



## **SUSTAINABILITY RELATIONSHIP BETWEEN SPACE CONFIGURATION, ACTIVITY PATTERNS, AND MOSQUE ACOUSTICS QUALITY**

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### **Nur Rahmawati Syamsiyah**

Architecture Department of Engineering Faculty, Universitas Muhammadiyah Surakarta Indonesia

#### **Corresponding Author:**

[nur\\_rahmawati@ums.ac.id](mailto:nur_rahmawati@ums.ac.id)

### **Atyanto Dharoko**

Architecture Department of Engineering Faculty, Universitas Gadjah Mada Yogyakarta Indonesia

### **Sentagi Sesotya Utami**

Physics Department of Engineering Faculty, Universitas Gadjah Mada Yogyakarta Indonesia

### **Afizah Ayob**

Faculty of Civil Engineering Technology, Universiti Malaysia Perlis, Malaysia

### **ABSTRACT**

The Great Mosque of Yogyakarta was built in 1773. This mosque has a traditional architectural style. This study investigates the relationship between the mosque's architectural form, the activities inside it, and its acoustic characteristics. It employed quantitative and qualitative methods, including sound pressure level (SPL) measurement, reverberation time, and architectural and activity observations. Acoustic measurements, architectural observations, and activities are conducted inside and outside the mosque from morning to night for one week. The research finding is a spatial continuity pattern identified as the gradation of SPL value. Consistent continuity of SPL values in accordance with the nature of activities hierarchy. The result of this study is to improve mosque noise control by arranging outdoor and indoor spaces in a sustainable manner.

### **KEYWORDS:**

Acoustics Quality; Hierarchy; Spatial Configuration; Continuity of Space; Mosque; Sustainable Architecture

## **INTRODUCTION**

Space in architecture has values, properties, and meanings. The basic nature of space is determined by its boundary, which separates the outside and the inside. The description of the quality of exterior and interior space is not limited to physical elements such as geometric shapes, broad, narrow, low, high, and so on, but rather each space must display a complete 'cultural image' through proportions, light penetration, acceleration, acoustics, structure and interior arrangement [1]. Each space has a character according to the cultural image displayed. Similarly, the space in a mosque must have a calm character and a solemn atmosphere, which can make anyone concentrate inside. The mosque is not just a place of worship but must have the value of majesty and appreciation of the divine presence [2]. The mosque must have an atmosphere that can form the behavior of pilgrims always subject to and obeying God.

The concept of space can be tangible and intangible. The real concept of space is tangible elements of space, consisting of lines, fields, colors, and textures that are composed according to the function of space [3]. Meanwhile, the intangible concept is in the interaction between actors and spatial elements. The effect of the performance of spatial elements can be felt by humans, such as echo

sounds, as the impact of spatial elements in reflecting sound. Sound effects that are formed in a mosque room, for example, will provide information, how the performance of elements of space and human conditions in the mosque. Space elements include the geometry of floors, walls, ceilings, and finishing materials. The human condition includes activities and the number of activity actors. The acoustic phenomena in mosques formed as a result of interactions between space performance and human activities will indicate whether the mosque's rooms reflect sound or absorb sound. This information provides clarity that soundless architecture will be meaningless. It is very understandable because psychologically, the sound effects formed will affect someone's behavior, including behavior in architectural action. It has been understood that a mosque, where the main activity of worship at the mosque, is prayer, which is very dependent on the voice of the prayer leader or imam. The worshipers need the imam's voice as an order for the prayer movement and a religious message that must be heard.

Mosques in the world have various forms. The mosque is built based on local community knowledge and has a strong local character. It can be called a traditional mosque or an ancient mosque. Generally, this traditional mosque is preserved because it was built before the 20th century [4]. This mosque differs

from more modern and futuristic mosques, whose form is sometimes incompatible with the local community's culture. Aristotle interpreted space and place in traditional concepts as a flowing quality. Something that flows can be tangible or intangible. They can be activities and objects that are observed or the form of sounds that are not observed but can be felt or heard [5]. Even Aydin, Yalzd, and Siramkaya [6] said that it is essential that traditional buildings are still conserved to be used to maintain the sustainability of the past socio-cultural life. Transferring cultural heritage and experience from the past to future generations is an inseparable part of our modern social responsibility and a condition for social progress.

