_1}) as much more important than the other two performance attributes. Also, the weighting of hygiene and health (U_{2_2}) between female and male residents is almost identical.

At level 3, under the category of comfort (U_{2_1}), female students placed the least importance on thermal comfort ($U_{2\_1\_1}$) while their emphasis on visual comfort ($U_{2\_1\_2}$) and acoustic comfort ($U_{2\_1\_3}$) are similar. For male student residents, they considered thermal comfort ($U_{2\_1\_1}$) and acoustic comfort ($U_{2\_1\_3}$) almost equally important but gave a slightly higher weighting to visual comfort ($U_{2\_1\_2}$). In summary, female and male student residents do not have significant difference in importance of weightings, while they do have slightly different concerns on each performance attribute.

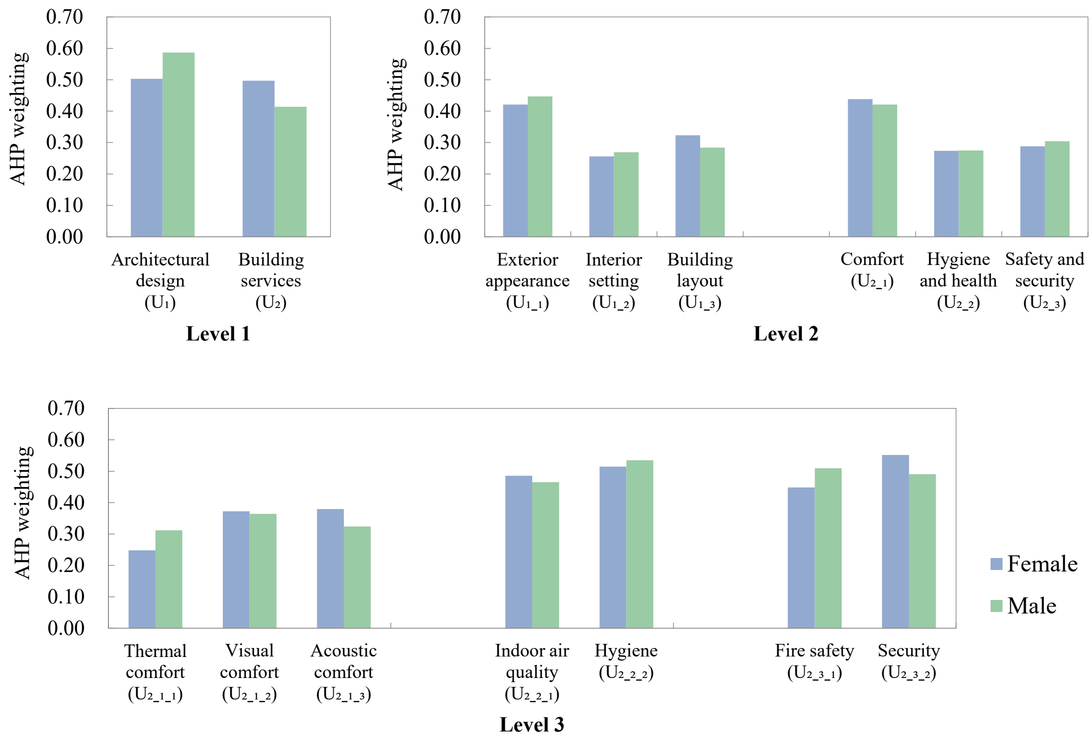

Figure 6. AHP weightings between different genders

4.3.2 Comparison by nationality – local or non-local student

Figure 7 shows the AHP weightings between local (Dutch) and non-local (non-Dutch) student residents. According to the comparison results at level 1, both local and non-local student residents gave equal weight to architectural design (U_1) and building services (U_2). Architectural design received 0.11 more weight than architectural design.

Exterior appearance (U_{1_1}) is regarded as the most important factor for both local and non-local student residents at level 2, under architectural design (U_1), as it received a high level of weighting from two groups of student residents. Local student residents valued both the interior setting (U_{1_2}) and the building layout (U_{1_3}) equally, but non-local student residents valued the building layout (U_{1_3}) more. Local student residents almost unanimously ranked comfort (U_{2_1}) and safety and security (U_{2_3}) as the most critical building performance under building services (U_2). Comfort was the most important concern for non-local student residents (U_{2_1}), followed by hygiene and health (U_{2_2}) and safety and security (U_{2_3}).

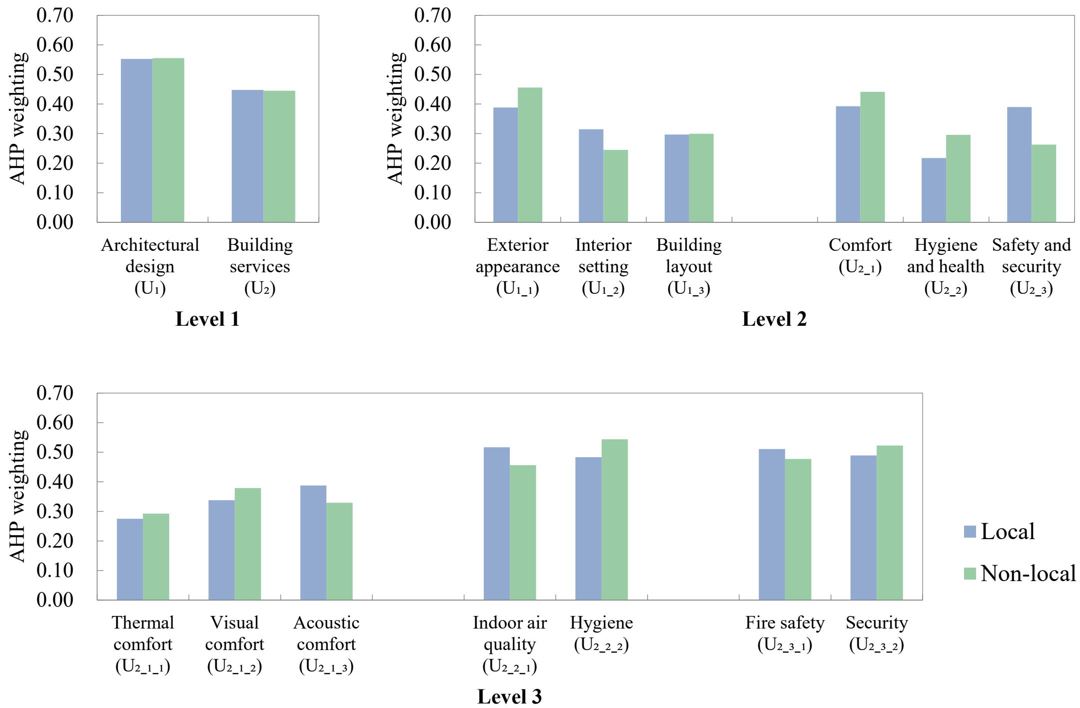

Figure 7. AHP weightings between local (Dutch) and non-local (non-Dutch) student residents

4.3.3 Comparison by educational background

Figure 8 shows the AHP weightings between undergraduate and postgraduate student residents. According to the comparison results at level 1, postgraduate student residents regarded architectural design (U_1) as significantly more important than building services (U_2), with a 0.18 AHP weighting difference. However, undergraduate student residents considered building services (U_2) slightly more critical than architectural design (U_1).

