Analytic evaluation of facilities performance from the user perspective: case study on a badminton hall

Structured abstract

Purpose

The purpose of this study is to identify key performance indicators (KPIs) for badminton halls and, through a case study, illustrate how the facilities performance of a university badminton hall can be evaluated from the user perspective.

Design/methodology/approach

After a desktop literature review, the findings were discussed by a focus group and the discussion result formed the basis for establishing an analytic hierarchy of facilities performance for the badminton hall. Then, interviews were made with 169 badminton hall users to solicit their perceived facilities' importance and performance levels of the hall. Using MATLAB, a computer program incorporated with an Analytic Hierarchy Process (AHP) was devised to compute the importance weights of the performance attributes under assessment. The outcomes were interpreted using an importance-performance evaluation matrix.

Findings

A facilities performance hierarchy, comprising nine KPIs, was established for the badminton hall. The factors influencing the users' perceptions, the importance and performance levels of the KPIs, and the areas of the hall requiring improvements were identified.

Research limitations/implications

Future studies can take a similar approach of this study to develop KPIs and facilities performance hierarchies for other types of sports venues.

Practical limitations/implications

The method used to identify the improvements required for the badminton hall can be applied to investigations on other sports facilities.

Originality/value

The methodology of this research was first applied to study a badminton hall - as reported in this paper.

Paper type

Research paper

Keywords

AHP; Badminton; POE; KPI; Sports; User satisfaction

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Introduction

People's daily life is not confined to work and rest. Instead, people have become increasingly aware of the importance of living standard and health. Essential to the wellness of people are exercises; the demand for sports venues, therefore, continues to grow. Different from ordinary buildings, sports complexes are unique by their nature, usage patterns and comfort requirements (Revel and Arnesano, 2014). Most indoor sports venues, besides the provision of areas for rest and drinking, are installed with built facilities such as air-conditioning and lighting. Badminton halls, specifically, are used by those who play badminton - one of the most popular indoor sports around the world (Phomsoupha and Laffaye, 2015).

Given that badminton players need to have object control, ball focus, reaction, perception and coordination characteristics, there are specific requirements on the facilities in badminton halls (Akin et al., 2017). For example, the requirement on air velocity is strict if the air-conditioning system fails to operate properly, the indoor air movement and hence the trajectory of shuttlecocks would be affected (Shi and Liu, 2010). Lighting and background color, which are crucial factors of the indoor environment of badminton halls, are sometimes even more important than energy saving issues (Jinsung et al., 2013). Regardless of their types and functions, facilities in badminton halls should be operated and managed to provide an environment that satisfies their users, thus ensuring the usage of the venues (Bradley, 1992). Closely connected with user satisfaction is a type of psychological feeling, which involves happiness, pleasure or disappointment. This feeling occurs when facilities users compare their expectations with their perceived satisfaction (Lai, 2013).

Post-occupancy evaluation (POE), which is a process of consistently assessing the performance of buildings after they have been occupied, is of vital importance to the achievement of high-quality design, construction and management of school facilities (Hassanain and Iftikhar, 2015, Preiser, 1988). For instance, it has been pointed out that interior designers usually need to comprehensively conduct unbiased POEs in order to understand how their design decisions influence occupants' satisfaction (Freihoefer et al., 2015). Over the past few decades, the field of facility management (FM) has undergone significant development, for which a main reason is the increased performance requirements from facility users (Lavy and Shohet, 2009). In practice, FM involves a wide range of issues intending to benefit the performance of organizations (Grussing and Liu, 2014). Connected to effective maintenance, operation, and control of buildings, FM integrates various built environment disciplines by coordinating users, systems, space, and technology (Kobal Grum, 2018). The relationship between the built environment and outcomes in domains such as resident quality of life, resident safety, and staff and organizational outcomes was examined, and the impact of the facility scale and size on the elderly users was analyzed (Joseph et al., 2015). When facilities are not properly managed, defects would arise, resulting in nuisance to their users (Akinsola et al., 2012).

While more and more effort has been dedicated to studying the performance of built facilities (Lai and Man, 2017), research on the performance of facilities in badminton halls has not been common. Sports facility evaluation systems centered on users' subjective feelings could hardly be found from the existing literature. With limited knowledge in this area, answers to questions such as the following are yet to be available: What sorts of facilities are critical to badminton halls? What attributes are influential to the performance of such facilities? To the facilities' users, will familiarity with the facilities affect their perceived satisfaction with the facilities?

Aimed at contributing knowledge to the above area, a research study was conducted to evaluate the facilities performance of a university badminton hall based on the hall users' perception. In the next section, a review of the literature germane to the topic of the study is reported. Then, the method used to collect data for the study and how the data were analyzed are described. After showing and discussing the analyzed results, the final section provides the conclusions drawn from the study.

Literature review

Facility performance measurement

Facility performance, if properly measured, can inform whether the concerned facilities could provide a comfortable environment for their users. In the past few decades, plenty of research and tools have been introduced to study people's satisfaction with building services and equipment, and lots of efforts have been made to measure facility management (FM) performance. For instance, a case study was presented for the need for, and benefits of, performance measurement systems in FM environments (Amaratunga and Baldry, 2002). Different models had been built to measure the performance of buildings, of which the main ones include the Balanced Scorecard (BSC), the Business Excellence Model (BEM), the key performance indicators (KPIs) and the Capability Maturity Model (CMM) (Meng and Minogue, 2011). In developing a performance evaluation scheme for engineering facilities in commercial buildings, Lai and Man (2017) reviewed various notable schemes: the Building Quality Assessment (BQA), the Serviceability Tools and Methods (STM), and the Operation and Maintenance Rating System (OMRS). In particular, a performance measurement system (PMS), developed through interviews with key stakeholders, identification of KPIs and application of the Analytic Hierarchy Process (AHP), has been established for teaching hotels (Lai and Choi, 2015).

In addition to the above models, schemes and systems, some methods have been developed to measure the performance of certain environmental factors in buildings. For instance, Illuminating Engineering Society described a method for measuring overall lighting quality (1974). Given that factors like temperature, relative humidity, and wind velocity can be readily measured by engineering instruments, a monitoring methodology that covers comfort in a smart metering system for sports facilities was developed (Revel and Arnesano, 2014). Terrill and Rasmussen (2016), furthermore, made an in-depth analysis of heating, ventilation and air conditioning (HVAC) systems and occupant comfort in two religious facilities. Different reference indicators were proposed to measure embodied carbon and energy of HVAC facilities in healthcare centers (García-Sanz-Calcedo et al., 2021). Besides providing an overview of the technical standards of the American Society for Testing and Materials (ASTM) International, Schnitta (2015) indicated that building acoustic requirements are not only essential to building code but also useful for managing clients' expectations.

Customer satisfaction in facility management

With increased awareness of their rights, nowadays customers demand a higher degree of quality service, and the concept of customer satisfaction converts all businesses from "production centralized" to "user based" (Yang and Peng, 2008). Common to typical customer research, satisfaction is a direct indicator evaluating the efficiency and quality of FM services (Torbica and Stroh, 2001). In addition, satisfaction is an appreciable judgment that could be directly regarded as a comprehensive feeling, defined as a function of perceived quality (Bastos and Augusto, 2008). Campbell and Finch (2004), moreover, considered that not only the technical facility performance but also an intricate set of exchange processes involving the customers determine customer satisfaction.

