



IMPORTANCE OF INTERNAL COURTYARDS IN DESIGNING HISTORICAL AND CONTEMPORARY MASJID

| Received July 1st, 2022 | Accepted September 15th, 2022 | Available online December 15th, 2022 |
| DOI <http://dx.doi.org/10.18860/jia.v7i2.16065> |

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ABSTRACT

The architecture of Masjids has spread in areas with harsh climates and natural conditions. In previous decades, the Masjid's design was a large flat area with an inner courtyard in the middle. This architectural design of the Masjid was appropriate to the nature of the hot climate. Recently, the design of Masjids became closed and flat areas that lack ventilation and good lighting. The research paper is based on an analytical descriptive study to determine the importance of internal courtyards in historical Masjids in Egypt and the elements that affect the significance of the courtyard in contemporary Masjids. The results show the importance of using the inner courtyard when designing a modern Masjid, which achieves many positive results, regarding the climatic and social aspects, by increasing the thermal and psychological comfort of the prayers

KEYWORDS:

Masjid; Courtyard; ventilation; lighting; Islamic architecture

INTRODUCTION

Due to the similarity in the climates around the Islamic world, Inner Courtyards have been used in most heritage buildings as pure and moderate temperate air storage. Even so, today, we witness a change that forces a complete disconnection and cuts our relationship with the past, overturning all concepts and

values. Opening to the outside with no selectiveness reached the extent that the ideas of inwards and outwards clashed. Studies have appeared that favor the traditional architectural heritage of mosques with no openings in favor of other architectural goals of the building, such as energy and its rationalization. But the openness to exterior architecture led to crises regarding energy consumption in Muslim Arab countries, especially within the Arab Gulf, to the extent that the consumption of the urban environment exceeded 70% of the total energy in Arab countries.

In contrast, $\frac{3}{4}$ of the mosques' energy requirement is expended during summer only due to cooling needs. Around 80% of the mosques' energy consumption is for cooling; this leads to the sacrifice of openings and natural lightning to decrease this energy waste [1]. One of the most important results of inwards architecture is to reduce solar exposure, as

direct solar exposure is the main reason for higher temperatures within the buildings, meaning that the benefits of inwards architecture are great.

The purpose of the research article is to identify the factors that influence the relevance of internal courtyards in modern Masjids as well as the significance of internal courtyards in historical Masjids in Egypt. The findings highlight the significance of incorporating an inner courtyard into modern mosque designs since it improves the thermal and psychological comfort of the prayers, which has a favorable impact on social and climatic factors.

THE IMPORTANCE OF INNER COURTYARDS WITHIN MASJIDS AND THEIR HUMAN AND FUNCTIONAL VALUE

The researcher shall discuss the importance of Inner Courtyards within the Masjid. Such values include symbolic, social, and functional values that comprise natural ventilation and natural lighting.

• Symbolic Value

Inner Courtyards are considered an essential element of the internal space that makes up the religious building, as it directly connects with the sky. As in cosmology, the four sides of the inner courtyard symbolize the four pillars bearing the dome of the sky [2], [3] (Figure 1).

The Inner Courtyard combined three intertwining concepts through its symbolism; The sky (it is a space open towards the sky), The earth (It is a grounded space), and light (It spreads and regulates the light within the whole area). So, the Inner Courtyard symbolizes complete unification (monotheism) "Allah is the light of the heavens and the Earth," and there is a connection between the ground and the heavens, where the mosque's minarets lie higher. The sky descends onto the courtyard, filling it with mercy within and throughout and in the spaces between the cresting, which are similar in shape. And we see the pairing between the mass and the area as positive and negative. They also symbolize the pairing of the body and soul or the sky and earth [2].

Religious buildings were also required to confirm the essential connections within the structure of Islam. So, the Inner Courtyard needed to symbolize absolute unification / monotheistic belief between the heavens and life on earth (Figure 2).

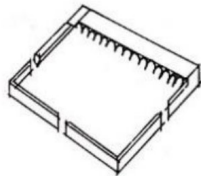


Figure 1. The Mosque of the Messenger of God was built in 7 AH. The courtyard shows the connection of the earth with the sky [4].