At level 2, under architectural design (U_1), both undergraduate and postgraduate student residents ranked the exterior appearance (U_{1_1}) as the most essential of the three attributes, and the importance of building layout (U_{2_3}) as almost equal. Under building services (U_2), comfort (U_{2_1}) is the priority for undergraduate and postgraduate residents. The difference between graduate and undergraduate residents on the perceived importance of building performance at this level is minimal, at within 0.05

At level 3, under the category of comfort (U_{2_1}), the importance of thermal comfort ($U_{2\_1\_1}$), visual comfort ($U_{2\_1\_2}$), and acoustic comfort ($U_{2\_1\_3}$) were regarded with a high level of homogeneity by undergraduate student residents, while postgraduate student residents placed more importance on visual comfort ($U_{2\_1\_2}$). Under the category of hygiene and health (U_{2_2}), undergraduate and graduate residents assessed the importance of indoor air quality ($U_{2\_2\_1}$) and hygiene ($U_{2\_2\_2}$) to be equivalent. Under the category of comfort (U_{2_3}), postgraduate residents are more concerned with safety ($U_{2\_3\_2}$) when compared with undergraduate residents.

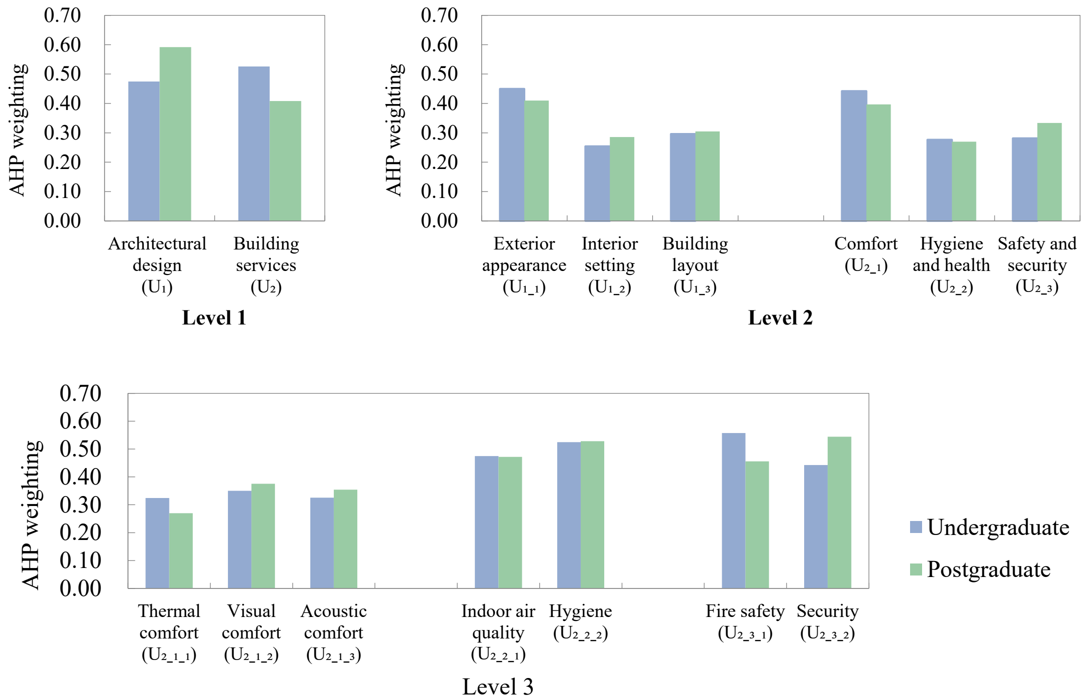

Figure 8. AHP weightings between various educational background

4.3.4 Comparison by length of stay (months)

With 4 months being the most common length of stay, the data was divided into two groups: student residents with length of stay 1) less than or equal to 4 months, and 2) length of stay over 4 months. Figure 9 illustrates the AHP weightings between the two groups length of stay (<= 4 months and > 4 months).

According to the comparison results at level 1, student residents with shorter periods of stay (<= 4 months) gave a weighting 0.25 higher to architectural design (U_1) and 0.13 lower to building service (U_2) than student residents with longer periods of stay (> 4 months).

At level 2, under architectural design (U_1), residents with longer periods of residence considered all three attributes as equally essential, whereas student residents with shorter periods of stay (<= 4 months) placed greater emphasis on appearance (U_{1_1}). Under building services (U_2), comfort (U_{2_1}) was the top priority for student residents with shorter period of stay (<= 4 months), while safety was higher on the priority for those staying longer (> 4 months).

At level 3, under the category of comfort (U_{2_1}), visual comfort ($U_{2\_1\_2}$) was most critical indicator to student residents with shorter periods of stay (<= 4 months), while acoustic comfort was most important to those staying longer (> 4 months). Under the category of hygiene and health (U_{2_2}), student residents with longer periods of stay (> 4 months) valued indoor air quality ($U_{2\_2\_1}$) more than hygiene ($U_{2\_2\_2}$). The importance of fire safety ($U_{2\_3\_1}$) and security ($U_{2\_3\_2}$) was not considerably different among residents staying for different lengths of time.