A variety of works have been undertaken to investigate customer satisfaction. For example, the American Customer Satisfaction Index (ACSI), which consists of three parts: perceived quality, perceived value, and customer expectations, has been widely used to measure the satisfaction in many industries (Fornell et al., 1996). Effects of daylight design features on visitors' satisfaction were studied for a museum (Kaya and Afacan, 2018). For a student hall of a university, the satisfaction levels towards six dimensions of residential facilities were surveyed and investigated (Amole, 2009). In the study of Yang and Peng (2008), questionnaire data collected from project clients were analyzed and a client satisfaction measurement model for measuring the performance of construction project management service was developed. A system called Facilities Management Help Desk (FMHD), which assesses users' satisfaction with facilities and services, has been developed for public higher educational institutions (Shafie et al., 2012). Based on the characteristics of hospitals, the relationship between FM and customer satisfaction was examined (Pitt et al., 2016). In respect of residential estates, the critical variables of customer satisfaction towards FM services were investigated (Hui and Zheng, 2010). An extended work further identified and analyzed the crucial dimensions of FM services that affect customer satisfaction with shopping malls (Hui et al., 2013). Recently, Saw et al. (2020) processed questionnaire survey data by the Principal Component Analysis and Cross Tabulation Analysis to investigate the effect of passengers' perception of various factors that influence passenger satisfaction towards public infrastructures, facilities and services.

Studies on sports facilities

The Physical Education and School Sport Environment Inventory (PESSEI) was designed to audit physical education and school sport spaces and resources. To assess preliminary validity and reliability of the PESSEI, Fairclough et al. (2012) studied eight secondary schools. The effect of sports facilities in a school was investigated, which showed that inadequate sports facilities decreased the possibilities of attending physical activities during adulthood (Black et al., 2019). An intelligent program called Prosaico was used for personalized sport advising in sports facilities. This program was developed for suggesting a suitable type of exercise for sports players according to their own characteristics (Mosqueira-Rey et al., 2012). Through a questionnaire survey on participants' expectations, the performance of facilities in three different fitness centers was measured (Onchang and Panyakapo, 2016). Sports and recreational facilities located close to living places were found to be contributory to the physical activities of young women (Cohen et al., 2018). Aiming to investigate the performance of communalized recreation services of sports facilities in a college, the Delphi method was used to classify the systematic evaluation indicators of several dimensions (Liao and Cheng, 2012). Using two methods, the utilization and performance of sports facilities in nine sports halls were evaluated and compared (Iversen, 2015). In the customer behavior study domain, researchers found that new sports facilities created novelty feeling to users, which would attract more customers (Soebbing et al., 2016).

Various kinds of performance evaluation systems were developed for evaluating sports facilities. For example, an evaluation index system, which consists of three first-level indicators and eleven second-level indicators, was developed for assessing indoor fitness environments (Zahedi, 1986). Two other notable developments in the domain of sports facilities evaluation are: National Benchmarking Services (NBS); and

Customer Experience Research Metrics Performance Indicators Project (CERM-PI). Developed by an English sports council named Sports England, NBS is a framework of performance measurement for sports halls and swimming pools (Taylor and Godfrey, 2003). Originated from Australia in the early 1990s, CERM-PI covers a number of indicators, such as those in the aspects of finance, attendance, user's satisfaction, and service quality (Howat et al., 1996). For badminton halls, an evaluation index system consisting of three primary indicators (external form design, internal layout design and application function design) and twelve secondary indicators was designed (Wang, 2013).

The Analytic Hierarchy Process

The AHP has been applied different uses, namely project planning, selecting the best alternative, resources allocation and resolving conflicts (Saaty, 1994). According to an earlier review, the applications of the AHP fall into five broad themes: operations strategy, product and process design, planning and scheduling resources, project management, and supply chain management (Subramanian and Ramanathan, 2012). The theme of product and process design covers six areas, in which the distributions of research articles are: product planning (31%), forecasting (9%), quality management (12%), layout of facilities (11%), managing capacity (6%), and measuring and improving performance (31%). The latter area is the focus of the current study.

Applicable to various areas including the service sector, the AHP has been used to study human factors (Sipahi and Timor, 2010). For example, the AHP was used in a study that investigates the knowledge gap between fire engineers and building service engineers (Doheim et al., 2016). In the field of building and construction, for instance, the AHP was used to devise the Building Performance-Risk Rating Tool, which is useful for ranking the indicators of building performance and users' risk (Khalil et al., 2016b, Khalil et al., 2016a). For green buildings, a combined use of the AHP with the National Evaluation Standard for Green Building can lead to a comprehensive evaluation index system that enables accurate and objective building evaluation results (Sun, 2012).

In the realm of FM, the AHP was used to establish a method for holistic evaluation of FM services for residential buildings (Lai and Yik, 2011). In a further study, Lai made use of the AHP method to conduct a comparative study on the FM performance of two housing estates (Lai, 2011). Among the essential steps of the AHP method, checking can be made on the consistency of perceived judgments given by interviewees (Lai and Yik, 2007, Lai and Yik, 2009). For studies on sports, according to a literature review, the AHP has been widely applied to select players with high athletic performance, determine the training items in schedules, and decide the optimal exercise management strategies (Nisel and Özdemir, 2016).

In summary, the above review shows that a variety of studies have been conducted on facility performance measurement, customer satisfaction in FM, and sports facilities. The AHP has also been widely applied in research on many areas. Yet, studies that use the AHP to process subjective perceptions for investigating the FM performance of badminton halls were not found.

Method and data

Figure 1 depicts the theoretical framework based on which this study was conducted. As indicated, facilities performance hinges on how well the FM team has managed the operation and maintenance of the facilities. Through a facilities service delivery process, the end users will perceive the importance and performance levels of the facilities. Analysis of such perceptions through a rigorous performance evaluation, which includes checking the consistency of the end users' perceived judgments, categorization of the users and determination of importance and performance levels of the facilities, will result in performance feedback to the FM team. The feedback will inform any of the facilities that require improvements.

"Insert Figure 1 here"

The badminton hall and performance measurement hierarchy

The badminton hall (Figure 2), built in 1990, is located in a sports complex of a university in Hong Kong (China). The design of this badminton hall is similar to that of the badminton halls in the other universities and public sports centers in Hong Kong. As the summary in Table 1 shows, there are four courts in the badminton hall, which can be booked for use daily, from 08:30 to 22:30. Throughout this period, building services systems including air-conditioning and lighting are operational. At the ceiling level, conditioned air is supplied through the air diffusers and the illumination comes from the fluorescent tubes. Each court is used by four players at maximum.

"Insert Figure 2 here"

"Insert Table 1 here"

In order to design a robust data collection tool for the current study, at the beginning stage, the major aspects of facilities performance that may affect the satisfaction of badminton players were identified from the preceding literature review. Referring to their meanings, they were divided into 6 main groups, namely, lighting, air-conditioning, space, background color, acoustics and other facilities. In each group, as the performance measurement hierarchy in Figure 3 shows, there are 2 to 3 attributes – as summarized in Table 2.

"Insert Figure 3 here"

"Insert Table 2 here"

To collect data for determining the importance weights of the 6 main groups in Figure 3, 15 pair-wise comparisons between these groups are needed, not to mention the additional pair-wise comparisons needed for the various attributes in the lowest of the hierarchy. Getting consistent judgments on such a large number of pair-wise comparisons, according to past experience, are hardly practicable (Lai, 2013, Lai and Choi, 2015). In order to find ways for refining the hierarchy for use in the study, a focus group meeting was convened to solicit the expert opinions of 6 badminton coaches, 20 players and 2 experienced researchers in the context of this study. During the meeting, the participants were facilitated to vote on the importance and applicability of the facilities in reflecting the facilities performance of the badminton hall. After deliberation, two groups of facilities were eliminated: (i) acoustics - generally the noise environment of the badminton hall is good enough and thus has little influence on the users; and (ii) others – facilities such as booking system are auxiliary provisions to the hall. The result of the meeting, with the essential performance attributes shortlisted and classified into different groups, forms the basis for modifying the initial performance measurement hierarchy. The final hierarchy (Figure 4) consists of 2 main groups – "building services" and "space & background", with each of them embracing 2 subdivided groups, which are: lighting, air-conditioning, space, and background color. Under each of these subdivided groups, there are 2 to 3 performance attributes (Table 2). Figure 5, showing 2 adjacent badminton courts, illustrates the various distances (SS, SW and BW) of the “space” aspect.

