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User-centric analytic approach to evaluate the performance of sports facilities: A study of swimming pools

Erica Lau [a], Huiying (Cynthia) Hou [b,*], Joseph H.K. Lai [a], David Edwards [c], Nicholas Chileshe [d]

[a] Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong
[b] Faculty of Architecture, Delft University of Technology, the Netherlands
[c] School of Engineering and the Built Environment, Birmingham City University, UK
[d] UnISA STEM: Circular Economy and Scarce Resources (ScARCE), University of South Australia, Australia

A R T I C L E I N F O

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A B S T R A C T

While the performance of sports facilities such as swimming pools is crucial to the health, safety and enjoyment of pool users, little research has been conducted to explore how to analytically evaluate the holistic performance of such facilities from the users' perspective. Even an evaluation framework portraying the key performance attributes of swimming pools is yet to be available. Recognising this research gap, this study aims to adopt a user-centric approach to evaluate the performance of swimming pools and a multi-stage study was initiated. After a thorough literature review, a performance attribute hierarchy for swimming pools was established through a focus group study and then two surveys, covering four swimming pools and 103 pool users interviewed, were conducted in Hong Kong. Analysing the responses using the Analytic Hierarchy Process (AHP) method illustrates that the building services (i.e. utilitarian) aspect of swimming pools is more important than the architectural counterpart, and survey participants cared more about the performance attributes inside water than those outside. This study's novelty lies in that it adopted the user-centric approach, which can differentiate between the relative importance of different swimming pool components and prioritize resources for their maintenance and management. The evaluation framework as well as the findings of the study provides facilities managers with important benchmark criteria for optimising the performance of these sports facilities. In the long run, this study contributes to enabling the project stakeholders to conduct evidence-based decision making over the life cycle of sport facilities development and management.

1. Introduction

Research reveals that users' perception of the physical environment created within sports facilities affect users' attitude and behaviours related to sport activities [1]. Positive perception of the physical environment increases users' motivation and willingness to attend or participate in sport events but of course, the converse is also true [2–7]. Sport marketing and facilities management researchers proffer that users' satisfaction of sports facilities is an important research agenda that influences the strategic planning and design of these facilities [8]. Consequently, a user-centric research approach has emerged, which incorporates the principles from human factors and ergonomics to create and adapt a human-made environment to suit individual users within sports facilities [1,9]. In built environment studies, the same approach to incorporating human perception is used to evaluate the performance of facilities [10–12]. In the higher education sector, understanding users' perception of university facilities is quintessentially important because it affects campus asset management strategies, physical and mental health/well-being of facilities users, and long-term environmental sustainability of the institution [13].

Swimming pools are ubiquitous facilities found both outdoors and indoors, and they can be used for multiple purposes including sport, leisure, education and therapy [14,15]. Health and safety considerations are two fundamental requirements of swimming pools, which must be fulfilled through proper provisions in two main aspects: architectural (e.g. size, pool tank, pool wall, pool decks, and pool bottom) and building services (e.g. air, temperature, lighting, water quality, and acoustics). Such provisions are usually governed by laws (e.g. Swimming Pools

* Corresponding author.
E-mail addresses: erica.sw.lau@connect.polyu.hk (E. Lau), h.hou@tudelft.nl (H.(C. Hou), bejlai@polyu.edu.hk (J.H.K. Lai), drdavidedwards@aol.com (D. Edwards), Nicholas.Chileshe@unisa.edu.au (N. Chileshe).

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Regulation (Cap. 132) of the law of Hong Kong), which are translated into practical guidelines or codes of practice (e.g. Refs. [16,17].

While swimming pools are typically designed and constructed in compliance with specified requirements, how well they are operated and managed invariably determines users' satisfaction. Users of university swimming pools, in particular, include not only amateur swimmers but also professional swimmers, e.g. university students who are national swimming team members [18]. Unlike facilities for other sport activities such as football and basketball [19], swimming pools have received scant academic attention. Over the past decade, user-centric performance evaluation of sport facilities has started to gain increasing attention [20,21]. While the performance of swimming pools is crucial to the health, safety and enjoyment of the pool users, what attributes are key to achieving optimum performance of this facility are uncertain. A means of holistically evaluating the performance of swimming pools, especially from the users' perspective, is also unclear.

To address the above uncertainties, a multi-stage research study was conducted on four swimming pools with the aim of ameliorating the architectural design of, and building services provided within these facilities. Concomitant objectives of this study sought to provide the basis for benchmark criteria that could underpin a decision support tool for facilities managers who seek to augment users' experience, and engender wider polemic debate and discussion in this hitherto largely underexplored area of facilities management research.

In the next section, the findings of a review of the literature germane to the study are reported. Then, the research design, data collection and analysis of the data collected are recounted. Drawn from the analyzed results, finally, conclusions are given and future works in the area of this study are suggested.

2. Literature review

The literature review started with an overview of existing studies on sports facilities, followed by a strategic scanning on studies of facilities evaluation from users' perspective. The research deficiency in the field was revealed to be evident through the literature review, which is that a user-centric approach supported with scientific methodology for swimming pool evaluation is absent. Regarding that users' judgement in facilities evaluation involves certain levels of subjectivity, literature on scientific methods for decision/importance rating – multi-criteria decision-making (MCDM) are reviewed. In the last part of this section, a review of the MCDM method is provided to support the development of the AHP-based performance evaluation framework for swimming pool facilities. The details of the review results are shown as follows.

2.1. The performance of sports facilities

The performance of sports facilities has significant impacts on users' sport performance and their satisfaction with the facilities and relevant services [8,22]. Pertinent studies in this field can be divided into two dichotomous streams: functional performance and service performance.

Studies focused on the functional aspects of sports facilities utilise technical methods to investigate specific building services performance attributes, such as air quality [23–27]; thermal condition [28,29]; heating energy consumption [30,31], indoor lighting evaluation [19,32], acoustics condition [33]. These studies, often from the financial or environmental perspective, used engineering investigations (such as computer simulations and physical measurements) to identify the technical performance of sports facilities [31].

Studies that holistically investigate the performance of swimming pools are limited and the work conducted often focuses on the functional performance of certain attributes, such as: thermal condition [34]; water quality [35–37]; air, heat and moisture flow for an indoor swimming pool [15]; heating for indoor swimming pools [38,39]; water evaporation rate for indoor swimming pools [40]; and thermal performance for outdoor swimming pools [41].

Evaluating the overall performance of facilities from a "service" quality perspective has gained increasing traction in parallel to the need to understand users' perceived performance of facilities, where such knowledge is used to optimize facilities' design requirements and management efficiency. Realising that physical surrounding has significantly impacted upon human's consuming behaviour [42,43], framed a concept "servicescape" to describe the environment-use relationships in service organisations and further elaborated that physical and social environments would lead to one's intention to stay, explore, affiliate and return or avoid [3]. interpreted "servicescape" and proposed "sportscape" to describe the physical and social environments of sport facilities. They investigated the effects of stadium factors (e.g. parking, cleanliness, food service, perceived crowding and fan behaviour control) on spectators' desire to stay at the stadium and their intention to return in the future (i.e. repeated business).

