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# UNDERSTANDING OF KEY BUILDING PERFORMANCE CRITERIA FOR CONTEMPORARY MOSQUE FACILITIES

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**Abstract:**

Mosque facilities that fail to perform either physically, environmentally, or functionally can cause harm, discomfort, and dissatisfaction to users and eventually demotivate the community to the mosque. This scenario demonstrates the need to improve mosque facilities to meet the contemporary needs of the community. The purpose of this study is to document key building performance criteria for contemporary mosque facilities which will be used to guide the development of its classification in a future study. Literature review search through Web Of Science from 1997 to 2020 was conducted using the terms "mosque building performance criteria", "mosque facility performance criteria", "building performance criteria", and "facility performance criteria". By applying the "Literature Review Synthesis Process", the authors conducted cross-analysis, synthesis, and categorization into meaningful themes that represent building performance criteria for mosque facilities. The result of the review highlighted three (3) building performance criteria for contemporary mosque facilities; physical, environmental, and functional. Results are expected to develop a future framework of building performance criteria for mosque facilities that supports the fundamental functions of mosque for the contemporary community needs. It will significantly guide architects and facilities managers to develop community-centric facilities guidelines in the field of architecture and facilities management.

**Keywords:**

Building Performance Criteria, Physical Performance, Environmental Performance, Functional Performance, Mosque Facilities

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## Introduction

The success of mosque institution relies on the quality and quantity of its congregants. Studies substantiated various contributory factors to the decline in mosque attendance, such as political (Tezcur et. al, 2006), secularization (Maliepaard et al, 2012), and sickness absenteeism (Hays et. Al, 2011). However, there is evidence that this phenomenon can be revived by providing good facility management practice. Previously, Maliepaard et al (2012) reported a decline in mosque attendance due to secularization among Muslim Turkish and Moroccan descends in the Netherlands. However, their later study reported otherwise, where an increase in the number of mosque attendance was evident among second-generation Muslim minorities. The change of scenario demonstrated community needs on mosque function, which renders the needs for facilities to perform according to the needs of contemporary mosque community.

Mosque or 'masjid' in Arabic, is a place of worship in Islam whose primary function for conducting congregational prayer and may be located anywhere on earth (Shalih al-Fauzan, 2011). However, another important function of mosque is to serve its community through various social programs. Consequently, mosque functions can be distinguished into two (2) programs; religious and secular (Es, 2016). In this study, these programs will be addressed as a spiritual and non-spiritual function of mosque as displayed in Figure 1. The spiritual function of a mosque comprises religious activities and events such as congregational prayer, Quran recitation, and religious lecture. On the other hand, the non-spiritual function of the mosque involved educational, social, cultural, political, economic, commercial, and recreational activities.

Facility is defined as physical setting such as building, space, component, equipment, system, other construction or infrastructure, and others; as well as its use or function (ISO 15686-10:2011). Therefore, mosque facilities can be described as building, space, component, equipment, system, and related infrastructure that facilitate various use and function of the mosque. This review identified three (3) basic categories of mosque facilities: (1) spiritual facilities, (2) non-spiritual facilities, and (3) community amenities. The first two categories relate to the mosque building and its components. The last category refers to public infrastructure that facilitates community to the mosque; as illustrated in Figure 2.

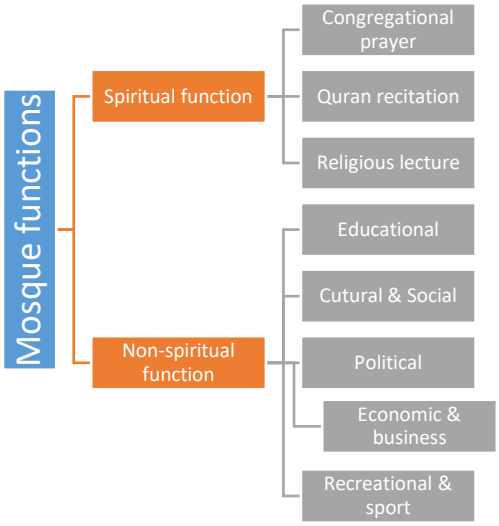


**Figure 1: Two Core Functions of Mosque and Example Program**

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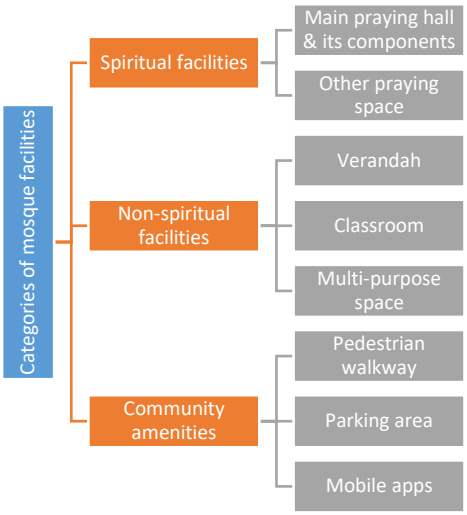