“Insert Figure 4 here”

“Insert Figure 5 here”

The questionnaire and interviews

In order to investigate users’ subjective feeling of the facilities in the badminton hall, an interview questionnaire was designed referring to the performance measurement hierarchy in the previous section. The questionnaire comprised three sections. The first section was to inquire about the personal information of the interviewees, such as gender, height, weight, and clothing. The second section asked them to, using a 7-point scale (Table 3), indicate their degree of satisfaction with the performance of each item being rated. The final section requested the interviewees to indicate their perceived relative importance between each pair of the items using a 9-point scale (Table 4), which is widely used in surveys for obtaining data for processing by the AHP method to determine the weight coefficients of multiple attributes of a complex issue. In this section, a total of 9 pair-wise comparisons were required.

“Insert Table 3 here”

“Insert Table 4 here”

The questionnaire was tested in a pilot run to evaluate its practicality. Upon receipt of the feedback from the pilot interviewees, minor modifications were made on the descriptions of some questions, making them clearer and easy to understand. The questionnaire thus finalized was used to interview the badminton court users in full swing. To collect reliable responses, each user was interviewed face-to-face on a voluntary basis and each interview took about 6 to 7 minutes to complete. The interviews were conducted in 2019 over a period of one and a half months during the hall’s peak usage period in late afternoons and evenings.

Calculations

The AHP is a popular Multi-Criteria Decision-Making (MCDM) tool to formulate and analyze decisions (Saaty, 1994, Saaty, 1995). The four steps of the AHP application to a decision problem are: structure the decision problems; make pair-wise comparisons and obtain the judgmental matrix; compute local weights and consistencies of comparisons; and finally aggregate the local weights (Li et al., 2016). Following these steps, the importance weights of individual attributes, calculated based on the pairwise comparison ratings, were calculated by a computer code written with MATLAB 2014. The code is shown in the Appendix.

In the calculation process, the consistent ratio (CR) of each dataset was determined by in Eq. (1), where λ_{max} is the principal eigenvalue, RC is the random consistency determined according to the matrix order (Table 5), N is the number of attributes being studied. For instance, for a 4×4 matrix, the RC equals 0.9. For datasets with calculated CR values within the limit of 0.1, they were considered as consistent and hence valid for use in the subsequent analysis process; else, they were discarded.

"Insert Table 5 here"

$$CR = (\lambda_{max} - N)/[(N-1) \cdot RC] \qquad \text{Eq. (1)}$$

Results and discussion

The respondents

The responses to the questionnaire were summarized in Table 6. In total, there were 169 respondents, among them 141 completed all questions in the questionnaire and these responses were taken for analysis. The total response rate was 83.43%.

"Insert Table 6 here"

Of the 141 respondents, 98 were male and 43 were female. About 71% had not received any formal badminton training; the remaining 29% indicated that they received training twice a week for at least half a year before. This latter group, according to the earlier focus group experts, was regarded as having received proper badminton training. As regards play frequency, the majority (69%) played badminton once a week, 21% twice a week and only 9% three times a week. Regarding the clothes they wore, the choice of short-sleeved T-shirt/shorts was overwhelming (73%). Only about 11% and 16% wore short-sleeved T-shirt/pants and long-sleeved T-shirt/pants, respectively.

Referring to the calculated CR values of the 141 datasets, 113 (i.e. 80.14%) passed the consistency check for the AHP method. The pass rate of each subgroup of samples, which was the ratio between number of samples that passed the consistency check and number of samples in the respective subgroup, was calculated. The calculated results were summarized in Table 7. The male subgroup had a higher pass rate than the female subgroup. The pass rate of the samples in the subgroup that had received training, compared with that of the subgroup without training, was higher. As regards the pass rates of the subgroups with different play frequencies, the pass rates of the "twice" and "thrice" were similar; they both were much higher than the pass rate of the "once" subgroup. This implies that those who received training or played more frequently, thus were more familiar with the badminton hall, were more likely to make consistent judgments in their responses to the questionnaire.

"Insert Table 7 here"

Performance and importance of the attributes

From the valid questionnaire responses, the mean performance rating and importance weight of the rated attributes were calculated, as summarized in Table 8. The performance ratings ranged from 3.540, i.e. between "slightly low" and "fair", to 5.655 (between "slightly high" and "very high"). Among the attributes at the bottom layer of the performance assessment hierarchy, distance between baseline and wall (BW) recorded the highest rating (5.345), while the performance rating of ceiling color was the lowest (3.540).

"Insert Table 8 here"

When making inspections on the importance weights which were obtained from the pairwise comparisons made by the respondents, the number of items in each individual cluster was taken into consideration. In the lowest layer of the hierarchy and for those clusters each with two items, the greatest and smallest importance weights were 0.601 and 0.399, corresponding to air velocity and temperature, respectively. When it comes to the "space" cluster, which embraces three items, distance between sideline and wall (SS) recorded the greatest weight (0.370). Distance between baseline and wall (BW), with a weight of 0.304, was regarded as of the least important.

With reference to the evaluation matrix shown in Figure 6, the performance and importance levels of the attributes can be analyzed in a collective manner (Lai and Yik, 2009). There are four quadrants of the matrix and their interpretations are: (i) improvement is needed when the attribute has a low performance rating but a high importance weight; (ii) the attribute needs to be monitored when both of its performance and importance levels are low; (iii) the performance of the attribute should be maintained if the attribute is of low importance; and (iv) the attribute should be capitalized if both of its importance and performance levels are high.

"Insert Figure 6 here"

The mean importance weights and performance ratings of the items in the first and second layers of the performance assessment hierarchy were plotted in Figure 7. As Figure 7(a) shows, building services (BS) was regarded by the users as more important than space and background color (S&B). With both of the performance rating above the median value (4 = "fair") of the 7-point scale, the performance of S&B needs to be maintained and that of BS be capitalized. For the items in the second layer (Figure 7(b)), the performance ratings of all of them (except background color) were above the fair level and none of them fall into the "improve" region (cf. Figure 6).

Among the clusters in the third layer of the hierarchy, "space" embraces 3 attributes. Each of these attributes, if of equal importance, carries a weight of 1/3 (i.e. 0.33). As Figure 8(a) shows, the performance ratings of both distance between sidelines of two adjacent courts (SS) and distance between baseline and wall (BW) were above 5, but on the other hand, improvement was needed for the distance between sideline and wall (SW). In Figure 8(b), it can be observed that brightness and air velocity are 2 attributes whose performance should be capitalized, whereas the performance of dazzling needs to be monitored. The positions of the other two attributes, namely, color of walls and color of ceiling, were close to the dividing line between the "monitor" and "improve" regions.

"Insert Figure 7 here"

"Insert Figure 8 here"

Influence of familiarity

In order to reveal whether familiarity influences the respondents' perceived importance and performance levels, the comparatively static aspects ("Space" and "Background color") and their associated attributes were taken for further examination. For this purpose, the calculated importance and performance levels were divided into sub-groups and plotted against two factors (play frequency and training experience) that contribute to familiarity.

Play frequency

As shown in Figure 9(a), by referring to the responses of all the users, the importance level was the highest with SW, followed by SS and BW. In contrast, the performance ratings calculated based on all the responses reverse in order, i.e. the highest was found with BW, followed by SS and SW (Figure 9(b)). The performance ratings of SW, notably, are much lower than the counterparts of BW and SS. In fact, the overall performance rating as well as the sub-group performance ratings of SW are lower than 4 (fair), which means that the users were not satisfied with the distance between the sideline of the courts and the walls of the badminton hall.

