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Perception of Importance and Performance of the Indoor Environmental Quality of High-Rise Residential Buildings

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Abstract

The quality of buildings, including their performance in a range of indoor environmental attributes, is influential to the living quality of habitants. Many studies on appropriate importance weights for the attributes have been reported but few embraced both human perception of the importance of such attributes and the related performance of buildings. Focusing on typical public and private high-rise residential buildings in Hong Kong, users' perceived importance of four key attributes, namely thermal comfort, air cleanliness, odour and noise, and their perceived performance of the buildings in these attributes were studied. Perceptions collected from 563 respondents were processed through an analytical hierarchy process to generate importance weights for the attributes. Correlation analyses corroborate that perceived importance may vary among buildings of different types and between residents and visitors. Thermal comfort was perceived by the vast majority as the most important. Using a performance-importance plot, it is shown how the gaps between perceived performance and perceived importance can be identified. The results can help determine the areas for improvement in new building designs and facilitate prioritization of limited resources for upgrading building performance.

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Introduction

High-rise residential buildings are ubiquitous in Hong Kong due to its high population density. Recently, the stocks of public and private residential flats have exceeded 682,000 and 1,346,000 respectively [1]. Public housing flats for accommodating low income households have standard layouts and are generally small, which can hardly cater for varied living patterns and preferences [2]. Private flats are generally occupied by middle- to high-income owners or tenants. Although the living spaces in these flats are larger, the typical cruciform layout coupled with a compact core design lowers the quality of the communal areas in such buildings [3].

Besides flat size and layout, many other factors such as the outdoor environment [4], nearness to infrastructures and facilities [5] and internal housing features like location of living room [6] affect the living quality of habitants. The multifaceted environmental performance of a building, in respect to the quality of the indoor thermal, visual and aural environments and indoor air quality, also impacts the health of occupants and their satisfaction with the habitats [7].

For enhancing building environmental performance, many voluntary assessment schemes have emerged, such as the Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK [8] and the Leadership in Energy and Environmental Design

(LEED) Green Building Rating System in the US [9]. In Hong Kong, the HK-BEAM Society has been reasonably successful in widening subscription to its voluntary Hong Kong Building Environmental Assessment Method [10]. All such schemes invariably embrace assessments on a number of indoor environmental quality (IEQ) attributes; each of which carries certain credit points to the overall result.

Increasingly, the analytical hierarchy process (AHP) is used to process perceptions, for deriving relative importance weights among the assessed attributes which are needed to aggregate the itemized assessment results into a combined score (e.g. [11,12]). A study on commercial buildings found that different psychophysical factors affect subjective judgments on perceived importance [13]. For residential buildings, however, little is known about habitants' perception of the attributes' importance. Although facilities management companies may conduct regular surveys of residents' satisfaction with their living environment, i.e. the perceived performance of the buildings under their management, so as to identify areas for improvement, there is a lack of guidance on how to prioritize them such that the greatest improvement can be achieved within a constrained budget. This study was meant to bridge this knowledge gap in the Hong Kong context.

The following section describes the design of the questionnaire and the data collection method used in the study, and the derivation of the perceived importance ratings for four key IEQ attributes namely thermal comfort, air-cleanliness, odour and noise. Concordance analyses of the importance weights of these attributes are then reported, followed by the users' perception of the performance of buildings and the factors which give rise to their variations. The last part elaborates a practical approach for identifying gaps between perceived importance and perceived performance with regard to these attributes.

The questionnaire survey

A questionnaire, split into two parts, was designed for use in a survey on building end users. Because people with different perceptual experiences and adaptations to environmental stimuli would have different perceptions of the importance of IEQ attributes [14,15], the first part asks the respondent whether he/she is a resident or visitor and, for a resident, the length of residence in the building. The second part requests the respondents to indicate their perceived relative importance between pairs of IEQ attributes using a 9-point scale as shown in Table 1 (adapted from [16]), which was explained to them beforehand. The final set of questions in this part asks the respondent to express his/her perceived performance of the attributes in the common area and the living/visited area of the building, using a 7-point ordinal scale (1 = 'unacceptable', through 4 = 'neutral' to 7 = 'excellent').

The desire to elicit genuine responses and the need to minimize the duration of an interview to avoid withdrawal of the respondent confined the scope of the study to four attributes, and thus only six pair-wise comparisons. Since the two building types (private and public) under investigation typically differ by having openable windows or not in their communal areas, which directly affect ventilation and noise propagation there, thermal comfort, air-cleanliness, odour and noise were selected as the four attributes. Furthermore, they are among the critical IEQ attributes which most people know what they mean, have experience with environments at different levels in these attributes and can readily express their perception about the environment with respect to these attributes.

A team of trained research personnel conducted the questionnaire survey through interviews with people they met at entrances to typical public or private high-rise residential buildings. Generally each interview took around 10 minutes and the responses were recorded on printed questionnaires. Totally 563 individuals participated voluntarily in the survey. 483 of them were residents and the remaining were visitors.

Analysis and discussion

Perceived Importance of IEQ Attributes

Software packages, e.g. [17], are available to process perceived importance ratings given by respondents and check on the spot the consistency of their judgments. Where inconsistency is found, the sample is usually rescued by asking the respondent to adjust his/her judgment until the consistency check is satisfied. Instead of this practice, which may introduce artificial intervention to the collected data, the first response given by the respondents in respect of their perceived importance of the IEQ attributes was recorded, while consistency check was done only subsequently.

According to the AHP method [18], the importance weights among the four IEQ attributes were computed based on the pair-wise relative importance ratings given by each respondent using a program written in FORTRAN for this purpose. As shown in Figure 1, the major function of the program was to handle data input and output while the importance weights were computed by calling the EVCRG standard subroutine for eigenvalue and eigenvector calculations, which is available from the well-established International Mathematical and Statistical Library (IMSL) in the software package Microsoft Developer Studio FORTRAN

PowerStation. Additionally, the program would extract the principal eigenvalue and eigenvector from those calculated by EVCRG, compute the consistency ratio (*CR*) of each data set according to Equation (1) [18], as well as normalize the elements in the principal eigenvector to yield the importance weights (such that their sum equals 1).

$$CR = \frac{\lambda_{\max} - n}{n-1} \cdot \frac{1}{RC} \qquad (1)$$

In Equation (1), $\lambda_{\max}$ is the principal eigenvalue computed by EVCRG; n equals 4 (as four attributes are being studies); and *RC* is the random consistency. According to Saaty [18], for pair-wise comparison of 4 attributes involving the use of a 4×4 comparison matrix, the value of *RC* is 0.89 and the *CR* limit is 9%. Therefore, data sets with calculated *CR* values exceeding this threshold were regarded as inconsistent and thus had to be discarded.

Out of the 563 samples, 184 passed the consistency check, including 106 from private buildings users and 78 from public building users. The overall usable rate of the samples is, therefore, 33% (Table 2); those of the private and public building user groups are 32% and 34% respectively, which are comparable. Although the post-survey check removed a substantial amount of the collected data (67%), it can ensure the quality of data used in the analysis.

As shown in Table 3, the mean *CR* value of the usable samples in the private building group is greater than that of the public building group but both their standard deviation and range are smaller, yet all by just a small margin. Among the samples giving inconsistent judgment on the perceived importance of the IEQ attributes (i.e. $CR > 0.09$), the standard deviation of the private building group is marginally smaller than that of the public building group but the reverse is true for their range values. On the whole, the differences between the values of mean, standard deviation and range (i.e. difference between the maximum and minimum values of data) of the two groups are minimal.