**Figure 2: Categories of Mosque Facilities and Some Examples**

## Method

This review paper is a part of a research project on developing a framework of building performance criteria for contemporary mosque facilities. The authors utilize the unique "Literature Review Synthesis Process" (Ibrahim and Mustafa Kamal, 2018) for developing raw writing materials for a text manuscript based on identified indexed journal articles on selected topics under Building Performance Criteria. Topics were identified using Ibrahim's research question's construct (RQC) categorization technique (Ibrahim, 2008, 2011) for identifying three different RQ constructs – "WHO", "WHAT" and "HOW" - in formulating the main research question. Ibrahim (2008,2011) defines "WHO" construct as the element used or impacted by the research, "WHAT" construct as the information required to solve a research question, and "HOW" construct as the action or impact on the element or information of the research. The review examined building performance criteria in mosque and other types of building and described how the criteria impacted users in terms of safety, comfort, and efficiency.

Articles identification was conducted using Web Of Science using the terms "mosque building performance criteria", "mosque facility performance criteria", "building performance criteria" and "facility performance criteria", for indexed journal articles from 1997 to 2020 with a focus on the fundamental function of mosque for contemporary community needs. A separate search returned a total of 150 articles. Articles were screened and subsequently selected for their relevance to building performance criteria that meet the fundamental function of mosque for contemporary community needs. A total of 75 papers were initially selected according to their direct relevance to the topic. These articles were further reviewed according to relevance to the three themes. Finally, the review ended with 49 articles; 24 related to physical criteria, 16 under environmental criteria, and 9 under functional criteria.

The results are categorized into (1) physical performance criteria, (2) environmental performance criteria, and (3) functional performance criteria; with building performance criteria as the main construct. For each theme, major Works by previous scholars and how their works could support future studies are presented. The paper subsequently discusses the cross-analysis, integrates possibilities, and prioritizes the synthesized information gearing towards high probable solutions that could improve the management of mosque facilities with Building

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Performance Criteria. This paper concludes with a discussion on potential integrated solutions for future development of a theoretical framework for supporting building performance criteria for mosque that meets the fundamental function of mosque for contemporary community needs.

## Building Performance Criteria

### *Physical Performance Criteria Of Mosque*

The review identified two (2) criteria for physical performance of mosque facilities; structural and non-structural performance. Further description of the elements under structural and non-structural performance will be elaborated in the following sections.

### *Structural Performance*

Structural performance relates to the physical capability of structural members in mosque complex; such as foundation, ground beam, beam, column, and roof structure. This includes the minaret, which is a tower for announcing 'Adzan' and provides a landmark for the mosque. Due to its tall and slim physical structure, the minaret is susceptible to damage due to natural disasters such as earthquakes and strong wind. This section distinguished structural performance of physical mosque into three (3) main categories; seismic performance, material engineering properties, and wind loading.

For the past two decades, various studies were conducted on the seismic performance of historical mosque (Dogangun, A.,Sezen & H., 2012; Oliveira et al., 2012; Ural & A., 2013; Muvafik & M, 2014 and Erdil et al., 2018; Altunışık et al., 2016; Altunışık, C., Genç & F., 2017 and Altunişik et al., 2019). These structures were built either in masonry or timber, more than a century ago, and are located strategically in the volcanic ring of fire. This review identified three (3) areas of interest regarding seismic performance; seismic behavior of mosque structure due to the effect of an earthquake, restoration of mosque structure damaged by earthquake, and retrofit technology and material for earthquake resistant mosque structure.