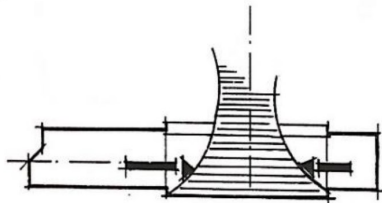


Figure 2. A section that shows the relationship between the covered void and the exposed space (researcher drawings) [4]

- **Social Aspect**

The Inner Courtyards of large mosques acted as the main yard for the Islamic city, where people moved towards prayer and other social activities. Later, these social activities and groupings moved to take place around the palaces of the rulers, and as such, Inner Courtyards lost some of their importance.

- **Functional Aspect**

The courtyard was the heart of the Masjid. The Courtyard part was covered to manage the climatic factors and achieve thermal comfort for the building to fulfill the functional requirements. Such as providing natural lighting for the mosque throughout the day, providing natural ventilation without opening up the area due to high temperatures, and providing shade for the inner areas. It achieves thermal comfort within the mosque and minimal noise, providing quiet for worship and prayer.

THE EVOLUTION OF THE INNER COURTYARDS DESIGN THROUGHOUT THE AGES

The architecture of Masjids in Arab countries in the ages had similarities to them. Such as their connection to the inner exposed area as the heart of the mosque. The existence of a covered area is what was needed due to environmental and social factors.

- **Inner Courtyards at the beginning of Islam**

The prophetic mosque (Masjid-Al-Nabawi) in Medina-Munawara mainly consists of a rectangular shaded prayer hall, and the mosque does not have a minaret or a courtyard. The doors led directly to the shade [5] (Figure 1). Also, in the age of the righteous caliphs (Khulafa Rashidin), the mosque of Amr-Ibn-Al-'Aas was built with simple architecture and without a courtyard (Abdel-Wahab, 1994, p 23). Still, in the Amawi era, its area was increased and utilized a courtyard.

- **Inner Courtyards in the Tulunid and Fatimid eras**

With increased urbanization in the Tulunid and Fatimid eras, and while cities were building, a new urban formation for mosques appeared, which took from urbanized cities, with the desert environment affecting the design. Masjids in this era expressed welcoming and openness toward the sky through their uncovered courtyard area, and lighting spread fluidly through the mosque, which was present in the mosque of Ibn-Tulun in Cairo (Figure 3), the mosque of Al-Hakim (Figure 4), and Al Aqmar Mosque (Figure 5).

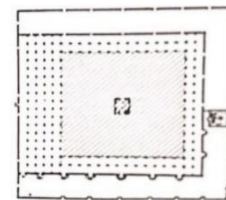


Figure 3. Ibn Tulun Masjid [4]

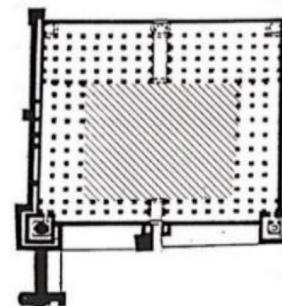


Figure 4. Al-Hakim Masjid [4]

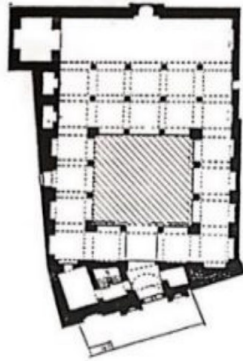


Figure 5 Al Aqmar Masjid [4]

• **Inner Courtyards in the Mamluk Bahri era**

The design of the horizontal plan of religious buildings was directed inwards, with two main patterns. First Pattern: The Masjid is made up of an uncovered Inner Courtyard surrounded by four shadows. An example of this is the mosque of Zahir Baybars. Figure 6. Second pattern: Schools consisting of a horizontal plan with four iwans, with the oldest known example of this being the school of Zahir Baybars. This pattern continued appearing in the schools (Madrasa) Qalawun, Sarghatmish, and Sultan Hassan Figure 7.