Traditional mosques are interesting objects to study because there is usually something tangible in the form of space and its elements, as well as an intangible form like sound, which is unique and different from modern mosques. Sound effects arising from a preserved building or region (building heritage or urban heritage) are included in the category of intangible cultural heritage [7]. This research used The Great Mosque of Yogyakarta as the object, a royal mosque built in 1773. The structure and construction of this mosque have not changed significantly since it was built (see figure 1). Another interesting thing to study is the function of the mosque, which is not only for prayer, but the mosque yard also functions as a place for public activities. Community social activities occur every day, such as trading food and drinks, a place of interaction for elementary school students, the place where picking up students, drum band exercises, sports, and at certain times holding religious rituals. These activities are all local and characteristic of this mosque.



Figure 1. Yogyakarta Grand Mosque: (a) the mosque is unique in the past (1925), and (b) the mosque still looks the same now (2019)

The routine activities that take place are exciting to investigate. As a result, this research aims to determine the noise level generated by these routine activities, also the connection between spatial formation and acoustic quality. These acoustic characteristics are related to space configuration, ritual worship events, social events, and historical events that occur regularly. In this study, the formation of the mosque space has a temporal dimension, which means the activity time in specific periods and periods that occur every day. The two time periods have naturally different activities, which affect the configuration of the spatial pattern and its acoustic properties.

As a religious building, the mosque prioritizes the cultural image of space supporting the convenience of worship. Sound aspects must keep the comfort of activities inside mosques, the geometrical shape of the room influences audial comfort in the mosque. Several studies related to the geometrical shape of the mosque's space resulted in the finding that the angular shape of the room gives effect the acoustic quality better than the near-circle shape, such as an octagon which is a terrible effect on the quality of the room acoustics [8]. The geometrical shape of the space, including the mosque's roof, and the flat shape of the roof is of better acoustic quality than a conical roof [9] [10]. It contrasts with the research by Syamsiyah et al. [11], where the roof of the pyramid as a form of Traditional Javanese Architecture, has a good effect on the acoustic quality of space [11].

Meanwhile, the dome shape gives an acoustic quality effect which is not very good, even the concentration of the voice occurs [12]. However, several studies on the acoustic quality of mosque spaces with multi-dome Ottoman periods in Turkey (see figure 2) still provide good acoustic effects [10] [13]. Dome-roofed mosques must consider falling sound that is focused according to the height of the listener's ear position [14].

The geometrical shape of the mosque pays attention to not only size but also the completion of elements in the interior space [15] [16]. Modern mosques generally prioritize the design and use of luxury finishing materials, such as granite, marble on the floor, and glass walls. Still, the material is bad in acoustic quality [15]. Meanwhile, traditional mosques use more wood and brick material for finishing walls, ceilings, and floor elements, generally using tiles and carpets, and have a good effect on the acoustic aspect. Traditional mosques were built before the 20th century and are preserved until now. Traditional mosques usually have closed, gloomy, dark, and contemplative spaces in them [17]. The use of appropriate spatial elements and materials supports closed and contemplative characteristics. Thus, the comfort of the atmosphere is formed [8]. The addition of mosque components, such as the pulpit or mihrab room niches, apparently did not affect the formation of acoustic characteristics. The finishing material of the spatial element is most clearly given the cultural effect of space.



Figure 2. Multi-dome mosque of Ottoman Periods in Turkey

Recent research by Elkhateeb et al. [18] found that each mosque space can be distinguished because it has the characteristics of the geometric shape of the mosque, the nature of the sound sources used in the mosque, and the effect of the behavior of worshipers in a mosque [18]. The mosque must have an atmosphere that can form the behavior of pilgrims always subject to and obeying God. Therefore, it is closely related to the meaning of space. As Rasmussen said, architecture and sound are different, but both require the enrichment of the five senses [19]. Both are needed to produce audial beauty that can support worship activities. Sound exists in architectural compositions, which can be enjoyed audibly or visually [19] [20].