Majority of studies on seismic behavior of mosque structure under earthquake loading focused on masonry minaret of historical mosques located in Turkey (Dogangun, A., Sezen & H., 2012; Oliveira et al., 2012; Ural & A., 2013; Muvafik & M, 2014 and Erdil et al., 2018). The purpose of this research is to enhance the structural integrity and safety of masonry minaret structure. However, these studies only focused on the seismic performance of the minaret structure and disregarded other mosque facilities which have the potential to attract the community to the mosque. Therefore, based on Dogangun et al., (2012), Oliveira et al., (2012) Ural & A. (2013), Muvafik & M (2014), and Erdil et al., (2018), this study will focus on improving the seismic performance of mosque structure as well as other performance criteria that can facilitate the needs of users and community on mosque function.

Recent studies focused on seismic performance evaluation of restored mosque structure damaged by earthquake using case study historical mosque in Turkey (Altunışık et al., 2016; Altunışık, C., Genç & F., 2017 and Altunişik et al., 2019). However, these studies only focused on improving the structural performance of old mosque buildings damaged by earthquakes. Therefore based on Altunışık et al., (2016), Altunışık et al., (2017) and Altunişik et al., (2019), this research will focus on improving the seismic performance of restored mosque to provide safety mosque structure and attract visitors to the mosque.

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Effective structural engineering technology and materials such as seismic isolation retrofit and shape memory alloy wires can help to improve the seismic performance of old mosque structure (Artar et al., 2019; Aşıkoğlu et al., 2019 and Hamdaoui et al., 2019). However, these studies only focused on improving the seismic performance of mosque structure through seismic isolation retrofitting procedure. Therefore based on Artar et al., (2019) and Aşıkoğlu et al., (2019), this research will focus on improving mosque structure to withstand seismic force through seismic isolation retrofit to provide safe structural performance of mosque that will attract the community to the mosque.

Some historical mosques were built in masonry which possessed good material engineering capability, as demonstrated by historical masonry mosques in Turkey (Seker et al., 2014; Hacıefendioğlu, K., Maraş & E., 2016 and Selim et al., 2019. This study highlighted that good physical, mechanical, durability, and hygrothermal properties of masonry mosque structure can improve the physical and structural performance of mosque. However, improving the integrity in material engineering properties of mosque structure is not enough for attracting community to the mosque. Therefore based on Seker et al., (2014), Hacıefendioğlu et al., (2016), and Selim et al., (2019), my study will focus on providing good material engineering properties to ensure safety mosque structure as well as upgrading other mosque facilities that can make the mosque attractive to the community.

Another significant consideration for improving mosque structural performance is wind load (Ural, A., Firat & K., 2015). However, wind load consideration is not enough for facilitating the needs of contemporary mosque community. Therefore, based on Ural et al. (2015), this study will consider wind load and meteorological factors for improving mosque structure as well as other building performance criteria that can help for making the mosque a centre of attraction for the community.

***Non-Structural Performance***

The non-structural components of mosque comprised of façade and interior space. This review identified two (2) non-structural performance criteria for mosque; aesthetics and predictive maintenance.

**The aesthetic performance of mosque physical relates to the designed architectural style found on mosque façade and other components (R**ossi et al., 2015**).** However, **aesthetic performance is insufficient for attracting** community to the mosque. Therefore, this study will focus on enhancing the aesthetic elements of mosque façade and interior that can make the mosque visually attractive and pleasing to the community.

Another important criterion for improving physical performance of mosque is preventive maintenance (Flores-Colen et al., 2010). However, relying on preventive maintenance on façade and interior is not enough for improving mosque facilities if the environmental and functional aspects of mosque are still lacking. Therefore based on Flores-Colen et al., (2010), this study will focus on implementing predictive maintenance on mosque façades and interior to improve the physical and aesthetical performance of mosque that will attract community to the mosque.

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***Environmental Performance Of Mosque***

The review identified four (4) criteria under environmental performance of mosque facilities; thermal comfort, air quality, acoustic comfort, and lighting quality (refer to Figure 2). Further description of these performance criteria will be elaborated in the following sections.

***Thermal Comfort***

Thermal comfort is described as the state of mind of building occupant that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55-2017). Thermal comfort in building can be maintained using three (3) ventilation schemes; natural ventilation, mechanical ventilation, and mix-mode systems. Mosque building consists of a large praying hall used at intermittent time according to the five daily prayers. This review will discuss and analyse issues on thermal comfort in mosque in light of the three (3) ventilation systems.

