Accessibility and spatial integration evaluation of masjid in Saudi Arabia using space syntax.

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ABSTRACT

Besides its religious role, the masjid has also played a significant role in Muslim society's social and economic life. That is, Masjids act like a community center surrounded by public spaces and functions. Therefore, the movement around and inside a masjid was and still vital. Due to the recent changes caused by the pandemic COVID-19 conditions, the safety precautions significantly impact our life pattern. Knowing this fact, one may question the compatibility of a Masjid as a building during the safety precautions in terms of circulation, proportions of major spaces, spatial arrangements, and utilization of entrances. This study presents existing case studies findings by evaluating the accessibility and spatial integration of two central masjids located in Riyadh, Kingdom of Saudi Arabia, using Space Syntax. Space evaluation will be conducted in two typical scenarios: before and after COVID-19. This study considers the pre-COVID-19 scenario with a maximum occupancy of the physical space as opposed to the active-COVID-19 scenario of lower occupancy. Any physical space can be represented as a matrix of connected relationships leading to a matrix of mathematical properties that can be analyzed using computer simulations. It was noted that the existence of a masjid Sahan (court) played a significant role in tying up the Masjid internally (within its function) and externally (within its context) before and after the COVID-19 pandemic.

Keywords: Space Syntax, Masjids, Accessibility, Spatial Integration, Pandemic COVID-19

INTRODUCTION

Throughout history, Muslim communities have always been attached to Masjids in one form or another. The masjid was not restricted only to be a place of worship. Instead, Masjids have developed into institutions that provide Muslim communities with an extensive

array of religious and cultural services (Abdel-Hady, 2010) (Al-Krenawi, 2016). From many narrations and hadiths, there are at least five functions of the masjid during the time of the prophet Mohammed (peace be upon him), namely as a place of worship, learning, deliberation, caring for the sick, and boarding (Fakriah, 2019). The masjid is the focal point of the political, social, cultural, and ritual life. These essential roles ascribed to the masjid are crucial to creating a dynamic society, both religious and mundane, spiritual and physical. Each role has a different significance depending on the different contexts of places and time. As far back as the Othman period, the functional efficiency of masjid layouts was significantly affected by spatial configuration. Nowadays, Masjids are commonly designed to provide anything needed by people living around them since the Masjids are the focal point of all activities linked directly to the community's needs (Laugu, 2007).

Space syntax researchers aim to develop strategies for describing the configurations of occupied/inhabited spaces to articulate underlying social meanings. These meanings are represented in numerical and graphical forms, thus facilitating the scientific interpretation of masjid layouts (Ali and Sanusi, 2013). Space syntax is a robust technique for describing and analyzing architectural space patterns at the building and urban levels. It attempts to explain human behaviors and social activities from a spatial configuration point of view. Space Syntax originated and developed in the 1970s at the Bartlett Unit for Architectural Studies, University College, London (Tarabieh et al., 2019). From an analytical point of view, the Space Syntax technique provides a comprehensive and consistent framework for understanding spatial arrangements and their likely human effects, which we can term as buildings' social performance. However, the issues of 'plan layout' has been mostly addressed from various optimization points of views; most of which deem configuration as an order that can be 'found' through thousands of trials and errors in putting spaces together in different ways to maximize certain qualities (Nourian et al., 2013). Ali and Sanusi (2013) clarify adopting space syntax to deal with the syntactical characteristics of the spatial configuration of masjid layouts for the following reasons:

- ✓ This method combines physical and social indicators in explaining the spatial and functional systems to identify configurations in terms of similarities and differences, thus enabling the diagnosis of the strengths and weaknesses of structures, types, and patterning of masjid layouts.
- ✓ This method adopts spatial configuration's syntactic characteristics (i.e., symmetry–asymmetry and distributedness–non-distributedness) in interpreting different Masjid layouts' structures.

- ✓ This method facilitates the analysis, evaluation, and comparison of various systems.
- ✓ This method can assess, understand, describe, and model various formal and spatial systems, thus providing sufficient credibility and reality.

This paper explores the compatibility of a masjid as a building and its functions in terms of circulation, proportions of major spaces, spatial arrangements, and utilization of entrances before and after COVID-19. Using the Space Syntax technique, we will compare the compatibility of a masjid as a building and its functions of two case studies in Riyadh, Saudi Arabia. The case studies are 1) Imam Turki bin Abdullah Grand Masjid and 2) Alkindy Square Masjid. The analysis of the collected results will help evaluate the accessibility and spatial integration of masjids in Saudi Arabia.

