

Post Occupancy Evaluation of the Built Environment: A Case Study of Mosque Facilities

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ABSTRACT

Mosques are religious and cultural facilities that are used as a place of worship, social gatherings, and religious events by Islamic communities. The built environment in these facilities should meet certain technical, functional, and behavioral requirements for worshippers. Mosques could endure critical defects and inadequate performance, with gaps in knowledge, of appraisal tools for their overall performance assessment. Therefore, this research was motivated by the need to identify and purpose an exemplary systematic process upon the conduct of post-occupancy evaluation, owing to the fundamental need for satisfactory conditions that need to be met by mosque facilities. Thus, this paper presents an exemplary post-occupancy evaluation of mosque facilities in Saudi Arabia; as a religious built environment. A triangulation approach of data collection and assessment methods were followed and discussed in this research. A case study mosque was selected, following a review of literature. Interviews and walkthrough inspection identified 34 performance elements. Users' satisfaction survey data were collected and analyzed. Recommendations were proposed towards improving performance of the case study mosque as a religious built environment that demands satisfactory occupancy conditions. The findings indicated that worshippers were strongly satisfied with the conditions of the built environment in the case study facility; including acoustical comfort, spirituality, and aesthetic performance elements. This paper expands the boundaries of knowledge in terms of identification of mosques' performance elements.

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1. Introduction

A mosque is a built facility used by Islamic communities as a house of prayer, a center of cultural activities, an area for social gatherings, a courthouse, and an educational facility (Neufert and

Neufert, 2012). Mosques are built to be daily occupied lively at different times, where mainly five prayers take place, at designated times. Contemporary mosques mainly have five architectural elements that distinguish its function, namely: prayers hall, dome, towers announcing call for prayers referred to

as minarets, a sanctuary for the lead prayer referred to as mihrab, and an ablution space for pre-prayer wash (Alnajadah, 2017). The functional and environmental aspects of mosques are performance elements that provide a well-maintained contemporary space of worship (Asfour, 2016). Operational conditions of thermal (Al-ajmi, 2010; Asfour, 2009; Mushtaha and Helmy, 2016), acoustical (Eldien and Al Qahtani, 2012; Ismail, 2013; Kavraz, 2014; Karaman and Güzel, 2017), and illumination (Hassan and Arab, 2013; Belakeha et al., 2016; El-Darwish and El-Gendy, 2016) performance elements in mosques, must be provided and maintained to serve a satisfactory performance for its users. It is necessary to optimize the worship space design and utilization for efficiency, achieving sustainability principles, within a social and cultural context of service that is required in mosques. These aspects are among the critical dimensions, which set responsibilities for designers, contractors, and facilities managers, simultaneously. Many mosques suffer from common building defects and design problems in various built-elements, systems and components (Mustafaraj and Yardim, 2013). For example, many mosques in Malaysia faced diverse forms of structural defects, service systems, fenestrations' components, circulation, finishes and walls (Johar et al., 2013; Alauddin et al., 2018). Thus, it is important to perform an effective and systematic management and monitoring procedures for evaluation of their assets and systems, for enhancing their overall conditions, as well as reducing required maintenance and renovation costs, caused by such defects (Mohd-noor et al., 2016). This requirement necessitates to develop a holistic approach for assessing the overall performance and condition of mosques. In fact, post occupancy evaluation is one of the useful methods that provides an overall perception of a building performance and its condition (Ali and Alfalah, 2010; Pereira et al., 2016). Post occupancy evaluation is defined as "the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time" (Preiser et al., 1988). Post occupancy evaluation can be conducted over three levels of effort; namely indicative, investigative and diagnostic (Preiser et al., 1988). The motivation for this research evolved from the following research questions, in the context of post occupancy evaluation of mosques, as a common built environment in Saudi Arabia:

- RQ1. How did the literature approach post occupancy evaluation of the built environment in the context of mosques?
 RQ2. What are the considerations and performance elements that derive satisfactory users' occupancy at mosques?
 RQ3. What are the systematic steps for indicatively assessing users' satisfaction in mosques?

In response to the research questions motivated by the researchers and the review of literature, this research aims to present an indicative post occupancy evaluation findings, by evaluating major performance elements of a built environment in a case study mosque facility, located in the Eastern Province of Saudi Arabia. This research expands the knowledge boundaries, about performance elements, in places of worship, specifically mosque facilities, and introduces a methodological assessment framework.

2. Research Methodology

The research is designed to conduct an indicative post occupancy evaluation, which comprised of the following activities, namely: a

literature review, an indicative walkthrough, interviews with users, collection of users' satisfaction surveys and data analyses.

2.1 Literature Review on the Performance Considerations and Elements

A literature review was performed on relevant sources, including previous studies, handbooks, and standards. This activity aimed at interpreting focal points of observations for carrying out an indicative walkthrough, while identifying major performance considerations and elements, in the context of mosque facilities. Several performance considerations and elements were identified under the following dimensions (Preiser et al., 1988):

- Technical elements: constitute environmental attributes, which are measurable, sensible, and physically tangible.
- The functional elements: constitute the elements affecting building activities and utilization by its users within its spaces.
- Behavioral elements: constitute the psychological and sociological well-being of occupants in response to design of buildings.

A set of 5 elements under each category except the behavioural where three elements were identified namely, technical (such as thermal comfort, fire safety, acoustical comfort, indoor air quality and visual comfort), functional (such as interior and exterior finishes, furniture quality, cleanliness, plumbing systems, and circulation efficiency) and behavioural (such as aesthetics and spirituality). On the other hand, A set of 14 technical, 16 functional and 4 behavioral performance considerations of mosques, relating to the identified performance elements, under each category were identified.

2.2 Selection of A Case Study Mosque

A large mosque located in the Eastern Province of Saudi Arabia, that was constructed in 2018 was selected as a case study facility for this research. The mosque has a gross area of 800 m² and a prayer hall of 20 prayer rows, that can accommodate up to 600 users. It has an ablution area, and toilets. Further, it provides a car parking and services for its users, including announcement screens, high quality finishes, furniture, decorations, a good utilization of daylighting and a closed-circuit television system.

2.3 Indicative Walkthrough

An indicative walkthrough inspection was implemented at the case study mosque during different weekdays, at deferring times (prayers and non-prayers). This activity aimed at forming a perception about the overall condition and performance, considering variations of activities, occasions and deferring occupation levels, throughout the weekdays. The walkthrough inspection contributed to identifying and documenting the main defects in the case study mosque. These defects were discussed and considered for the succeeding research activities.