Natural ventilation provides passive cooling effects in mosque building through openable fenestration system (Faghih, K., Bahadori & N., 2010), glazed finish of domed roof (Faghih, K., Bahadori & N., 2011), and underground passive cooling structure known as windcatcher or "Shavadan" (Sadoughi et al., 2019). However, natural ventilation and passive cooling system alone may be insufficient to maintain thermal comfort in mosque located in hot-humid and hot-dry climate. Therefore, based on Faghih et al., (2010), Faghih et al. (2011), and Sadoughi et al., (2019), this study will focus on identifying criteria that can provide ideal thermal comfort and environmental performance for mosque users that will attract the local community to the mosque.

Urban heat island and global warming phenomenon causing increased in indoor air temperature. Consequently, natural ventilation system is insufficient to maintain optimum thermal comfort in mosque. Therefore, active heating and cooling system or HVAC (heating, ventilating, air conditioning) system become necessary in many mosque particularly located in hot-humid and hot-dry climatic zone. Mechanical fan dan exhaust fan is the most basic mechanical ventilation system for increasing thermal comfort in mosque. A simulation study by Kamar et al., (2019) reckoned installing multiple exhaust fans on the south wall of the main praying hall can improve indoor thermal comfort. Even though this option is economical, these systems do emit unwanted noise which contradicts the tranquil atmosphere of the main praying hall. Therefore based on Kamar et al. (2019), this study recommends an efficient and quiet mechanical ventilation system that will increase thermal comfort indices and thus result in enhanced thermal comfort in mosque.

However, mechanical fan and exhaust fan cannot cope to maintain optimum thermal comfort in mosque located in hot-humid and hot-dry climates. Consequently, air-condition system need to be installed. The success of the air-conditioning system in delivering optimum thermal comfort depends on four (4) contributory factors; envelope thermal design (Al-Homoud & S., 2009), HVAC operational strategies (Budaiwi, I., Abdou & A., 2013), automated HVAC control system with occupancy recognition (Aftab et al., 2017), and design of the air distribution scheme (Samiuddin, S., Budaiwi & M., 2018). Nevertheless, these authors only focused on the design, operation, and performance of air-conditioning in mosque, and therefore the findings lack emphasise on building performance criteria can that contribute to improving mosque facilities that is much needed by the community. Therefore, based on Homoud & S., (2009), Budaiwi, I., Abdou & A., (2013), Aftab et al., (2017), and Samiuddin, S., Budaiwi &

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M., (2018) this study will focus on improving the service of air-conditioning system in mosque that can attract community to join mosque activities.

A recent study highlighted the use of mixed-mode or hybrid ventilation systems in mosque (Yüksel et. Al, 2020). This system requires the combination of intelligent building façade with strategic operation of air-conditioning system for achieving optimum thermal comfort and at the same time, saving energy cost. Some examples of mixed-mode strategies are; controlled opening of windows to improve air quality but prevent indoor relative humidity, controlled use of fan for reducing air pollution but preventing users' discomfort caused by peak airspeed; and turning on the air-conditioning system only for pre-cooling the mosque (Yüksel et. Al, 2020). The review revealed that this is probably the best system to achieve optimum thermal comfort in mosque that will attract community to the mosque.

***Indoor Air Quality***

The indoor air quality (IAQ) in mosque space refers to the quality of air against the health and safety of occupants from contamination of gases, particles, microbial, and pollutants. Among common contaminations found in mosque interior are Carbon Dioxide ($CO_2$ ) (Yüksel et. Al, 2020), atmospheric particulate matter (APM) (Ali Shah et. Al, 2019), excessive temperature, and wind speed (Munir et. al, 2013). However, these authors only addressed pollutants to the indoor air quality in mosque and did not focus on physical and functional aspects of mosque that are needed by mosque community. Therefore, this study will focus on environmental, physical, and functional performance criteria in mosque that are needed by the contemporary mosque community.

***Acoustic Comfort***

The traditional mosque was designed with passive architectural acoustic features such as molded wall and ceiling for enhancing space acoustic quality (Suárez et al., 2004); as advocated by architect Mimar Sinan in the design of Ottoman mosques in Turkey. At the turn of the 20$^{th}$ century, mosque was equipped with active acoustic system or sound system, such as microphone, amplifier, and sound speaker (Gül, S., Çalışkan & M., 2013). Modern mosques are usually designed with passive and active acoustic system as well as AV technology such as digital board. Historical and heritage mosque designed with architectural acoustic but undergone adaptive reuse such as Cordoba Cathedral Mosque, will require improvement on the existing acoustic quality (Suárez et al., 2004). This is because acoustic performance is critical particularly for the main praying space (Gül et al., 2013). Furthermore, the acoustic performance in many modern mosque must be supported with effective visual performance technology such as digital board. Therefore, based on Suárez et al., (2004) and Gül et al., (2013), this study will focus on identifying criteria for acoustic, audio, and visual quality that can improve the environmental performance in mosque to attract community to the mosque.