LITERATURE REVIEW

The masjid and its evolution in form have been active discourse and debate for many years. Every masjid has a program that depends on the Muslim community where the masjid is built. A large community aims to serve a much bigger congregation, which in this case it translates into a brief of a masjid or a Jami masjid or a congregational masjid that can host Friday prayers. In any masjid, the central prayer hall is the spatial nexus; it is where the act of formal transformation begins. The spiritual space itself is extended from a point in the center and extends forwards and backward. The key aim is to contain, celebrate and facilitate the acts of devotion and submission that occur in mainly the prayer hall. The masjid space layout functionality can result in two key syntactic characteristics: symmetry, asymmetry, and distributedness–non-distributedness (Ali and Sanusi, 2013) (Kassim, 2016).

Ezani et al. (2017) studied the complexity of three different Masjid floor plans using space syntax. The masjid spatial integration and depth value (hierarchical transition among spaces) were analyzed to help imitate users' possible movement scenarios within the various Masjids by topologically converting the plans into the axial line of respective nodes and links. It was shown that one of the masjids attained the most integrated ablution area, indicating that the designer has beforehand considered the importance of this space. Contrarily, other Masjids obtained a more segregated ablution area hindering user's navigation. Besides, a reduced depth value signifies easy access within the space, whereas high depth causes inconvenient navigation through space. Thus, guiding designers in the design process identifies the suitability and accessibility of complex function spaces (Ezani et al., 2017).

Tarabieh et al. (2018), in a similar study, analyzed a typical "static space" in terms of its spatial logic, considering a typical configuration for a prayer hall consisting of a bilateral symmetry space with four columns. This configuration is manifested in many religious buildings and assessed using visibility graphs, axial lines, and various isovist field properties and measures. An isovist gives a 2D polygon corresponding to the viewshed at that given point which is relevant for an in-depth exploration of a specific location. Tarabieh indicated how the most basic alterations to the plan's configuration could affect the spatial experience and cognition of the place. Besides, special Space Syntax measures that are relevant to the design of the static spaces are extracted and discussed, and the consequences of an omni-visual observer of typical Space Syntax compared to the directional observer in a static space (Tarabieh et al., 2018).

Asif et al. (2018) substantiated the reason behind the development of the Space syntax tool (syntactical analysis), which deepens the understanding of how syntactic analysis can extract social information embedded in traditional architectural practice. Space syntax is a simple form because of the proposition that human society holds integrated spatial information and that the spatial environment or inhabited space is embedded with social information. Therefore, the syntactic properties of a particular configuration within a particular region reflect the traditions of the people in that region. Space Syntax is useful in describing and analyzing architectural space patterns at both the building and the urban level in terms of spatial systems' configuration properties, likewise the relationship between spatial cognition and configuration. Throughout history, the masjid has taken various forms from the hypostyle to the dome masjid. The most important space in the masjid is the prayer hall, which usually takes a square or a rectangle form so worshippers can line up in equally spaced rows during prayers. Accordingly, other forms of the prayer hall, such as a circle or a hexagon, are uncommon, resulting in lines of unequal lengths (Asif et al., 2018).

Tarabieh et al. (2019) proposed scaling of the space syntax field for the inclusion of other parameters, such as daylighting, and integration of the associated performative measures to space syntax analysis of the Masjid typology to aid in the studying of overall space cognition based on comfort and environmental parameters. The study presents a case study on a typical Masjid layout using multi-objective optimization. The analysis presented implications for the architectural designs of spaces for glare management and daylight potential. Moreover, it is unique and builds on our previous work to explore comfort, visibility, and proximity thresholds for stationary observers (Tarabieh et al., 2019).

Many studies have emphasized the importance of prayer halls in the masjids. Despite

the studies done on the masjids using space syntax tools, there is still room for evaluating the accessibility and spatial integration of the masjid's other public services and studying their relationship with the prayer halls. Though the form is fixed, however, the spaces' functionality varies, especially with the world's current changes (pandemic COVID-19). Thus, paving a gap to explore and compare two Masjids in two typical scenarios: pre-COVID-19 and active COVID-19 via space syntax.