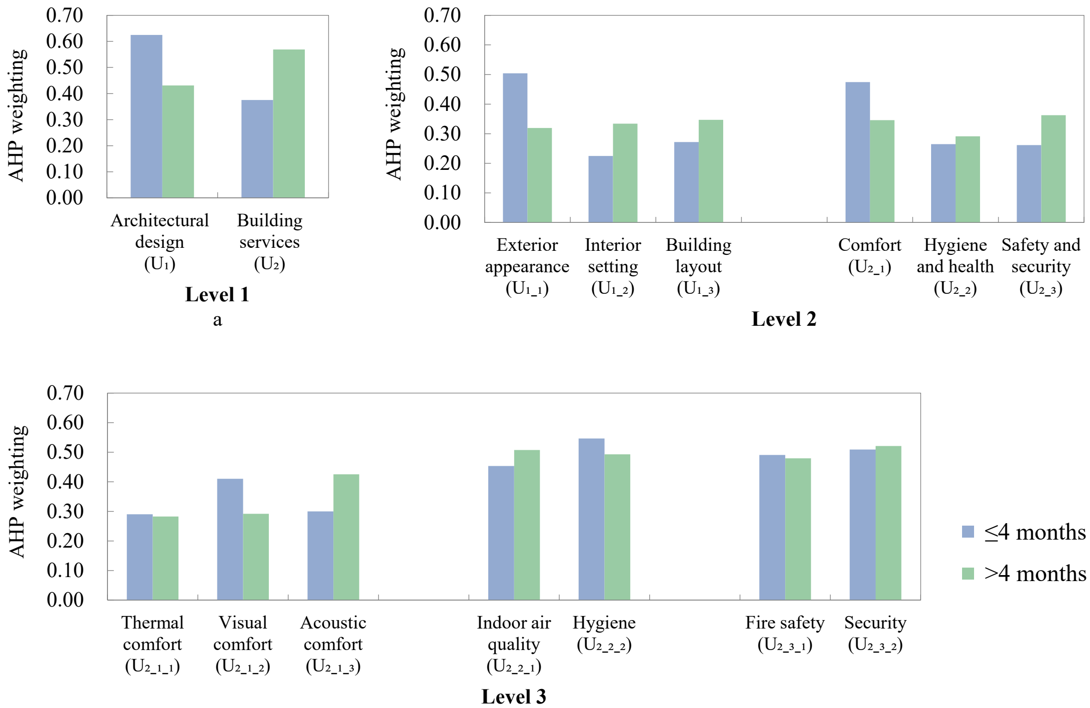

Figure 9. AHP weightings and ranking between various lengths of stay (months)

4.4 Comparison of satisfaction of building performance aspects among sub-groups

In this study, the perceived importance of the student residential apartment performance attributes was combined to calculate the satisfaction level of the overall residential apartment and each indicator. Moreover, the satisfaction of sub-groups was assessed (e.g., gender, educational background, length of stay in the residential apartment). Table 5 shows the satisfaction level of student residential apartment performance attributes from the residents. The satisfaction scores assist in determining the aspects that are not effectively meeting the student's expectation and can be used as a reference to enhance the functionality of the residential apartment.

Table 5. Satisfaction of student residential apartment performance attributes

Hierarchy level	Code	All student residents	Gender		Educational background		Length of stay (months)		Local (Dutch) or non-local (non-Dutch)	
			Female	Male	Under-graduate	Post-graduate	<=4	>4	local	No-local
Overall Satisfaction		5.449	5.342	5.523	5.393	5.477	5.706	5.027	5.599	5.402
Level 1	U_1	5.495	5.308	5.611	5.406	5.535	5.755	5.038	5.669	5.433
	U_2	5.390	5.377	5.397	5.381	5.394	5.625	5.018	5.512	5.363
Level 2	U_{1_1}	5.489	5.389	5.552	5.400	5.531	5.733	5.059	5.692	5.412
	U_{1_2}	5.319	5.000	5.517	5.067	5.438	5.467	5.059	5.692	5.176
	U_{1_3}	5.660	5.444	5.793	5.733	5.625	6.033	5.000	5.615	5.676
	U_{2_1}	5.335	5.236	5.393	5.240	5.386	5.639	**4.806**	5.571	5.299
	U_{2_2}	5.448	5.448	5.443	5.632	5.360	5.676	5.061	5.501	5.428
	U_{2_3}	5.417	5.523	5.362	5.348	5.440	5.550	5.184	5.458	5.399

Level 3	$U_{2\_1\_1}$	5.170	5.111	5.207	5.267	5.125	5.467	**4.647**	5.615	5.000
	$U_{2\_1\_2}$	5.340	5.278	5.379	5.067	5.469	5.667	**4.765**	5.308	5.353
	$U_{2\_1\_3}$	5.468	5.278	5.586	5.400	5.500	5.767	**4.941**	5.769	5.353
	$U_{2\_2\_1}$	5.447	5.333	5.517	5.667	5.344	5.567	5.235	5.538	5.412
	$U_{2\_2\_2}$	5.447	5.556	5.379	5.600	5.375	5.767	**4.882**	5.462	5.441
	$U_{2\_3\_1}$	5.340	5.278	5.379	5.200	5.406	5.533	5.000	5.308	5.353
	$U_{2\_3\_2}$	5.489	5.722	5.345	5.533	5.469	5.567	5.353	5.615	5.441

Note: U_1: Architectural design; U_2: Building services; U_{1_1}: Exterior appearance; U_{1_2}: Interior setting; U_{1_3}: Building layout; U_{2_1}: Comfort; U_{2_2}: Hygiene and health; U_{2_3}: Safety and security; $U_{2\_1\_1}$: Thermal comfort; $U_{2\_1\_2}$: Visual comfort; $U_{2\_1\_3}$: Acoustic comfort; $U_{2\_2\_1}$: Indoor air quality; $U_{2\_2\_2}$: Hygiene; $U_{2\_3\_1}$: Fire safety; $U_{2\_3\_2}$: Security

The result reveals that the levels of satisfaction were "somewhat good" for both the overall residential apartment and each building attribute, demonstrating that the modular buildings can satisfy students' expectation and receive positive feedback. Student residents were most satisfied with the building layout (U_{2_1}) (satisfaction rating: 5.660 out of 7) and least satisfied with thermal comfort ($U_{2\_1\_1}$) (satisfaction rating: 5.170). Although the importance rating building layout (U_{2_1}) received was the second lowest among three performance attributes under architectural design (U_1) (Table 4), it received the highest satisfaction rating of all performance attributes. Thermal comfort ($U_{2\_1\_1}$) was rated the least important of the three performance attributes under comfort (U_{2_1}) and was least satisfied by student residents of all the performance attributes. The satisfaction ratings for the remaining building performance attributes range between 5.310 and 5.495, indicating that student residents are relatively satisfied with these building performance attributes. The findings revealed that the AHP-FCE method provides a mechanism for integrating the importance and satisfaction rating in order to accurately reflect student residents' evaluations of building performance.