***Lighting Quality***

Mosques receive lighting from daylight and artificial light sourced from various types of fenestration and lamp. Generally, the lighting system in mosque is used for carrying out various spiritual and non-spiritual tasks such as prayer, Quran recitation, religious lecture, social gathering, and recreational activity. The review identified that a combination of lighting systems in mosque can benefit users by providing an environment with hygienic (Darula et al., 2009) and spiritual human comfort (El-Darwish, I., El-Gendy & A., 2016). In lieu of this, lighting system can also create historical and aesthetic ambiance in mosque that is sustainable

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by fitting energy-efficient lamps such as LED into historical lantern or chandelier (Atılgan et al.,,2017).

However, the review reveals the contribution of artificial lighting on improving lighting, health, and energy performance (Atılgan et al., 2017; Darula et al., 2009 and Harmathy et al.,2016); and daylighting performance (El-Darwish et al., 2016). Therefore based on Darula et al., (2009), El-Darwish et al., (2016), Harmathy et al., (2016), and Atılgan et al., (2017), this study will focus on identifying criteria in lighting quality that can improve the environmental performance in mosque that will attract community to the mosque.

***Functional Performance Of Mosque***

A Survey of the literature identified three (3) dominant components that drive the functional performance of mosque: spatial criteria, circulation, and technology.

***Spatial Function***

The space functions in mosque can be divided into two distinct programs; spiritual or religious and non-spiritual or secular (Es & M., 2016). The spiritual program represents daily religious activities in mosque such as congregation prayer, religious lecture, Quranic learning and recitation, fasting, and celebration of Islamic festivals (Es & M., 2016). While the non-spiritual activity represents laid-back programs that fulfill social, cultural, intellectual, and economic needs of Muslim society.

This study supports the combination of both spiritual and non-spiritual activities to be carried out in mosque space. This is due to the concept of mosque as a community centre that constitutes mosque fulfilling the needs of all members of society; from young to old and for Muslims and non-Muslims. The review revealed characters on the spatial function of mosque in three (3) dominated criteria: multi-purpose activity, gendered friendly, and ethnic friendly spaces.

The function of mosque extends beyond a house of worship. It also operates as community centre for Muslims in Western countries (Mueller & D., 2017). Multi-purpose space criteria will allow mosque to house events such as artistic sonic gathering, social mobilization activities and deliver religious instruction that complies with cultural and society's norms (Marsden & M.,2007 and Mueller & D., 2017).

All the above studies demonstrated that various activities can be conducted in the spaces of mosque; such as i.e. Islamic lecture, health supplemental immunization program, and religious instruction.

At this juncture and based on findings by Marsden & M. (2007), Weiss et al., (2013), and Mueller & D. (2017), the functions of mosque space which caters for spiritual and programs will attract more users of a variety of intent. Therefore, this study will focus on exploring criteria in space and functional performance of mosque that satisfy the contemporary needs of all members of the local community.

Islam guides the Muslim community on the practice of gender segregation in their daily social settings including in the mosque. There are many instances where the practice of gender segregation in mosque space is implemented. This involved clear division between male and

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female praying areas; which is translated differently in different countries based on local custom (or urf) and norm.

The review indicated that the function of mosque as a community centre requires spaces to be gendered friendly in addressing the needs of men and female users of various ages. Traditional mosque space particularly the main praying area has successfully fulfilled the needs of male users. However, the needs of female users are often neglected as evident in the study by Prickett & J. (2015) who conducted five-year ethnographic fieldwork research on negotiating gendered religious space.

In view of attracting women to the mosque, future mosque design should consider welcoming space that is against prejudice towards women of any age group. Therefore, based on Prickett & J. (2015) this study will focus on identifying criteria that will improve the functional and space performance of mosque to transform mosque into a functional community centre that is needed by the community.