This synthesis of extant literature on the performance of sports facilities reveals two prominent observations: first, a narrow array of pertinent existing literature exists in this area; and second, there is a notable absence of a user-centric approach to study the overall performance of swimming pools. This gap in the prevailing body of knowledge justifies the present study.

2.2. Users' perception of swimming pool performance

Realising that technical performance indicators may be inadequate for assessing a building's holistic performance, researchers have shifted to taking a behavioural approach to building evaluation [44,45]. A users' satisfaction survey is commonly used to indicate the performance of facilities. However [46], proffered that user perception is different from user satisfaction: user perception refers to users' observation, opinion and awareness of the service that they receive while users' satisfaction is indicated by comparing their initial expectation and their final opinion of the service rendered [47]. also emphasized that facilities related services shall be structured based on user orientation. According to Ref. [48]; the measurement of facilities performance should be governed by involving users in the measurement framework development.

For building performance evaluation purposes, Huang et al. [49] assessed the perceived importance of indoor environmental quality in long-term care facilities of three groups of building users (viz.: facilities managers; residents; and residents' family members), and found that building users' perception provides reference for the design and management of the indoor environment in long-term care facilities [50]. adopted the patient-centred care concept to identify the servicescape features in healthcare facilities and examine users' perceived physical conditions, satisfaction and their approach behaviour [51]. investigated the relationship between indoor environmental factors (thermal, acoustic, luminous environment) and human perception factors (individual factor comforts, individual factor satisfactions, and the overall satisfaction) [52]. investigated building design for people with dementia and revealed that design facilitates resident navigation and wayfinding around a care home.

While this prevailing body of knowledge reviewed illustrates that the solicitation of users' perception has gained momentum in studies on built environment performance, it also highlights the need for a framework (or hierarchy) that portrays the key performance attributes of swimming pools. Such novel work, which could be applied to systematically evaluate the performance of swimming pools from a user perspective, is a further research gap that has yet to be addressed. These observed knowledge gaps are conspicuous by their absence and further justify the present study.

2.3. Multi-criteria decision-making method applications

The multi-criteria decision-making (MCDM) method has been widely adopted in sport studies, including those on: sport strategies and technique [53–56]; selection of sport players [57]; sport injury repairs [58];

sport activities marketing and outsourcing [59,60]; engagement and participation in sport [61,62]; prioritisation of factors affecting the privatisation of sport club [63]; sport centre business management strategies [64]; and facilities performance measurement system development [65].

The Analytic Hierarchy Process (AHP) method [66], one of the most commonly used MCDM methods, is based on an area of behavioural sciences known as psychophysics [67]. While fuzzy AHP method has been increasingly used to reduce the fuzziness involving the mapping of one's preference to an exact number or ratio, AHP is still widely adopted under the circumstance that the rated number in each hierarchy is less than 4 [68]. Communication with occupants and the transient nature of occupancy are two key challenges to evaluating occupants' perceived comforts of sport facilities [69]. The AHP method serves as a straightforward way for the occupants or facilities users to understand the evaluation process as well as a logical guide for them to relate their daily experience to their perception of the built environment features [70]. Several studies confirm the usefulness of the AHP method in evaluating users' perceived importance of facilities performance [70–74]. Yet hitherto, scant academic attention has been given to applying the AHP (or any other MCDM) method to evaluate sports facilities performance.

3. Methods and data

3.1. Research design

To address the aforementioned research gaps: (1) lack of a user-centric approach to study the overall swimming pool performance, (2) absence of a framework portraying the key performance attributes of swimming pools, and (3) how such a hierarchy could be applied to systematically evaluate the performance of swimming pools, this study was initiated. Fig. 1 presents a process flow chart that elucidates upon the stages and activities adopted within the research design. Specifically, the study commenced with an extensive literature review of: sports facilities performance evaluation; users' perspectives on key swimming pool performance; application of multi-criteria decision-making methods in sports facilities management; and professional swimming pool design guidelines. Premised upon this review, an initial version of a performance attribute hierarchy was constructed. Based on focus group participants' feedbacks, the hierarchy was revised and then used to guide the design of an AHP-based questionnaire (Survey I). One criterion for setting the sample frame was that the targeted survey respondents should have recent experience of using swimming pools, which is to guarantee the validity of their opinion. In the process of questionnaire distribution, this criterion was fulfilled through randomly approaching [75] the users of the swimming pools. The swimming pool users were invited to participate in the survey on a voluntary basis; where the study's purpose was introduced to them prior to seeking their informed consent to participate in the survey [76]. Upon consent being granted, the study's background and survey's structure was further elaborated to survey participants. Though only minimal risk was involved in the survey, the project administrator confirmed with the survey participants that all data would remain strictly confidential; that their anonymity would be preserved; and that all data would be securely disposed of post results being published (cf [77]. In total, 103 swimming pool users at four swimming pools in Hong Kong agreed to participate in the AHP-based survey (Survey I), through which the importance weightings of the performance attributes were determined.

Among the four pools, two are university swimming pools (located in one university: P1 - indoor pool; and P2 - outdoor pool) and the other two are public swimming pools (both are indoor pools: P3, P4). Table 1 summarises the dimensions of the four pools. P1 and P2 are university