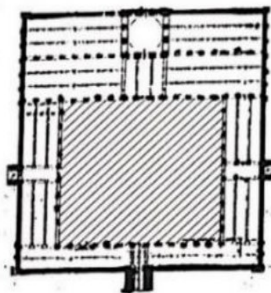


Figure 6. Mosque of Zahir Baybars [4]



Figure 7. Madrasa of Sultan Hassan [4]

• **Inner Courtyards in the Mamluk Burji period**

It is noticed that there are three main patterns of horizontal plans. First Pattern: Small mosques/schools, in which the mosque or the school was grouped with Sabil and kuttab. Second Pattern: It had an uncovered

courtyard surrounded by four iwans in the case of mosques, schools, or Khanqahs, like the Khanqah of Faraj-binBarquq (Figure 8) and the school and Khanqah of AlZahir Barquq (Figure 9). Third Pattern: The smallest in size of a masjid. It mainly consisted of a shrine (Dargah) placed in the middle, with a ceiling typically a wooden shuksheika (wooden lantern) and sometimes with a wired web, And Iwans surrounded the Dargah. An example of this pattern is the school of Sultan Qait-bai.

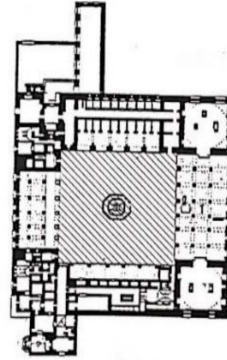


Fig. 8. Khanqah of Faraj-bin-Barquq [4]

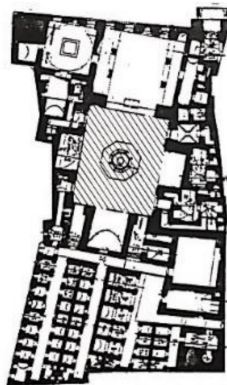


Fig. 9. Madrasa and Khanqah of El Zaher Bin Barquq [4]

• **Inner Courtyards in the Ottoman era**

First Pattern: Mosques were influenced by the architecture of ottoman mosques in Turkey to deal with the issue of the cold climate. Despite the hot climate, this system was transported entirely to Egypt, changing the concept and method of organizing the inner space for prayer within mosques. So, the prayer house in the Masjid was separated from the courtyard like Suleiman Basha (Figure 10).

Second pattern: it became acceptable for the architect not to include a courtyard. In that era, Masjids were formed by transforming the vertical axis of an uncovered space into a covered, roofed one with a dome above it through the vertical axis. The courtyard area kept shrinking until its disappearance, as is seen in the mosque of Sanan Basha (Figure 11) and the mosque of Muhammad Bek Abu El Dahab.

Third Pattern: Schools which consisted of an uncovered courtyard surrounded by four shaded prayer halls, each of them consisting of a room

opening into a hallway with windows and overlooking the courtyard through arched corridors, as in the Sulaymaniyah school Fig 12, and in the school of Sultan Mahmud. Through analyzing the plan, we find that having rooms opening in the hallway, which opens into the courtyard, is similar to the designs of modern school buildings, where classes open up on a corridor and through it onto the courtyard [6].

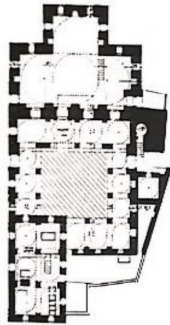


Figure 10. Masjid Suleiman Basha in Mohamed Aly citadel in Cairo [4]

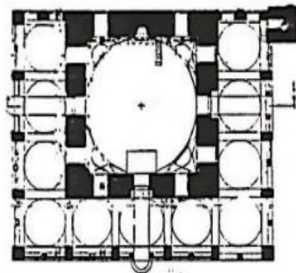


Figure 11. Masjid Sanan Basha in Cairo [4]

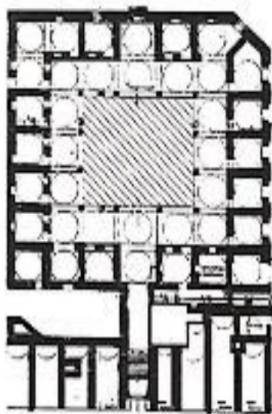


Figure 12. Sulaymaniyah school in Cairo [4]

- **Modern Masjid without an Inner Courtyard**

The absence of the Inner Courtyard is evident from the study of the contemporary Masjid. There is a tendency toward building modern mosques which do not contain the traditional courtyard element. It is due to the lack of awareness regarding the importance of the courtyard. What it represents, and its treatment of climatic and environmental factors. Also, as the human, spiritual, and symbolic meanings it carries. It is also due to the small areas of land in modern cities. The

strong need to expand and accommodate the most significant number of worshippers in the mosque led to the building of mosques of many floors and other functions such as a praying area for women, areas dedicated to Quran



Figure 13. Futuristic trends - abstraction, simplicity, and Symbolism [7]-[12].