The 21$^{st}$-century witness growth in Muslim population in Western and Eastern countries due to Muslim diaspora and conversion to Islam. It is estimated that over 1/5 of the world's Muslim population today lives in Europe, North America, and Australia. This is based on a statistical report on the estimated number of Muslims who reside in Europe is at 44,138,000 while in the USA at 5,256,000 (Social Science University of Ankara,2018). The sudden increase of various ethnic Muslim migrants posted social and racial issues to the local population of host countries, particularly Western countries in Europe, the USA, and Australasia. This is evident with the increase of Islamophobia and xenophobia incidents as well as White supremacy violence against Muslim ethnic minorities post-September 11 attacks. The social and racial issues towards ethnic Muslim migrants and reverts may also exist among the local community in mosque space.

Es & M. (2016) studied Turkish–Dutch mosques and the formation of moral subjects. His study explores how mosque spaces have become a daily site for ethnic Turkish-Muslim community from both immigrants and Netherlands citizens of Turkish descent. However, Es & M. (2016) only focused on mosque space and its impact on social performance and therefore the findings lack emphasise on the structure, fabric, and services system of the mosque which contributes towards physical performance and environmental performance in mosque.

In view of attracting citizen and non-citizen Muslims to the mosque, future mosque design should consider welcoming space that is against prejudice towards Muslim converts and non-citizens of other ethnicities. Mosque space that is ethnic friendly supported by welcoming mosque staff has the potential to attract new Muslims and non-citizens to the mosque as exemplified by the Grand Mosque in Mecca and the Prophet Mosque in Medina. Therefore based on Es & M. (2016) my study will focus on criteria for making mosque spaces to be ethnic friendly and meet the needs of the local and foreign Muslim community.

***Circulation***

The function of circulation in mosque is to ensure safe and comfortable ingress and egress of pedestrians and vehicles particularly during peak events such as Friday and Eid prayer. Specifically, the role of pedestrian circulation in mosque complex is to provide a link between spiritual space (i.e.: praying area and ablution) with non-spiritual space (i.e.: verandah, lecture

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room, multi-purpose room, toilet, ablution area, and kitchen) as mentioned in section 1.0. At the same time, the design of internal circulation needs to facilitate gender segregation, which is a distinct characteristic of mosque. As discussed previously in section 3.3.1., space segregation in the praying area can be in form of separate rooms for male and female congregants, installation of partition between male and female praying area; or the male and female praying area are located far apart, therefore, do not require partition.

This is demonstrated by pedestrian movement in mosque study by Abdelghany et al., (2005) and Zainuddin, Z., Aik & E. (2012).

However, Abdelghany et al., (2005) only focused on solving overcrowding phenomena among pedestrians in the 'mataf' or circumambulation area of Al-Haram Mosque in Makkah and therefore the findings cannot be generalised to solve overcrowding phenomena in the praying space of urban community mosques in Malaysia, particularly the Friday prayer. Furthermore, the scope of circulation performance is specifically for meeting the needs of pedestrians in mosque, and therefore, their findings do not represent other community needs on mosque. The same scenario is evident in Zainuddin et al., (2012) which only focused on verifying the accuracy of response surface analysis on predicting crowd dynamics during tawaf and therefore the findings do not emphasise on improving mosque facilities to meet the growing demand of contemporary Muslim community.

Therefore based on Abdelghany et al., (2005) and Zainuddin et al., (2012), this study will focus on improving space and functional performance in mosque by alleviating overcrowding and providing emergency response programs as means of providing safe mosque space that can attract community to the mosque.

***Technology***

Since the turn of the 20$^{th}$ Century, technology has become a vital component in the function of the house of worship such as the mosque. Several Western scholars reported on the active use of social media and ICT as means conveying religious knowledge and storing large mosque data. Hirschkind & C. (2012) conducted experiments in devotion online using the YouTube khuṭba in the USA. His study focused on the kind of devotional discourse and ethical associate enacted online in response to short video segments of the Friday sermon. Barik et al., (2019) studied on hybrid mist-cloud systems for large-scale geospatial big data analytics and processing by focusing on opportunities and challenges behind the system.

However, Hirschkind & C. (2012) only focused on social media of Youtube platform for recording of Friday khutba for purpose of increasing religious performance among the local community of the mosque. Therefore, his findings lack emphasis on other building performance criteria that can improve mosque facilities to fulfill the needs of the Muslim community. Barik et al., (2019) on the other hand, focused on the ICT of cloud computing which may not be needed by mosque organizations or communities, and be more of the interest of government agencies. Furthermore, the finding does not directly emphasise on mosque facilities per se such as spaces, structures, and others.

Therefore based on Hirschkind & C. (2012) and Barik et al., (2019), this study will focus on the application of technologies such as social media, ICT, the internet, and others that are

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needed by the contemporary society and indirectly will attract Muslim community to visit the mosque.