2.4 Users' Interviews

In this activity, face-to-face interviews were conducted with a selected sample of five frequent worshippers at the case study

mosque. The activity aimed at exploring users' perception towards the overall condition and performance of the building. Moreover, the interviews aimed at investigating users' views about observed and documented building defects that were identified during the walkthrough, as well as their performance elements that were identified from the review of literature. The interviews were qualitatively used to formulate the users' satisfaction surveys.

2.5 Users' Satisfaction Survey

In this activity, a users' satisfaction survey was developed, pilot-studied, and then conducted on the permanent worshippers of the case study mosque facility. The pilot study aimed to ensure the readability and clarity of the questions asked in the surveys and the time sufficiency for collecting responses from the users, effectively. The results of the piloted surveys led to enhancement of the language and reduction of preliminary redundant questions within the surveys. This activity aimed at determining the level of users' satisfaction with the identified major mosques performance elements. The survey adopted a 4-point Likert scale, in which the respondents were asked to indicate their levels of satisfaction against each performance element by selecting among: "strongly satisfied", "satisfied", "dissatisfied" and "strongly dissatisfied". The four point Likert scale was preferred, to assure a determined negative or positive users' feedback on the performance elements; avoiding neutral opinions. In this study, 92 surveys were distributed to the permanent users of the case study facility, 35 reliable responses (which accounts for 38% response rate) were collected and analyzed. The selection of 35 users, as a representative sample size conforms to the central limit theorem, which mandates that surveys in social and practical research studies, would involve at least a minimal of 30 respondents to achieve a normal distribution of the processed data.

2.6 Data Analysis

The received data from the users' satisfaction survey was sorted and analyzed, so that the findings, discussion, and conclusions were derived accordingly. The weighted mean response (S_j) was calculated for all performance elements that were included in the users' satisfaction survey, to determine the rates of satisfaction. The following formula was used to calculate the weighted mean response (Hassanain and Iftikhar, 2015):

$$S_j = \frac{(\sum_{i=1}^4 w_{ij} n_i)}{(\sum_{i=1}^4 n_i)}$$

Where:

S_j is the weighted mean response.

n_i is the number of respondents who assessed the element j of performance in the survey.

w_i is the assigned corresponding weight to the satisfaction level ($i = 1, 2, 3$ or 4).

Each satisfaction level was given a corresponding weight (W_i), as follows: "strongly satisfied" = 4; "satisfied" = 3; "dissatisfied" = 2; and "strongly dissatisfied" = 1. In order to express the satisfaction

rate of each performance element, the following calibration was adopted to calculate a weighted mean for the responses:

- "strongly satisfied" = 3.50 – 4;
- "satisfied" = 2.50 – 3.49;
- "dissatisfied" = 1.50 – 2.49;
- and "strongly dissatisfied" = 0 - 1.49.

These weights are calibrated evenly, to avoid specific bias in users' feedback. The users were informed of the calibrated ranges ahead of their feedbacks and opinions. These ranges also reflect the four-point scale deterministic objective for selection as discussed.

2.7 Development of Recommendations

A set of recommendations were proposed for formulating a plan of action. This activity aimed at developing effective recommendations that have the potential to enhance the overall performance and condition of the case study facility. The recommendations were mainly stemmed from the findings and conclusions of the conducted post occupancy evaluation .

3. Previous Studies on Performance Considerations

The following studies were reviewed and synthesized from literature. The studies concluded that indoor environmental quality of mosques require effective maintenance up to appropriate levels of performance. Further, mosques need to have contemporary architectural elements without compromising its cultural identity and functional need, to serve as a mosque facility. The following considerations were identified:

3.1 Thermal Performance Considerations

Asfour (2009) studied the impacts of the architectural style on thermal comfort at mosque facilities. The study analyzed four different models of mosques that were different in terms of geometry and geographic location. An energy simulation software was used to investigate the thermal performance within the case study facilities, at two different cities from Europe and the Middle-East; Rome, Italy and Riyadh, Saudi Arabia. The study revealed that there is a direct impact of the architectural style on the thermal performance of mosques. Mushtaha and Helmy (2016) conducted an analytical examination to assess the impact of passive parameters, which are related to the thermal performance and indoor thermal comfort of mosques; in Sharjah, United Arab Emirates. The assessed passive parameters included thermal insulation, shading devices and natural ventilation. The study revealed that passive design strategies are not effective to enhance the thermal performance of mosques, alone. Moreover, it revealed that active strategies need to be considered for achieving a more efficient thermal performance.

3.2 Acoustical Performance Considerations

Eldien and Al-Qahtani (2012) studied the impacts of acoustical design considerations for mosques, as a place of worship, in Saudi Arabia. Measurements were conducted on typical contemporary mosques with different architectural styles. The study revealed that many design decisions, including form and space of mosques, had a direct bearing on acoustical performance. Accordingly, the study concluded that designers must take into account the acoustical aspects at the early design phase. Karaman and Güzel (2017) conducted a case study in a mosque at Manisa, Turkey, to investigate the acoustical properties in the main prayer hall of the case study facility. Measurements were conducted at different receptive locations, within its prayer hall. The research concluded that the case study facility has satisfied the recommended levels of acoustical performance, despite the challenges of optimizing acoustical requirements due to the mosque's architectural style.

3.3 Illumination Performance Considerations

Hassan and Arab (2012) analyzed illumination performance in two mosque facilities with a singular pendentive dome, one located in Turkey and other in Bosnia-Herzegovina, during summer solstice. The study revealed that the mosques had a high potential, to satisfy the recommended illumination performance levels and its indoor quality requirements. El-Darwish and El-Gendy (2016) studied daylight performance in six-historical mosques that were built in the 19th century, in Alexandria, Egypt. The study revealed that the case study mosques had a specific strategy for daylighting, utilizing fenestrations, as an autonomous medium for effectively enhancing access to daylight.

3.4 Architectural Elements as Functional Considerations

Asfour (2016) studied the architectural elements that need to be utilized in contemporary mosques. The study adopted a method that enabled the identification of historical design elements which contribute to the functional role of mosques. A critical observation of several- contemporary cases revealed that modern mosques need to align cultural-architectural aspects (including main prayer hall, minaret, courtyard, ablution, and female zone) and modern treatment elements (e.g. sound systems).

3.5 Durability Considerations

Johar et al. (2013) conducted a preliminary condition assessment survey and analysis of building defects, for traditional timber-built mosques in Malaysia. The study covered 52 traditional mosques, where common defects were identified at roofs due to dampness, and defects related to aesthetic elements. Further, the study found that the primary cause of defects was related to poor conduct of periodic maintenance. Alauddin et al. (2018) investigated critical defects of five heritage mosques located in Perak, Malaysia. The methodology adopted in the study was mainly based on field observations that were guided by a developed checklist. The checklist was based on a review of literature, on common defects at heritage facilities. There were four critical defects identified in the context of heritage mosque facilities, namely: cracks, peeled paint, fungus and missing broken parts.