Under the sub-groups of gender, educational background and nationality (Dutch or non-Dutch student residents), there were no significant differences in the satisfaction of student residents, which were all somewhat good (satisfaction ratings are all above 5.000) . However, student residents with a longer period of stay (> 4 months) had lower satisfaction levels than those with shorter periods of stay (<= 4 months), particularly for comfort (U_{2_1}), which scored only neutral. Specifically, thermal comfort ($U_{2\_1\_1}$) was the most unsatisfactory attribute for longer-staying residents, followed by visual comfort ($U_{2\_1\_2}$) and acoustic comfort ($U_{2\_1\_3}$). As shown in Table 5, the satisfaction ratings for comfort (U_{2_1}), thermal comfort($U_{2\_1\_1}$), visual comfort ($U_{2\_1\_2}$) and acoustic comfort ($U_{2\_1\_3}$) are less than 5.000. According to Hou et al. [5]'s study, the longer student residents stay in the building, the less satisfied they are with the building's performance.

4.5 Comparison of residents' satisfaction among various studies

As student residential apartment design is considered to be universally similar, a comparison of student residents' satisfaction among various studies is scientifically reliable and would provide a deeper insight on general student residents' perception on student residential apartment performance. The residents' satisfaction rating obtained from this study is thus compared to those by Hou et al. [5], Ning and Chen [9], Hassanain [13], Toprakli [56], Sanni-Anibire and Hassanain [19], Lai [51], and Kim and Kim [57]. As these studies adopted different rating scales for satisfaction evaluation (e.g., the rating scale employed by Hassanain [13] and Toprakli [56] were 4-point; Sanni-Anibire and Hassanain [19], Kim and Kim [57], Ning and Chen[9] were 5-point;

Lai [51] and Hou et al. [5] were 7-point), *Equation (7)* was used to standardize the rating value on a 7-point scale to assure fair comparison.

$$\frac{\text{Satisfaction rating}}{\text{i}} \times 7 \qquad (7)$$

where i represents the rating scale used in different studies.

4.5.1 Satisfaction rating comparison on architectural design attributes

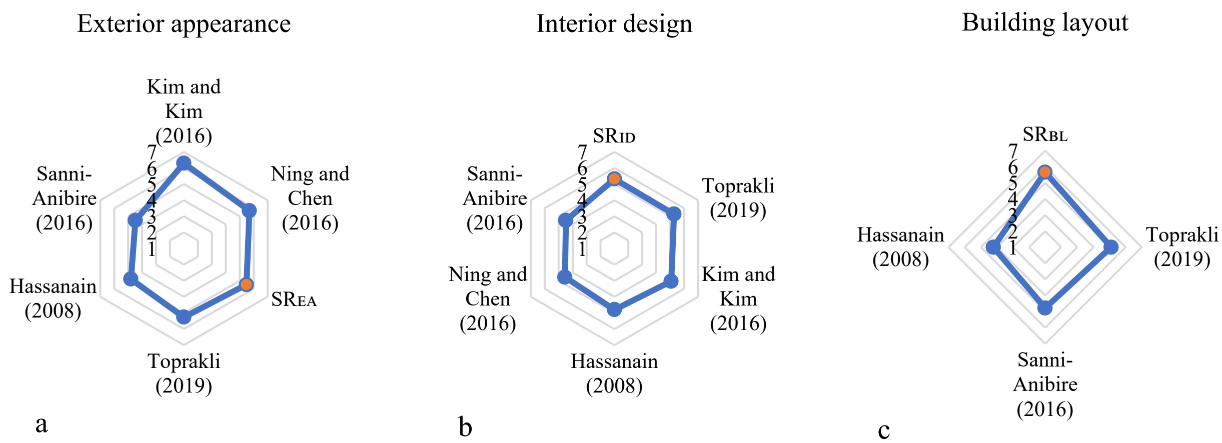

Figure 10. Satisfaction rating comparison on exterior appearance, interior setting and building layout

Note: SR refers to the satisfaction rating value obtained in this study. SR_{EA}, SR_{IS}, and SR_{BL} represent the satisfaction rating of exterior appearance, interior setting, and building layout in this study, respectively.

Figure 10 shows the satisfaction ratings from different studies [12, 15, 21, 64, 69] on architectural design attributes, including exterior appearance, interior setting and building layout. The comparison results indicate that residents' satisfaction rating on the exterior appearance, interior setting, and building layout ranged from neutral to good (satisfaction rating ranging between 3 to 6). Also, the residents in this study expressed a slightly higher level of satisfaction with the three performance attributes. Especially for building layout, the satisfaction rating obtained in this study is 0.5-1.5 higher than that in other studies. The comparison results suggest that these three performance attributes in a modular student residential apartment were ranked higher than those of traditional student residential apartments.

4.5.2 Satisfaction rating comparison on building services attributes

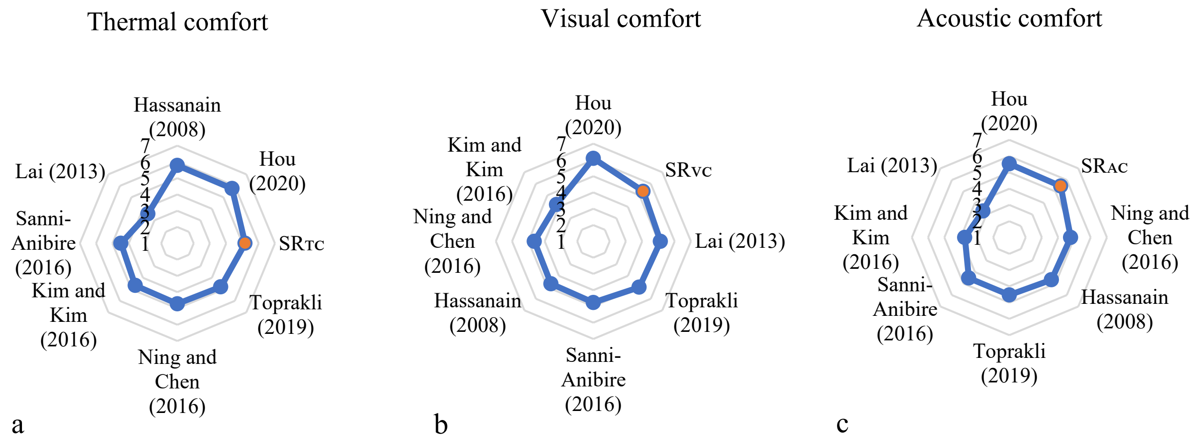

Figure 11.Satisfaction rating comparison on thermal comfort, visual comfort and acoustic comfort

Note: SR refers to the satisfaction rating value obtained in this study. SR_{TC}, SR_{VC}, and SR_{AC} represent the satisfaction rating of thermal comfort, visual comfort, and acoustic comfort in this study, respectively.