Figure 2 shows the distribution of the number of samples and the rate of usable samples in the residents group by the years of residence of the respondents in their buildings, and the cumulative usable rate of the samples. The longest residence period among the respondents was 35 years and no respondents had a residence period of 27, 29, 33 or 34 years. As expected, the extreme usable sample rates (at 0% or 100%) were pertaining to residence periods with small number of samples. Despite the variations in sample number over the different years of residence, the cumulative usable rate of samples rises quickly beyond the first year and approaches the maximum (about 30%) at around 10 years of residence. This trend implies that residents would be better able to consistently judge the relative importance of the IEQ attributes when they have acquainted with the living environment.

The AHP weights of the four IEQ attributes calculated from individual usable samples were averaged to yield the mean importance weights. The results, in descending order, are 0.3382 for thermal comfort, 0.2305 for noise, 0.2290 for air cleanliness and 0.2023 for odour. Separate results from usable samples in the two main user categories, i.e. private and public building users, are shown in Table 4. The margin of error (E) of each importance weight was calculated based on a 95% level of confidence under the Student's t-distribution. The importance ranks of the attributes, determined based on the importance weight values, reveal that thermal comfort was regarded as the most important and odour the least in both categories. The ranking orders of air cleanliness and noise reversed between the two categories. When the responses were segregated into residents and visitors, similar findings were observed, including the reverse in ranking orders of air cleanliness and noise between the two groups (Table 5).

As Figure 2 shows the obvious difference in usable rate between residents with a residence period of less or more than 10 years, the averaged AHP weights pertaining to these two subgroups were examined (Table 6). The importance of thermal comfort rated by both subgroups was the highest and that of odour was the lowest. The ranking orders of air cleanliness and noise reverse between the two subgroups. Given the marginal difference between the importance weights of air cleanliness (0.2257) and noise (0.2224), their rankings by the new residents (residence ≤ 10 years) may be interpreted as nearly equal. Together with the result that the visitors regarded cleanliness as more important than noise while old residents (residence > 10 years) valued more the aural environment (Table 5), the perceived equal order of new residents is between visitors and old residents. In other words, the new residents are on the way of converting from visitors' preference to that of old ones in terms of air cleanliness and noise.

Table 7 shows the results where the private building users were subdivided into resident and visitor subgroups. Thermal comfort was ranked most important by both subgroups whereas the attribute that was regarded least important differs between the private building residents (noise) and private building visitors (odour). Observing the weights and ranks of attributes determined from responses of the resident and visitor subgroups in the public building user group (Table 8) shows that they were consistent in what they regarded as most (thermal comfort) and least (odour) important attributes but had different opinions about the relative importance of air cleanliness and noise.

Concordance of Perception between Respondent Groups

Spearman's rank correlation was used to test if there is concordance in perceptions between different groups and subgroups of respondents. The value of the Spearman's rank correlation coefficient (r_s), calculated using Equation (2), may range from "−1" (entirely opposite ranking) through "0" (no correlation) to "+1" (perfect agreement in ranking) [19]. In Equation (2), d_a is the difference in rank between pairs of attributes being compared and n_p is the number of pairs.

$$r_s = 1 - \frac{6\sum_{a=1}^{n_p} d_a^{\,2}}{n_p^{\,3} - n_p} \qquad (2)$$

The Spearman's rank correlation coefficients between the respondent groups and subgroups are summarized in Figures 3 and 4. As shown in Figure 3, the Spearman rank correlation coefficients of the two pairs of respondent groups are coincidently identical, with both exhibiting strongly positive correlation (r_s=0.8). Although further examination between pairs of the subgroups reveals a perfect match between the importance of IEQ attributes rated by the visitors to private and public buildings (r_s = 1.0) and a strongly positive correlation between the ratings given by the public building residents and visitors (r_s = 0.8), the correlation of ranks between the private building residents and visitors is only moderately positive (r_s = 0.4) and that between the private building residents and public building residents is weak (r_s = 0.2).

Psychophysical reasons for the above variations in correlation include: (i) psychophysical scaling is not only affected by the stimulus being judged, but also other stimuli surrounding the stimulus [20]; (ii) rather than an exact copy of the stimuli, the perception that the respondents indicated could be a distortion based on their own interpretations [21]; and (iii) other than the earlier mentioned personal factors, variables such as personal experiences, beliefs, emotions and memories also affect individual interpretations [22-24].

Despite that the concordance in the importance ranking of the IEQ attributes among the four subgroups of respondents varies from weak to perfect (r_s = 0.2 to 1.0; Figure 4), the Spearman's rank correlation coefficients are all positive in value. The Kendall coefficient of concordance (W) was, therefore, used for a further test of whether or not there is statistically significant agreement in the rankings unveiled by all the subgroups. W was calculated using Equation (3) where S, determined using Equation (4), is the sum of the squares of the deviations of the row rank sums (R_i) from their mean value $m(n+1)/2$ pertaining to the n attributes rated by the m subgroups, and u_j is the number of consecutive members of the j^{th} tied rank. The value of W may fall between 0 and 1, corresponding to no community of preference to perfect agreement [19].

$$W = \frac{12S}{m^2(n^3 - n) - m\sum_j (u_j^{\ 3} - u_j)} \qquad (3)$$

$$S = \sum_{i=1}^{n} \left[R_i - \frac{m(n+1)}{2} \right]^2 \qquad (4)$$

The Kendall coefficient of concordance found was 0.700, which provides sufficient support to regarding the subgroups as not significantly different in their ranking of the importance of the IEQ attributes. Therefore, the average importance weights for the four IEQ attributes computed from the ratings given by all respondents (thermal comfort: 0.3382; noise: 0.2305;

air cleanliness: 0.2290; and odour: 0.2023) can represent the importance weights perceived by all of them for high-rise residential buildings in Hong Kong.

Perceived Performance of IEQ Attributes

The ratings (from 1 to 7) that reflect individual respondent's perceived performance of the common area (e.g. lift lobby, corridor) and the living/visited area (e.g. living room, bedroom) in each of the IEQ attributes were averaged to provide a general picture. The results are shown in Figure 5, which show that the performance of those spaces was regarded by the respondents as just above average (rating = 4), with comparable performance across thermal comfort, air cleanliness and odour but lower in noise.

Between the living/visited area and the common area, the differences in performance ratings of thermal comfort and noise (0.14 and 0.16 respectively) are less than those of air cleanliness and odour (0.23 and 0.25 respectively). The higher scores of the attributes in the living/visited area should be due to the following reasons:

1. Occupiers, including those who own or rent the flats, have the exclusive right to dwell in the living/visited area and, therefore, for their own utility, will make efforts to improve the environmental conditions therein until the conditions are acceptable to them. Relative to private flat owners, public flat tenants have less incentive, degree of freedom and financial ability to make improvements and, therefore, may not be able to improve the environmental conditions in their dwellings to their desired level.

2. Common area is accessible to all building users, including visitors, and its environmental quality is looked after by the building management but could be abused by uncaring users. In this respect, private flat owners have greater incentive to more conscientiously use the common area outside their flats to avoid devaluation of their property.