METHOLOGY AND PROCEDURE

This paper collects quantitative data utilizing a Space Syntax simulation technique to study accessibility and spatial integration of masjids in Saudi Arabia. It attempts to test and analyze the two different case studies to measure a Masjid's compatibility as a building in terms of circulation, proportions of major spaces, spatial arrangements, and utilization of entrances before and after the pandemic COVID-19. It should be noted that both case studies which are Imam Turki Bin Abdullah Grand Masjid and Al Kindy Square Masjid, are both located in Riyadh, the most crowded city in KSA, and have similar socio-cultural characteristics. Besides, both masjids have won local and international architectural prizes.

Evaluating the accessibility and spatial integration of the Masjid will be analyzed using "DepthmapX" software. The masjid AutoCAD plans constitute the primary source of this analysis, taking into account only physical barriers that obstruct movement and vision (walls). After importing the layouts, we have to select the areas to be analyzed then start making the graphical representation of visibility. Every visual field from each point of the analyzed layout is calculated, and the level of visibility is identified. The level of Connectivity, Visual Integration, and Visual Step Depth graph will be measured accurately in the selected Masjids (Table 1). The results obtained are represented by a color scale ranging from red to blue. Red shades correspond to areas with the highest visibility, while blue corresponds to more restricted visual fields.

Table 1: Some of the terms used in “DepthmapX” software

Term	Meaning
Visibility graphs analyse (VGA)	Visibility graphs analyse the extent to which any point in a spatial network is visible from any other. Where points are not directly visible, graph measures of a matrix of points can be calculated to test how many intervening points are needed for one point to see others (Desyllas & Duxbury, 2001).
Connectivity	The objective concept of connectivity means spatial connections, whose numerical value represents the number of accesses leading to space. It measures the number of immediate neighbors directly connected to space (Askarizad & Safari, 2020).
Visual Integration	The integration of space is a function of the mean number of lines and direction changes that need to be taken to go from that space to all other spaces in the system. Therefore, greater integration indicates that the spaces are more integrated (Askarizad & Safari, 2020).
Visual Step Depth	The visual step depth of space calculates how many ‘steps’ it takes to cover the entire area, where the ‘steps’ are measured by how far you can see.

Maximum Depth (MxD)	Maximum Depth is the total number of steps of the analyzed plan.

ANALYSIS AND RESULT

Both case studies have an open-plan layout surrounded by different spaces designated for religious, commercial, entertainment, or other, for different ages and races. Further information about them can be found in (Table 2).

Table 2: General information about Imam Turki Bin Abdullah Grand Masjid, and Alkindy Square Masjid

	Imam Turki Bin Abdullah Grand Masjid	**Alkindy Square Masjid**
Location	Riyadh, Saudi Arabia	Riyadh, Saudi Arabia
Built year	1992	1986
Area	16800 m^2	3200 m^2
Capacity	17000 worshippers	7000 worshippers
Style	Contemporary design inspired by Najd traditional architecture	Contemporary design inspired by Najd traditional architecture
Accessibility to the Prayer hall	Linear movement	Central movement

The architectural layout of the masjid's context (Figure 1,2) is based on a functional schema of places. Yellow places are for the prayer area, light gray for the *Sahan* area and dark gray places are for circulation and public services spaces. It should be noted that both masjids have two main entrances with the addition of emergency exits used as entrances when needed. However, emergency exits will not be considered as entrances in the analysis.

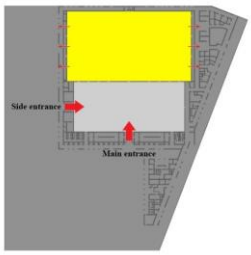


Figure 1: The Architectural layout of Imam Turki Bin Abdullah Grand Masjid.

Figure 2: The Architectural layout of Al Kindy Square Masjid

IMAM TURKI BIN ABDULLAH GRAND MASJID

The Imam Turki Bin Abdullah Masjid is considered one of the most famous Masjid in Riyadh and was a meeting place for scholars and students of knowledge. Imam Turki Bin Abdullah Masjid's context consists of *Assafah* Square connected to the *Sahan* of 4,800 square meters, main prayer hall, library, school, and 50 shops.

The findings from the Visual Graph Analysis (VGA) was done by DepthmapX software calculate the Connectivity level, Integration level, and Step Depth of Imam Turki Bin Abdullah Grand Masjid (Figure 3).