4. Literature Review on The Performance Elements of Mosques

The literature review aimed to survey the relevant studies that were conducted on mosque facilities. The studies presented and described and led to identification of a set of major performance elements, as follows:

4.1 Technical Performance Elements

The technical performance elements are concerned with a fundamental aim for survival of users, such as: health, safety and security (Preiser et al., 1988). Based on the review of literature, five major categories, in the context of mosque facilities were identified, namely: “thermal comfort”, “acoustical comfort”, “visual comfort”, “indoor air quality”, and “fire safety”.

4.1.1 Thermal Comfort

It is defined as a mental condition that expresses individuals' subjective satisfaction with their surrounding thermal environment (ASHRAE 55, 2017). Several parameters need to be considered within the context of thermal comfort assessment, due to their direct impact on users' satisfaction with thermal environment (Hassanain, 2008). There are five major parameters affecting thermal comfort, namely air temperature, air humidity, air motion, clothing insulation and metabolism (Nicol and Roaf, 2005). At mosques, satisfying thermal comfort represents an environmental challenge, because of the diversity of users' characteristics, such as: age, clothing type, activity rate, place, ethnics, color and other considerations (Al-ajmi, 2010).

4.1.2 Acoustical Comfort

It is defined as the absence of unwanted sound and quality performance of acoustical propagation, that ensures clear hearing and privacy of individuals' activities and communication, without causes of acoustical abnormalities or nuisance (Rasmussen and Rindel, 2003). At mosques, acoustics are essential to be fulfilled within an appropriate level of performance (e.g. reverberation and propagation), due to the nature of individual and group formations for worships and rituals (Karaman and Güzel, 2017). Acoustics in mosques are characterized by placing an audible, intelligible, and spacious reach of sound recitations and speech (Eldien and Al Qahtani, 2012).

4.1.3 Visual Comfort

It is defined as the occupants' subjective well-being of visual conditions at a built-environment (BS EN 12665, 2018). Visual comfort is a fundamental human need that has potential to influence individuals' task performance, health, safety, mood and atmosphere satisfaction (IES, 2011). In general, visual comfort can be achieved by providing three main elements including the control over glare, adequacy of illumination levels (e.g. by use of natural and artificial light) which supports tasks performance, conduct of activities, and comprehending visible aesthetics (Giarma et al., 2017). Light in mosques is a principal element that influences spiritual symbolism and adds ambiently to the tranquility of mosques' interiors and exteriors. This is by ensuring

a functional adherence of individuals to sense the place of worship (Arel and Öner, 2017). Several active and passive strategies can be used to meet requirements of light performance aspects, in which daylighting techniques are considered as the most effective, and sustainable approach, that is adopted historically in mosques (El-Darwish and El-Gendy, 2016).

4.1.4 Indoor Air Quality

It is defined as air quality aspects that are ensuring health and comfort of building occupants (EPA, 2018). Indoor air quality is a major element that needs to be assessed and maintained, due to its direct influence on users' performance and productivity. In mosques, indoor air quality needs to be assessed in alignment to the wider context of indoor environmental quality, as a technical performance element (Al-ajmi et al., 2017).

4.1.5 Fire Safety

It is defined as a facility fire prevention and control measures, which sustain occupants' life, minimize property damages, and control against fire spread (IFC, 2018). This can be achieved by satisfying fire codes requirements, during the design process following a performance-based approach (Maluk et al., 2017). The assessment of fire safety levels in existing buildings is an essential task that must be carried out through following an inspection-based approach which assesses the compliance to fire safety requirements of all active and passive systems for the occupancy type of the building (Hassanain and Ashwal, 2004). In fact, mosques are considered as a highly occupied facilities that must provide an appropriate safety level for their occupants; to avoid risks of fire-hazard to lives (Alnabulsi and Drury, 2014).

4.2 Functional Performance Elements

The functional performance elements are concerned with enablement of conditions that ensure occupants' productivity and efficiency (Preiser et al., 1988). Based on the literature review, five major categories of the functional performance elements were identified for mosques, namely: "interior and exterior finishes' systems", "furniture quality", "efficiency of circulation", "plumbing system", and "cleanliness".

4.2.1 Interior and Exterior Finishes' Systems

Condition of finishing materials and building façade is among the elements that can affect users' satisfaction with their built-environment (Loftness et al., 2009). However, the deterioration of finishes, for different building elements is among the common defects that appear in existing buildings. Such defects occur due to different causes, related to design, workmanship, material, occupancy, and maintenance (Chong and Low, 2006). Finishes used in mosques are considered as one of the factors that has an impact on users' perception (Taib et al., 2016). One major element of contemporary mosques is the protection of cultural identity, in terms of style, and type of used construction materials. In addition, such materials need to be installed in a manner that is compatible with modern textures, colors, proportion, and form (Asfour, 2016). Mosque performance as a facility can be impacted by critical defects in interior and exterior

elements of finishes (Alauddin et al., 2018). Consequently, efficient maintenance and assessment of defects and materials used in mosques need to be carried out periodically (Mohd-noor et al., 2016).

4.2.2 Furniture Quality

Mosques are historically among the buildings that were internally furnished and decorated (Alnajadah, 2017). Poor furnishing selection causes users' discomfort (Parcells et al., 1999). They must provide a sufficient number of cabinets or shelves to store volumes of contextual books (Mokhtar, 2009). In addition, they must be furnished with suitable chairs, to ensure inclusiveness for the elderly and disabled users, who might not be able to perform worship activities easily (Daghistani, 2016). Moreover, the floors of mosques are usually covered by carpets, in which such carpets should be in an appropriate level of cleanliness and purification to satisfy the needs of worshippers and their activities.

4.2.3 Circulation Efficiency and Adequacy

Circulation is the physical movement of occupants or goods through a facility, either vertically (e.g. stairs and elevators) or horizontally (e.g. entrances, corridors, walkways and lobbies) (Preiser et al., 1988). The efficiency of building circulation is a crucial aspect that needs to meet users' behavior in terms of internal and external (Lee et al., 2010). Several spatial properties define the efficiency of the circulation routes in buildings, including travel distance, dimensions of the route, security and safety measures and relation with the net area of the building and its rooms (Lee, 2011). Thus, designers and facility managers must consider circulation efficiency through assessing spatial properties (Lee and Kim, 2014). At mosques, circulation efficiency is among the elements that have a vital role in satisfactory implementation of worshipping activities. This requires a spatial organization of the passageway and corridors in a manner that is integrated with the internal and external environments of the mosque. They must satisfy wayfinding by design, and layout of separated passageways (Mustafa and Hassan, 2013).