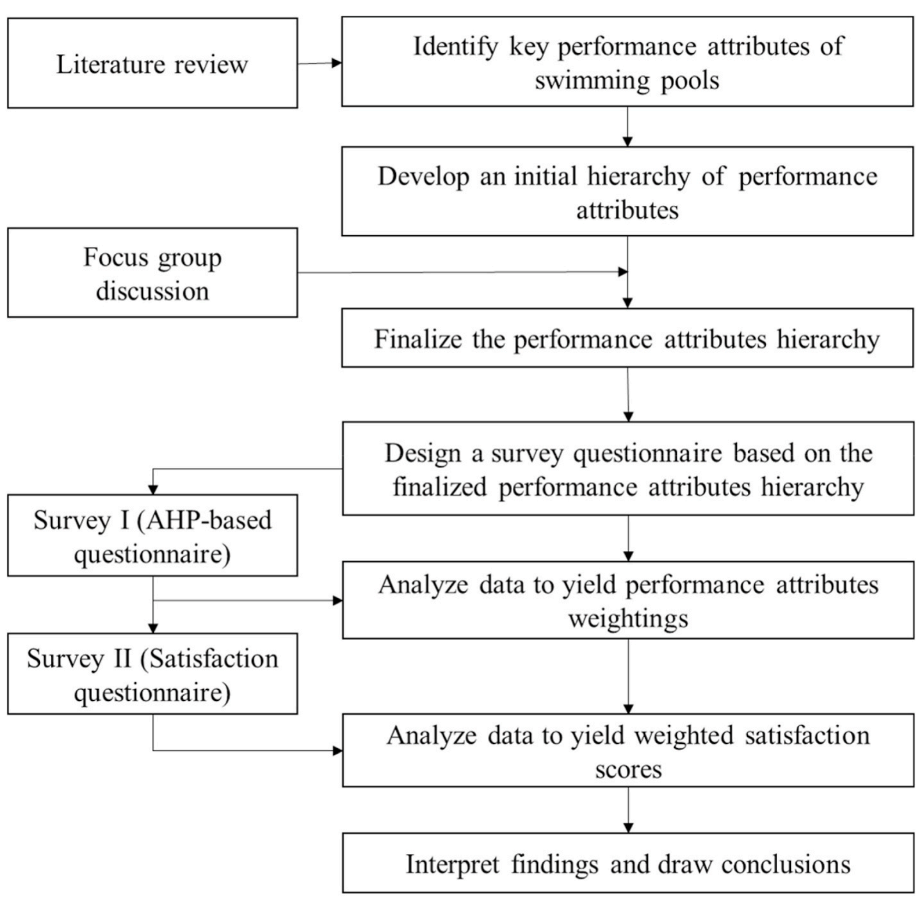

Fig. 1. The research process.

Table 1
Dimensions of the four swimming pools.

Swimming pool	Dimensions
P1	Length: 25 m; Depth: 1.2 (with starting blocks)/1.4 m (without starting blocks); Width: 15 m
P2	Length: 50 m; Depth: 1.3–4.0 m; Width: 25 m
P3	Length: 50 m; Depth: 2 m; Width: 25 m
P4	Length: 50 m; Depth: 2 m; Width: 25 m

swimming pools used for leisure, education and training. P3 and P4 are public pools that are also used for training (with prior registration), and they were selected because they share similar design and functions.

Among the 103 respondents, 30 were university swimming pool users who were invited to complete a second questionnaire (Survey II) to indicate of their levels of satisfaction with the two university swimming pools. Survey responses, together with the performance attributes weightings determined from the data of Survey I, were processed to generate findings that reflect the weighted performance of the two university pools.

3.2. Development of a swimming pool performance attribute hierarchy

The performance of swimming pools is dependent on factors including: pool design; water circulation and treatment; pool equipment and accessories; and auxiliary services such as bathing facilities [78]. According to Ref. [79]; performance indicators of sports facilities must provide adequate data for performance comparison and management, which allow standards and targets to be generated and guide users' expectations. For developing a swimming pool performance attribute hierarchy, the attributes selected shall be elements that contribute to users' safety and health and enjoyment. These elements are specified in internationally authorised guidelines, including: (1) CIBSE Guide G – published by the Chartered Institute of Building Services Engineers (CIBSE) to provide guidance to professionals who are involved in advising, designing and/or building public health engineering facilities [16]; and (2) FINA facilities rules: 2017–2020 - issued by the Fédération Internationale de Natation (FINA), an international federation recognized by the International Olympic Committee, to provide detailed swimming pool facilities conforming to exacting design and technical specifications [17].

Using the aforementioned international guidelines, three levels of swimming pool performance attributes were identified. As shown in Fig. 2, architectural aspect and building services aspect are included as the first level of the hierarchy to reflect the equal importance of physical surroundings and the functions of the facilities (Bitner, 1992; [3,43]. At the second level, there are ten performance attributes, viz. in the architectural aspect - size; pool tank; pool wall; pool deck; and aiding facilities; and in the building services aspect - air; temperature; lighting water; and acoustics Under each of these ten attributes, the sub-attributes, at the third (bottom) level of the hierarchy, range from one to four. Appendix 1 summarises the specifications for all the attributes and sub-attributes.

3.3. Focus group discussion for refining the hierarchy

Key stakeholders' opinions are important in performance attribute hierarchy development [80]. As the focus group method is useful for collecting qualitative data from different perspectives [81], a semi-structured focus group meeting was orchestrated, with swimming pool users facilitated to discuss and shortlist the key performance attributes that should be included in the performance attribute hierarchy. The five focus group experts, at professional swimming levels, included two males (M1: 18 years old, national level water polo player with 7 years of swimming experience; M2: 24 years old, regional level swimmers with 16 years of swimming experience) and three females (F1: 18 years old, institutional level swimmers with 4 years of swimming experience; F2: 24 years old, regional level swimmers with 16 years of swimming experience; F3: 27 years old, former national level swimmers with 21 years of swimming experience). Given this range of experience and expertise, the focus group members were deemed suitable participants who would contribute informed and insightful comments in the ensuing discourse.

The focus group meeting was divided into two stages. First, the participants were given a structured list of the performance attributes (identified from the two international guidelines) and were asked to vote for the performance attributes that should constitute the hierarchy. Second, they were required to share their insightful opinions on the voting results, including reasons for any revisions they consider necessary for the listed attributes or the hierarchy. Performance attributes that received votes from more than half of the participants were shortlisted, based on which the performance attribute hierarchy was revised.

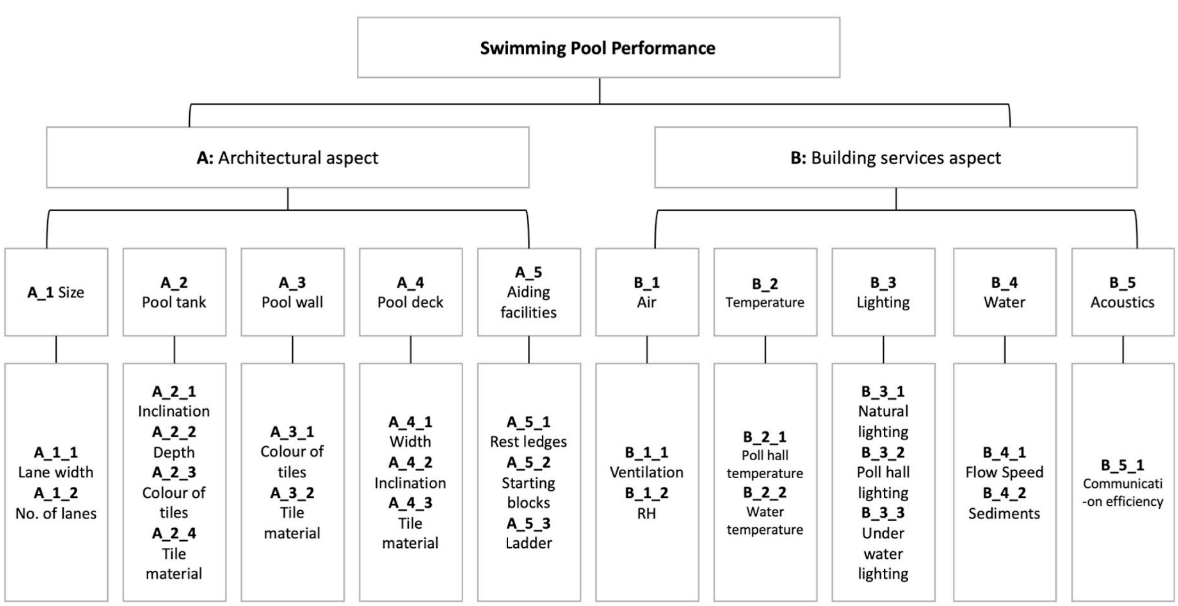

Fig. 2. Swimming pool performance attribute hierarchy (initial version).