**Summary and Analysis**

This section summarises and analyses the review on physical, environmental, and functional performance criteria of mosque.

The review summarised physical performance of mosque into two (2) distinctive criteria; structural and non-structural. The majority of the literature was written on the structural performance criteria particularly on seismic performance. Perhaps because this is a critical subject on the stability of mosque building. (refer to section 3.1.1.1). Figure 3 below illustrates the criteria and sub-criteria for the physical performance of mosque based on a survey of the literature.

However, structural and non-structural criteria of physical mosque are insufficient for fulfilling community needs on mosque facilities. Therefore, consideration for environmental and functional performance in mosque spaces particularly the main praying hall is critical for attracting community to the mosque.

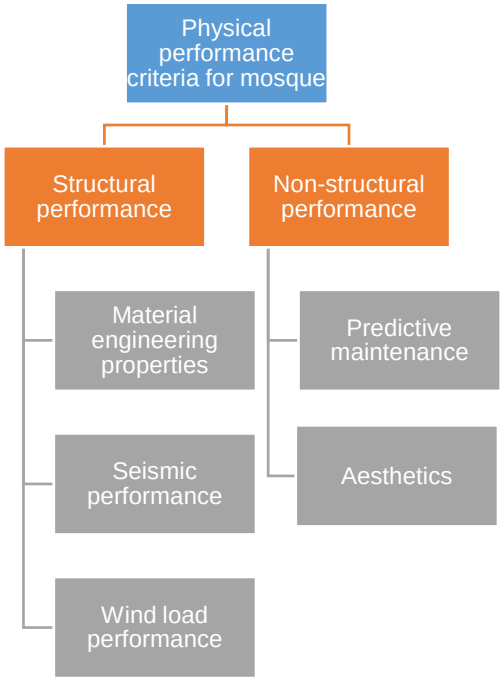


**Figure 3: Criteria and Sub-Criteria for Physical Performance of Mosque**

The environmental performance of mosque relates to the indoor environmental quality (IEQ) which comprises of four (4) factors; thermal comfort, indoor air quality, acoustical comfort, and lighting quality. Thermal comfort in mosque is provided through natural ventilation, mechanical ventilation, and a combination of both systems in the unit measurement of dry-bulb and radiant temperature (Amoako-Attah, J., & B-Jahromi, A. (2016). Figure 4 below illustrates the criteria and sub-criteria for the environmental performance of mosque based on a survey of the literature.

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The first criteria are thermal comfort, which is obtained through natural ventilation is obtained through cross-ventilation and passive cooling effects on passive solar design systems such as domed roof (Faghih & Bahadori, 2010), Faghih & Bahadori, 2011) and underground passive cooling structure; such as the traditional Shavadan system (Sadoughi et. Al, 2019). Secondly, thermal comfort in mosque is also provided through mechanical ventilation systems such the air-conditioning and exhaust fans. The ventilation efficiency of an air-conditioning system depends on HVAC operational strategies (Budaiwi & Abdou, 2013), automated HVAC control system with real-time occupancy recognition (Aftab et. al (2017), and the design of air distribution scheme (Samiuddin & Budaiwi, 2018). Exhaust fan is a more economical system where multiple fan units can be installed on the south-facing wall of mosque to provide significant improvement on the thermal comfort (Kamar et. Al, 2019). Finally, a mixed-mode system (i.e. combination of both natural and mechanical ventilation systems) provides a better solution for improved thermal comfort in mosque. For examples; thermal retrofit on building envelope (Budaiwi et. Al, 2013) or controlled use of fenestrations (Yüksel et. Al, 2020) alongside good HVAC system operational strategies can provide a better solution for improved thermal comfort in mosque.

The second criteria are indoor air quality (IAQ) which can be degraded through uncontrolled exposure to air pollutants such as Carbon Dioxide ($CO_2$) concentration (Yüksel et. Al, 2020) and atmospheric particulate matter (APM) concentration (Ali Shah et. Al, 2019). Among the main catalysts for increased APM concentration in mosque are temperature and wind speed (Munir et. al, 2013).

The third criterion is acoustical comfort, particularly for the main praying hall. This factor depends on the designed acoustics of the space (Suárez et. al, 2004) measured by acoustical comfort parameters (Gül & Çalışkan, 2013). The final criteria are lighting quality; which depends on the quality of daylighting from the fenestrations (El-Darwish & El-Gendy, 2016), and artificial lighting or lamps such as LED system of decorative lanterns in mosque (Atılgan & Yurtseven, 2017).