Among the comparison results illustrated in Figure 11, the satisfaction ratings on the three performance attributes related to comfort range from 3 to 6 out of 7. The satisfaction ratings on thermal comfort and acoustic comfort from Lai [51]'s study were significantly (ranging between 3 and 4) lower than those from other studies. The student residential apartment investigated in Lai [51]'s study was a high-rise building located in a central urban area in Hong Kong. The satisfaction rating shows that student residents living in that student residential apartment (in Lai [51]'s study) were not satisfied regarding the thermal comfort and acoustic comfort. Also, in Kim and Kim [57]'s study, the satisfaction rating of the three performance attributes were also relatively low, ranging between 3 and 5 out of 7. The average level of satisfaction rating on acoustic comfort is much lower compared to those for thermal comfort and visual comfort.

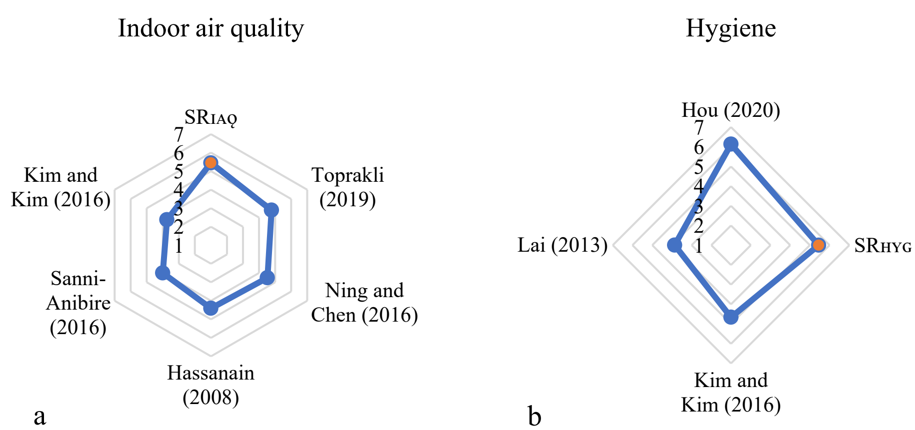

Figure 12. Satisfaction rating comparison on indoor air quality and hygiene condition

Note: SR refers to the satisfaction rating value obtained in this study. SR_{IAQ} and SR_{HYG} represent the satisfaction rating of indoor air quality and hygiene, respectively.

According to Figure 12, residents' satisfaction rating on indoor air quality among the six studies were relatively low on average (ranging between 3 and 4 out of 7). Residents from the student residential apartments investigated were less satisfied with indoor air quality. Four studies investigated the hygiene performance attribute in student residential apartments from different regions and the comparison results show that, again, student residents' satisfaction rating on hygiene in Lai [51]'s study was significantly lower than those from other studies.

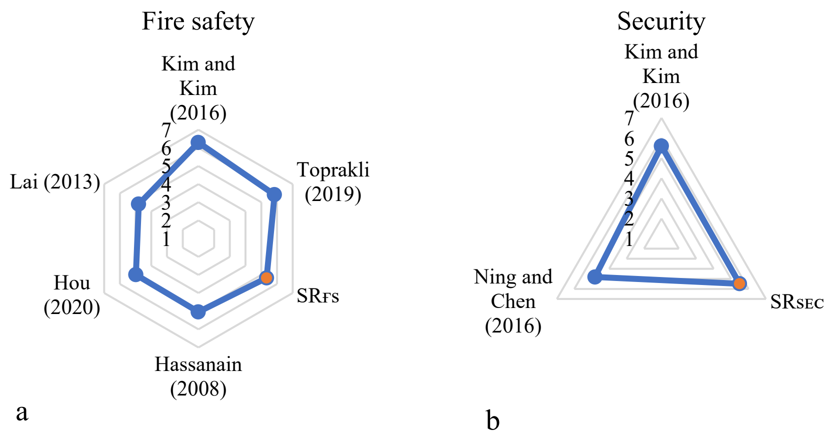

Figure 13. Satisfaction rating comparison on fire safety and security

Note: SR refers to the satisfaction rating value obtained in this study. SR_{FS} and SR_{SEC} represent the satisfaction ratings for fire safety and security in this study, respectively.

Six studies evaluated fire safety performance attributes from the residents' perspective, while only three studies, including this study, investigated the security performance attribute. In general, the residents' satisfaction rating on both of the performance attributes were above average (above 4 out of 7).

Overall, the satisfaction rating of the ten performance attributes in the student residential apartment investigated in this study is relatively high, and the satisfaction rating for each performance attribute is relatively even, ranging between 5 and 6 out of 7.

5. Discussion

Previous studies on student residential apartment performance only used satisfaction ratings to assess student residents' perceptions of student residential apartment performance. Lai [51] and Hou et al. [5] collected data on both student residents' perceived importance and satisfaction with each building performance attribute, and they discussed perceived importance and satisfaction with each building performance attribute separately. Their studies did not address how the perceived importance of each performance aspect affected the satisfaction scores. This study recognised that a person's expressed satisfaction may not acutely reflect his or her perception. As previous research [5, 51] has suggested that one's perceived importance of building performance attributes influences one's satisfaction, it is necessary to incorporate the perception variation into the rating system in order to reveal more accurate satisfaction. AHP-FCE method was used in this study to obtain more accurate and reliable rating results. The findings may allow for a more accurate comparison of various studies conducted on various student residential apartments.

This study adopted an occupant-oriented approach to examine the physical performance of a student residential apartment. Aside from perceived importance of and satisfaction with student residential apartment performance, the survey also collected background information from student residents. Inter-group comparisons were carried out in order to investigate the relationships between student residents' background information and their variation in perceptions. For example, while the overall perceived importance weighting indicated that student residents from the selected student residential apartment complex valued architectural design attributes slightly more important than building service attributes, inter-group comparison results revealed that student residents with longer lengths of stay valued building services attributes more than architectural design counterparts. Inter-group comparison can help residents from various backgrounds understand their needs more precisely. The studies of Lai [51] and Hou et al. [5]'s also looked at the relationships between student residents' background and their perception. However, the results of this study differed because it was based on two student residential apartments in Hong Kong.

This is one of the first studies to create a systematic performance evaluation framework to aid in the evaluation of student residential apartment performance. Previous research on student residential apartments focused primarily on building services design attributes such as thermal comfort, acoustic comfort, visual comfort, IAQ, while architectural design attributes received less attention. The building performance attributes were systematically classified in this study to allow for scientific evaluation. Furthermore, the framework was created from the perspective of the residents through the use of the focus group discussion method. Building professionals' evaluation frameworks may not fully reflect actual building performance because some functional facilities are only accessible to residents. It is necessary to involve student resident representatives in the development of the SRAPEF and in evaluating the performance of specific student residential apartment projects/buildings. This is especially important for the Netherlands, where a number of modular student residential apartments are being built or will be built in response to the rising trend in student enrolment. A thorough understanding of residents' feedback/perceptions on the performance of the student residential apartment in which they live would aid in providing insights for future student residential apartment development projects or the refurbishment of existing student residential apartments. This is especially important for the Netherlands, where a number of modular student residential apartments are being built or will be built in response to the rising trend in student enrolment. A thorough understanding of residents' feedback/perceptions on the performance of the student residential apartments in which they live would aid in providing insights for future student residential apartment development projects or the refurbishment of existing student residential apartments.