Referring to this initial hierarchy developed (Fig. 2), the focus group recommended some further refinements as follows.

For the architectural aspect, the participants recommended removing "size" and "aiding facilities" from the second hierarchy level and changing "pool tank" to "pool bottom". For the performance attributes at the third level, some were removed and some were renamed to provide more direct meanings of the attributes. Under "pool deck", "width" and "inclination" were removed, and "starting block" and "ladder" were added. Under "pool wall", "colour of tiles" was removed, and "lane width" and "rest ledge" were added; "inclination" and "depth" were suggested by the focus group participants as the third level attributes under "pool bottom".

For the building services aspect, the focus group recommended restructuring the second and third levels of the hierarchy and rephrasing the building services performance attributes. First, they pointed out that swimmers would find it difficult to rank the relative importance among "air", "temperature", "lighting", water" and "acoustics." For example, "air" and "temperature" might appear to be reflecting the same matter – thermal comfort, and thus perceived by pool users as equally important. Also, "lighting" may be perceived differently depending on whether swimmers are inside or outside the pool water. Swimmers have different requirements regarding lighting performance inside and outside water. Lighting inside the water can strengthen swimmers' visibility while they are swimming, whereas lighting outside the water should not be too glaring. The focus group further explained that for activities such as water polo, players need to get in and out of the water throughout the game and thus, lighting inside and outside the water can significantly affect their performance. After deliberation, it was decided to use "visibility" and "poolhall lighting" to indicate the perceived lighting performance inside and outside the water respectively.

Furthermore, the focus group believed that swimmers usually comment on the swimming pool performance based on their personal sensation, no matter outside or inside the water. Thus, "acoustics" was suggested to be removed as it does not discernably impact upon the swimmers' sensation inside the water much. Participants also commented that instead of including "air" (and its sub-attributes "ventilation" and "RH (relative humidity)") in the hierarchy, "breathe" should be used to indicate users' sensation of air quality, and "stuffiness" and "smell" should be grouped under "breathe." "Visual" and "skin" were recommended for replacing "temperature" and "water." Instead of using "under water lighting", "visibility" was used to indicate the lighting performance under the water. "Visibility" and "sediments" were suggested to be grouped under "visual"; "water temperature" and "flow rate" were regarded as performance attributes that can be felt by skin and thus, were included in the "skin" group. "Pool hall lighting" and "pool hall temperature" were suggested to be grouped under "visual" (outside water) and "skin" (outside water) respectively.

Upon making the above revisions, the performance attribute hierarchy was finalized, as shown in Fig. 3. Comprising four levels, each branch of the hierarchy is made up of at most three performance attributes.

3.4. The two surveys

Survey I, an AHP-based questionnaire survey, was carried out at the four selected swimming pools. The questionnaire sought demographic information from participants such as: gender; age and background; type of sport they use the swimming for; and their professional level of that sport. A total of 103 swimming pool users participated in this survey; 51.5% were male. Most of the respondents (69.9%) were aged between 19 and 30, and 87.3% were students. The respondents used the swimming pools mainly for two types of sport: swimming (94.2%) and water polo (5.8%) – refer to Table 2.

Fig. 4 shows the number of survey respondents against their number of pool visits per month, with indications of the responses categorised by pool venues (i.e. public swimming pools or university swimming pools). Of all the respondents, 70 used swimming pools 20 times or less per month; the most frequent group, who used swimming pools 31 to 40 times per month, covered 10 respondents.

In Survey I, the performance attributes at each hierarchical level were paired up against each other for comparison to be made by the survey respondents. On a nine-point rating scale [66]: from 1 (equally important) to 9 (most important, no compromise acceptable), the respondents were asked to indicate their level of preference between each pair of the attributes. For example, if architectural aspect is absolutely more important than building service aspect and is rated at 9, then building service aspect must be absolutely less important than architectural aspect and is valued at 1/9. Each survey respondent need to carry out the pair wise comparison for all performance attributes and a matrix is constructed expressing the relative values of all attributes. The next step is the calculation of a list of the value of the attributes (the list is called an eigenvector). The final stage is to calculate a Consistency Ratio (CR) to measure how consistent the judgements are.

For each set of the responses, a consistency test (Eq. (1)) was conducted, where λ is the principal eigenvalue of the pairwise comparison matrix, n is the number of attributes, and r is the random index. The CR is compared against the CR limit (0.1). Responses with CR > 0.1 were to be discarded. Each branch of the final hierarchy (Fig. 3), comprising at most three attributes, required more than three pairwise comparisons. All the survey responses were found to be drawn from consistent

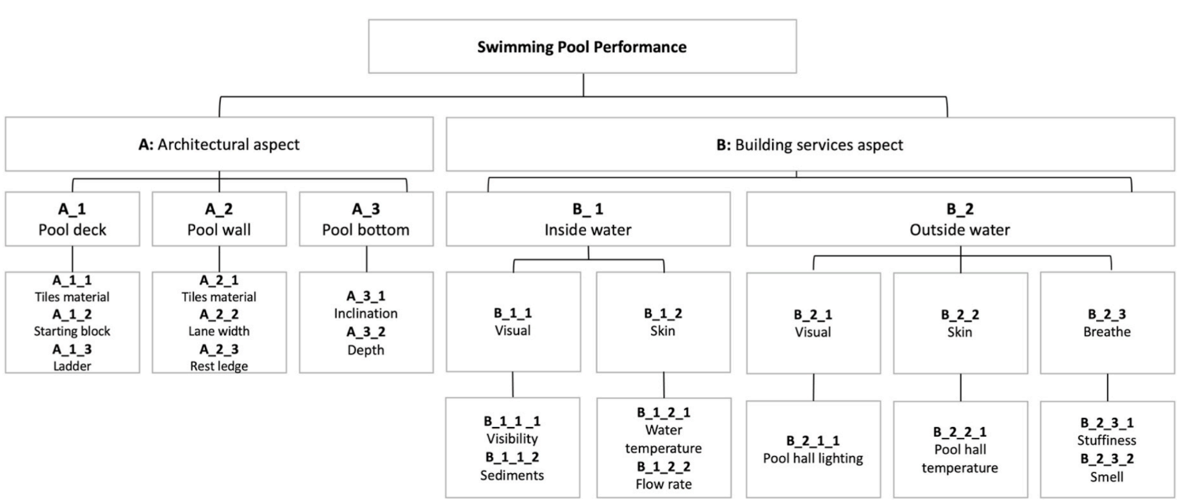

Fig. 3. Swimming pool performance attribute hierarchy (final version).