The separately calculated averaged performance ratings given by the private and public building residents, as shown in Figure 6, support well the above deductions. Similar observations were noted from the ratings given by the visitors, as shown in Figure 7. The fact that private buildings are provisioned with higher-quality materials and facilities should have also contributed to the higher perceived performance.

For some IEQ performance of the living/visited and the common area, the visitors ranked them higher than the residents did. For instance, all the four averaged performance ratings for the four IEQ attributes given by the visitors for the living/visited area in private buildings exceed 5.1 but the highest averaged rating given by the residents is lower than 5.0 (Figures 6 and 7). Similar relation exists for living/visited area in public buildings, though not for all IEQ attributes.

The lowest performance rating given by the residents was on the noise attribute for all the four types of areas (Figure 6). Unlike visitors whose perceptual experience of the aural environment is restricted to the relatively short period of their visit, the residents stay in the buildings for much longer period of time, including during bedtime. Any noisy disturbance during such period would intensify their dissatisfaction, thus a perception of low performance. Furthermore, typical public and private buildings differ in their corridor designs which affect their noise performance. Openable windows are provided in standard public housing blocks but rarely in private residential buildings (Figures 8 and 9). Many public building residents are accustomed to keeping their main entrance doors open for better natural ventilation which would help minimize electricity cost for running fans or air-conditioners. Thus, any noise generated at or transmitted via the corridor would lead to poor perceived noise performance.

Individuals' Perceptions and Tendencies of their Perceptions

It is a common facilities management practice that regular customer (user) satisfaction surveys are conducted to collect perceptions about the environmental performance of common areas in a building, but without examining at the same time the users' perceived importance of the environmental performance. When underperformed aspects are identified, more resources would be deployed for their improvement. It would not be a problem if ample resources were available. But since facilities management budget is often limited, managers are forced to prioritize the needed improvement measures for implementation. By taking into account also users' perceived importance of the environmental performance, resources could be directed to tackle aspects of poor performance that are perceived as important to the users.

For the abovementioned purpose, the relation between perceived performance and perceived importance about the IEQ attributes, as unveiled by the respondents who were residents, was further examined. One key issue that needs to be investigated first is whether perceived importance would affect one's perception about performance, and vice versa. Figure 10 summarizes the plausible tendencies in judgement, denoted by the arrows labelled from A to H, which might arise due to mutual influences between perceived performance and perceived importance. If such tendencies are significant, they should be taken into account in order to avoid making wrong facilities management decisions.

As suggested by Figure 10, if there is systematic interdependence between perceived performance and perceived importance, the combined perceptions of the respondents, when plotted on a graph similar to Figure 10, would tend to cluster around the diagonals of the graph. Figures 11 to 14 show the scattered plots of the perceived performance against the perceived importance of the respondents for the four key IEQ attributes studied. As these graphs show no apparent correlation between perceived performance and perceived importance, the hypothesis that there existed interdependence between the two may be rejected.

Aligning Performance with Importance

Having shown that existence of systematic interdependence between perceived performance and perceived importance in the judgements of the respondents was unlikely, the following analysis examines the average performance ratings and importance weights drawn from all usable responses of the respondents. The ranks of the perceived performance ratings and those of the perceived importance of the attributes were as shown in Tables 9 and 10, which correspond to the private building residents and the public building residents respectively. Here, a performance-importance plot is used to identify whether and to what extent the ranks of perceived performance align with the perceived importance ranks of the attributes.

Figure 15 depicts the results of the private building residents group. The performance of thermal comfort aligns with its importance perceived by the residents. The biggest gap is associated with odour but its performance is 2 ranks above its importance. The performance of both noise and air cleanliness is 1 rank below the rank of importance that the residents perceived.

The results of the public building residents group are plotted in Figure 16. Thermal comfort and noise, perceived by the public residents as the two most important attributes, have both their performance ranks lower than their importance ranks. On the other hand, while the performance of air cleanliness is the highest, it was only rated as the third important attribute. As for odour, a much smaller gap between its performance and importance is noted.

Perfect alignment between perceived performance and perceived importance of all the IEQ attributes does not appear in either case but clearly, both the frequency and extent of gaps are higher in the case of public residents. This shows the poorer alignments between the ranks of performance and the ranks of importance that the residents perceived about the common area of the pubic buildings.

Besides enabling facilities managers to make decisions on the priority of resources allocation for environmental condition improvements, the results drawn from the performance-importance analysis are useful information to project managers and building designers. Once the deficient areas are identified, the building environmental conditions can be improved through refurbishments or new designs. For instance, if thermal comfort in the common area of an existing building is found to have the highest importance rank while its performance is ranked bottom by the end users, the facilities manager would realise the priority of improving the ventilation there. Possible refurbishments may include providing additional openings for natural ventilation or adding a mechanical ventilation system. Such an experience would also be a useful feedback for designers in designing buildings with similar configurations in future. When more study findings about other important attributes become available, building users would be more likely to enjoy a quality living environment.

Conclusions

Residents who have familiarised over time with their living environment tend to give more consistent judgement of the relative importance between pairs of the four key IEQ attributes: thermal comfort, air cleanliness, odour and noise. Regardless of the intervention of types (private or public) and purpose (resident or visitor) of users on their perceived importance of the attributes, thermal comfort was constantly regarded as the most important.

The performance of the attributes in the common area that the users perceived was generally lower than the counterpart in the living/visited area, among which noise was the worst. An open-corridor design is good for natural ventilation in the public buildings. But the custom that the residents keep their household doors open in order to minimize energy cost for fans or air-conditioners promotes the propagation of noise, which contributes to its low performance rating.

Rather than investigating only the perceived performance of the attributes, it is also crucial to find out their importance as perceived by the users. The performance-importance analysis, based on the overall response of the users, has demonstrated how the gaps between them can be identified. This is the kind of information that facilities manager should consider in optimising the use of the often constrained resources to manage buildings. Furthermore, it can inform the areas for improvement in existing buildings and the necessary modifications for building design in future.

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Figure Captions

Figure 1 Steps for calculation of importance weights and consistency ratio

Figure 2 Distribution of number and usable rate of resident samples

Figure 3 Spearman rank correlations between: (i) private and public users; (ii) resident and visitor

Figure 4 Spearman rank correlations between subgroups (resident and visitor) of private and public users

Figure 5 Performance rating of IEQ attributes of common area and living/visited area

Figure 6 Performance of IEQ attributes rated by residents

Figure 7 Performance of IEQ attributes rated by visitors

Figure 8 A typical floor of public residential buildings (corridor with openable window)

Figure 9 A typical floor of private residential buildings (internal corridor without openable window)

Figure 10 Tendencies of perception and perceptions of importance and performance

Figure 11 Distribution of individual response on thermal comfort

Figure 12 Distribution of individual response on air cleanliness

Figure 13 Distribution of individual response on odour

Figure 14 Distribution of individual response on noise

Figure 15 Gaps between performance and importance of IEQ attributes (private residents)

Figure 16 Gaps between performance and importance of IEQ attributes (public residents)

Tables

Table 1 Definition and explanation of the importance ratings

Rating	Definition	Explanation
1	Equal importance	Two attributes perceived as equally important.
3	Moderate importance of one over another	Experience and judgment moderately favour one attribute over another.
5	Strong importance	Experience and judgment strongly favour one attribute over another.
7	Very strong importance	An attribute is strongly favoured and its dominance demonstrated in practice.
9	Extreme importance	The evidence favouring one attribute over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between the two adjacent judgments	The importance is between levels one point above and below.