Further inspections on the importance and performance levels of the sub-groups with different play frequencies (once, twice or thrice a week) found that there were no definite patterns (Figure 9(a) and 9(b)). This suggests that play frequency was not an influential factor of the users' perception on importance or performance of the spatial attributes.

"Insert Figure 9 here"

In Figure 10(a), the importance level (based on all the responses) of wall color was slightly higher than that of ceiling color. The sub-group findings showed that the importance levels of these two attributes converge with increase in play frequency. As regards performance levels (Figure 10(b)), the patterns of the plots for wall color and ceiling color were similar. For both of the two attributes, their performance levels rose with play frequency. This suggests that for users who played more in the badminton hall, they had accustomed to the colors of the walls and ceiling, thus becoming more satisfied with the performance of the two attributes. Nevertheless, the users were not satisfied with the ceiling color irrespective of whether they play in the badminton hall once, twice or thrice a week. This was evidenced by the findings that all the performance ratings pertaining to ceiling color (Figure 10(b)) were below 4 (fair).

"Insert Figure 10 here"

Training experience

The pattern in Figure 11(a) shows that for users who were not provided with proper badminton training before, their perceived importance ratings for SS, SW and BW were not largely different. But when referring to responses given by those who received proper badminton training before, the importance levels of the spatial attributes were different, with the highest found with SW, followed by SS and BW. This shows that training experience was a significant factor that affected judgments on the importance of the spatial attributes of the badminton hall.

In Figure 11(b), the plots for SW, SS and BW exhibited the same trend: users without proper badminton training, when compared with those who received proper training before, rated the performance of the three attributes higher. This suggests that the latter group of users, who knew better what were considered as proper provisions for badminton halls, had a higher level of expectation on the spatial attributes.

"Insert Figure 11 here"

As for "background color", Figure 12(a) shows that the importance levels of wall color and ceiling color were comparable. Even the importance levels of the two subgroups – those with training and those without – were not largely different. The same observation was noted from Figure 12(b) where the performance ratings of the subgroups were plotted. This shows that training experience was not a significant factor that affected the users' judgment on the importance or performance of the color attributes. Nonetheless, as Figure 12(b) shows, the performance rating of wall color was significantly different from that of ceiling color, which was clearly below 4 (fair).

"Insert Figure 12 here"

Distribution of individual response

In order to scrutinize in more detail the importance and performance of the rated attributes, the individual responses for indicators in the "background color" and "space" aspects were plotted (Figure 13 to 14) and compared against the importance-performance evaluation matrix in Figure 6.

Referring to Figure 13, which is a scatter plot of the performance and importance levels given by the individual respondents on the distance between sideline and wall (SW), the majority of the respondents indicated a performance score of 4 (fair) or below. The highest perceived performance level was only 5 (slightly high), while the lowest score was even down to 2 (very low). Notably, more dots cluster in the lower left quadrant, meaning that SW was a low-importance-low-performance attribute. In fact, the recommended distance between the sideline of a badminton court and the adjacent wall, which determines the running area, should be at least 1.5 m (Sport England, 2011). The actual distance measured on-site, however, was only 1.3 m. To solve this problem, the concerned court lines should be removed while new court lines that meet the recommended separation distance should be painted on the floor.

"Insert Figure 13 here"

Wall color and ceiling color are the two attributes in the aspect of background color. Figure 14(a) shows that most of the individual responses on wall color were in lower left ("monitor") or lower right ("improve") quadrants. The highest performance score was 7 (extremely high) and the lowest was 2 (very low). The importance weights ranged from about 0.3 to 0.7.

Besides, the individual responses on ceiling color (Figure 14(b)) show that the highest performance rating was 6 (very high), which was lower than the counterpart of wall color. The lowest performance score was even down to 1 (extremely low). Similar to the observation from Figure 14(a), a comparatively large portion of the responses on ceiling color fell in the lower two quadrants. This implies that the ceiling color needs monitoring; if resources are available, improvement should be provided. Normally, the color of shuttlecock is close to white. As observed on-site, the whole ceiling area and most of the wall areas were in beige color, which is also called off-white (i.e. similar to white but slightly grayish or yellowish). This background color failed to contrast with the color of shuttlecocks. The recommended background color is green, blue or blue-green, which will not impair the visibility of badminton players on shuttlecocks

(Sport England, 2011). To achieve this, improvement work such as repainting should be carried out for the ceiling and walls.

"Insert Figure 14 here"

Conclusions

The study reported above found that prior research that investigates the post-occupancy facilities performance of badminton halls in an analytic manner could hardly be found. Through a focus group meeting, the critical facilities of a university's badminton hall were identified, based on which an analytic hierarchy of facilities performance was established.

By interviewing the users of the badminton hall, the perceived importance and performance levels of the facilities were collected. Processing such data by the AHP, which resulted in the detection and disposal of the responses that were drawn from inconsistent judgments, ensured that only the reliable responses were included in the subsequent analysis. Interpreting the analysis results with the aid of the importance-performance evaluation matrix illustrated that the matrix is useful for determining which of the attributes need to be improved, maintained, monitored or capitalized. Other major conclusions include:

1) Referring to the examination on the results with respect to the users' familiarity with badminton, play frequency and training experience could influence users' perceived importance and performance of the badminton hall's facilities.
2) Based on the evaluation results, especially those obtained with the aid of the importance-performance evaluation matrix, the priority of the facilities to be improved could be determined.
3) The detailed scrutiny on the individual perception responses together with the on-site measurements enabled identification of areas that requirements (e.g. distance between badminton court's sideline and its adjacent wall, color of the ceiling/walls) and hence formulation of the corresponding improvement measures.

It has been demonstrated how an analytic evaluation could be made on the facilities performance of a badminton court. Following the approach of this study, further research can be conducted on other badminton courts or venues for other types of sports such as squash, basketball and volleyball. When more research findings of this kind are obtained, more knowledge will become available for improving or enhancing the facilities in sports venues, thereby contributing to the wellness of people in the built environment. Importantly, this research provides a basis upon which architects and designers can optimize future designs to ensure a smoother soft landing when handing over a sports hall to its client, and this elicit a preferential POE. The work will also prove equally important for FM teams who seek to refurbish existing facilities to an optimum level. By creating sports facilities that optimize user experience, it is envisaged that the improved environment will yield greater user satisfaction, thus leading to an increased usage of sports facilities. In so doing, this could have major societal impact in terms of improving the public's health and well-being whilst simultaneously reducing the strain upon health services.

Declaration

The authors declare that there is no conflict of interest.

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Appendix – The AHP computer program

Computer software:

MATLAB R2014b

Program code (with an example of input data):

```
close all;
clc;
clear all;
A=[1 5 1/3 ;
   1/5 1 1/2;
     3 2 1];
[x,y]=size(A);
RI=[0 0 0.58 0.90 1.12 1.24 1.32 1.41 1.45 1.49 1.51];
R=rank(A);
[V,D]=eig(A);
t=max(D);
B=max(t);
[row, col]=find(D==B);
C=V(:,col);
CI=(B-y)/(y-1);
CR=CI/RI(1,y);
        disp('CI=');disp(CI);
        disp('CR=');disp(CR);
           Q=zeros(y,1);
        for i=1:y
               Q(i,1)=C(i,1)/sum(C(:,1));
    end
        Q
```

Result based on the input data:

```
CI=
       0.2342
CR=
       0.4037
Q =
       0.3420
       0.1339
       0.5241
```

Note: The consistency ratio (CR) of the above sample exceeds 0.1, indicating that the response was drawn from inconsistent judgment. Hence, the sample was discarded.