Table 2
Demographic information.

Variable		Overall	Survey location	
			University swimming pools	Public swimming pools
Gender	Male	53 (51.5%)	17 (56.7%)	36 (49.3%)
	Female	50 (48.5%)	13 (43.3%)	37 (50.7%)
Age	<19	24 (23.3%)	7 (23.3%)	17 (23.3%)
	19–30	72 (69.9%)	22 (73.3%)	50 (68.5%)
	31–45	4 (3.8%)	0	4 (5.5%)
	46–65	3 (2.9%)	1 (3.3%)	2 (2.7%)
	=>66	0	0	0
Background	Student	90 (87.3%)	27 (90%)	63 (86.2%)
	Employed	13 (12.6%)	3 (10%)	10 (14%)
Type of sport	Swimming	97 (94.2%)	28 (93.3%)	69 (94.5%)
	Water Polo	6 (5.8%)	2 (6.7%)	4 (5.5%)
Professional level	National	26 (25.2%)	9 (30%)	17 (23.3%)
	Regional	40 (38.8%)	11 (36.7%)	29 (39.7%)
	Institutional	26 (25.2%)	7 (23.3%)	19 (26%)
	Leisure	11 (10.7%)	3 (10%)	8 (10%)

judgements of the respondents, as the calculated CR values of the 103 datasets were all below the CR limit.

$$CR\frac{\lambda - n}{n-1}X\frac{1}{r} \quad (1)$$

where λ is principal eigenvalue, n is number of rated items, and r is random index.

Succeeding Survey I, a satisfaction survey (Survey II) was conducted. Among the respondents of Survey I, 30 users of the two university swimming pools were asked to further participate in Survey II and rate their satisfaction with the performance of the two pools. The scale of satisfaction levels adopted for the current study, similar to that used in similar post occupancy evaluation studies previously conducted (cf. [65, 70], ranges from 1 to 7 (1: extremely low; 2: very low; 3: slightly low; 4: fair; 5: slightly high; 6: very high; 7: extremely high). Two weighted satisfaction scores were computed for the two university swimming pools to explain and compare users' perception on each performance attributes of the two swimming pools. The statistical treatment by integrating satisfaction scores and perceived importance scores helps to further interpret users' understanding and preference of swimming pool facilities. The comparison of the weighted satisfaction scores between the two swimming pools reveals the actual facilities performance of the two swimming pools.

4. Results and discussion

4.1. Weightings of the performance attributes

Based on the 103 user responses, the AHP weightings of the performance attributes were calculated, based on which the rankings of the attributes were also determined (Table 3).

At level 1, the users considered "building services aspect" (B) as more important than "architectural aspect" (A). At level 2, under A, the users ranked "pool deck" (A_1) to be the most important performance attribute (weighting: 41.17%), followed by "pool wall" (A_2) (weighting: 34%) and "pool bottom" (A_3) (weighting: 24.41%). Under B, the users ranked "inside water" (B_1) higher than "outside water" (B_2), with weighting of B_1 (75.34%) being substantially higher than that of B_2 (24.66%). This illustrates that the users perceived performance attributes in the "inside water" group as more important than the counterpart "outside water". A probable reason for this is the attributes inside the water affect the users' sport activities more.

At level 3, under "building services aspect" (B), based on their inside water experience the users ranked "skin" (B_1_1) (weighting: 74.68%) higher than "visual" (B_1_2) (weighting: 25.31%). While for "outside water", the users ranked "breathe" (B_2_3) (weighting: 49.8%) as the most important attribute, followed by "skin" (B_2_2) (38.82%); and "visual" (B_2_1) (weighting: 11.39%). Here, as only one sub-attribute B_2_1_1 "pool hall lighting" is under attribute B_2_1 "visual" (also see Fig. 3), they both bear the same weighting. The same applies to attribute B_2_2 "skin" and its sub-attribute B_2_2_1 "pool hall temperature."

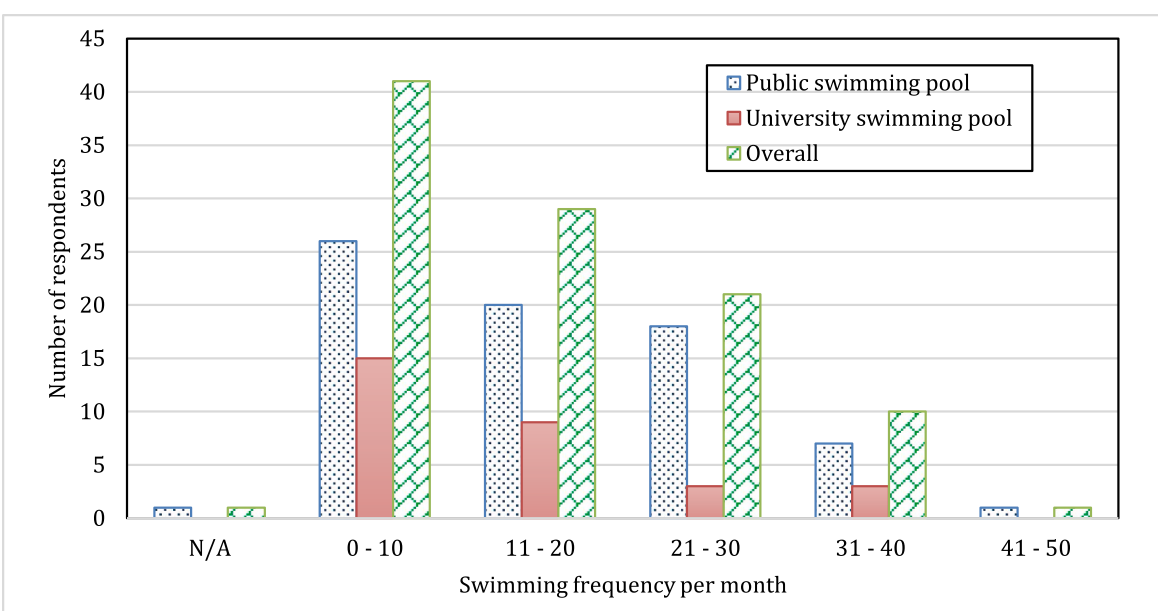

Fig. 4. Number of respondents against number of pool visits per month.