Table 2 Classification of the samples

	Overall	**Private user**	**Public user**
Total sample	563	332	231
Usable sample (*CR* ≤ 0.09)	184	106	78
Non-usable sample (*CR* > 0.09)	379	226	153
% usable sample	33%	32%	34%

Table 3 Consistency ratio of the samples

	Private user			Public user		
	Mean	S.D.	Range	Mean	S.D.	Range
Usable sample (*CR* ≤ 0.09)	0.0311	0.0273	0.0868	0.0289	0.0289	0.0900
Non-usable sample (*CR* > 0.09)	0.3702	0.3628	2.7589	0.3861	0.3713	2.5934

Table 4 AHP weights and ranks of IEQ attributes rated by private and public users

	Private user (n = 106)			**Public user (n = 78)**		
	Weight	*E*	Rank	Weight	*E*	Rank
Thermal comfort	0.3353	0.0295	1	0.3422	0.0359	1
Air cleanliness	0.2239	0.0211	2	0.2358	0.0264	3
Odour	0.2203	0.0204	4	0.1779	0.0175	4
Noise	0.2205	0.0206	3	0.2441	0.0259	2

Table 5 AHP weights and ranks of IEQ attributes rated by residents and visitors

	Resident (n = 144)			**Visitor (n = 40)**		
	Weight	*E*	Rank	Weight	*E*	Rank
Thermal comfort	0.3376	0.0261	1	0.3404	0.0467	1
Air cleanliness	0.2240	0.0174	3	0.2466	0.0432	2
Odour	0.2048	0.0164	4	0.1936	0.0278	4
Noise	0.2336	0.0192	2	0.2194	0.0281	3

Table 6 AHP weights and ranks of IEQ attributes rated by subgroups of residents

	Resident with residence > 10 years (n = 72)			**Resident with residence ≤ 10 years (n = 72)**		
	Weight	*E*	Rank	Weight	*E*	Rank
Thermal comfort	0.3395	0.0385	1	0.3356	0.0363	1
Air cleanliness	0.2224	0.0234	3	0.2257	0.0264	2
Odour	0.1932	0.0238	4	0.2163	0.0229	4
Noise	0.2449	0.0298	2	0.2224	0.0246	3

Table 7 AHP weights and ranks of IEQ attributes rated by private residents and visitors

	Private resident (n = 87)			**Private visitor (n = 19)**		
	Weight	*E*	Rank	Weight	*E*	Rank
Thermal comfort	0.3427	0.0332	1	0.3014	0.0679	1
Air cleanliness	0.2188	0.0228	3	0.2470	0.0591	2
Odour	0.2209	0.0234	2	0.2177	0.0427	4
Noise	0.2176	0.0241	4	0.2340	0.0370	3

Table 8 AHP weights and ranks of IEQ attributes rated by public residents and visitors

	Public resident (n = 57)			**Public visitor (n = 21)**		
	Weight	*E*	Rank	Weight	*E*	Rank
Thermal comfort	0.3298	0.0435	1	0.3757	0.0658	1
Air cleanliness	0.2320	0.0278	3	0.2463	0.0675	2
Odour	0.1801	0.0203	4	0.1718	0.0371	4
Noise	0.2581	0.0314	2	0.2062	0.0441	3

Table 9 Performance and importance of IEQ in common area perceived by private residents

	Performance			Importance		
	Rating	*E*	Rank	AHP weight	*E*	Rank
Thermal comfort	4.8345	0.1239	1	0.3353	0.0295	1
Air cleanliness	4.7379	0.1423	3	0.2239	0.0211	2
Odour	4.7897	0.1474	2	0.2203	0.0204	4
Noise	4.5276	0.1606	4	0.2205	0.0206	3

Table 10 Performance and importance of IEQ in common area perceived by public residents

	Performance			**Importance**		
	Rating	*E*	Rank	AHP weight	*E*	Rank
Thermal comfort	4.5855	0.1550	2	0.3422	0.0359	1
Air cleanliness	4.6269	0.1649	1	0.2358	0.0264	3
Odour	4.5544	0.1932	3	0.1779	0.0175	4
Noise	4.1088	0.1946	4	0.2441	0.0259	2