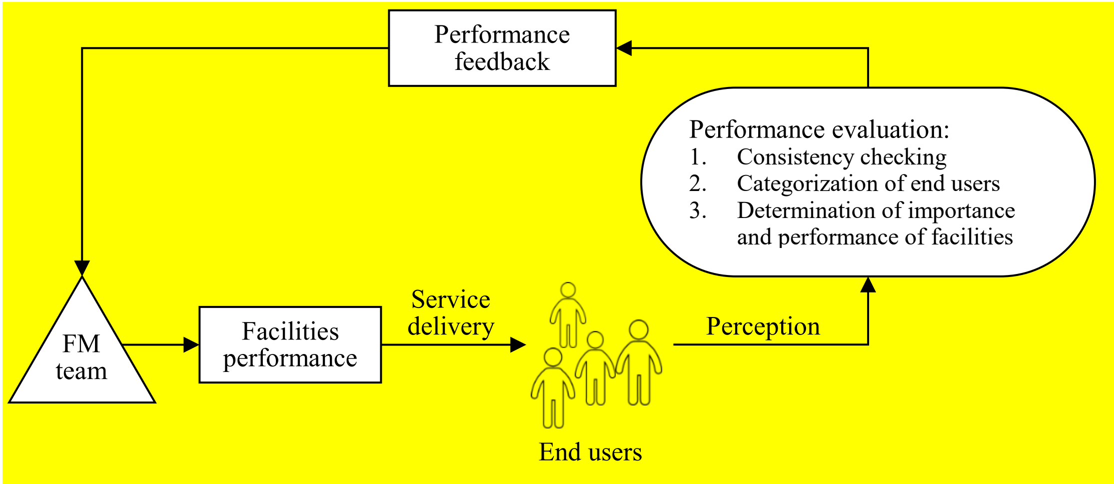


Figure. 1 Framework of facilities performance evaluation (adapted from Lai and Man, 2017)

Figure. 2 The badminton hall

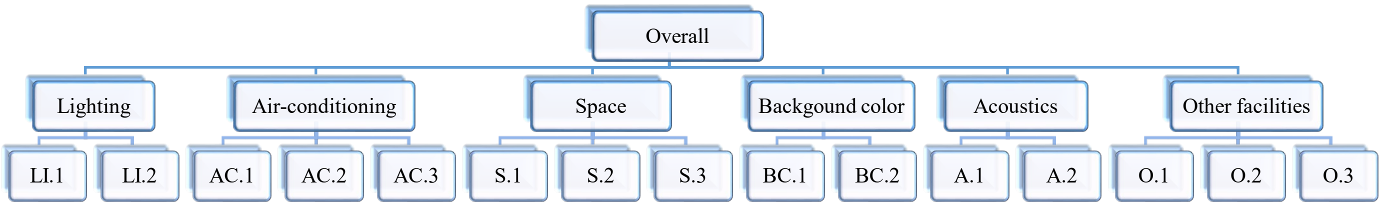


Figure. 3 Initial performance measurement hierarchy

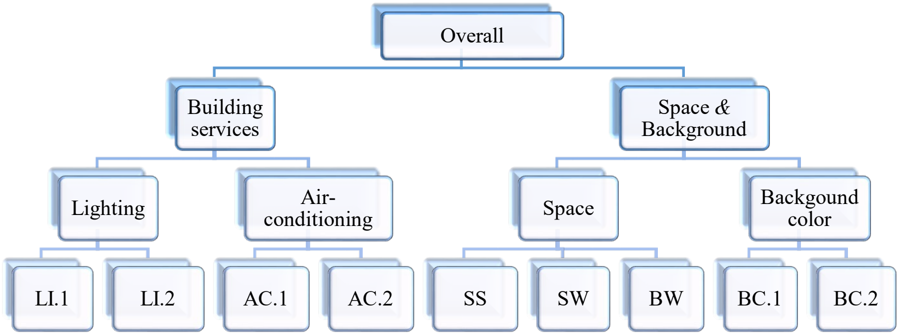


Figure. 4 Final performance measurement hierarchy

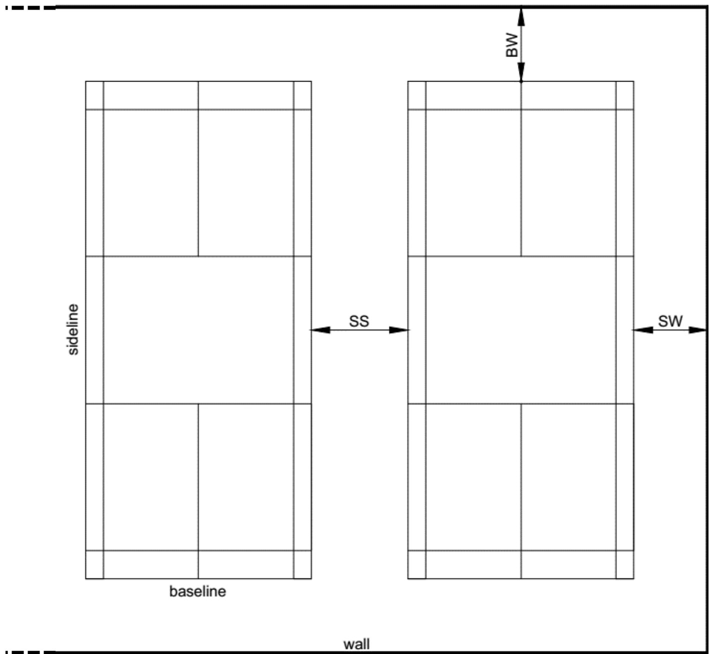


Figure. 5 Part plan of the badminton hall

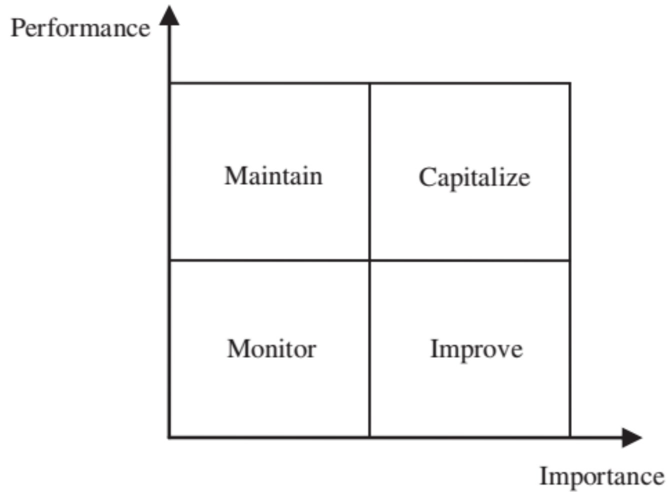


Figure. 6 Importance-performance evaluation matrix (Source: (Lai and Yik, 2009))