4.2.4 Plumbing Systems

Plumbing system includes water distribution, sewerage, treatment, equipment, and their appurtenances, in built facilities (IPC, 2018). At mosques, designers of plumbing systems must consider space technical requirements for ablution areas. Ablution areas accommodate a set of taps provided with platforms, used by worshippers to carry out ablution ritual prior to prayers. Such spaces must be designed and constructed in a manner that meets the requirements of location, accessibility, safety, privacy, density (number of ablution taps), dimensions, inclusiveness of the elderly and physically challenged needs, ventilation, quality of fittings and materials (Mokhtar, 2003).

4.2.5 Cleanliness

Cleanability of the building spaces is a performance criteria that needs to be met in all buildings (Preiser et al., 1988). Cleanliness of the building has a direct bearing on its image, as well as its compliance with the indoor environmental quality requirements. Additionally, the level of cleanliness is important for occupants, since it affects their comfort, satisfaction, and productivity (Khalil and Husin, 2009). Consequently, it is necessary to assess and maintain the overall cleanliness, as well as the level of cleaning service provided within the facility (Frontczak et al., 2012). At mosques, cleanliness and purification is traditionally a major attention. This implies that prayer halls, furniture, ablution areas and bathrooms need to be provided with an appropriate level of cleanliness and hygiene (Mokhtar, 2009).

4.3 Behavioral Elements of Performance

The behavioral performance elements are concerned with satisfactory social, psychological needs of occupants, such as: occupants’ density, privacy, and social interaction (Preiser et al., 1988). Based on the literature review, two major categories of behavioral elements were identified at mosques, namely “spirituality”, and “aesthetics”.

4.3.1 Spirituality

It is a major element in the religious life, and it is correlated with individuals’ religious expression. Social and environmental surroundings influence the spirituality of religious people. This implies that built-environment has an impact on spirituality. Since spirituality is an invisible dimension, architects and designers need to consider the integration of aesthetic religious influences (Barrie et al., 2016). At mosques, the same concept is applied, in which the masses (physical design elements) must satisfy the religious design needs of spirituality.

4.3.2 Aesthetics

At mosques, aesthetic elements have a direct bearing on the spiritual feelings of occupants (Asfour, 2016). Aesthetics as a performance element is concerned with provision of beauty and style, to different elements of the built-environment through environmental design and materials selection. It is influenced by philosophical, cultural, historical, and traditional aspects (Manning, 1991). Previous research indicated that the architectural aesthetics have direct impacts on morals and well-being of occupants (Grimm, 2010). In mosques, assessing aesthetic quality is critical, for addressing users’ satisfaction with the built facility, specifically in this context mosques as a place of worship.

Based on the reviewed literature, a gap on assessing mosques indicatively, as addressed by the research questions has been identified. The review of literature indicated the lack of holistic studies that cover the mosque facilities in its context, through identifying all performance considerations as in this research, while implying a systematic mean of evaluation. The reviewed studies covered partially specific, and scattered performance elements, rather than collectively.

Thus, this research aims to propose a methodological framework for the assessment of mosque facilities. The followed framework in this study is meant to be indicative, to measure the users’ satisfaction upon technical, functional, and behavioral performance elements. Additionally, the applied framework assists to identify the deficiencies in a case study facility as a built environment, to provide facility managers with a systematic method, that can be applied to measure the users’ satisfaction and recognize the deficiencies within the built environment. The framework consists of five main stages namely: identify the case study facility, conduct an indicative walkthrough, interview the permanent users, develop a satisfaction survey, and derive recommendations for the case study-built facility. The framework is illustrated in figure 1.

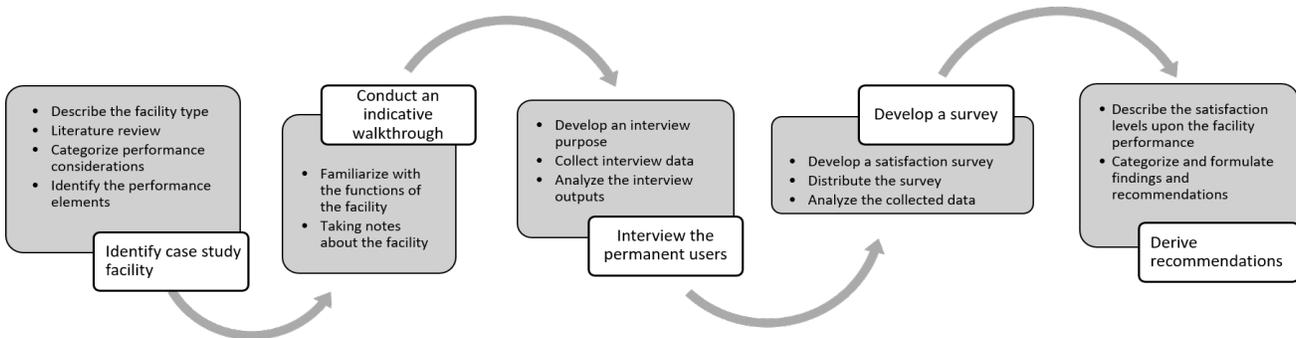


Figure 1. An Indicative post occupancy evaluation framework for built facilities

5. Findings and Discussion

The research is designed to conduct an indicative post occupancy evaluation. Accordingly, the mean rate of satisfaction for technical, functional, and behavioral elements of performance are

illustrated in Figures 2, Figure 3 and Figure 4. The findings are discussed as below:

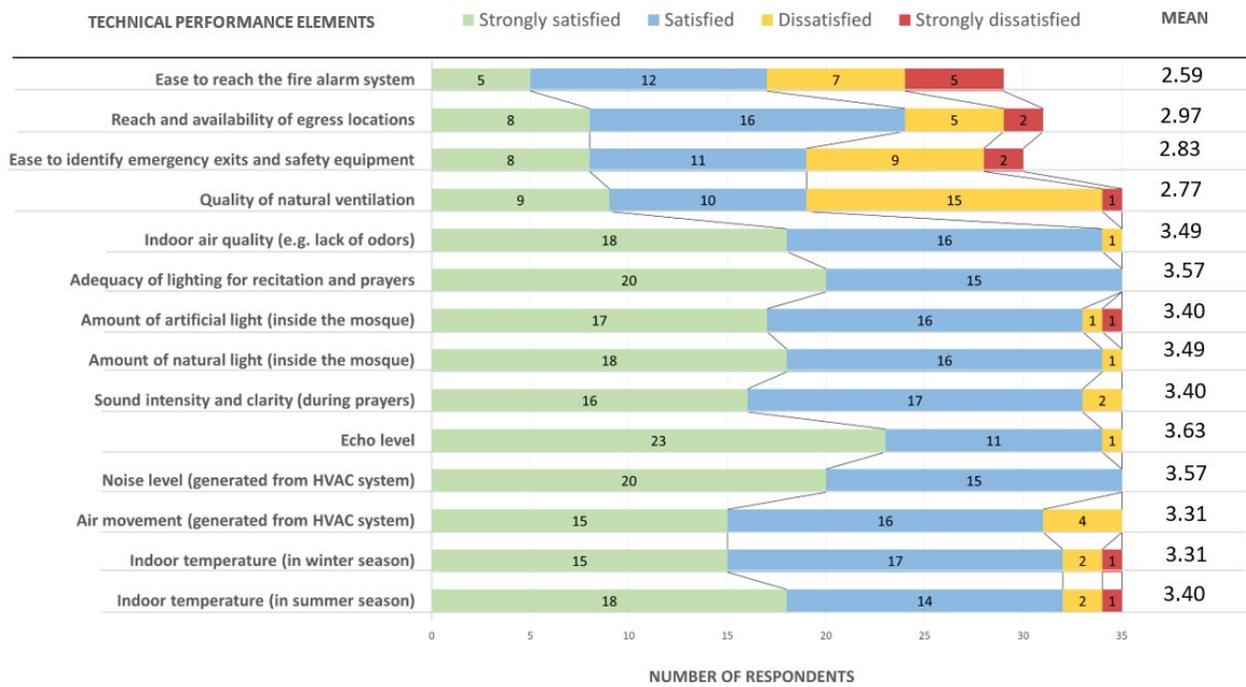


Figure 2 Technical performance considerations

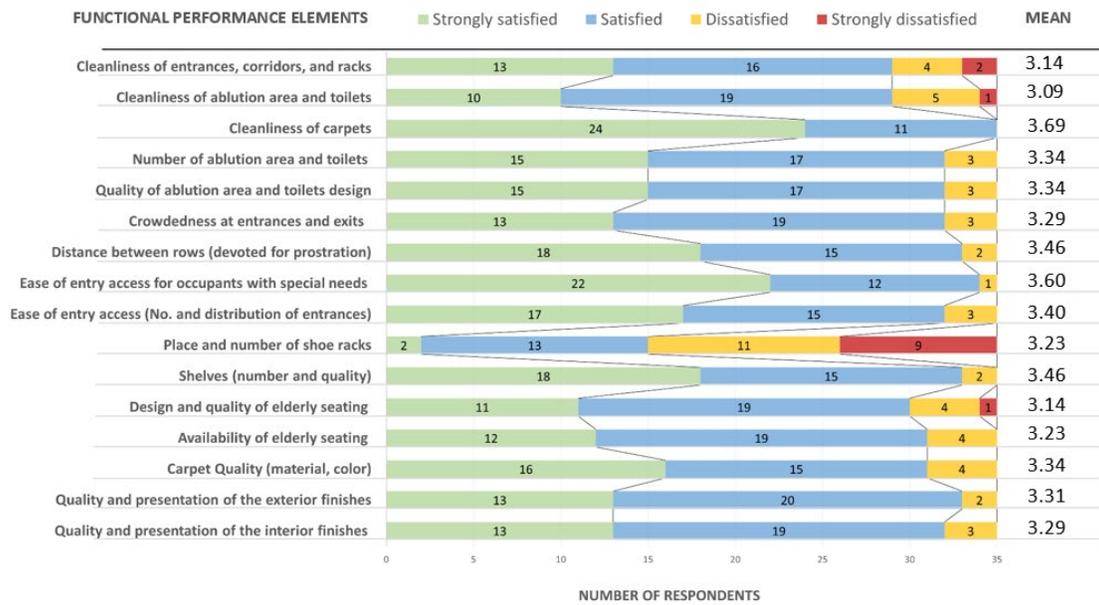


Figure 3 Functional performance considerations



Figure 4 Behavioral performance considerations

5.1 Technical Performance Elements

The mean rates of satisfaction are illustrated in figure 5, where:

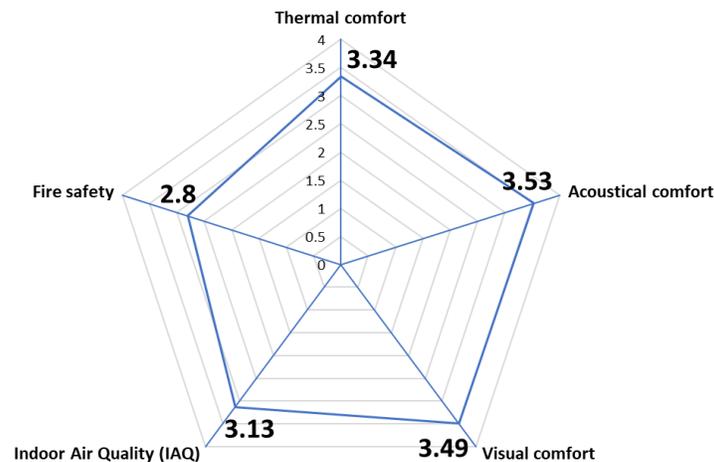


Figure 5 Mean satisfaction by categories - Technical elements

5.1.1 Thermal Comfort

The walkthrough inspection indicated that the modern central air conditioning system was provided for cooling interior spaces. air conditioning inlets and outlets were distributed symmetrically throughout the prayer hall, as well as the other interior spaces of services. However, the interviews with frequent occupants indicated that air conditioning control panels are accessible, where some occupants manipulate the operation settings randomly without any coordination with the building operator. This behavior led to a fluctuation in the occupants' thermal comfort during the non-hot periods of the year. As shown in Figure 2, the average satisfaction mean of the thermal elements of performance is 3.34, which reveals that the occupants were "satisfied" with the thermal conditions in the mosque.

5.1.2 Acoustical Comfort

The walkthrough inspection during the prayers and non-prayers times reported that there were no sensible sources of noise, neither internally (e.g. equipment and appliances) nor externally (e.g. traffic), since the case study mosque is located in a sufficient distance away from the main roads. Interviews with frequent occupants indicated that they feel comfortable with the acoustical quality and clarity to the digital speaker system. The results

revealed that the average satisfaction mean of the acoustical performance elements 3.53, which indicates that occupants were "strongly satisfied" with the acoustical environment in the mosque.

5.1.3 Visual Comfort

The walkthrough inspection indicated that daylighting was adequately provided during daytime, through windows and translucency of the dome. Further, sufficient artificial lighting was provided during the day through a symmetrical distribution of spot and hidden lights, across the ceiling. Interviews with frequent occupants indicated that they feel that the building illumination provides adequate light for recitation as well as conduct of religious rituals and activities. The average satisfaction mean of the visual performance element is 3.49, which indicates that worshippers were "satisfied" with the building illumination.