Undoubtedly the four criteria of environmental performance are critical for improving users' comfort and satisfaction with mosque space. Nevertheless, physical and functional aspects of mosque are also a priority to ensure stability and efficiency of mosque building.

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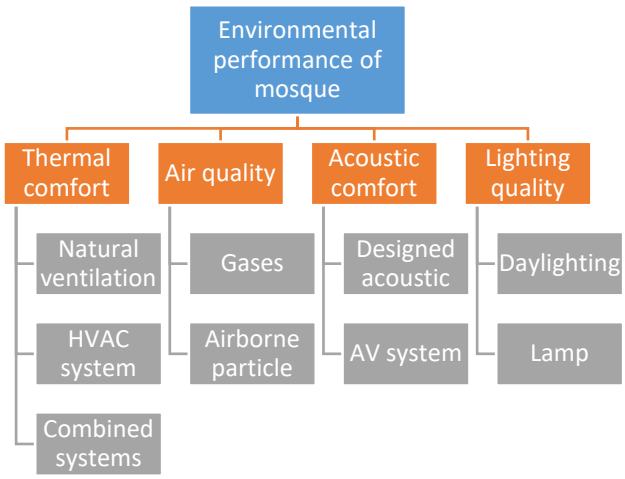


**Figure 4: Criteria and Sub-Criteria for The Environmental Performance of Mosque**

The functional performance of mosque is comprised of three (3) factors; activities, space, circulation, and technology that will make the mosque active, attractive, and supportive to the needs of mosque community. Figure 5 below illustrates the criteria and sub-criteria for functional performance of mosque based on a survey of the literature.

Mosque space that is multi-purpose for various activities (eg: sonic gatherings (Marsden & M., 2007), social mobilization activities (Weiss et al., 2013) and delivery of religious instructions (Mueller & D., 2017), gendered friendly (Prickett & J., 2015) and ethnic friendly criteria have to potential to make the mosque as a daily site for the Muslim community from various ethnics and citizenships (Es & M., 2016). Another important factor is circulation in the mosque that can solve overcrowding issues during peak times such as Friday prayer caused by multidirectional pedestrian movement in congested area (Abdelghany et al., 2005) and safe evacuation during overcrowding (Zainuddin et al., 2012). Finally, the availability of technologies in mosque such as ICT through YouTube khuṭba (Hirschkind & C., 2012) and hybrid mist-cloud system that can store large scale geospatial big data of mosque (Barik et al., 2019) can support mosque function and attract users to visit the mosque.

However, for mosque to function well, it must first fulfill the physical performance criteria to ensure the safety of users in mosque building. Secondly, the internal environment of mosque needs to achieve the expected comfort and health requirement of users. Once these criteria are in place, then functional performance criteria of mosque can be established.

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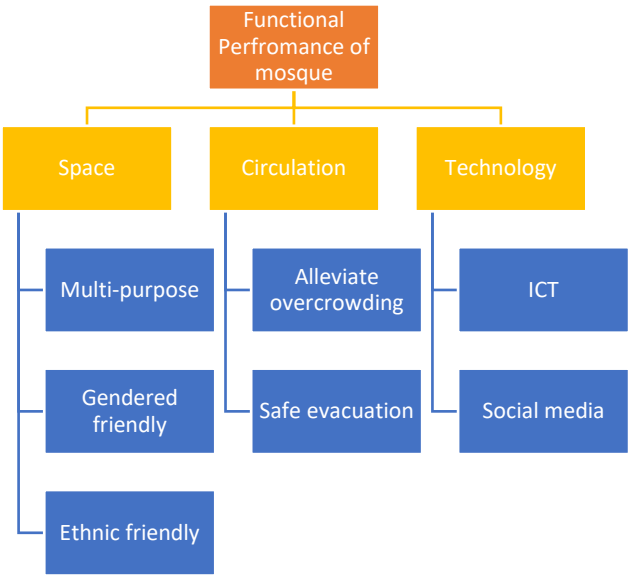


**Figure 4: Criteria and Sub-Criteria fFor Functional Performance of Mosque**

## Conclusion

This review is the first part of the research series on developing a framework of community-centric building performance criteria for mosque. Comprehension of three performance criteria (physical, environmental and functional) will be integrated with several new concepts as means for developing the framework and addressing the main research question.

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