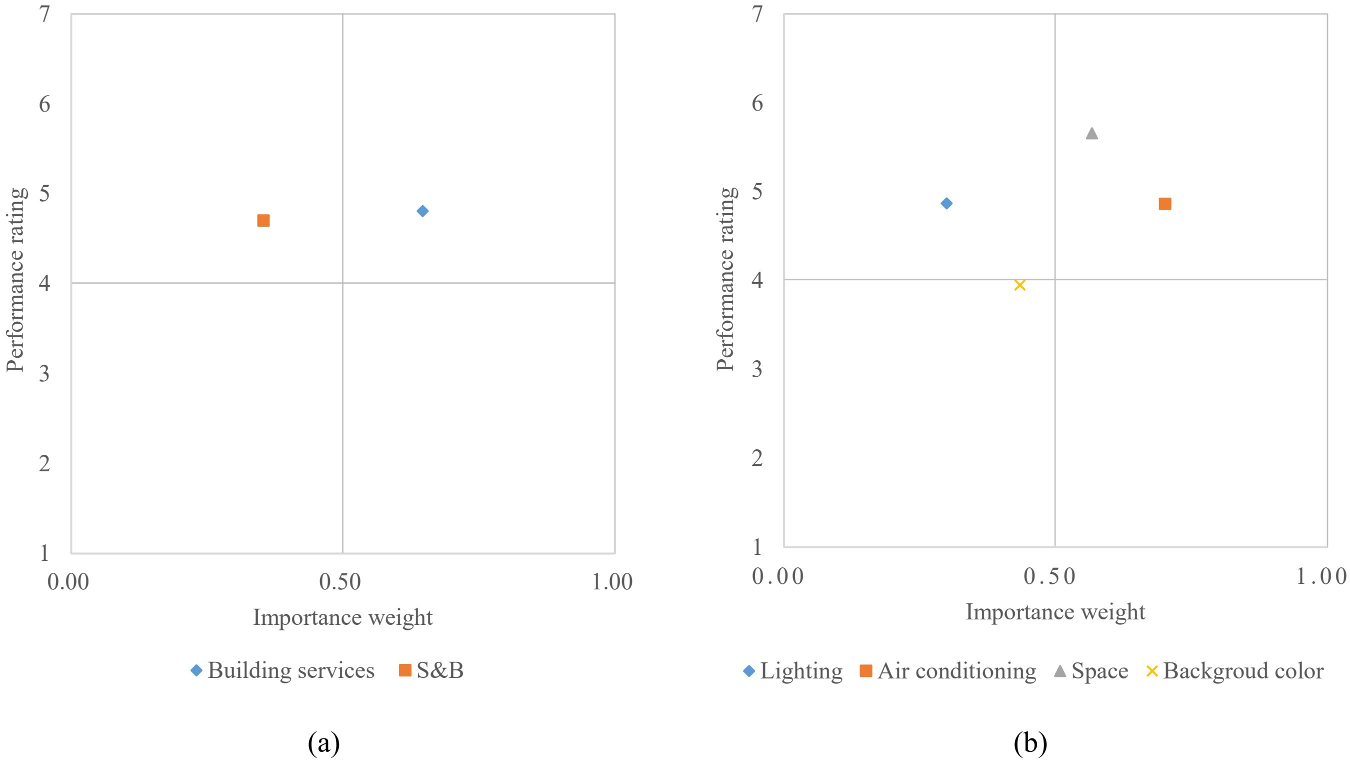
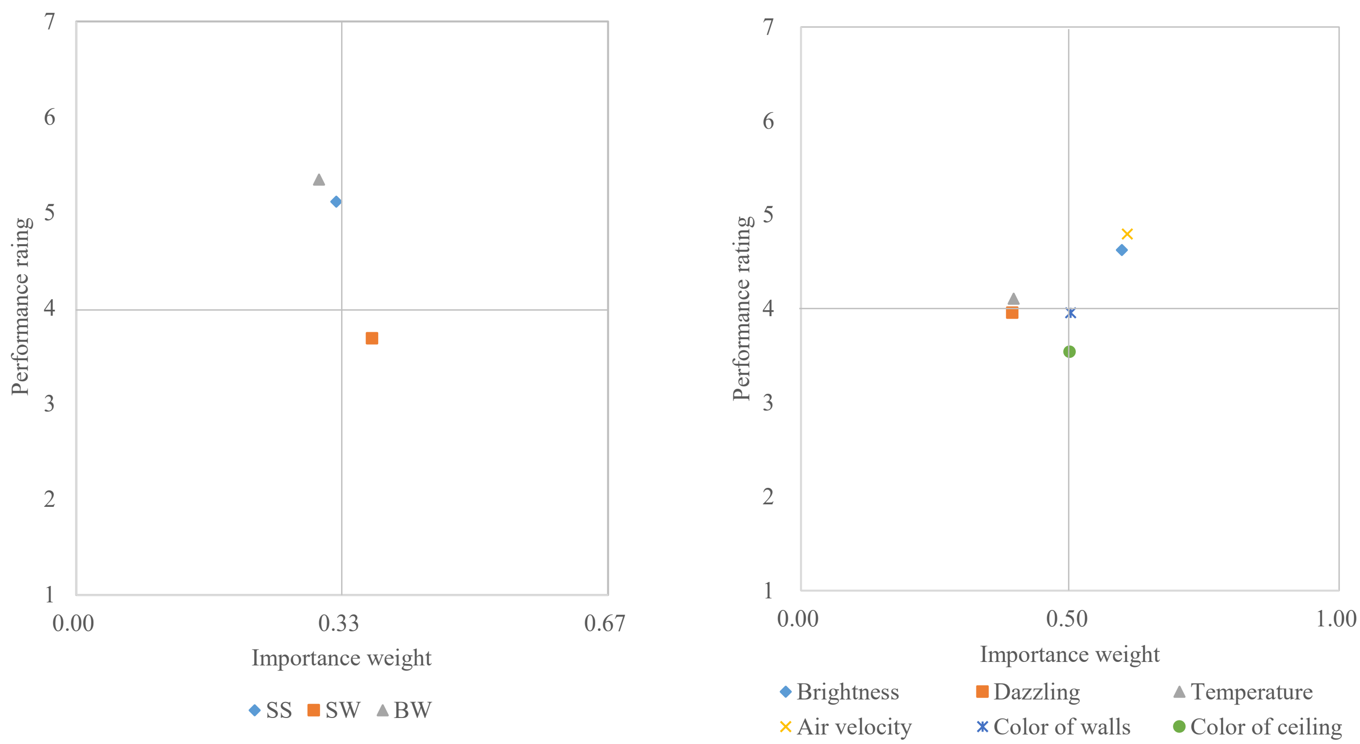


Figure. 7 Importance and performance levels of items in the (a) first layer and (b) second layer of the hierarchy



(a) (b)

Figure. 8 Importance and performance levels of items in the third layer of the hierarchy, in clusters with (a) 3 items and (b) 2 items

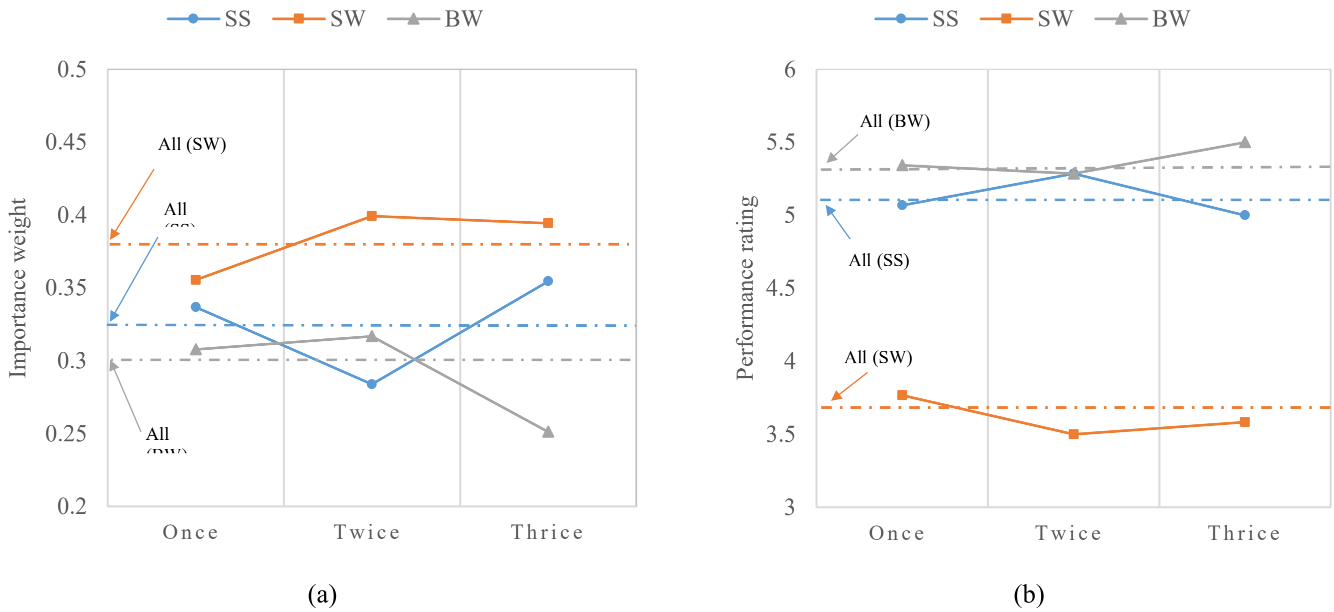


Figure. 9 (a) Importance and (b) performance of spatial attributes against play frequency