6. Conclusion

An occupant-oriented approach has been adopted to guide the design of this study, which includes two main steps of research activities: first, a performance evaluation framework for the student complex investigated was developed based on literature review and a focus group discussion with student residents representatives; second, considering that individuals' fuzziness and randomness when indicating the perceived importance of a specific type of built environment attribute and perceived importance would affect the satisfaction level, an AHP-FCE evaluation method was used to analyse student residents' perception of the student complex's built environment performance. This method not only reflects the weighting of each built environment performance attribute in each level of the hierarchical framework (Figure 4), but also reveals the inter-relationships between the performance attributes.

The case study results indicate that overall student satisfaction with the student residential apartment was positive, and student residents perceived architectural design attributes slightly more important than building services attributes. The case study results also show that residents of different backgrounds (gender, education level, length of stay) perceived the performance of the student residential apartment differently, such as male residents perceiving building service attributes as more important, while their female counterparts' view was the opposite. This implies that the FCE-AHP method allows a more in-depth and accurate understanding of building residents' perceptions. The method has proved to be useful for investigating student residential apartment performance and can be applied in student residential apartments at other higher educational institutions. This study provides significant implication on future student residential apartment design and management practice, especially on how to scientifically integrate end-users' opinions on guiding design activities and post-occupancy evaluation. Furthermore, this is the very first study that evaluate modular buildings and it offers practical insights on future modular building development.

The limitation of this study lies in that 1) only one student residence complex was studied and 2) only subjective data was collected. Thus, more student residential apartments should be included in future studies. Also, measurable objective data should be collected on site to verify the residents' perception and the effectiveness of the framework.

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Reference

[1] F. Yang, Y. Sun, P. Wang, L.B. Weschler, J. Sundell, Spread of respiratory infections in student dormitories in China, Science of The Total Environment. 777 (2021) 145983.

[2] P. Araujo, J. Murray, Estimating the effects of dormitory living on student performance, Economics Bulletin. 30 (2010) 866-878.

[3] M. Daliri Dizaj, T. Hatami Khanghahi, Students' residential preferences: a case study is dormitories of University of Mohaghegh Ardabili, Journal of Asian Architecture and Building Engineering. 21 (4) (2022) 1348-1363.

[4] C. Hou, J. Lai, User-centric student housing performance evaluation approach: a case study in the Netherlands, IOP conference series : earth and environmental science, IOP, 2022, 062015.

[5] H. Hou, J.H.K. Lai, D. Edwards, Gap theory based post-occupancy evaluation (GTbPOE) of dormitory building performance: A case study and a comparative analysis, Building and Environment. 185 (2020) 107312.

[6] H. Hou, J.H.K. Lai, D. Zhang, Development of a post-occupancy evaluation framework for modular student housing – a case study in the Netherlands, Proceedings of the 26th International Symposium on Advancement of Construction Management and Real Estate, Springer, 2022, 1481-1495.

[7] A. Almalki, Postoccupancy evaluation for student housing with a focus on maintenance planning, design process, and client requirement, Journal of Performance of Constructed Facilities. 36 (1) (2022) 04021117.
[8] J. Thomsen, Home experiences in student housing: about institutional character and temporary homes, Journal of Youth Studies. 10 (5) (2007) 577-596.
[9] Y. Ning, J. Chen, Improving residential satisfaction of university dormitories through post-occupancy evaluation in China: A socio-technical system approach, Sustainability. 8 (10) (2016) 1050.
[10] M.-T. Nazarpour, S. Norouzian-Maleki, A comparative study of satisfaction evaluation between students of mid-rise and high-rise student housing, Facilities. 39 (7/8) (2021) 508-524.
[11] D. Amole, Residential satisfaction in students' housing, Journal of Environmental Psychology. 29 (1) (2009) 76-85.
[12] F.A. Mustafa, Performance assessment of buildings via post-occupancy evaluation: A case study of the building of the architecture and software engineering departments in Salahaddin University-Erbil, Iraq, Frontiers of Architectural Research. 6 (3) (2017) 412-429.
[13] M.A. Hassanain, On the performance evaluation of sustainable student housing facilities, Journal of Facilities Management. 6 (3) (2008) 212-225.
[14] M.T. Nazarpour, S. Norouzian Maleki, The evaluation of effective factors on female students' residential satisfaction in dormitories, Quarterly of Applied Psychology. 13 (1) (2019) 163-179.
[15] H. Oppewal, Y. Poria, N. Ravenscroft, G. Speller, Student preferences for university accommodation: An application of the stated preference approach, in Housing, space and quality of life. (2017) 113-124.
[16] P. Toyin Sawyerr, N.A. Yusof, Student satisfaction with hostel facilities in Nigerian polytechnics, Journal of Facilities Management. 11 (4) (2013) 306-322.
[17] Z. Dong, K. Zhao, M. Ren, J. Ge, I.Y.S. Chan, The impact of space design on occupants' satisfaction with indoor environment in university dormitories, Building and Environment. 218 (2022) 109143.
[18] J.T. Gbadegesin, M.O. Komolafe, T.F. Gbadegesin, K.O. Omotoso, Off-campus student housing satisfaction indicators and the drivers: From student perspectives to policy re-awakening in governance, Journal of Human Behavior in the Social Environment. 31 (7) (2021) 889-915.
[19] M.O. Sanni-Anibire, M.A. Hassanain, Quality assessment of student housing facilities through post-occupancy evaluation, Architectural Engineering and Design Management. 12 (5) (2016) 367-380.
[20] N.U.M. Najib, N.A. Yusof, Z. Osman, Measuring satisfaction with student housing facilities, American Journal of Engineering and Applied Sciences. 4 (1) (2011) 52-60.
[21] M.A. Ajayi, A. Nwosu, Y.A. Ajani, Students' satisfaction with hostel facilities in Federal University of Technology, Akure, Nigeria, European Scientific Journal. 11 (34) (2015) 402-415.
[22] A. Standard, Standard 55–2017 thermal environmental conditions for human occupancy, Ashrae: Atlanta, GA, USA. (2017) 62.