Table 3
AHP Weightings and ranking of the Swimming Pool Performance Attributes.

Hierarchy level	Code	Performance attributes	Weighting (%)	Ranking
Level 1	A	Architectural aspect	29.31	2
	B	Building services aspect	70.74	1
Level 2	A_1	Pool deck	41.17	1
	A_2	Pool wall	34.00	2
	A_3	Poll bottom	24.41	3
	B_1	Inside water	75.34	1
	B_2	Outside water	24.66	2
Level 3	A_1_1	Tiles material	36.89	2
	A_1_2	Starting block	51.41	1
	A_1_3	Ladder	15.61	3
	A_2_1	Tiles material	17.5	3
	A_2_2	Lane width	38.75	2
	A_2_3	Rest ledge	45.03	1
	A_3_1	Inclination	36.43	2
	A_3_2	Depth	63.57	1
	B_1_1	Visual	25.31	2
	B_1_2	Skin	74.68	1
	B_2_1	Visual	11.39	3
	B_2_2	Skin	38.82	2
	B_2_3	Breathe	49.8	1
Level 4	B_1_1_1	Visibility	77.04	1
	B_1_1_2	Sediments	22.96	2
	B_1_2_1	Water temperature	70.95	1
	B_1_2_2	Flow rate	29.63	2
	B_2_1_1	Pool hall lighting	11.39	N/A
	B_2_2_1	Pool hall temperature	38.82	N/A
	B_2_3_1	Stuffiness	71.28	1
	B_2_3_2	Smell	18.75	2

As regards the architectural attributes at level 3, under "pool deck" (A_1), "starting block" (A_1_2) was rated as the highest, followed by "tiles material" (A_1_1), and "ladder" (A_1_3). Note that the weighting of "tile material" (A_1_1) under "pool deck" is over twice the weighting of "tile material" (A_2_1) under "pool wall." Safety can be a major concern leading to this significant difference in importance weightings. Hence, the material of the tiles on the pool deck need to be of high anti-slippery quality to ensure users' safety while traversing around pool.

Level 4 consists of only performance attributes in the building services aspect. Between "visibility" (B_1_1_1) and "sediments" (B_1_1_2), the former attribute was weighted much higher than the latter one (77.04% vs. 22.96%). "Water temperature" (B_1_2_1) was weighted much higher than "flow rate" (B_1_2_2), viz. 70.95% vs. 29.63%. Also, the weighting of "stuffiness" (B_2_3_1) is much higher than that of "smell" (B_2_3_2), viz. 71.28% vs. 18.75%. These findings indicate that when using the swimming pools, the users care about: (1) visibility inside water; (2) water temperature; and (3) capability to breathe smoothly outside water.

4.2. University swimming pool performance evaluation

As one type of important campus facilities that serve the purposes of professional training and leisure use, swimming pools are prized among concerns of both university administration and students. Forming part of the physical education environment of universities, swimming pools have a positive influence on students' physical health and campus life [13]. Pictures of the two university swimming pools are shown in Fig. 5.

The performance of the university swimming pools was evaluated in two processes: namely, (1) comparison of the weighted satisfaction scores of the different performance attribute groups between the two pools; and (2) comparison of the satisfaction ratings of each performance attribute between the two pools. The first step involved combination of both the importance weightings and satisfaction ratings. The second step sought to identify the performance levels of the individual attributes.

4.2.1. Comparison of weighted satisfaction scores of performance groups

The calculation of the weighted satisfaction scores of each performance attribute group entailed three steps, using Eqs. (2)–(4). In step 1, a weighted satisfaction score for the performance attributes at the fourth level of the hierarchy (WS_y) was obtained by aggregating the satisfaction scores (S_x) and the perceived importance scores (I_x); in step 2, a weighted satisfaction score for the performance attributes at the third

Fig. 5. The two university swimming pools.

level of the hierarchy (WS_Z) was obtained by aggregating the weighted satisfaction score obtained from Eq. (2) (WS_y) and the perceived importance scores at the third level of the hierarchy (I_y); in the last step, the overall weighted satisfaction scores (WS) was obtained by aggregating the weighted satisfaction score obtained from Eq. (3) (WS_z) and the perceived importance scores at the second level of the hierarchy (I_z). Table 4 shows the importance weightings, rankings and the calculated weighted satisfaction score of each attribute.

$$WS_y \sum_{x=1}^{\alpha} S_x \text{X}\, I_x \tag{2}$$

$$WS \sum_{y=1}^{\beta} WS_y \text{X}\, I_x \tag{3}$$

$$WS \sum_{z=1}^{C} WS_z \text{X}\, I_z \tag{4}$$

Where

α is number of performance attributes at the fourth level of the hierarchy;
β is number of performance attributes at the third level of the hierarchy;
C is number of performance attributes at the second level of the hierarchy;
I_x is importance weighting of the xth performance attribute (x = 1, 2, … α);
I_y is importance weighting of the yth performance attribute (y = 1, 2, … β);
I_z is importance weighting of the zth performance attribute (z = 1, 2, … C);
S_x is satisfaction rating of xth performance attributes (x = 1, 2, … α);
WS_y is weighted satisfaction score of performance attribute group at the third level;
WS_z is weighted satisfaction score of performance attribute group at the second level; and
WS is weighted satisfaction score of performance attribute group at the first level.

Table 5 further shows the weighted satisfaction scores of the performance groups, which were calculated using Eqs. (2)–(4). The final two columns in this table are the shares of the weighted scores contributed by the corresponding groups of performance attributes. The results reveal that for both pools, the share of group B (i.e. "building services" aspect) significantly outweighs that of group A (i.e. "architectural" aspect). For the performance groups at level 2 (A_1, A_2, A_3, B_1 and B_2), the order of their shares is in line with their order of importance rankings.

At level 3, the order of the shares of B_2_1, B_2_2 and B_2_3 is slightly different from the order their importance ranking. This shows that for both swimming pools, the users tend to be more satisfied with the performance of "rest ledge" than with "lane width", while the importance ranking results show that the users regarded "rest ledge" as more important than "lane width." Generally, the findings reflect that

Table 5
Weighted satisfaction scores of performance groups.

Group	WS (outdoor pool)	WS (indoor pool)	Share, % (outdoor pool)	Share, % (indoor pool)
A	0.95	1.16	19	27
B	3.98	3.20	81	73
A_1	1.68	2.05	46	46
B_2	1.36	1.21	37	27
A_3	0.63	1.25	17	28
B_1	4.12	3.46	77	80
B_2	1.23	0.84	23	20
B_1_1	1.27	0.94	25	22
B_1_2	3.88	3.39	75	78
B_2_1	0.61	0.46	10	11
B_2_2	2.23	1.87	36	44
B_2_3	3.31	1.90	54	45

Table 4
AHP weighting and ranking of the swimming pool.