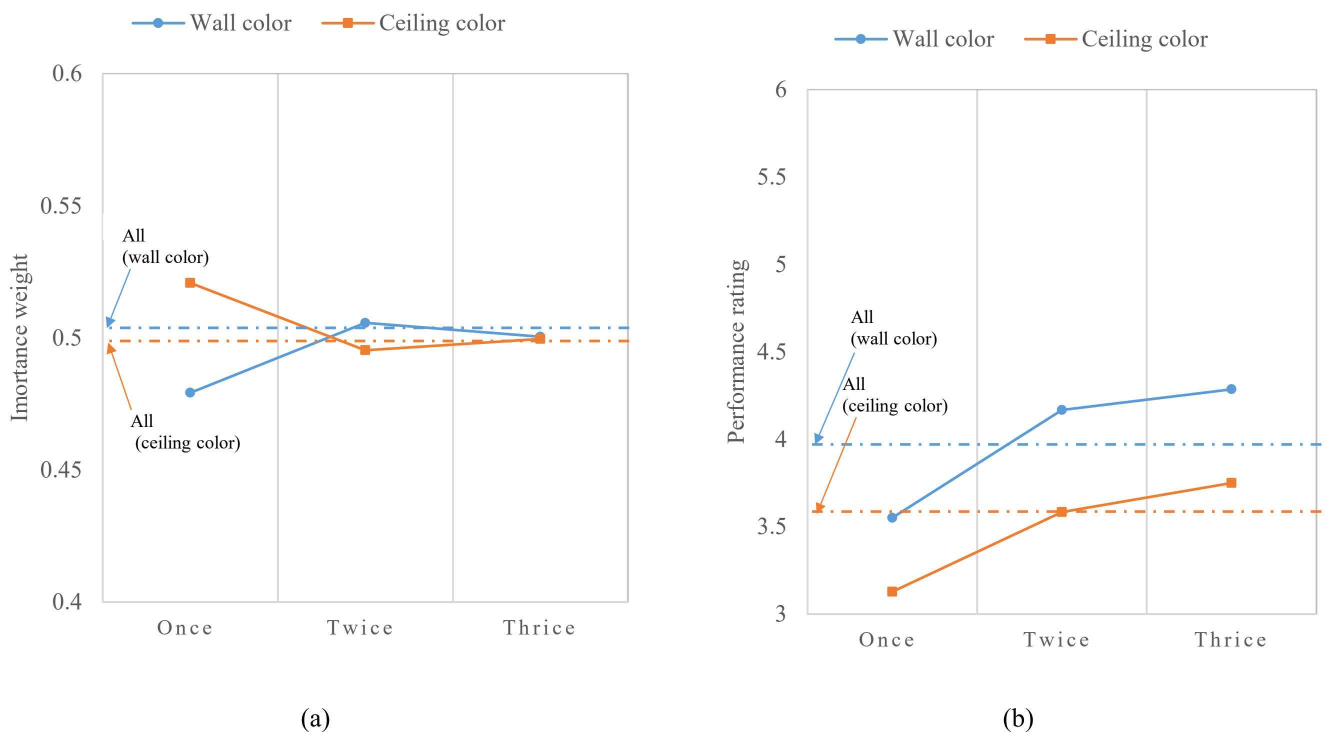


Figure. 10 (a) Importance and (b) performance of color attributes against play frequency

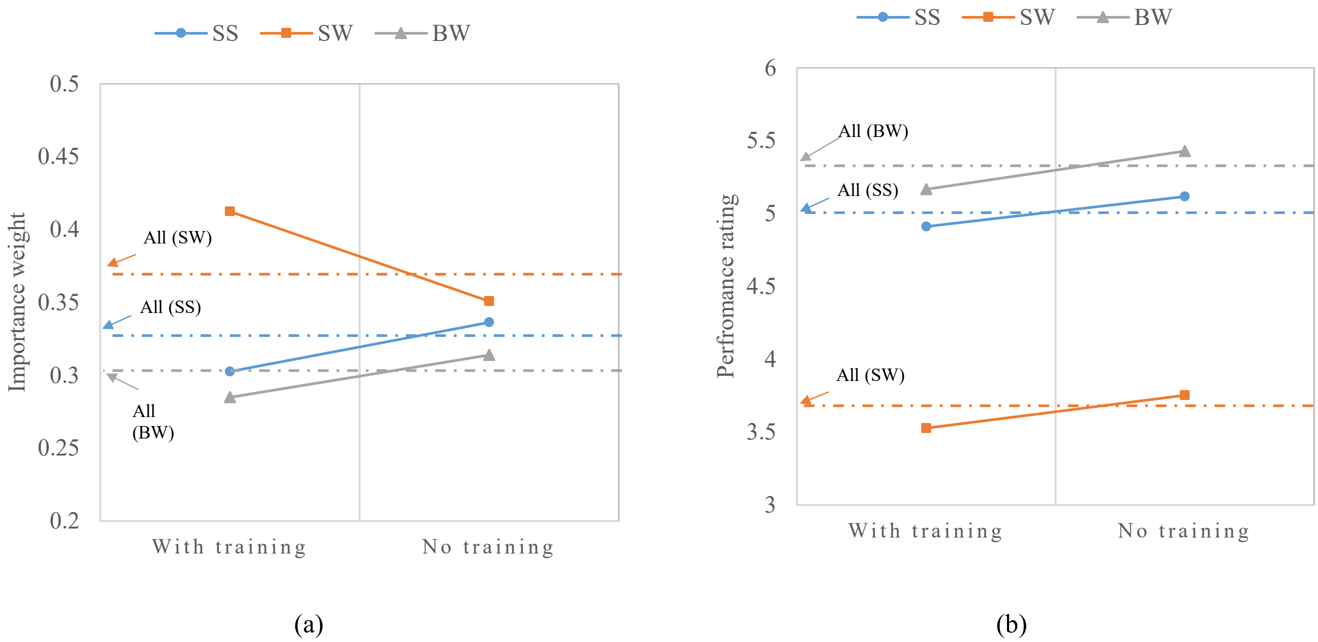
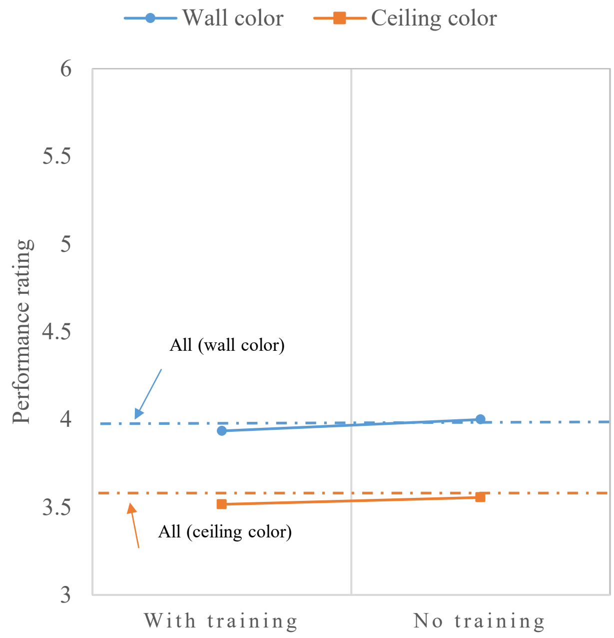