FUNCTIONAL ELEMENTS AFFECTING THE IMPORTANCE OF HAVING INNER COURTYARDS IN CONTEMPORARY AND FUTURE MASJIDS

The Inner Courtyard plays an essential role from the functional side, as it is – besides being an element of the mosque – a space that accommodates some activities. It plays another role due to its openness toward the sky as a way to allow sunlight and fresh air into the areas surrounding it, naturally ventilating and illuminating them. It means that the Inner Courtyard had many functions, whether ventilation, illumination, noise suppression, or an area to accommodate activities.

- **Ventilation**

It is considered an important factor that influences peoples' comfort and health by directly affecting the air's movement and purification and its effect on temperature and humidity levels. The Inner Courtyard helps naturally ventilate the areas of the mosque which surround it as follows: The ventilation process is the spontaneous motion of air from high-pressure areas (cooler air) into low-pressure areas (warmer air). This motion results as cooler air replaces warmer air which rises upwards, creating this movement within the Inner Courtyard and between the other spaces of the mosque (Figure 14).

Similarly, the wind moves from the shadier roads through passages, entrances, and hallways into the Inner Courtyards with less shade, to secure constant ventilation between the outside and inside of the mosque, renewing and refreshing the air constantly. In addition, the ventilation process leads to spontaneous air movement from the narrow entrance space toward the vast Inner Courtyard area. It also helps absorb the air and renew it within the building [13]. .

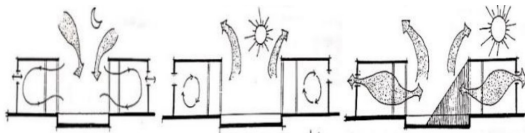


Figure 14. Natural ventilation across the Inner Courtyard of an Arab building demonstrates ventilation during different times: evening, noon, and morning [13].

The Inner Courtyard and Malqaf (Wind Catcher) work to ventilate the inner spaces, as, throughout the day, the Malqaf functions from the left/north, and warm air rises within the area. So, the cooler air comes from the Malqaf and passes into the courtyard through the mosque's spaces. Through the nighttime, cooler air descends to the bottom of the courtyard and enters nearby areas overlooking it, kicking out the warm air and pushing it towards the Malqaf. Malqafs were used within mosques commonly during the Abasi-era [4], which helped achieve thermal comfort (Figure 15).

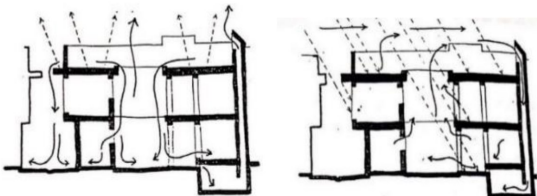


Figure 15. During the day, the Malqaf receives the air and works to moderate the temperature. During the night, the cold air falls into the courtyard and enters the spaces overlooking it to expel the hot air to the Malqaf [14].

• **Natural Lighting**

The reason for having openings is to illuminate the building's spaces. Buildings in areas with hot climates require protection against high temperatures and have to deal with the issues of natural lightings, such as dazzling brightness and over-illumination. One of the characteristics of buildings in these regions is having buildings close to one another in a compact form to decrease direct sun ray exposure and increase shaded areas. For this reason, it was necessary to have openings to be used as windows, and the need arose to have Inner Courtyards such that windows would open up on and overlook the Inner Courtyard, shading it and providing protection from direct sunlight. These windows can be considered openings in the roof [15].

Inner courtyards provide natural lighting for internal spaces and solve the issues caused by them as follows: When utilizing Inner Courtyards in buildings increases the surface area of the northern facades of the building, allowing the maximum amount of internal lighting with the minimum amount of dazzling brightness and regulating the lighting. The Inner Courtyard is used to strengthen natural lighting and deflect the light toward the openings requiring more illumination [15] (Figure 16).

The Inner Courtyard prevents unwanted direct light from entering the openings overlooking it during midday. It is accomplished by raising one side of the building slightly higher than the other and utilizing the

resulting shade from the buildings surrounding the courtyard or its fences [15] (Figure 17), confirming the Inner Courtyard's use as a protection against over-illumination and highly dazzling light.