Hierarchy level	Code	Performance attributes	Weighting (%)	Ranking	Weighted satisfaction score	
					Outdoor pool	Indoor pool
Level 1	A	Architectural aspect	25.76	2	0.98	1.34
	B	Building services aspect	74.36	1	3.96	3.14
Level 2	A_1	Pool deck	38.24	1	1.66	2.05
	A_2	Pool wall	38.20	2	1.33	2.05
	A 3	Poll bottom	22.09	3	0.63	1.24
	B_1	Inside water	80.06	1	4.10	3.43
	B_2	Outside water	19.94	2	1.26	0.85
Level 3	A_1_1	Tiles material	40.06	2	1.97	2.22
	A_1_2	Starting block	46.1	1	1.75	2.38
	A_1_3	Ladder	13.71	3	0.65	0.76
	A_2_1	Tiles material	15.14	3	0.68	0.89
	A_2_2	Lane width	43.28	1	2.37	2.27
	A 2 3	Rest ledge	41.54	2	0.51	0.00
	A_3_1	Inclination	25.65	2	0.63	1.44
	A_3_2	Depth	74.35	1	2.23	4.21
	B_1_1	Visual	22.38	2	1.30	0.97
	B_1_2	Skin	77.61	1	3.87	3.31
	B_2_1	Visual	10.18	3	0.61	0.46
	B_2_2	Skin	41.25	2	2.28	1.86
	B_2_3	Breathe	48.68	1	3.31	1.86
Level 4	B_1_1_1	Visibility	80.57	1	4.70	3.28
	B_1_1_2	Sediments	19.43	2	0.97	0.90
	B_1_2_1	Water temperature	75.44	1	3.72	3.23
	B_1_2_2	Flow rate	24.56	2	1.28	1.13
	B_2_1_1	Pool hall lighting	10.18	N/A	0.61	0.46
	B_2_2_1	Pool hall temperature	41.25	N/A	2.23	1.86
	B_2_3_1	Stuffiness	77.65	1	5.33	2.62
	B_2_3_2	Smell	22.29	2	1.46	1.27

although the satisfaction level of each performance attribute differs between the two pools, the magnitudes of the shares of the weighted satisfaction scores are consistent between the two pools.

4.2.2. *Comparison of satisfaction ratings of performance attributes*

Table 6 shows the results of the users' satisfaction with each performance attribute of the two university swimming pools. Note that as there was no rest ledge in the indoor pool, the corresponding satisfaction rating of this attribute (A_2_3) is not applicable to the indoor pool. Main observations from the results are discussed as follows.

First, the users regarded the architectural aspect (A) of the indoor pool (rating: 5.2) better than that of the outdoor pool (rating: 3.8), while the order of satisfaction ratings of the building services aspect (B) of the two swimming pools reverses: 5.32 for the outdoor pool and 4.22 for the indoor pool.

Second, the performance attributes of levels 2 and 3 under A and B were rated in consistent order with the performance attributes of aspects A and B at level 1: (i) for the attributes in the architectural aspect, the satisfaction scores of the outdoor pool are lower than those of the indoor swimming pool; and (ii) for the attributes in the building services aspect, the satisfaction scores of the outdoor swimming pool are higher than those of the indoor swimming pool.

Third, there are significant contrasts (rating difference > 2) between the two pools: pool bottom (A_3) (*Outdoor 2.84 vs. indoor 5.61*); outside water (B_2) (*outdoor 6.30 vs. indoor 4.24*); inclination (A_3_1) (*Outdoor 2.47 vs. indoor 5.62*); depth (A_3_2) (*Outdoor 3.00 vs. indoor 5.66*); breathe (B_2_3) (*Outdoor 6.79 vs. indoor 3.83*); and stuffiness (B_2_3_1) (*Outdoor 6.87 vs. indoor 3.38*). What constituted to these significant differences in satisfaction levels have yet to be investigated.

Fourth, attributes with particularly low ratings, namely: rest ledge (outdoor: 1.23); inclination (outdoor: 2.47); and pool bottom (outdoor: 2.84) warrant the attention of the facilities management team. To investigate why the users were dissatisfied with such attributes, further study is needed.

5. Discussion

From a purely theoretical perspective, this research constitutes the first attempt to employ the specific MCDM method – AHP to analytically evaluate the holistic performance of swimming pools from the users' perspective. This notable gap in the prevailing body of knowledge is enigmatic because ultimately users shape the future design and

Table 6
Satisfaction rating of the two university swimming pools.

Hierarchy level	Code	Performance attributes	Satisfaction rating	
			Outdoor swimming pool	Indoor swimming pool
Level 1	A	Architectural aspect	3.8	5.2
	B	Building services aspect	5.32	4.22
Level 2	A_1	Pool deck	4.35	5.37
	A_2	Pool wall	3.49	5.36
	A_3	Poll bottom	2.84	5.61
	B_1	Inside water	5.12	4.28
	B_2	Outside water	6.3	4.24
Level 3	A_1_1	Tiles material	4.93	5.55
	A_1_2	Starting block	3.8	5.17
	A_1_3	Ladder	4.77	5.52
	A_2_1	Tiles material	4.5	5.9
	A_2_2	Lane width	5.47	5.24
	A_2_3	Rest ledge	1.23	N/A
	A_3_1	Inclination	2.47	5.62
	A_3_2	Depth	3	5.66
	B_1_1	Visual	5.83	4.35
	B_1_2	Skin	4.99	4.27
	B_2_1	Visual	6.03	4.48
	B_2_2	Skin	5.53	4.52
	B_2_3	Breathe	6.79	3.83
Level 4	B_1_1_1	Visibility	5.83	4.07
	B_1_1_2	Sediments	4.99	4.62
	B_1_2_1	Water temperature	4.93	4.28
	B_1_2_2	Flow rate	5.2	4.62
	B_2_1_1	Pool hall lighting	6	4.48
	B_2_2_1	Pool hall temperature	5.41	4.52
	B_2_3_1	Stuffiness	6.87	3.38
	B_2_3_2	Smell	6.57	5.72
	Average satisfaction rating		**4.98**	**4.38**

specification of such sports facilities and the building services installed within them. Users are customers (whether fee paying students, tax paying members of the public or private members) and thus their insights and experience must be considered when commissioning future swimming pool projects or refurbishing existing facilities. Such user feedbacks are quintessentially important, especially if these sports facilities are optimized to enhance their utilitarian performance while remaining profitable and augmenting users' experience. In any developed nations, sports are widely acknowledged as representing a prominent means of retaining the physical and mental health of the population [82]). Therefore, improved design could lead naturally to higher utilization rates and lower rates of, for example, cardiovascular disease and other ailments that cost society at large [82]).