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Figures

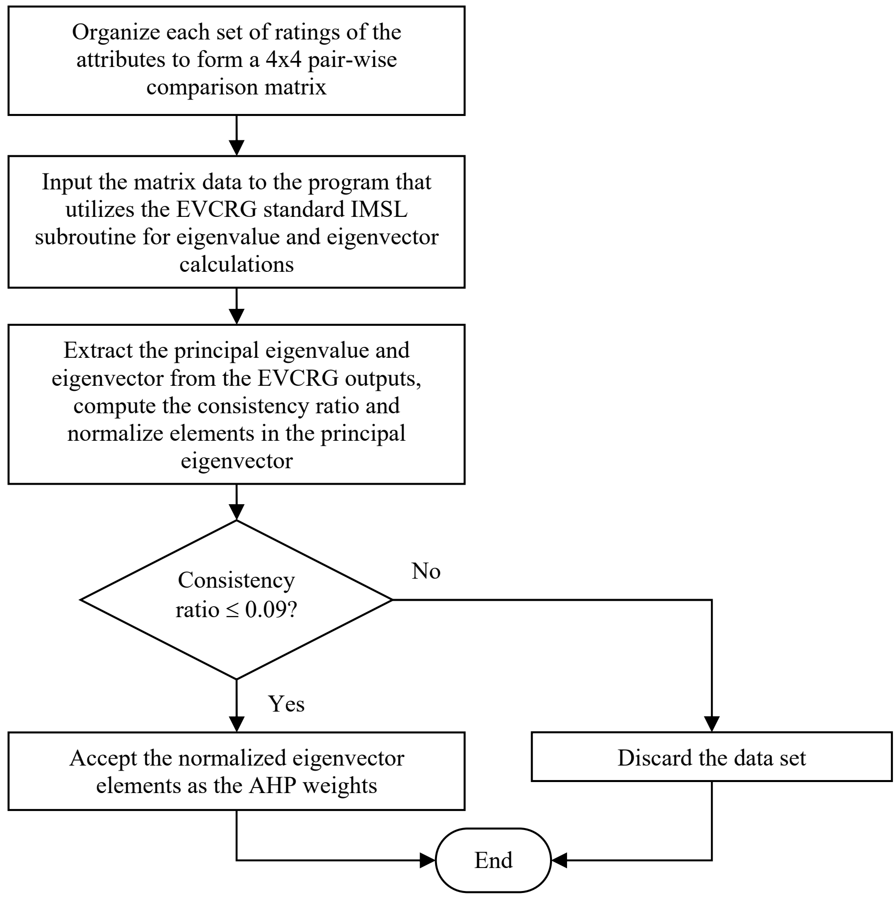

Figure 1 Steps for calculation of importance weights and consistency ratio

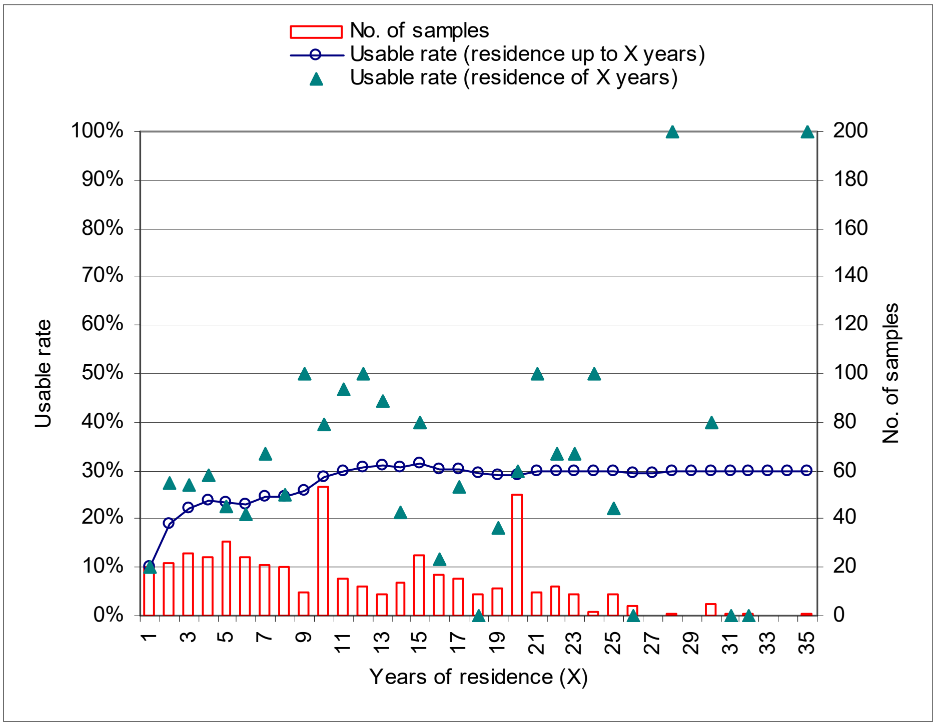

Figure 2 Distribution of number and usable rate of resident samples

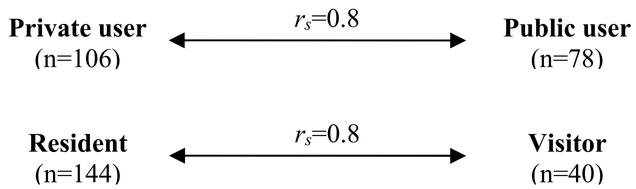

Figure 3 Spearman rank correlations between: (i) private and public users; (ii) resident and visitor

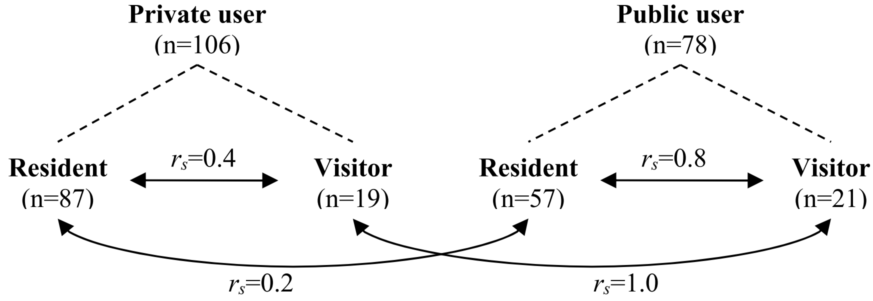

Figure 4 Spearman rank correlations between subgroups (resident and visitor) of private and public users

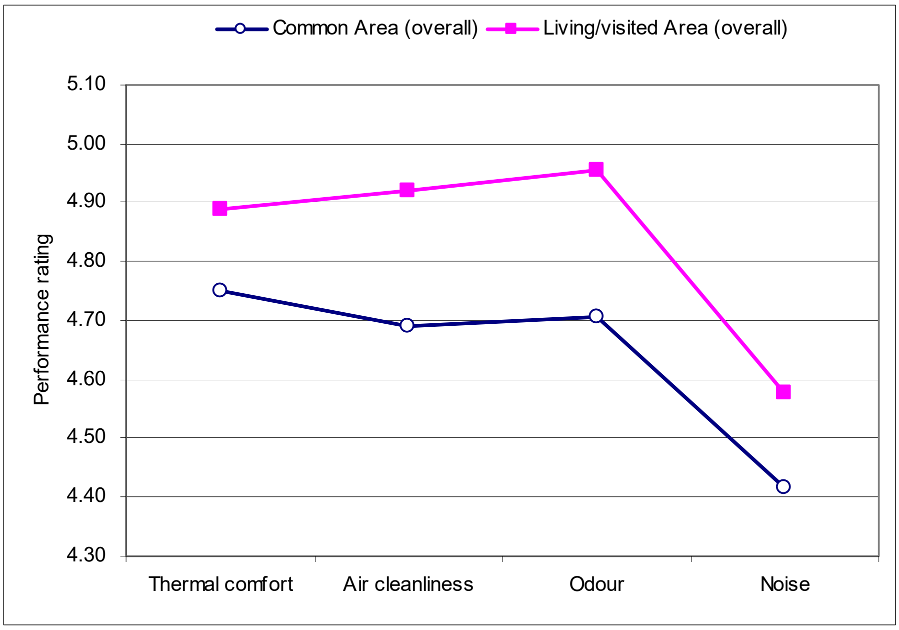

Figure 5 Performance rating of IEQ attributes of common area and living/visited area