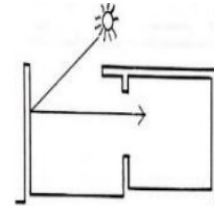


Figure 16. Enhancing natural lighting by reflected solar rays [16]

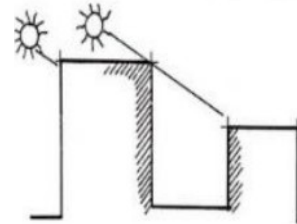


Figure 17. The height of the walls overlooking the courtyard protects the openings from rays [16]

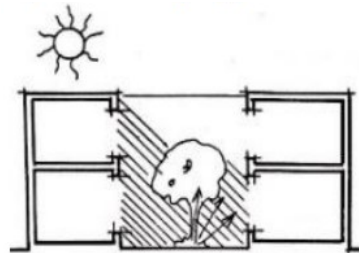


Figure 18. reflection Resistant to glare and dazzling inside the Inner Courtyard [16].

Inner Courtyards within mosques greatly limited dazzling brightness – considered a major annoyance and causing vision problems. It also affects contrast; the less contrast is present on surfaces, the less dazzling brightness. –they also played a role in securing a comfortable level of natural lighting, where trees and green surfaces played a major role in blocking intense sunlight and minimizing it before it reached the facades and the floors of the Inner Courtyard. Greenery in the courtyard also absorbed and scattered the sunlight, which decreased dazzle and gleaming (Figure 18).

Water surfaces in the Courtyard center lead to the reflection and scattering of light rays falling on them. The water surface leads to a reduction in the light's intensity. It is also greatly affected by the amount of shade the Inner Courtyard provides, which has a major role in reducing the sharpness of the illumination and decreasing the glow and dazzle.

• **Noise Reduction**

Noise avoidance and reduction are requirements for mosques as worshippers will spend long periods in prayer, away from noise and sound pollution, meaning they need calmness and serenity within the houses of the Divine. We find that the Inner Courtyard is a factor

that helps reduce noise as shown in figure 19.

A mosque with an Inner courtyard consists mainly of an emptied rectangle facing outwards towards the street with walls with no windows. Its shade falls upon the Inner Courtyard. A person will not see anything but the sky. A building of residence that utilizes an Inner Courtyard combines visual and aural privacy where the building provides isolation and protects the Inner Courtyard from the noise and pollution of the streets. This Inner Courtyard also adds an atmosphere of calmness and purity, a requirement for people performing different activities within the courtyard [17].

It can provide an acoustic shadow for the building, and residences with Inner Courtyards can be placed quite close to noise sources since the closer the courtyard is to the disturbance, the more the external noise is attenuated (although the weakness arising from a distance is smaller). Reconciling the urban land cost required to overcome the noise (by moving away from the source) and the acceptable noise level will determine the ideal distance for the house with the Inner Courtyard from the noise source. Houses with courtyards can be grouped to form a connected wall surrounding the area built, as the wall's continuity is important for protecting the site behind it [17].

In general, narrow Inner Courtyards protect the insides of mosques better, with loudness intensities ranging from 10 to 25 decibels [17], and Inner Courtyards meant to protect from noise must be no more than 2–4 times the height of the wall to achieve a comfortable aural environment and to protect from outside noise.

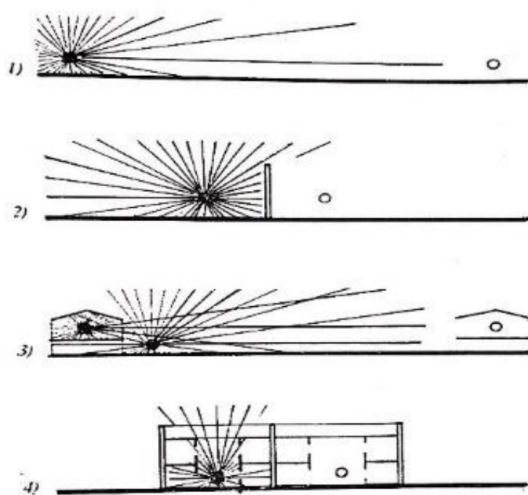


Figure. 19. Some ways to avoid noise and the best being Inner Courtyards [15]:

- 1-Keep as far away from noise sources as possible.
2. Placing suitable barriers in the paths of the noise.
3. Longer distances ensure avoiding noise and continuous ventilation in hot areas.
4. Buildings with courtyards achieve aural seclusion and noise protection, highlighting the significance of courtyards in Islamic architecture.