[23] S. Wafi, M.R. Ismail, Occupant's thermal satisfaction a case study in Universiti Sains Malaysia (USM) Hostels Penang, Malaysia, European Journal of Scientific Research. 46 (2010) 309-319.

[24] C. Liu, Y. Zhang, L. Sun, W. Gao, X. Jing, W. Ye, Influence of indoor air temperature and relative humidity on learning performance of undergraduates, Case Studies in Thermal Engineering. 28 (2021) 101458.

[25] M. Emmanuella, H. Alibaba, The assessment of indoor thermal comfort in a building: a case study of Lemar, Salamis Road, Famagusta, Cyprus, International Journal of Civil and Structural Engineering Research. 6 (2) (2018) 109-127.

[26] Z. Wu, N. Li, P. Wargocki, J. Peng, J. Li, H. Cui, Adaptive thermal comfort in naturally ventilated dormitory buildings in Changsha, China, Energy and Buildings. 186 (2019) 56-70.

[27] S. Dhaka, J. Mathur, A. Wagner, G.D. Agarwal, V. Garg, Evaluation of thermal environmental conditions and thermal perception at naturally ventilated hostels of undergraduate students in composite climate, Building and Environment. 66 (2013) 42-53.

[28] J. Mohelnikova, Light and lighting-basic terms and criteria for specifying lighting requirements, Journal of Light and Visual Environment. 32 (1) (2008) 20-26.

[29] A. Michael, C. Heracleous, Assessment of natural lighting performance and visual comfort of educational architecture in Southern Europe: The case of typical educational school premises in Cyprus, Energy and Buildings. 140 (2017) 443-457.

[30] Dahlan, Nur Dalilah, Phillip John Jones, Donald Kneale Alexander, E. Salleh, and J. Alias. "Daylight ratio, luminance, and visual comfort assessments in typical Malaysian hostels." *Indoor and Built Environment* 18, no. 4 (2009): 319-335.

[31] Moadab, Nima Hafezparast, Thomas Olsson, Géza Fischl, and Myriam Aries. "Smart versus conventional lighting in apartments-Electric lighting energy consumption simulation for three different households." *Energy and Buildings* 244 (2021): 111009

[32] B. Rasmussen, Sound insulation between dwellings-requirements in building regulations in Europe, Applied Acoustics. 71 (4) (2010) 373-385.

[33] N.D. Dahlan, Perceptive-cognitive aspects investigation in relation to indoor environment satisfaction collected from naturally ventilated multi-storey student accommodations in Malaysia, Indoor and Built Environment. 24 (1) (2015) 116-127.

[34] P.T. McGrath, M. Horton, A post-occupancy evaluation (POE) study of student accommodation in an MMC/modular building, Structural Survey. 29 (3) (2011) 244-252.

[35] A. Steinemann, P. Wargocki, B. Rismanchi, Ten questions concerning green buildings and indoor air quality, Building and Environment. 112 (2017) 351-358.

[36] K.W. Tham, Indoor air quality and its effects on humans-A review of challenges and developments in the last 30 years, Energy and Buildings. 130 (2016) 637-650.

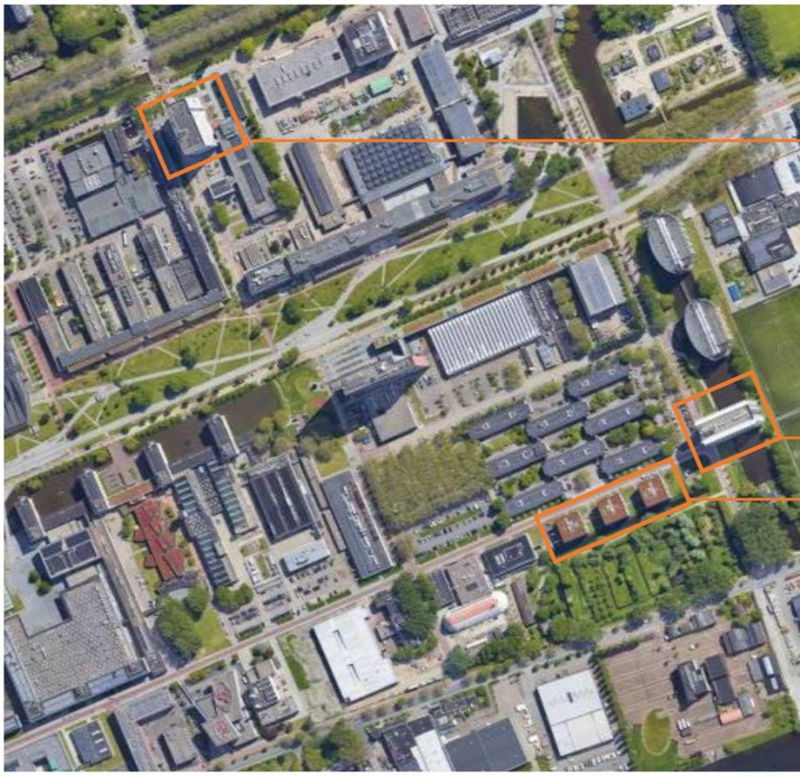
[37] L. Xu, Y. Hu, W. Liang, Subjective and objective sensory assessments of indoor air quality in college dormitories in Nanjing, Building and Environment. 212 (2022) 108802.

[38] Y. Sun, Y. Zhang, L. Bao, Z. Fan, D. Wang, J. Sundell, Effects of gender and dormitory environment on sick building syndrome symptoms among college students in Tianjin, China, Building and Environment. 68 (2013) 134-139.

[39] Y. Sun, J. Sundell, Y. Zhang, Validity of building characteristics and dorm dampness obtained in a self-administrated questionnaire, Science of The Total Environment. 387 (1) (2007) 276-282.