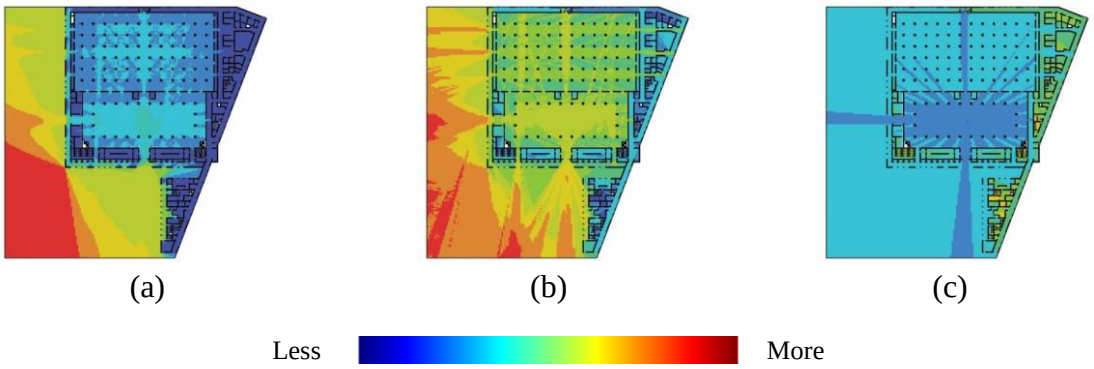


Figure 3: The syntactic analysis of the ground floor of Imam Turki Bin Abdullah Grand Masjid. From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.

The red color at the right end of the color scale represents the highest value of connectivity and integration level, and the blue color at the other end of the scale represents the lowest value of connectivity and integration. According to the results, there is a linear gradation in connectivity and visual integration level on Imam Turki Bin Abdullah Grand Masjid. The Sahan serves as a distributing point, moving the people from a public zone to a private zone. As shown in Figure 3 (a), Assafah Square has the highest connectivity level because it is visually connected to all other spaces in and surrounding the masjid. Figure 3 (b) shows that Assafah Square is well-integrated because the integration level is distributed equally in the space, providing fluency in the movement and prevents crowdedness in the masjid's gates. Figure 3 (c) shows the number of steps to cover the entire area, which clarifies the relations between the masjid spaces. There is a direct relation (one step away) between Assafah Square and the Sahan and the public services (School, Library, and Shops). The relation between the Sahan and the public services is direct also. The relation between Assafah Square and the prayer hall is indirect (two steps away). That indicates the centralization of the Sahan and its role in distributing the movement in the masjid. Figure 4

shows the Maximum Depth (MxD) that will determine the relationship between Imam Turki Bin Abdullah Grand Masjid spaces according to the zone (private and public) and movement.

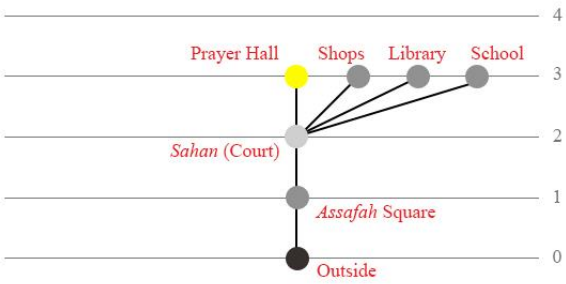
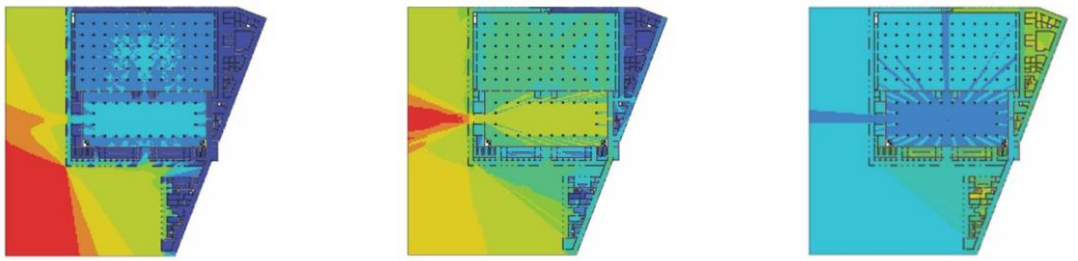