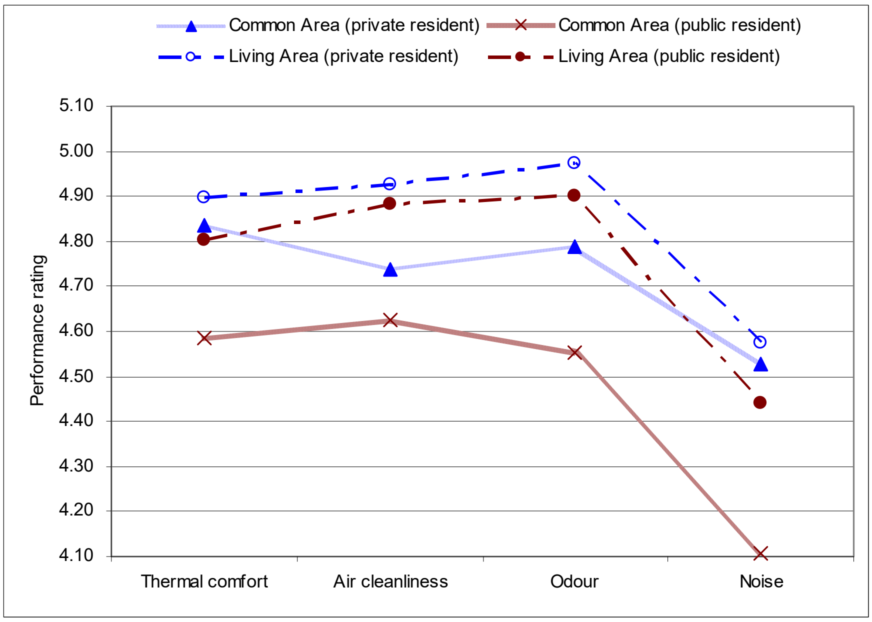

Figure 6 Performance of IEQ attributes rated by residents

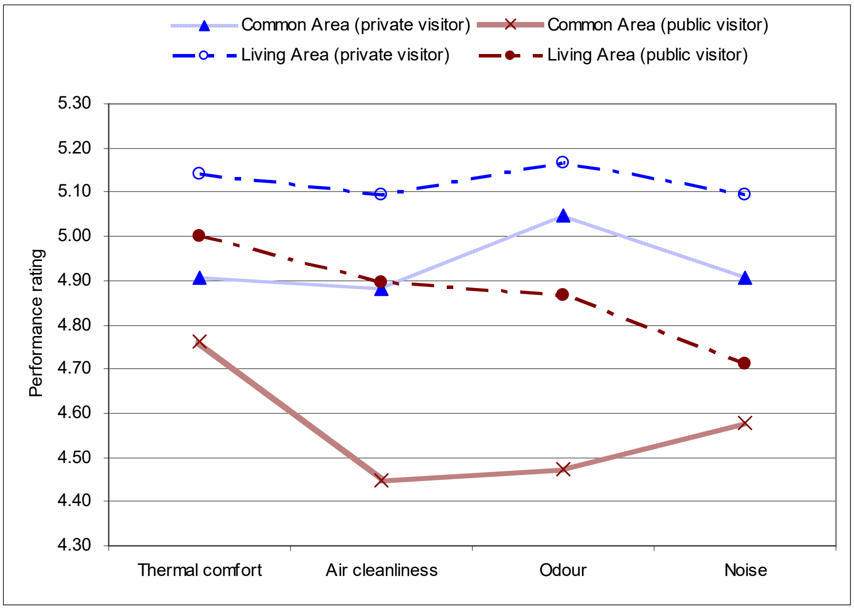

Figure 7 Performance of IEQ attributes rated by visitors

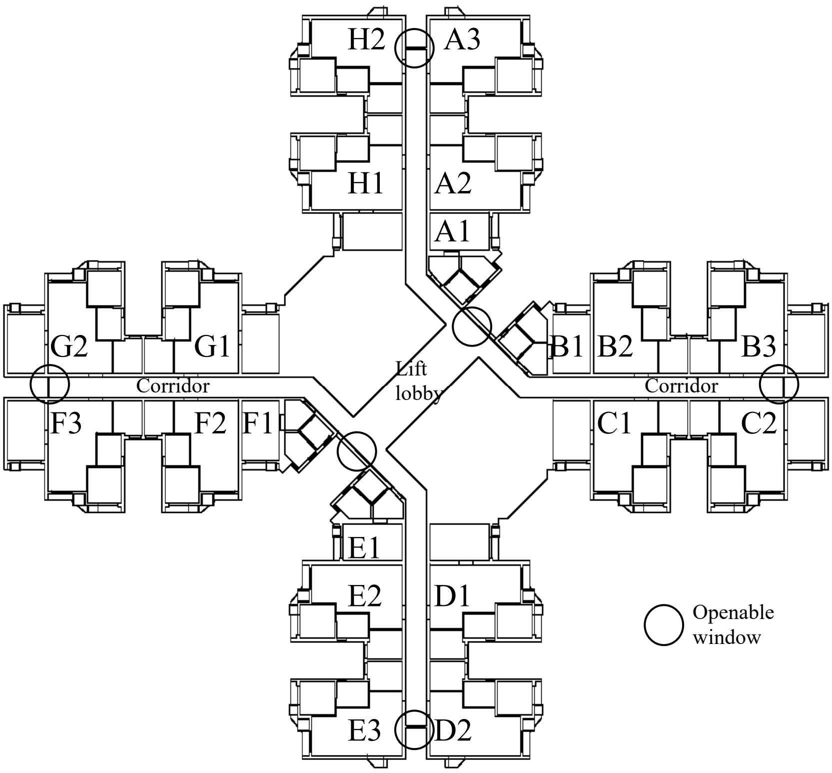

Figure 8 A typical floor of public residential buildings (corridor with openable window)

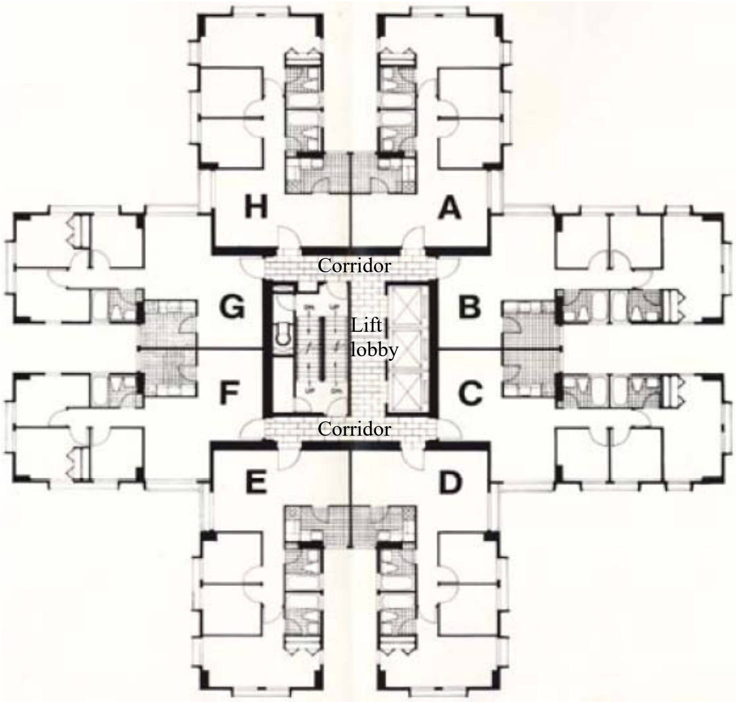

Figure 9 A typical floor of private residential buildings (internal corridor without openable window)

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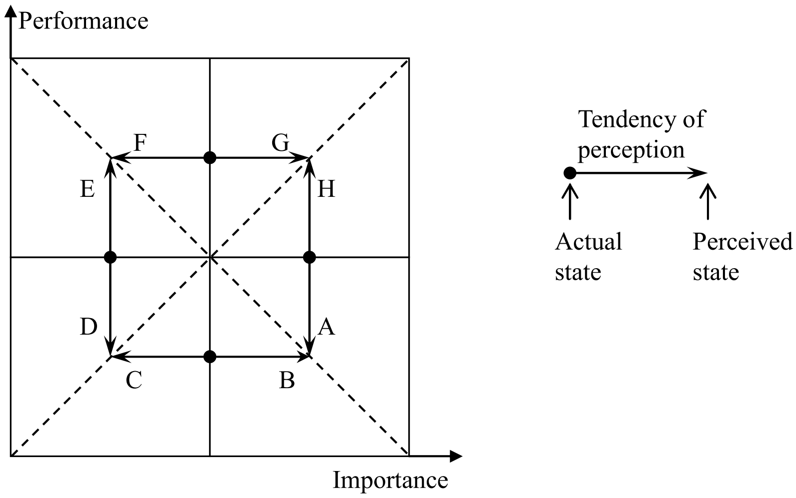

A: Perceived low performance due to high expectation commensurate with perceived high importance
B: Perceived high importance due to dissatisfaction with poor performance
C: Perceived low importance due to adaptation to poor performance
D: Perceived low performance due to lack of attention given rise by perceived low importance
E: Perceived high performance due to low expectation commensurate with perceived low importance
F: Perceived low importance with good performance taken for granted
G: Perceived high importance due to fear of poor performance (despite the already good performance perceived)
H: Perceived high performance relative to low performance experienced in other situations (while understanding the importance of the attribute)