[40] P. Strøm-Tejsen, D. Zukowska, P. Wargocki, D.P. Wyon, The effects of bedroom air quality on sleep and next-day performance, Indoor Air. 26 (5) (2016) 679-686.
[41] F. Simpeh, W. Shakantu, On-campus university student housing facility services prioritisation framework, Facilities. 38 (1/2) (2020) 20-38.
[42] Q. Chai, H. Li, W. Tian, Y. Zhang, L. Wang, A framework for assessing the performance of adaptively reused buildings from users' perspective: a case study of school building, Advances in Civil Engineering. 2022 (2022) 1339133.
[43] M. Kumar, S.H. Khan, Using post-occupancy evaluation as a methodological approach to assess residential hostels in CFTI, Archnet-IJAR: International Journal of Architectural Research. ahead-of-print (2022).
[44] F. Simpeh, S. Adisa, Evaluation of on-campus student housing facilities security and safety performance, Facilities. 39 (7/8) (2021) 470-487.
[45] D. Ikediashi, G. Udo, M. Ofoegbu, Post-occupancy evaluation of University of Uyo buildings, Journal of Engineering, Design and Technology. 18 (6) (2020) 1711-1730.
[46] H. Li, Z. Wang, T. Hong, Occupant-Centric key performance indicators to inform building design and operations, Journal of Building Performance Simulation. 14 (6) (2021) 814-842.
[47] H. Hou, D. Zhang, J.H.K. Lai, Qualitative and quantitative investigation into the indoor built environment of modular student housing: A multiple-room case study, Energy and Buildings. 280 (2023) 112734.
[48] S.-K. Wong, L. Wai-Chung Lai, D.C.-W. Ho, K.-W. Chau, C. Lo-Kuen Lam, C. Hung-Fai Ng, Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong, Habitat International. 33 (4) (2009) 463-471.
[49] J.H.K. Lai, F.W.H. Yik, Perceived Importance of the Quality of the Indoor Environment in Commercial Buildings, Indoor and Built Environment. 16 (4) (2007) 311-321.
[50] J.H.K. Lai, F.W.H. Yik, Perception of importance and performance of the indoor environmental quality of high-rise residential buildings, Building and Environment. 44 (2) (2009) 352-360.
[51] J.H.K. Lai, Gap theory based analysis of user expectation and satisfaction: The case of a hostel building, Building and Environment. 69 (2013) 183-193.
[52] D. Yang, C.M. Mak, An assessment model of classroom acoustical environment based on fuzzy comprehensive evaluation method, Applied Acoustics. 127 (2017) 292-296.
[53] D. Yang, C.M. Mak, Relationships between indoor environmental quality and environmental factors in university classrooms, Building and Environment. 186 (2020) 107331.
[54] T.L. Saaty, Decision-making with the AHP: Why is the principal eigenvector necessary, European Journal of Operational Research. 145 (1) (2003) 85-91.
[55] L. Zadeh, Fuzzy logic-a personal perspective, Fussy Sets and Systems. 281 (2015) 4-20.
[56] Y. Toprakli, A Post Occupancy Evaluation Study for University Students' Dormitory for User Satisfaction, Gençlik Araştırmaları Dergisi. 7 (18) (2019) 39-60.
[57] M. Kim, M.j. Kim, Affordable modular housing for college students emphasizing habitability, Journal of Asian Architecture and Building Engineering. 15 (2016) 49-56.

Appendix 1. Student residential apartments and their location in the university campus (Source: google map)



Appendix 2. Questionnaire

Section 1 – Personal Particulars

General information				
Gender	Male	☐	Female	☐
Local or non-local student	Local (Dutch)	☐	Non-local (Non-Dutch)	☐
Undergraduate or postgraduate	Undergraduate	☐	Postgraduate	☐
Length of stay in the student residential apartment (months)		________ Months (e.g. 24 months)		
Typical days per week staying (days)		________ days		

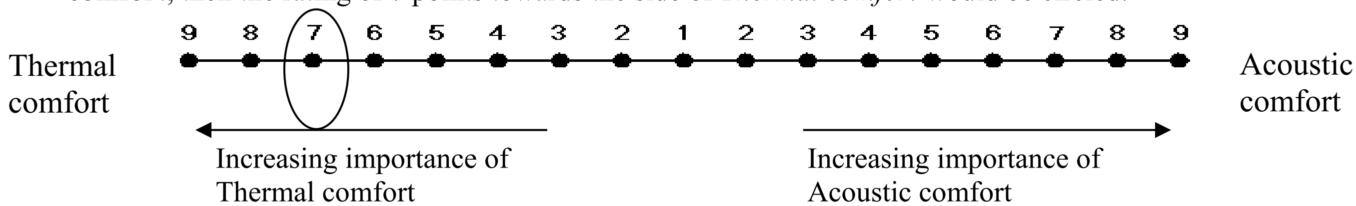
Section 2 – Importance weighting of the student residential apartment performance attributes

For each question, please **clearly circle** the appropriate point that matches with your judgment on the relative importance between the two attributes presented in the question using the follow rate scheme:

Point*	DESCRIPTION
1	Equally important
2	
3	Moderately more important
4	
5	Strongly more important
6	
7	Very strongly more important
8	
9	Extremely important

* Note that points 2,4,6,8 are for a level between levels one point above and below

Example: If one considers that **Thermal comfort is very strongly more important than Acoustic comfort**, then the rating of 7 points towards the side of *Thermal comfort* would be circled.



Please indicate below your judgment of the relative importance between each pair of attributes. (Please circle the number)

Architectural design attributes	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Building service attributes
Exterior appearance	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Building layout

Exterior appearance	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Interior setting
Building layout	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Interior setting

Comfort	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Hygiene and health
Comfort	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Safety and security
Hygiene and health	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Safety and security
Thermal comfort	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Visual comfort
Thermal comfort	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Acoustic comfort
Visual comfort	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Acoustic comfort
Indoor air quality	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Hygiene
Fire safety	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Security

Section 3 – Satisfaction rating of the student residential apartment performance

Circle the level of **SATISFACTION** of the following performance attributes in the student residential apartment **in general**: (please circle the number)

Performance attribute	Extremely low					Extremely high
1. Architectural design attributes (U_1)	1	2	3	4	5	6	7
2. Building service attributes (U_2)	1	2	3	4	5	6	7

3. Exterior appearance (U_{1_1})	1	2	3	4	5	6	7
4. Interior setting (U_{1_2})	1	2	3	4	5	6	7
5. Building layout (U_{1_3})	1	2	3	4	5	6	7
6. Comfort (U_{2_1})	1	2	3	4	5	6	7
7. Hygiene and health (U_{2_2})	1	2	3	4	5	6	7
8. Safety and security (U_{2_3})	1	2	3	4	5	6	7
9. Thermal comfort ($U_{2\_1\_1}$)	1	2	3	4	5	6	7
10. Visual comfort ($U_{2\_1\_2}$)	1	2	3	4	5	6	7
11. Acoustic comfort ($U_{2\_1\_3}$)	1	2	3	4	5	6	7
12. Indoor air quality ($U_{2\_2\_1}$)	1	2	3	4	5	6	7
13. Hygiene ($U_{2\_2\_2}$)	1	2	3	4	5	6	7
14. Fire safety ($U_{2\_3\_1}$)	1	2	3	4	5	6	7
15. Security ($U_{2\_3\_2}$)	1	2	3	4	5	6	7

---- End of Questionnaire ----