This latter presupposition conveniently leads to the practical contribution of this work – namely, the findings represent rich knowledge that contains the innate potential to form the basis of future decision making in the design, construction and/or maintenance of swimming pools. Some would proffer that standards already do this but basically, standards are a minimum level of conformance only, designed to preserve the health and welfare of users and not necessarily fulfil them or enrich their experience. Ironically, the inherent limitation (viz. the sample size in terms of the number of swimming pools examined) also engenders direction for future work. If a larger sample of other swimming pools are reviewed and analyzed in future work, it will be possible to cross compare and contrast against a larger sample of design features and building services attributes. This in turn will allow a hybrid knowledge management system to be developed that supports the decision-making process of facilities managers - as construction clients and operators of swimming pools after handover.

6. Conclusions

An extensive literature review at the beginning of this study found that little research had been conducted to evaluate the performance of swimming pools from the users' perspective, nor there was any systematic assessment framework for swimming pools. Through a focus group meeting, the key swimming pool performance attributes identified from the literature were studied, leading to the establishment of a performance attribute hierarchy for swimming pools. Grounded on this hierarchy, two surveys were designed. Responses to these surveys, centred on the perception of swimming pool users, were analyzed using the AHP method to determine the importance weightings and weighted satisfaction levels of the performance attributes.

Among the key conclusions drawn from the study's results is that through refining the initial performance attribute hierarchy to be made up of performance groups each comprising not more than three attributes, all the survey respondents managed to make consistent judgments on the attributes being compared. In determining the performance of swimming pools, the building services aspect is more important than the architectural aspect, and hence more attention should be given to manage the facilities in the building services aspect. Also, pool users tend to care more about the performance attributes inside water than those outside.

For those attributes found with significant differences in satisfaction levels between the outdoor and indoor pools and for attributes with particularly low satisfaction ratings. Further study is required to probe into their causes and identify any improvement needed for the respective facilities. In the future, the approach developed within this study can be taken to conduct research or performance evaluation on other swimming pools and lead to novel decision support tools. More than ever, the global pandemic has revealed the importance of sports facilities to preserve the physical and mental health of the general public. Hence, a concerted attempt should be made to better integrate users' perceptions into the design and/or refurbishment of such facilities.

While the study makes several contributions to the development of new techniques for addressing consensus and judgment for evaluating the performance of swimming pools from the users' perspective, the following limitations are acknowledged. First, the assessment framework, developed for swimming pools, was limited to Hong Kong. Therefore, future studies could be undertaken to validate the framework in different environments. Second, due to the limited availability of participants, cyclic data modelling was possible and a single focus group was used. Further research around this study could extend to cover a larger sample of participants.

Authorship contributions

Erica Lau: conceptualisation; methodology; formal analysis; investigation; data curation; writing-original draft; project administration.

Huiying (Cynthia) Hou: methodology; validation; formal analysis; investigation; writing-original draft; visualisation.

Joseph H.K. Lai: conceptualisation, methodology, validation, formal analysis; investigation; writing-reviewer & editing; visualisation, supervision, project administration.

David Edwards: validation, writing-reviewer & editing.

Nicholas Chileshe: validation, writing-reviewer & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Performance attributes specification [16,17]

Level 2	Level 3	Specification
Architectural aspect		
Size	Lane width	Lanes shall be at least 2.5 m wide
	Number of lanes	8 lanes, with two spaces of at least 0.2 m outside of the first and last lanes
Pool tank	Inclination of the pool	Water depth of less than 1.5 m: avoid abrupt changes of depth, with maximum gradient 1:10 (preferably 1:16)
		Water depth of less than 0.8 m: maximum recommended gradient
	Depth at the two ends	A minimum depth of 1.35 m, extending from 1.0 m to at least 6.0 m from the end wall is required for pools with starting block.
		A minimum depth of 1.0 m is required elsewhere.
	Colour of tiles	In water depths less than 1.35 m, changes in inclination must be marked by a contrasting colour.
	Material of tiles	Water less than 1.35 m deep: "Group A″ slip resistance as a minimum
		Water less than 0.8 m: "Group B″ slip resistance
Pool wall	Colour of tiles	No requirements, but usually plain turquoise, or mid/light blue
	Material of tiles	Must be smooth and free from structural protrusions down to 1.5 m, except for rest ledges
Pool deck	Width	Main access from changing room to pool: 3.0 m
		Where starting blocks are installed: 3.0 m
		Other surrounds generally: 2.5 m

(continued on next page)

(*continued*)

Level 2	Level 3	Specification
	Inclination	All floors in wet areas must have effective drainage, i.e. a fall of 1:50 to 1:20
	Material of tiles	All floors should have a minimum of 'A' slip resistance in terms of German standard DIN 51097, which defines three levels of slip resistance ('A', 'B' and 'C'), 'A' being the least resistant and 'C' the most resistant. Gradients steeper than 1:33 need greater slip resistance.
Aiding facilities	Rest ledge	Recommended in water depths greater than 1.4 m, must be between 1.0 m and 1.5 m from the water surface, width from 100 mm to 150 mm
		Must be not less than 1.2 m below the water surface and may be 0.1 m–0.15 m wide. Both internal and external ledges are acceptable (Internal edges preferred).
	Starting block	Shall be firm and give no springing effect
		Height above water surface: 0.5m–0.75 m
		Surface area: at least 0.5 m × 0.5 m, covered with non-slip material
		Max slope: 10° (may have an adjustable setting back plate)
		Handgrips for backstroke starts: 0.3m–0.6 m above water surface, parallel to the surface of the end wall and must not protrude beyond the end wall.
	Ladder	Distance between the pair of handrails: 432 mm–610mm
		Ladder height: 864 mm–965mm above pool deck
		Uniform distance between each tread: 178 mm–305mm
		Handrails shall be made of corrosion resistance material.
Building services aspect		
Level 2	Level 3	Design specification
Air	Air Ventilation	Recommended in proximity: 0.1 m/s
	RH	Between 40% and 80% (60% RH preferred)
Temperature	Pool hall temperature	2 °C above water temperature
	Water temperature	25–27 °C for training/competition pool
		25–28 °C for normal swimming pool
Lighting	Natural lighting	Maximum use should be made of natural light
	Pool hall lighting	Uniform illuminance of 200 lux
		Light intensity over starting platforms and turning ends shall not be less than 600 lux.
	Under water lighting	Recommended in pools with deep water.
Water	Flow speed	During competition the water in the pool must be at a constant level, with no appreciable movement.
		Inflow and outflow have to be regulated as follows:
		−220 to 250 m^3/h for 50.00 m pools
		−150 to 180 m^3/h for 33.33 m pools
		−120 to 150 m^3/h for 25.00 m pools
	Sediments	Transparency of water should be taken in to consideration Prevent pollutants from the bather, and other pollutants from additions of atmospheric debris such as dust, leaves, insects
Acoustics	Communication efficiency	Ensure effective communication

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