Figure 10 Tendencies of perception and perceptions of importance and performance

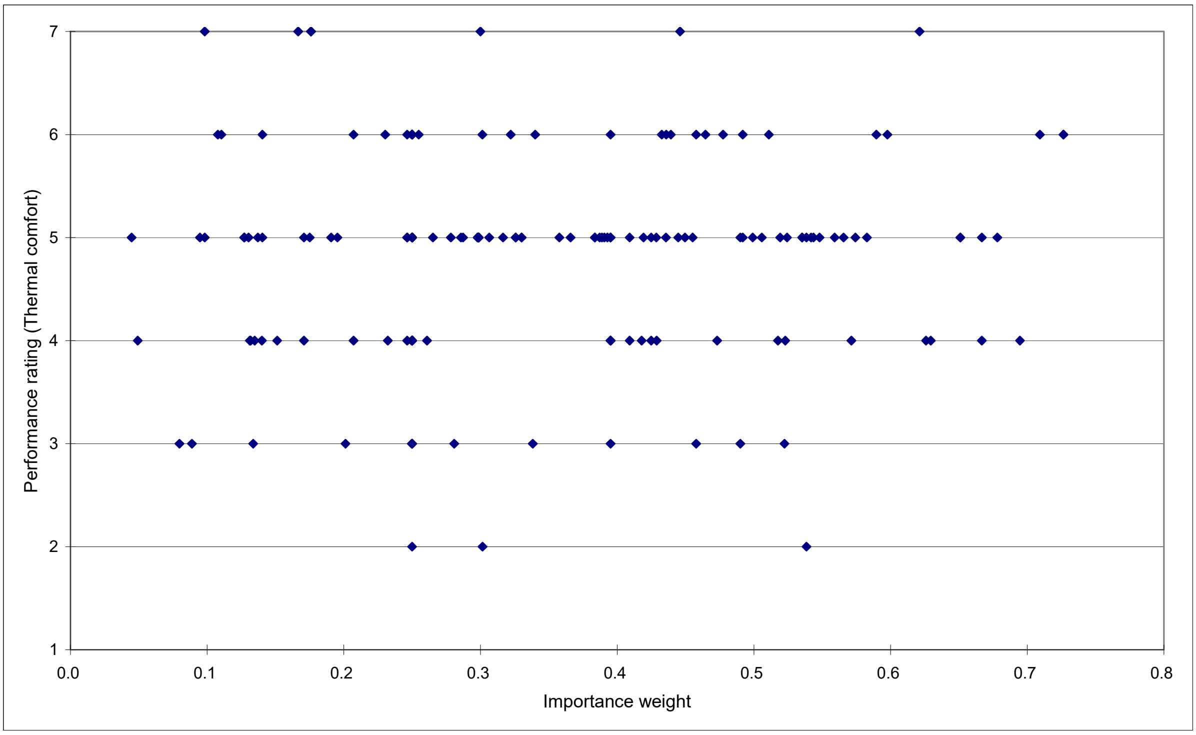

Figure 11 Distribution of individual response on thermal comfort

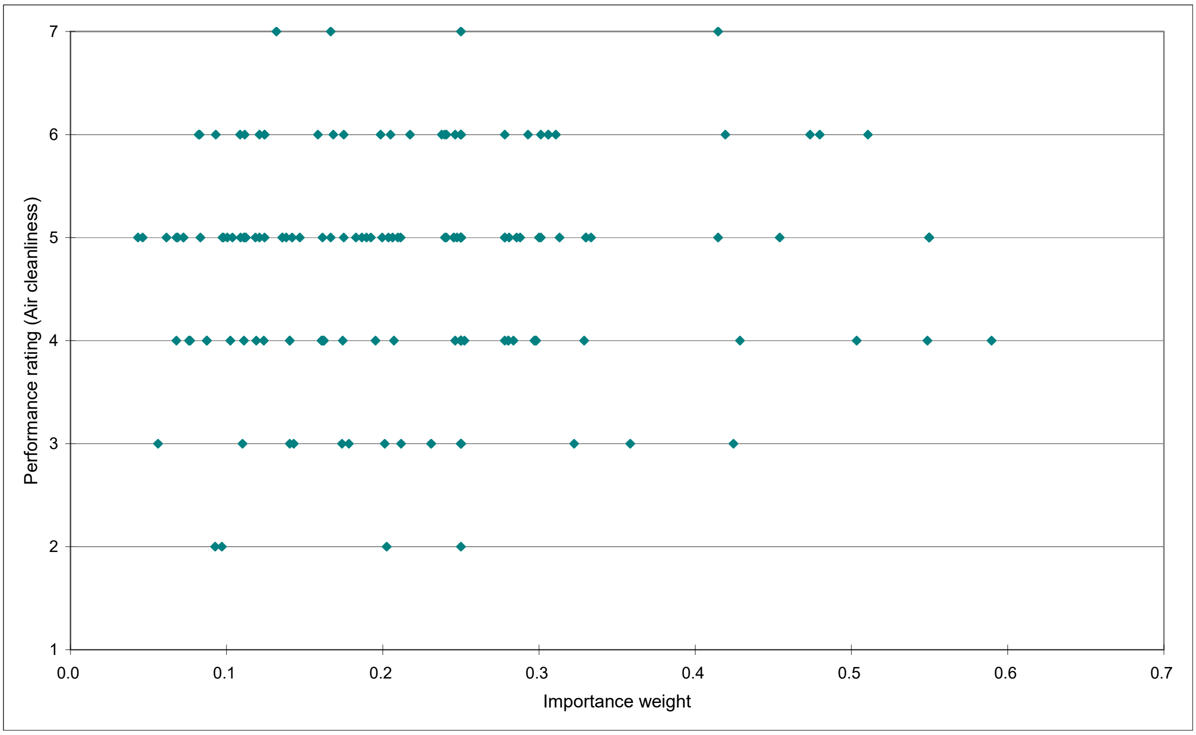

Figure 12 Distribution of individual response on air cleanliness

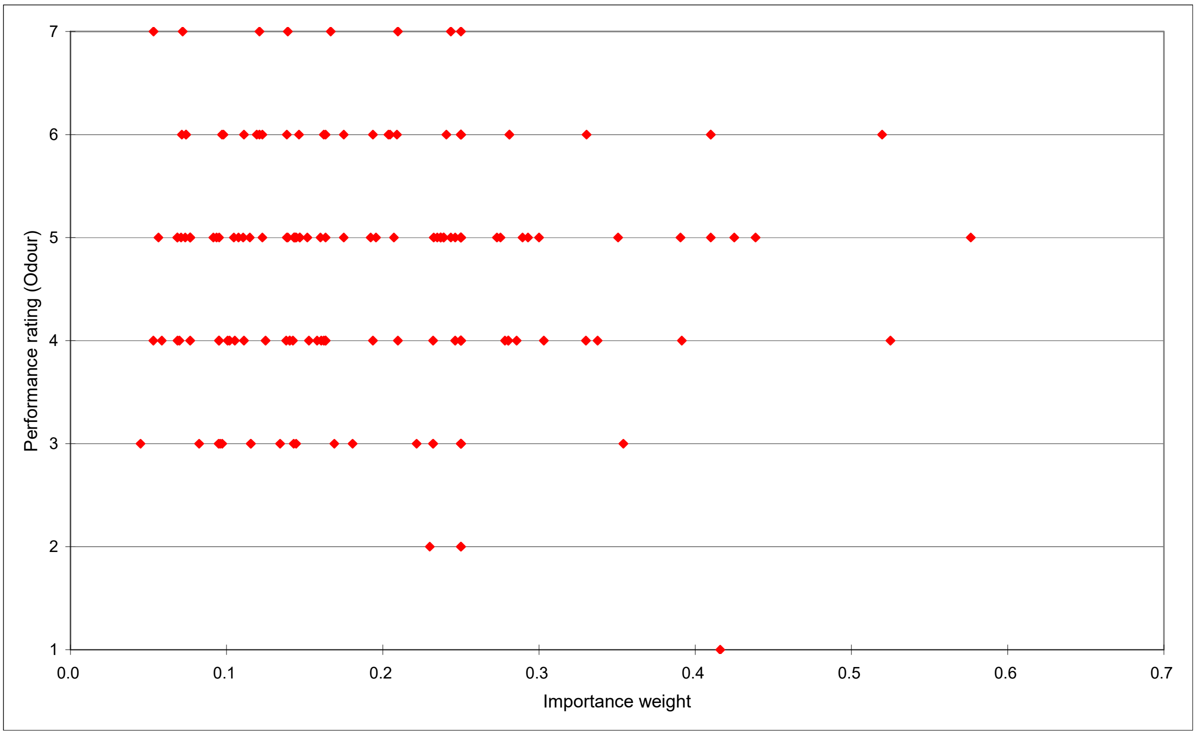

Figure 13 Distribution of individual response on odour