5.1.4 Indoor Air Quality

The walkthrough inspection indicated that the mosque was effectively ventilated by the air conditioning system. Further, there was no appearance of bad odors and dust in the internal air inside the mosque, as well as, in the other supporting spaces. However, it was noted that there was no consideration of the

passive ventilation techniques, where windows were not operable. Interviewed occupants mentioned that windows need to be controllable in order to allow for natural ventilation during the winter and spring seasons. The indoor air quality elements of performance received an average satisfaction mean of 3.13, which indicates that occupants were “satisfied” with the indoor air quality inside the mosque and its supporting spaces.

5.1.5 Fire Safety

The walkthrough inspection indicated that some of the fire safety systems and measures were provided in the mosque, namely: fire alarm system, smoke detectors and fire alarm system control panel. However, it was noted that exit signs, fire sprinklers,

extinguishers and emergency exits were not provided. Interviewed occupants mentioned that there is a lack of awareness about the fire safety measures among the permanent users of the mosque. Yet, elements of performance related to fire safety received an average satisfaction mean of 2.80, which indicates that users were barely “satisfied” with the safety condition of the mosque.

5.2 Functional Performance Elements

The mean rates of satisfaction are illustrated in figure 6, where:

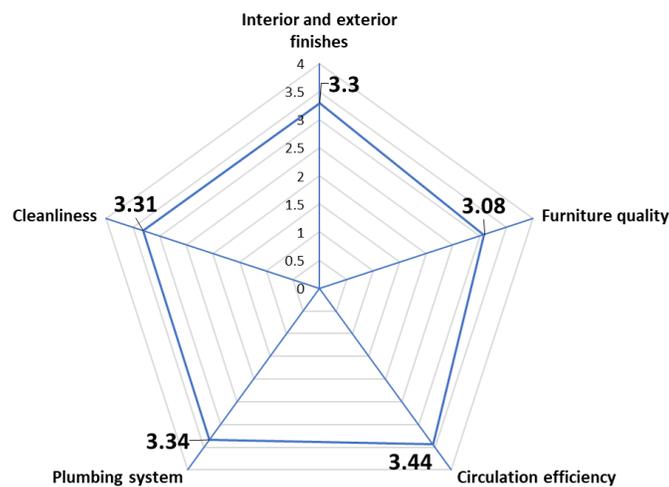


Figure 6 Mean satisfaction by categories - Functional elements

5.2.1 Interior and Exterior Finishes

The walkthrough inspection indicated that the case study mosque was constructed with luxurious selection of finishes for interior and exterior surfaces. Interviews with permanent occupants revealed that finishes and decorative elements seem to be consistent and satisfactory to the users. The results revealed that the average satisfaction mean of the performance elements related to building finishes is 3.3, which implies that occupants were “satisfied” with the quality of the mosque finishes.

5.2.2 Furniture Quality

The walkthrough inspection indicated that the provided furniture elements inside the mosque were adequately distributed and manufactured by high-quality materials. Interviews with permanent worshippers indicated that chairs and shelves of the mosque were sufficiently provided. However, they mentioned that they suffer from the shortage of the adequate number of shoe racks during the Friday prayer (for being the highest occupancy

time and day). However, the findings revealed that average mean response of the functional elements of performance related to furniture quality is 3.08, which indicates that worshippers were “satisfied” with the quality of the furniture of the mosque.

5.2.3 Circulation Efficiency

The walkthrough inspection indicated that there were sufficient number of avenues provided for circulation around and among the occupants’ rows of worship. Interviews with frequent occupants indicated that circulation means were clearly identified, through the usage of distinct flooring finishes, across the adopted avenues for occupants’ movement. The results revealed that the average satisfaction mean of the elements of performance related the circulation efficiency is 3.44, which implies that occupants were “satisfied” with the building circulation.

5.2.4 Plumbing System

The walkthrough inspection indicated that plumbing fixtures were adequately provided to occupants, since twelve water faucets for

ablution and eight toilets were offered and distributed in two separate spaces of service. Interviews with frequent users indicated that they feel comfortable with the number, distribution and quality of the plumbing services that were provided. Elements of performance related to the plumbing systems received an average satisfaction mean of 3.34, which indicates that users were “satisfied” with the provided ablution and toilets areas.

5.2.5 Cleanliness

The walkthrough inspection indicated that the mosque and its supporting facilities are operated and maintained in an appropriate level of cleanliness. Interviews with frequent occupants indicated

that there are at least two cleaning shifts, conducted every day throughout the mosque, in order to maintain a satisfactory level of hygiene and cleanliness for the users. The results of the occupants’ satisfaction survey indicated functional elements of performance, related to cleanliness received an average satisfaction mean of 3.31, which implies that the worshippers are “satisfied” with the achieved purity level at the mosque and its supporting facilities.

5.3 Behavioral Performance Elements

The mean rates of satisfaction are illustrated in figure 7, where:

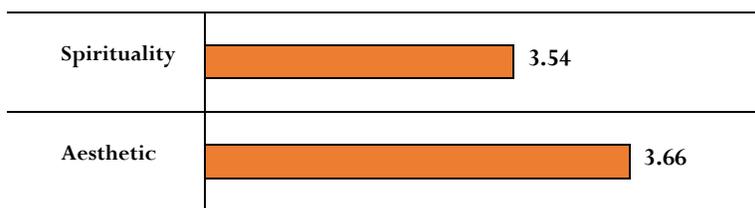


Figure 7. Mean satisfaction by categories - Behavioral elements

5.3.1 Spirituality

The walkthrough inspections that were conducted during prayer and non-prayer times indicated that the mosque’s design, character, and activities provide a religious environment towards spirituality. The interviewed frequent users mentioned that they feel spirituality during the prayer due to clarity, calmness and beauty of the lead prayer’s voice and tone during the prayers. The results of the survey indicated that behavioral elements of performance pertaining to spirituality received an average satisfaction mean of 3.54, which implies that users were “strongly satisfied” with the spiritual environment in the mosque.

5.3.2 Aesthetics

The walkthrough inspection indicated that the building finishes provide aesthetic elements that support a religious environment for prayers. Wall finishes, ceiling decorative elements and flooring patterns were designed and installed in a context that is in line with the religious culture. Interviews with frequent occupants revealed their acceptance and appreciation to the implemented innovative design of the aesthetic elements in the mosque. The behavioral elements of performance related to the indoor aesthetics received an average satisfaction mean of 3.66, which implies that worshippers were “strongly satisfied” with indoor aesthetics of the case study mosque.