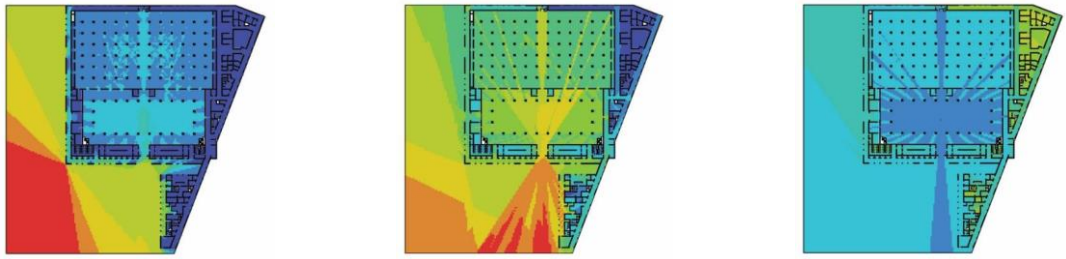
Figure 4: The MxD and the relation between the spaces of Imam Turki Bin Abdullah Grand Masjid.

The other VGA was done during the active-COVID-19 period on Imam Turki Bin Abdullah Grand Masjid's in two possible scenarios. The first scenario analyzed the Connectivity level, Integration level, Step Depth after closing the main entrance (Table 4) (Figure 5), and the second scenario analysis after closing the side entrance (Figure 6), noting that the emergency exits are closed in both scenarios.



(a) (b) (c)

Figure 5: The syntactic analysis of the ground floor of Imam Turki Bin Abdullah Grand Masjid in the first scenario. From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.



(a) (b) (c)

Figure 6: The syntactic analysis of the ground floor of Imam Turki Bin Abdullah Grand Masjid in the second scenario. From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.

Assafah Square has the highest connectivity level in both scenarios, as shown in Figure 5 (a) and Figure 6 (a). Figure 5 (b) shows that after closing the main entrance, the integration becomes centered at the side entrance only. On the other hand, Figure 6 (b) shows that *Assafah* Square becomes the most integrated space after closing the side entrance. The

level of integration is distributed unequally in the space. However, the unequal distribution lowers the crowdedness at the main entrance. There is a linear gradation in the visual integration level from *Assafah* Square to the prayer hall in both scenarios, emphasizing the importance of *Sahan* in the masjid design. Figure 5 (c) and Figure 6 (c) shows that the number of steps to cover the entire area has increased in both scenarios compared to the result of the pre-COVID-19 period.

The findings of the VGA of Imam Turki Bin Abdullah Grand Masjid in its initial status indicate that the average Connectivity level was 5352.47; this amount was reduced by 1.8%, and the average of Visual Integration was 11.1621, reduced by 29.7% in the first scenario (Figure 7,8). In the second scenario, the Connectivity average reduced by 1.8%, and Visual Integration reduced by 29.9% (Figure 7,8). This result shows that closing the main entrance or the second entrance will have almost the same significant effect on decreasing the accessibility and spatial integration of Imam Turki Bin Abdullah Grand Masjid and its surrounding. However, supporting the masjid with *Sahan* played a significant role in organizing the movement either at entering or exiting. Moreover, the availability of *Assafah* Square helps lowers the crowdedness at the gates. Figure 9 clarifies the level of accessibility and spatial integration of Imam Turki Bin Abdullah Grand Masjid before and after COVID-19.

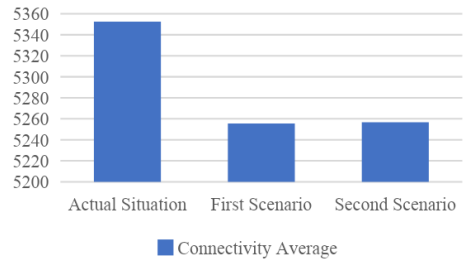


Figure 7: Comparison of Connectivity level before and after COVID-19 in Imam Turki Bin Abdullah Grand Masjid

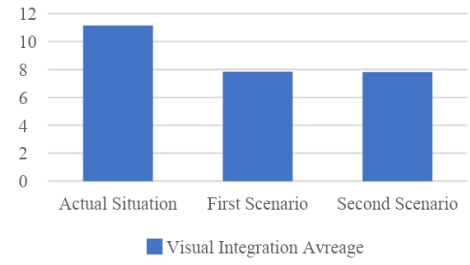


Figure 8: Comparison of Visual Integration level before and after COVID-19 in Imam Turki Bin Abdullah Grand Masjid