METHODS

Research Methodology is a descriptive-analytical study. It will describe and define the importance of internal courtyards in historical mosques and the elements affecting the importance of their presence in contemporary Masjids. In this paper, we will present the results of this study in a summarized and focused form to facilitate its use and benefit in the future.

RESULT AND DISCUSSION

Using the Inner Courtyard is a way to increase the functionality of masjids and achieve thermal and psychological comfort for the worshipers. Returning to the Inner Courtyard element when designing mosques, the Inner Courtyard should be considered an architectural concept that achieves many positives in the architectural design operation regarding climatic, social, and formational aspects. It also fulfills different human and spiritual values and affirms the necessity of reviving that beautiful architectural element that the Muslim Arab architect innovated.

It contributes significantly towards reminding and tying people to their history and heritage and raising their cultural awareness. Other than including a Courtyard, environmental treatments should contribute to achieving thermal comfort inside the mosques in case no courtyard is present in the building. Such treatments are as follows: Ceilings and their treatment: utilizing insulation for heat and humidity, building arches, or double ceilings to allow air movement between them. Walls: looking for building materials that can achieve insulation, building double walls with insulating layers between them, and using materials with high thermal aptitudes such as rocks/stones which absorb heat during the day and release it during the night without allowing it to penetrate the walls due to their thickness, utilizing various plant-based elements on the walls and surrounding the building to minimize the contact with sun rays, and using bright colors to paint the surfaces and inner and outer walls. I am researching and utilizing openings in a fashion that encourages ventilation and designing ventilation holes at the top of the inner space to dispose of warm air—using openings decrease the amount of solar radiation permeating into the internal areas. Especially the southern openings, which should preferably be high and narrow, covered by wooden netting, and utilizing a double layer of insulated glass, horizontal and vertical sunlight breakers should also be used. It's also a good idea to have the openings face inwards toward the Inner Courtyard (Confirming the need to study the position and orientation of the opening, the dimensions and measurements, and the type of material the opening consists of).

Having trees and plantations inside the Inner Courtyard ensures having sunlight blockers and contributes to humidifying the air within. In addition,

providing water surfaces and their aesthetic value plays an essential role in regulating the surrounding area's temperature, which helps create a miniature climate region in and around the building.

CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The Inner Courtyard is one of the most important elements and appearances within Muslim Arab architecture, which the Muslim Arab architect innovated. It is one of the building's spaces in regions of social and environmental aspects, which require the presence of the courtyard within the building; to achieve beneficial environmental, formational, and social goals. In the Masjid, the Inner Courtyard possesses a cultural dimension, as many study circles and cultural seminars are held in the courtyards of historical Masjids in Gaza, making it akin to a cultural center for its residents. Nevertheless, the Inner Courtyard has a spiritual dimension that gives a person looking up at the sky a sense of comfort. It is an innate sense within humanity as if it is an attempt by the worshippers to find a spiritual connection between them and the Divine through prayer in a place exposed to the sky. Masjids of historical areas that contained inner courtyards had many features, as they fulfilled the environmental aspect with their many considerations and had a social value. Moreover, they had respect for the worshippers and their traditions and the human and spiritual aspects, not to mention the authentic design of those Masjids.

It was noticed that worshippers headed to the hallways surrounding the courtyard to recite the Quran to avoid the high temperature within the Masjid. As for Masjids that do not contain an inner courtyard, it is noticed that worshippers would seek refuge from the high temperature of the prayer building, and head to the outer courtyards or the pavements surrounding the Masjid.

B. RECOMMENDATIONS

It is necessary to raise citizens' awareness about the importance of the Masjid's inner courtyard on environmental, climatic, human, and spiritual levels. We need to revive the courtyard, as the Muslim Arab architect innovated this architectural element, contributing significantly towards reminding and tying people to their history and heritage and raising their cultural consciousness. The courtyard also helps achieve thermal comfort and realizes the spiritual aspect. It is essential to study the inner courtyard throughout the early design stages and incorporate it when designing heating, ventilation, and natural lighting systems. We also recommend providing suitable shading methods and ventilation for the inner courtyard and interior spaces during the summer to avoid high temperatures.