6. Conclusions and Recommendations

In this research, an exemplary indicative post occupancy evaluation was conducted on a place of worship, for a mosque located in the Eastern province of Saudi Arabia. The research

comprised the conduct of a walkthrough across the case study building, in order to have an insight about the overall facility conditions and performance, as well as to document all apparent shortcomings and defects. A review of the relevant literature was performed to identify the technical, functional, and behavioral elements of mosques performance. Based on both activities, 34 major mosques performance considerations were identified and categorized into mainly three elements of performance, namely: technical, functional, and behavioral. Then, interviews were conducted with frequent occupants in order to get their feedback about the observed condition and shortcomings of the building, as well as to examine the adequacy of the identified elements of performance and their underlying considerations. Such interviews contributed to formulate interpretation about the observations obtained in the walkthrough inspection. The study then, conducted a users’ satisfaction survey based on a 4-points’ Likert scale, including the 34 identified performance considerations. The survey was utilized as a quantitative data collection and assessment tool. The survey was then launched, where 35 reliable responses (account for 38% response rate) of permanent users were adopted and processed for the data analysis and interpretation. Findings revealed that worshippers were strongly satisfied with the elements of performance related to “acoustical comfort”, “spirituality”, and “aesthetic”. It revealed also that worshippers were satisfied with the other elements of performance. Then the conducted post occupancy evaluation findings led to a set of recommendations, that are aimed to improve the mosque operational performance:

- Air conditioning control panels should not be accessible to all occupants in order to avoid the random adjustment of cooling controls.

- Windows should be replaced with operable type, in order to allow occupants to have natural ventilation during the winter and spring seasons of the year.
- Exit signs, fire sprinklers, extinguishers and emergency exits should adhere to the applicable building codes, in order to maintain an appropriate level of safety, that aims to protect users' lives, and assets.
- Adequate number of shoe racks should be provided to accommodate the maximum number of worshipers during Friday prayers.

This paper has a direct contribution to expanding the boundaries of knowledge about the performance elements at mosques, as well as providing methodological framework to assess such elements in a triangulated manner. The findings of this research will benefit regulators, designers, contractors, and facilities managers involved in mosques projects. The research has answered the questions introduced by investigating the relevant existing literature on the application of post occupancy evaluation as an approach to evaluate and assess users' satisfaction in the context of mosques, as a built environment. Additionally, the considerations and performance elements that derive satisfactory users' occupancy at mosques were identified and assessed. An indicative systematic framework and its underlying steps, for indicatively assessing users' satisfaction in mosques was introduced and applied. Future studies would focus on the application of data analyses could incorporate a digital mean of collection through the utilization of built environment sensors and systems, to monitor real-time feedback and provide a visually dashboard of users' satisfaction in link to the performance identified elements; this link alerts the facility managers with means to adjust the operation of the built facility and highlight recommendations for improving its qualities.

The aim of this study is to provide an exemplary means of conducting a systematic post occupancy evaluation in the context of mosque facilities, while grasping the reviewed literature by identifying critical performance elements and considerations permitting satisfactory occupation. The purpose of this study is to approach a case where the framework can be applied to present facility managers with knowledge that enable them to replicate and conduct an indicative post occupancy evaluation, not to comprehensively reflect a sample of mosques that evaluate the condition of mosques in Saudi Arabia.

The performance elements were firstly driven on the basis of the reviewed literature, then the survey questions developed were pilot tested to improve the identified considerations and elements of evaluation. The walkthrough and pilot tests are additions to the existing elements collected from the dispersed body of knowledge within this research context, to explicitly cover the post occupancy evaluation process of mosque facilities; comprehensively.

A future research direction could be linked to the application of the framework towards benchmarking several case studies of mosques either in a national or international coverage of context. Yet, the selected mosque facility is considered

sufficient in terms of occupying the contextual spaces addressed, serving behavioral, functional, and technical reflections of the reviewed performance elements of mosques; to holistically convey an exemplary case study.

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References

- Al-Ajmi, F. F. (2010). "Thermal comfort in air-conditioned mosques in the dry desert climate", *Building and Environment*, 45(11): 2407–2413.
- Al-Ajmi, F. F., Al-azmi, A. S., and Alrashidi, F. A. (2017). "Indoor environmental quality in air-conditioned mosque buildings in Kuwait", *American Journal of Civil Engineering and Architecture*, 5(4): 167–173.
- Alauddin, K., Ishak, M. F., Azim, M., and Wazir, M. A. M. (2018). "The critical defects of heritage mosque in Perak, Malaysia", *Proceedings of International Conference on Architecture 2017 (ICRP-AVAN), Unsyiah (Banda Aceh) and UiTM (Perak), October 18-19, 2017, Banda Aceh, Indonesia*.
- Alnabulsi, H., and Drury, J. (2014). "Social identification moderates the effect of crowd density on safety at the Hajj", *Proceedings of the National Academy of Sciences (PNAS)*, 111(25): 9091–9096.
- Alnajadah, A. S. (2017). "Islamic architecture and interiors: Challenges versus opportunities", *Journal of Researches in Science and Specific Arts*, 2(7): 6.
- Arel, H. S., and Öner, M. (2017). "Use of daylight in mosques: Meaning and practice in three different cases", *International Journal of Heritage Architecture*, 1(3): 421–429.
- Asfour, O. S. (2009). "Effect of mosque architectural style on its thermal performance", *The Islamic University Journal (Series of Natural Studies and Engineering)*, 17(2): 61–74.
- Asfour, O. S. (2016). "Bridging the gap between the Past and the Present: A Reconsideration of Mosque Architectural Elements", *Journal of Islamic Architecture*, 4(2): 77–85.
- ASHRAE 55. (2017). *Thermal Environmental Conditions for Human Occupancy*. Northeast Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
- Barrie, T., Bermudez, J., and Tabb, P. J. (2016). *Architecture, Culture, and Spirituality*. New York, USA: Routledge.
- BS EN 12665. (2018). *Light and lighting. Basic terms and criteria for specifying lighting requirements*. London: BSI.
- Chong, W.-K., and Low, S.-P. (2006). "Latent building defects: Causes and design strategies to prevent them", *Journal of Performance of Constructed Facilities*, 20(3): 213–221.
- Daghistani, F. (2016). "Conceptual design of congregational prayer chair", *Jordan Journal of Mechanical and Industrial Engineering*, 10(2): 133–140.