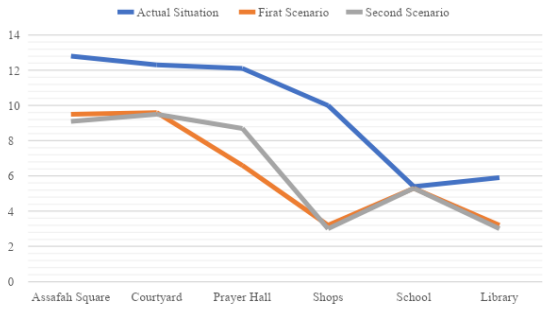
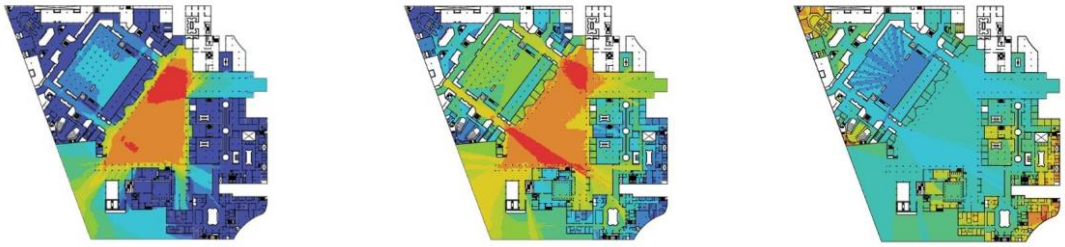


Figure 9: Comparison of the level of the accessibility and spatial integration of the Masjid in before and after COVID-19 in Imam Turki Bin Abdullah Grand Masjid

Alkindy Square Masjid

Alkindy Square Masjid is one of the most prominent and vital elements in the diplomatic quarter in Riyadh. The masjid design aims to preserve the traditional links of masjid by connecting it with public services. Alkindy Square Masjid is a focal point for the surrounding residential area and is integrated with the fabric both socially and physically. Alkindy Square Masjid's context consists of Alkindy Square connected to the *Sahan*, main prayer halls, library, lecture hall, and shops.

The findings from Alkindy Square Masjid's analysis done by DepthmapX software calculate the Connectivity level, Visual Integration level, and Visual Step Depth (Figure 10).



(a) (b) (c)

Figure 10: The syntactic analysis of the ground floor of Alkindy Square Masjid.
From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.

According to DepthmapX software results, there is a central gradation in connectivity and visual integration level on Alkindy Square Masjid. Alkindy Square serves as a distributing point, moving people in and around the masjid. Alkindy Square has the highest connectivity level, which is centralized on the right side of the Square, as shown in Figure 10 (a). Also, Alkindy Square has a high level of integration distributed equally on both sides, right and left of the Square, as shown in Figure 10 (b). This distributing point helps to control the movement and prevents crowdedness at the masjid's gates. Figure 10 (c) clarifies the number of steps to cover the entire area, clarifying the relations between the

masjid spaces. According to the results, Alkindy Square directly relates to the *Sahan* and shops (one step away). There is also a direct relationship between the *Sahan* and prayer halls (one step away).

On the other hand, the relation between Alkindy Square and the lecture hall and library are indirect (from three to four steps away), and the relation between the *Sahan* and the lecture hall and library are indirect (from two to three steps away). Also, the relation between Alkindy Square and the prayer hall is indirect (two steps away). That indicates the centralization of the *Sahan* and its role in distributing the movement in the masjid, moving people from a public zone to a private zone. Figure 11 shows the MxD that determines the relationship between Alkindy Square Masjid spaces according to the zone (private and public) and movement.

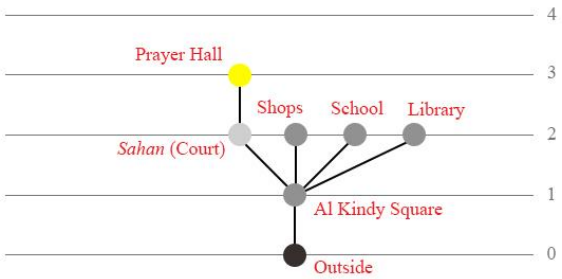
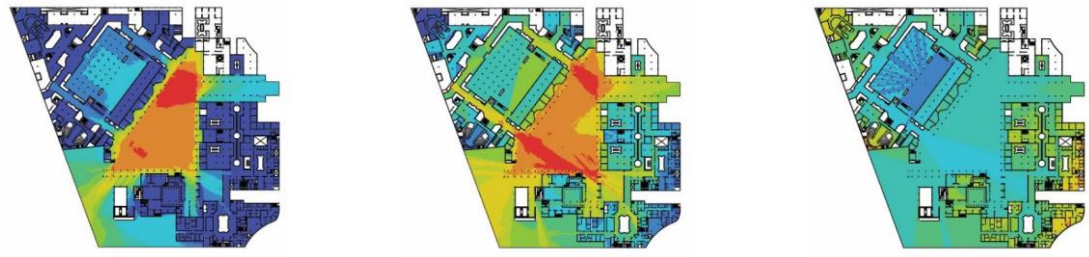