The architecture of Masjids should achieve comfort for humans to the greatest extent possible,

whether inside or outside the building, and through natural methods. It could be accomplished by utilizing trees, plantations, green surfaces, fountains, and ponds. We should also evaluate the interior conditions which achieve thermal comfort for the users of the building. The small land areas should not be an excuse to cancel and cross out the inner courtyard from the architectural design. Instead, it should be considered an architectural element that achieves many positives regarding environmental, social, and formational aspects. We also recommend designing openings for ventilation at the top of the inner spaces to get rid of warm air so that it is replaced by cooler air, consequently achieving thermal balance and comfort for the users.

ACKNOWLEDGMENT

The author would like to acknowledge the support of Prince Sultan University for paying the Article Processing Charge (APC) for this publication.

REFERENCES

- [1] G. M. Eibadat, "Masjid Almustaqbal: Altasmim Lilruwhaniat Walkhushue Bayn Al'asalat Walkhayal Walaibtikar , Almutamar Al'awal Lieimarat Almasajidi," *Aldamam*, vol. 5, no. 7, pp. 2–28, 2016.
- [2] T. Eukasha, *Alqiam Aljamaliat Faa Aleimarat Al'iislat*. Cairo: Dar Alshuruq, 1994.
- [3] E. J. Grube, J. Dickie, O. Grabar, E. Sims, and R. Lewcock, *Architecture of the Islamic World*. London: Thames & Hudson, 1995.
- [4] S. Dwidar, *The Opening in Islamic Architecture*. Alexandria: Alexandria University, 1998.
- [5] K. A. Sameh, *Aleimarat Faa Sadr al'iislam*. Cairo: alhayyat almisriat aleamat lilkitab, 1991.
- [6] Markaz Aldirasat Altakhtitiat Walmiemariat, Ass *Altasmim waltakhtit Alhadriu*. Cairo: Munazamat Aleawasim Al'iislat, 1990.
- [7] "King Abdullah Financial District Mosque," *FX Collaborative*, 2015. <https://www.fxcollaborative.com/projects/25/king-abdullah-financial-district-mosque/> (accessed Nov. 23, 2021).
- [8] "King Abdullah Petroleum Studies and Research Center Community Masjid," *hok*. <https://www.hok.com/projects/view/kapsarc-community-masjid-mosque/> (accessed Nov. 23, 2021).
- [9] A. Griffiths, "Daylight filters in through the roof and walls of Bangladeshi mosque by Marina Tabassum," *de zeen*, Mar. 05, 2017.
- [10] "King Abdullah Financial District Mosque," *Architizer*. <https://architizer.com/projects/king-abdullah-financial-district-mosque/> (accessed Nov. 23, 2021).
- [11] S. di C. Darsa, "BAIT UR ROUF MOSQUE," *The*

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- Aga Khan Award for Architecture, 2012. <https://the.akdn/en/how-we-work/our-agencies/aga-khan-trust-culture/akaa/bait-ur-rouf-mosque> (accessed Nov. 23, 2021).
- [12] "KAPSARC Mosque / HOK," *Archdaily*, Mar. 31, 2015. <https://www.archdaily.com/614616/kapsarc-mosque-hok> (accessed Nov. 23, 2021).
- [13] S. Al-Wakeel and M. Al-Siraaaj, *Almunakh Waeimarat Almanatiq Alharat*, t 3. Cairo: Ealam alkutub, 1989.
- [14] A. Konya, *Design Primer for Hot Climate*. London: Architectural Press, 1984.
- [15] M. Evan, *Housing, Climate, Comfort*. London: Architectural Press, 1980.
- [16] S. Dwidar and E. Abouwardah, "Internal Courtyards One of the Vocabularies of Residential Heritage Architecture and Its Importance in Building Contemporary National Identity," in *International Architecture and Urban Studies Conference house and home*, Mar. 2017.
- [17] S. Ettouney and F. Fricke, "Courtyard Acoustics," *Applied Acoustics*, vol. 6, no. 2, pp. 119–132, Apr. 1973.