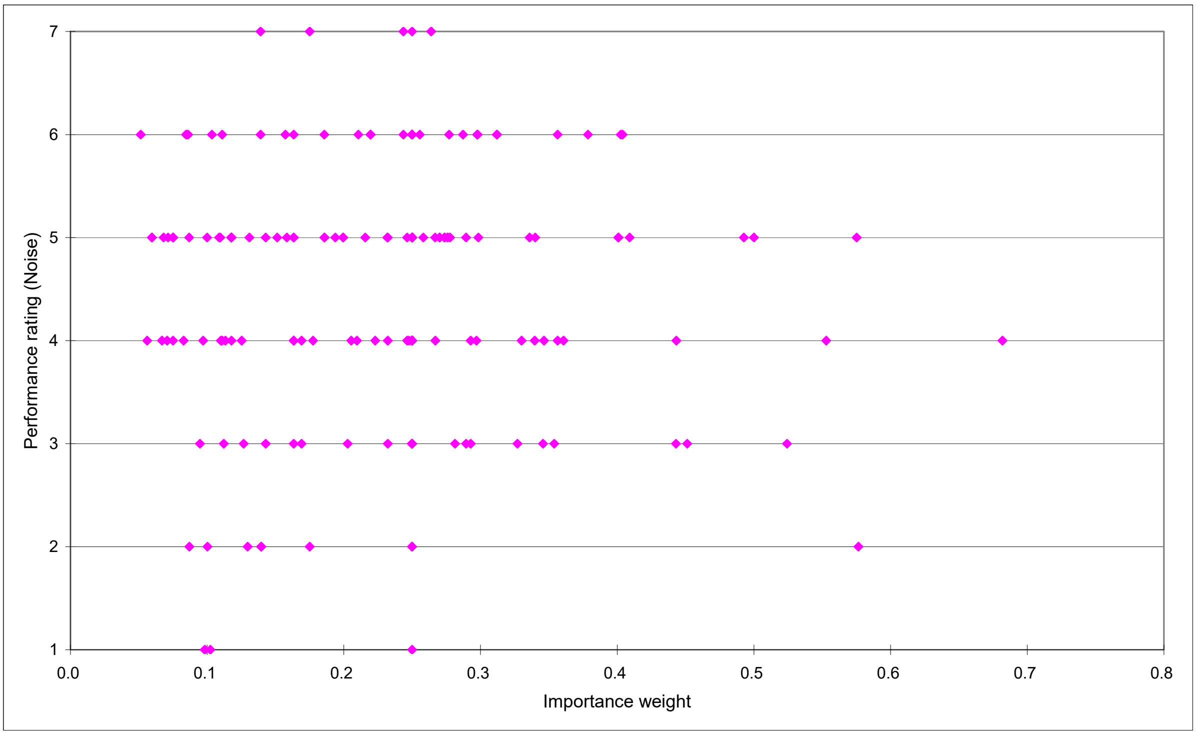

Figure 14 Distribution of individual response on noise

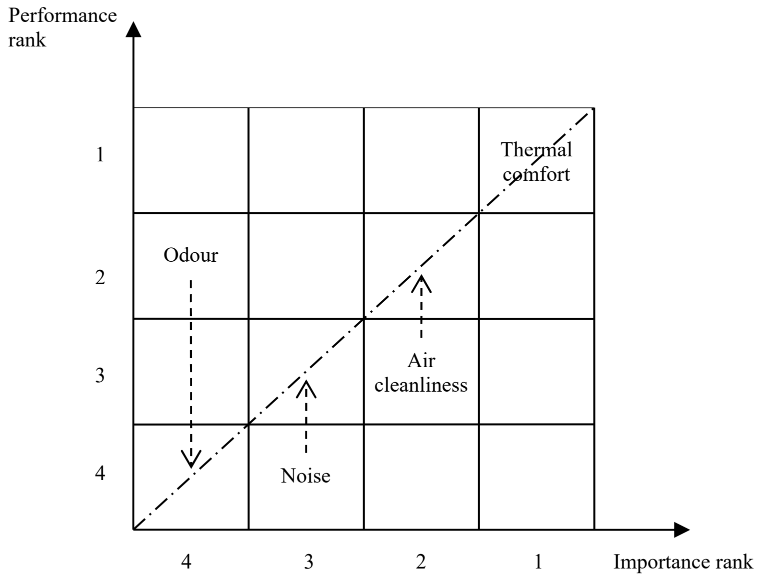

Figure 15 Gaps between performance and importance of IEQ attributes (private residents)

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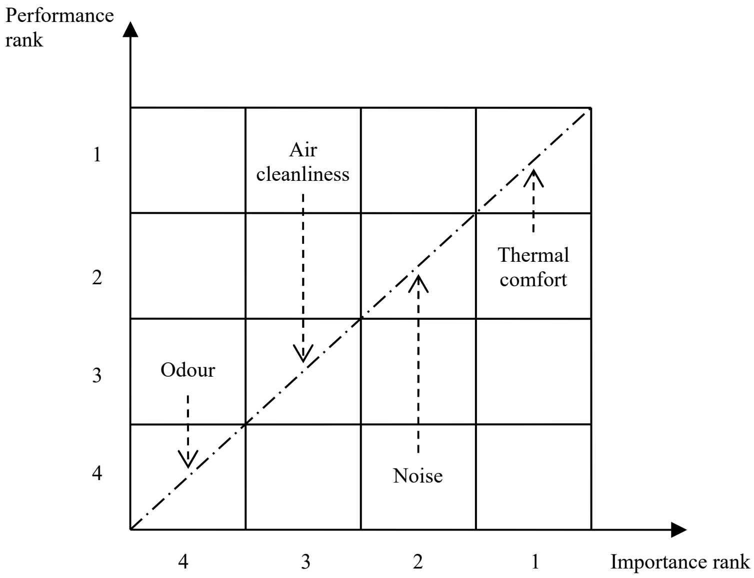

Figure 16 Gaps between performance and importance of IEQ attributes (public residents)