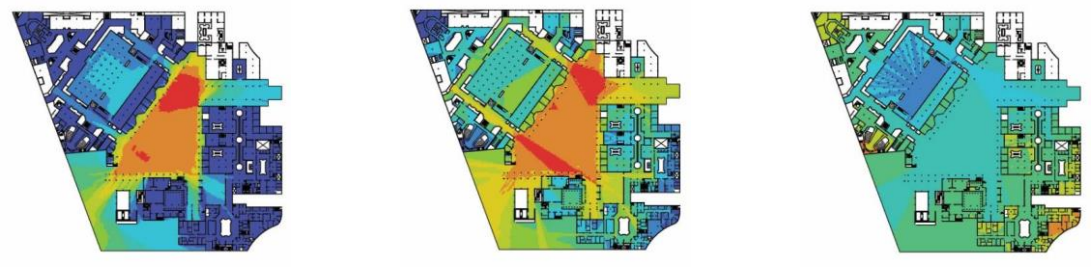
Figure 11: The MxD and the relation between the spaces of Alkindy Square Masjid.

Likewise, the other VGA was done during the active-COVID-19 period on Alkindy Square Masjid's in two possible scenarios. The first scenario analyzed the Connectivity level, Integration level, Step Depth after closing the right entrance (Figure 12), and the second scenario analysis after closing the left entrance (Figure 13), noting that the emergency exits are closed in both scenarios.



(a) (b) (c)

Figure 12: The syntactic analysis of the ground floor of Alkindy Square Masjid in the first scenario. From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.



(a) (b) (c)

Figure 13: The syntactic analysis of the ground floor of Alkindy Square Masjid in the second scenario. From left to right, (a) Connectivity, (b) Visual Integration, and (c) Visual Step Depth graphs.

According to the results, closing the right entrance or the left entrance does not significantly affect the Connectivity, Visual Integration, and Visual Step Depth. As shown in Figure 12 (a) and Figure 13 (a), the right side of Alkindy Square still has the highest connectivity level in both scenarios. Figure 12 (b) and Figure 13 (b) show that the integration level is distributed equally on both sides of Alkindy Square, which helps to control the crowdedness at the entrances. There is a central gradation in the Visual Integration level from Alkindy Square to the prayer hall on both scenarios indicating the importance of *Sahan* in the masjid design. Figure 12 (c) and Figure 13 (c) shows that the number of steps to cover the entire area has increased in both scenarios compared to the result of the pre-COVID-19 period.

The findings VGA of Alkindy Square Masjid in its initial status indicate that the average Connectivity level was 1953.41; this amount was reduced by 0.2%, and the average of Visual Integration was 5.13958, reduced by 3.9% % in the first scenario (Figure 14,15). Also, in the second scenario, the Connectivity average reduced by 0.2%, and Visual Integration reduced by 4.5% (Figure 14,15). Both scenarios have a low chance of affecting the accessibility and spatial integration in Alkindy Square Masjid. This result emphasizes the benefit of the centralization of the Square in the masjid context. Figure 16 clarifies the level of accessibility and spatial integration of Alkindy Square Masjid before and after COVID-19.

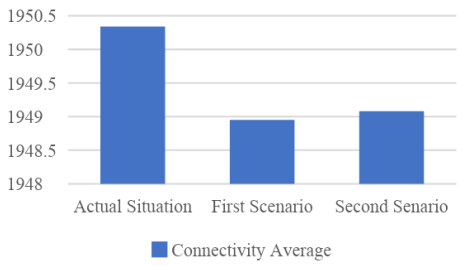


Figure 14: Comparison of Connectivity level before and after COVID-19 in Alkindy Square Masjid