Figure. 11 (a) Importance and (b) performance of spatial attributes against training experience

(a)



(b)

Figure. 12 (a) Importance and (b) performance of color attributes against training experience

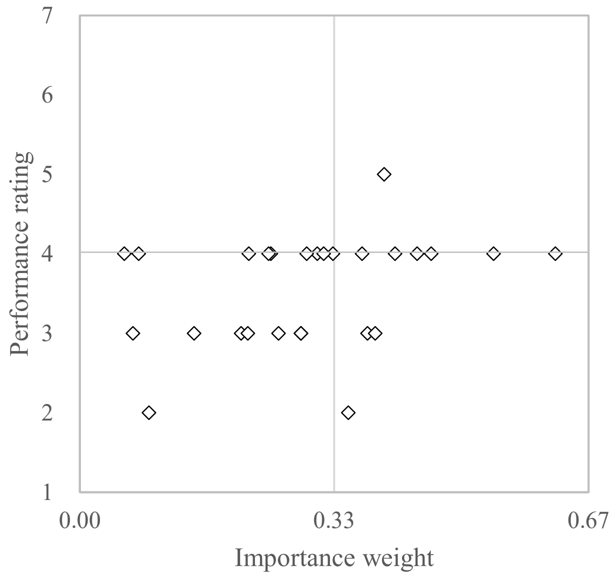
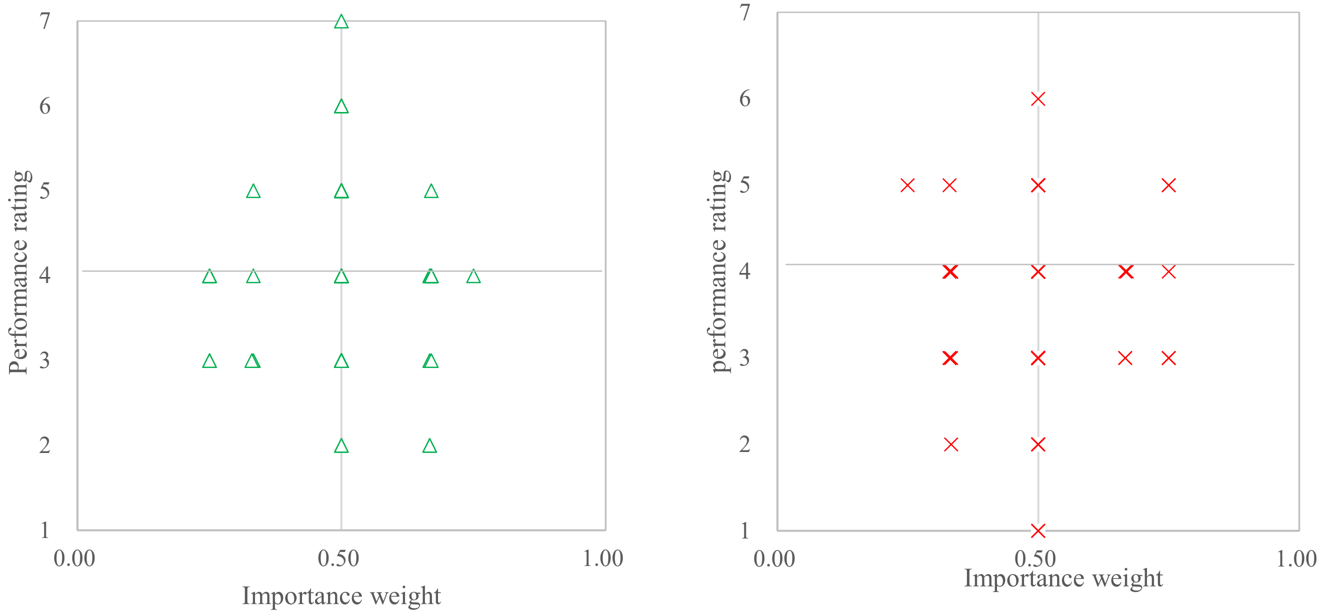


Figure. 13 Distribution of individual responses on SW



(a) (b)

Figure. 14 Distribution of individual responses on (a) wall color and (b) ceiling color

Table 1: Basic information of the badminton hall

Item	**Information**
Width x depth	41m x 20.5m
Height	8.5m
Number of badminton courts	4
Maximum number of players (per court)	16 (4)
Opening hours	08:20 - 22:50
Sessions available for use	08:30 - 22:30

Table 2: Summary of original and finalized performance attributes

Original attributes	Finalized attributes
Brightness (LI.1) Dazzling (LI.2)	Brightness (LI.1) Dazzling (LI.2)
Temperature (AC.1) Air velocity (AC.2) Relative humidity (AC.3)	Air temperature (AC.1) Air velocity (AC.2) -
Distance between sidelines of two adjacent courts (S.1) Distance between sideline and wall (S.2) Distance between baseline and wall (S.3)	Distance between sidelines of two adjacent courts (SS) Distance between sideline and wall (SW) Distance between baseline and wall (BW)
Color of walls (BC.1) Color of ceiling (BC.2)	Color of walls (BC.1) Color of ceiling (BC.2)
Background noise (A.1)	-
Sound insulation (A.2)	-
Online facility booking system (O.1) Emergency medicine for sports injury (O.2) Seats/toilets/changing rooms (O.3)	- - -

Table 3: 7-point scale for rating performance (Lai and Yik, 2009)

Point	Description
1	extremely low
2	very low
3	slightly low
4	fair
5	slightly high
6	very high
7	extremely high

Table 4: 9-point scale for rating relative importance (Lai and Yik, 2009)

Point	**Description**
1	Equally important
2	Intermediate level between the two adjacent levels
3	Moderately more important
4	Intermediate level between the two adjacent levels
5	Strongly more important
6	Intermediate level between the two adjacent levels
7	Very strongly more important
8	Intermediate level between the two adjacent levels
9	Most important; no compromise acceptable

Table 5: Standard value of random consistency (RC)

Matrix order	1	2	3	4	5	6
RC	0	0	0.58	0.9	1.12	1.24

Table 6: Summary of responses before consistency check

Category	Subgroup	Number	Proportion
Gender	Male	98	69.50%
	Female	43	30.50%
Training	Yes	41	29.08%
	No	100	70.92%
Times (per week)	Once	98	69.50%
	Twice	30	21.28%
	Thrice	13	9.22%
Clothing	Short-sleeved T-shirt/shorts	103	73.05%
	Long-sleeved T-shirt/pants	16	11.35%
	Short-sleeved T-shirt/pants	22	15.60%

Table 7: Summary of responses of the consistent group

Category	Subgroup	Number	Pass rate
Gender	Male	80	81.63%
	Female	33	76.74%
Training	Yes	36	87.80%
	No	77	77.00%
Times (per week)	Once	73	74.49%
	Twice	28	93.33%
	Thrice	12	92.31%

Table 8: Averaged performance rating and importance weight of each item

	Items	Performance	Importance
Layer 1	Building services	4.805	0.646
	Space & Background color	4.699	0.354
Layer 2	Lighting	4.858	0.298
	Air-conditioning	4.867	0.702
	Space	5.655	0.563
	Background color	3.947	0.437
Layer 3	Brightness	4.611	0.600
	Dazzling	4.014	0.400
	Temperature	4.106	0.399
	Air velocity	4.797	0.601
	Distance between sidelines of two adjacent courts (SS)	5.115	0.326
	Distance between sideline and wall (SW)	3.681	0.370
	Distance between baseline and wall (BW)	5.345	0.304
	Wall color	3.956	0.501
	Ceiling color	3.540	0.499