- El-Darwish, I. I., and El-Gendy, R. A. (2016). “The role of fenestration in promoting daylight performance: The mosques of Alexandria since the 19th century”, *Alexandria Engineering Journal*, 55(4): 3185–3193.
- Eldien, H. H., and Al Qahtani, H. (2012). The acoustical performance of mosques main prayer hall geometry in the eastern province, Saudi Arabia. In *Acoustics 2012*. 949–955. Retrieved from <https://hal.archives-ouvertes.fr/hal-00810652> Retrieved July 30, 2019
- EPA. (2018). Introduction to Indoor Air Quality. Retrieved July 30, 2019, from <https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality>
- Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., and Wargocki, P. (2012). “Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design”, *Indoor Air*, 22(2): 119–131.
- Giarma, C., Tsikaloudaki, K., and Aravantinos, D. (2017). “Daylighting and visual comfort in buildings’ environmental performance assessment tools: A critical review”, *Procedia Environmental Sciences*, 38: 522–529.
- Grimm, S. R. (2010). *Architecture and Spirituality: An Architecture-Genteteil Aesthetic Experience*. University of Hawai’i at Mañoa.
- Hassan, A. S., and Arab, Y. (2012). “Lighting analysis of single pendentive dome mosque design in Sarajevo and Istanbul during summer solstice”, *The Arab World Geographer*, 15(2): 163–179.
- Hassan, A. S., and Arab, Y. (2013). “Analysis of lighting performance between single dome and pyramid roof mosque in Mostar, Bosnia Herzegovina”, *Procedia Social and Behavioral Sciences*, 91: 1–12.
- Hassanain, M. A. (2008). “On the performance evaluation of sustainable student housing facilities”, *Journal of Facilities Management*, 6(3): 212–225.
- Hassanain, M. A., and Ashwal, N. Al. (2004). “An approach to assess fire safety requirements in library facilities”, *Facilities*, 23(5), 239–252.
- Hassanain, M. A., and Iftikhar, A. (2015). “Framework model for post-occupancy evaluation of school facilities”, *Structural Survey*, 33(4): 322–336.
- IES. (2011). *The Lighting Handbook*, 10th Ed., New York: Illuminating Engineering Society (IES).
- IFC. (2018). *International Fire Code*. New Jersey, USA: International Code Council.
- IPC. (2018). *International Plumbing Code*. Country Club Hills: International Code Council.
- Ismail, M. R. (2013). “A parametric investigation of the acoustical performance of contemporary mosques”, *Frontiers of Architectural Research*, 2(1): 30–41.
- Johar, S., Che-Ani, A. I., Tawil, N. M., Surat, M., and Kamaruzzaman, S. N. (2013). “Preliminary survey and defects analysis of traditional timber mosques in Malaysia”, *WSEAS Transactions on Environment and Development*, 9(1): 119–129.
- Karaman, Ö. Y., and Güzel, N. O. (2017). “Acoustical Properties of Contemporary Mosques: Case Study of “Bedirye Tiryaki Mencik Mosque”, Manisa”, *YBL Journal of Built Environment*, 5(1): 14–30.
- Kavraz, M. (2014). “The acoustic characteristics of the Çarşı Mosque in Trabzon, Turkey”, *Indoor and Built Environment*, 25(1): 128–136.
- Khalil, N., and Husin, H. N. (2009). “Post occupancy evaluation towards indoor environment improvement in Malaysia’s office buildings”, *Journal of Sustainable Development*, 2(1): 186–191.
- Lee, J. K. (2011). *Building Environment Rule and Analysis (BERA) Language And its Application for Evaluating Building Circulation and Spatial Program*. Georgia Institute of Technology.
- Lee, J. K., and Kim, M. J. (2014). “BIM-enabled conceptual modelling and representation of building circulation”, *International Journal of Advanced Robotic Systems*, 11(8): 127.
- Lee, J. K., Eastman, C. M., Lee, J. M., Kannala, M., and Jeong, Y. (2010). “Computing walking distances within buildings using the universal circulation network”, *Environment and Planning B: Planning and Design*, 37(4): 628–645.
- Loftness, V., Aziz, A., Choi, J., Kampschroer, K., Powell, K., Atkinson, M., and Heerwagen, J. (2009). “The value of post-occupancy evaluation for building occupants and facility managers”, *Intelligent Buildings International*, 1(4): 249–268.
- Maluk, C., Woodrow, M., and Torero, J. L. (2017). “The potential of integrating fire safety in modern building design”, *Fire Safety Journal*, 88: 104–112.
- Manning, P. (1991). Environmental aesthetic design: Identifying and achieving desired environmental effects, particularly “image” and “atmosphere.” *Building and Environment*, 26(4): 331–340.
- Mokhtar, A. (2003). “Challenges of designing ablution spaces in mosques”, *Journal of Architectural Engineering*, 9(2): 55–61.
- Mokhtar, A. (2009). “Design standards for Muslim prayer facilities within public buildings”, *Proceedings of the Annual Research Conference of the Architectural Research Centers Consortium (ARCC): Leadership in Architectural Research, Between Academia and the Profession* 163–169. San Antonio, Texas, USA: Architectural Research Centers Consortium (ARCC).
- Mushtaha, E., and Helmy, O. (2016). Impact of building forms on thermal performance and thermal comfort conditions in religious buildings in hot climates: a case study in Sharjah city. *International Journal of Sustainable Energy*, 36(10): 926–944.
- Mustafa, F. A., and Hassan, A. S. (2013). “Mosque layout design: An analytical study of mosque layouts in the early Ottoman period”, *Frontiers of Architectural Research*, 2(4): 445–456.
- Mustafaraj, E., and Yardim, Y. (2013). Repair and strengthening of historical structures: Naziresha’s Mosque in Elbasan. In *3rd Annual International Conference on Civil Engineering*.
- Neufert, E., and Neufert, P. (2012). *Neufert’s Architects’ Data* (4th ed.). Chichester, West Sussex, UK: Wiley-Blackwell.
- Nicol, F., and Roaf, S. (2005). Post-occupancy evaluation and field studies of thermal comfort. *Building Research & Information*, 33(4): 338–346.
- Parcells, C., Stommel, M., and Hubbard, R. P. (1999). “Mismatch of

classroom furniture and student body dimensions: Empirical findings and health implications”, *Journal of Adolescent Health*, 24(4): 265–273.

Pereira, N. B., Rodrigues, R. C., and Rocha, P. F. (2016). “Post-occupancy evaluation data support for planning and management of building maintenance plans”, *Buildings*, 6(4): 45.

Preiser, W. F. E., Rabinowitz, H. Z., and White, E. (1988). *Post Occupancy Evaluation*. New York: Van Nostrand Reinhold.

Rasmussen, B., and Rindel, J. H. (2003). “Sound insulation of

dwelling - Legal requirements in Europe and subjective evaluation of acoustical comfort”, *Proceedings of the DAGA 2003 Deutsche Gesellschaft für Akustik*, Aachen, 118–121.

Taib, M. Z. M., Ismail, Z., Ahmad, S., and Rasdi, T. (2016). Mosque development in Malaysia: Is it the product of evolution and social behaviour? *Environment-Behaviour Proceedings Journal*, 1(1): 36–43.