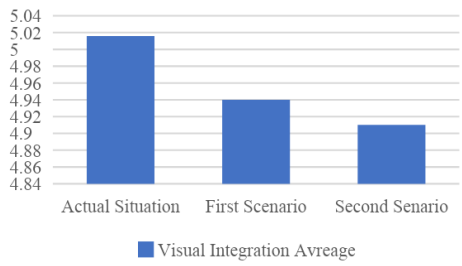


Figure 15: Comparison of Visual Integration level before and after COVID-19 in Alkindy Square Masjid

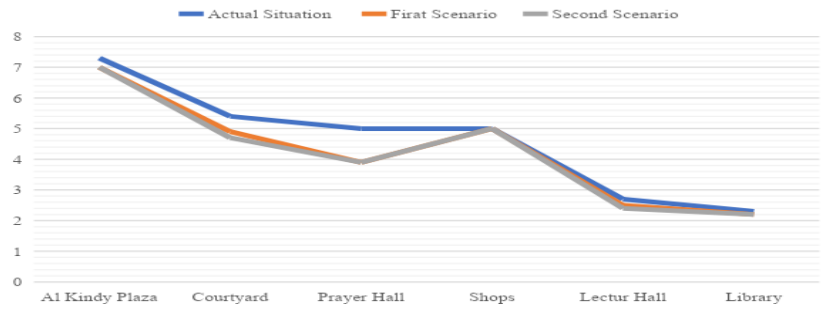


Figure 16: Comparison of the level of the accessibility and spatial integration of the Masjid in before and after COVID-19 in Alkindy Square Masjid

Based on the results from the VGA of the two case studies before COVID-19, we concluded that the Connectivity level in the Imam Turki Bin Abdullah Grand Masjid (Linear movement) is concentrated in the middle of the Square. The Square, therefore, serves as a focal point controlling the flow of movement in one direction to the masjid. However, in Alkindy Square Masjid (central movement), the Connectivity level in the Square is concentrated in the areas leading to the services. In this design, the Square serves as a distribution point diffusing, the movement direction of the people. The distribution of the Visual Integration level in both Masjids aids in directing the movement toward Masjids' gates. The Visual Step Depth in Imam Turki Bin Abdullah Grand Masjid was lower than Alkindy Square Masjid because of the difference between the movement design (linear or central) (Table 3,6). Despite the fact that both Masjids have the same public services, Alkindy Square Masjid has a high number of Visual Step Depth because of the central movement in the masjid.

The MxD of both Masjids was at the same level (Figure 4,11). The *Sahan* in the linear movement design is a distribution point to the masjids and its surrounding area (Figure 4), but in the central movement design, the *Sahan* is a transitional point from the public area to the private area, providing more privacy to the prayer halls (Figure 11)

In the active-COVID-19 scenarios of Imam Turki Bin Abdullah Grand Masjid, the accessibility and spatial integration were significantly affected by COVID-19 safety precautions (Figure 9). On the other hand, COVID-19 safety precautions hardly affect the accessibility and spatial integration in Alkindu Square Masjid (Figure 16). The central movement design is more efficient with the implementation of the safety precautions during the COVID-19 pandemic.

In both scenarios before and after COVID-19, the *Sahan* played a significant role in connecting the masjid spaces visually and physically. The *Sahan* is a fundamental element in

the masjid, must be taking into consideration when designing masjids with the similar condition of these two cases. The Square was a supporting element to the *Sahan*; it helped in minimizing the crowdedness and therefore better control of movement at main entrances.

Conclusion

This study evaluated the accessibility and Spatial Integration of Masjids in Saudi Arabia using Space Syntax. A simulation technique was applied to measure a Masjid's compatibility and its surroundings in terms of circulation, proportions of major spaces, spatial arrangements, and utilization of entrances before and after the pandemic of COVID-19.

The results of the two case studies found that the gradation movement between the areas due to the existence of *Sahan* in the masjid has facilitated accessibility and Spatial Integration. To be specific, the results pointed out the importance of the *Sahan* area in masjids similar to these case studies. In addition to its role as a transitional point from one zone to another, it helped minimize the crowdedness at the prayer hall entrance and regulate the flow of people. It was also observed that the existence of the masjid Square helped in distributing the flow of people to the main gates of the masjid.

It is important to acknowledge that Space syntax is a unique technique linking space and society. It helps to understand the environment in a particular context and analyze the flow of the movement in that environment through estimating where people are and how they move within the context. The authors suggested using the space syntax technique during the design process phase to evaluate and enhance the design before the application phase.

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