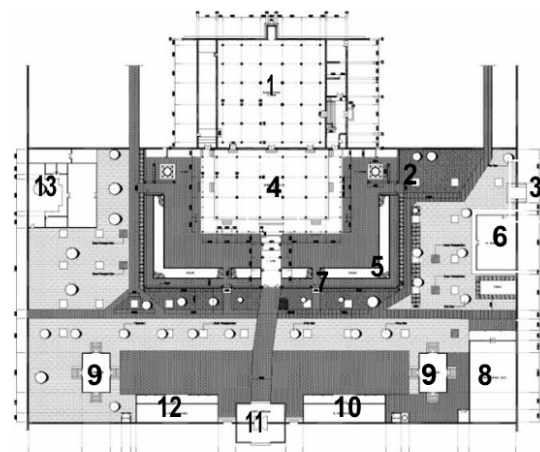
The spatial configuration of mosque spaces based on acoustic characteristics is interesting to study. It is based on connectivity, constituents of spatial depth, and level of control in different mosques compared to other places of worship such as churches or temples. B. M. Reza, J. Matin, and A. Samira [21] argue that a mosque's level of connectivity and level of control is high, and the depth constituents of space are low [21]. While the church or temple is the opposite. It is due to the entire mosque space, and even the courtyard is a sacred place and can be used for prayer, while churches and temples are only interior spaces that can be used for prayer. The opinion of B. M. Reza et al. [21] increasingly clearly supports that it turns out that acoustic quality is essential to be studied and its influence on the configuration of mosque spaces [21]. If praying can be done on the terrace or even the mosque yard, while the spaces are not quiet, then the formation of spatial configuration based on connectivity, depth of space, and level of control of space in the Great Mosque of Yogyakarta to be interesting to study.

## METHODS

This research used a mixture of quantitative and qualitative methods. The quantitative research variable is the value of background noise or sound pressure level (SPL) outside the mosque. The standard follows ISO 12931-1-2014 about soundscape, where the sounds to be measured are natural sounds and human activities. In addition, measurement procedures according to ISO 1996-3 about noise (procedures, systems, techniques for measuring noise, and analytical methods).

### CASE STUDY OF THE GREAT MOSQUE OF YOGYAKARTA

The Great Mosque of Yogyakarta is a royal mosque located in the palace. Everyone can access the mosque easily because the mosque is in an open area and has transportation routes. The mosque's landscape consists of the yard outside the mosque fence, the yard inside the mosque fence, and the building itself. The mosque consists of a terrace, the main building, and buildings for ablutions. The mosque is a building complex consisting of social service buildings that still function today (see figure 3).



- |                            |  |
|----------------------------|--|
| 1. Main room of the mosque | 8. Building of sport                             |
| 2. Place of ablution       | 9. Place for storing gamelan (traditional music) |
| 3. North gate              | 10. Social serving building                      |
| 4. Terrace                 | 11. Main gate                                    |
| 5. Pool and fountain       | 12. Social serving building                      |
| 6. Secretariat             | 13. Library                                      |
| 7. Fence of the mosque     |  |

Figure 3. Site plan of Great Mosque of Yogyakarta

The purpose of the measurement is to get the SPL from natural sounds and human activities. Meanwhile, the SPL value in the mosque space is 51.8 dB [22].

### RESEARCH INSTRUMENTS

Retrieval of objective data using H6zoom measurement tools. Data calculation using the Adobe Audacity program. The analysis process is done by mapping the acoustics of the Surfer Mapping System program v.11. Subjective data is taken by interviewing and observing the architecture and behavior of worshipers. In-depth interviews were carried out

mainly with adult visitors between 17-55 years old, totaling 72 people, consisting of 40 men and 32 women. In addition, a total of 50 people were respondents of mosque worshipers who regularly came to the mosque and 22 architecture students who, on the average first time, came to field research but understood acoustics. These respondents gave an acoustic quality assessment in all parts of the mosque (inside and outside the room).

Interviews were conducted freely, relating to background, experience, opinions, feelings, and knowledge relating to the convenience of worship activities in the mosque, both physical and auidal comfort [23].

**OBSERVATION**

The first analysis instrument is observation. Systematic observations were made on the worshipers' behavior, including the activity type and period and the space in which they are active (outside and inside the yard, terrace, and mosque). Intensive observations were made during the last ten days of Ramadan when worshipers almost filled the mosque daily. Observation considers temporal-spatial. The observation was done 24 hours, with data reading at 06.00, 11.30, 21.30, 23.00, 01.30, and 03.30. At this time, the worshipers have individual activities, such as reading the Qur'an, prayers, and communal activities, like listening to the reading of the Qur'an, and discussion.

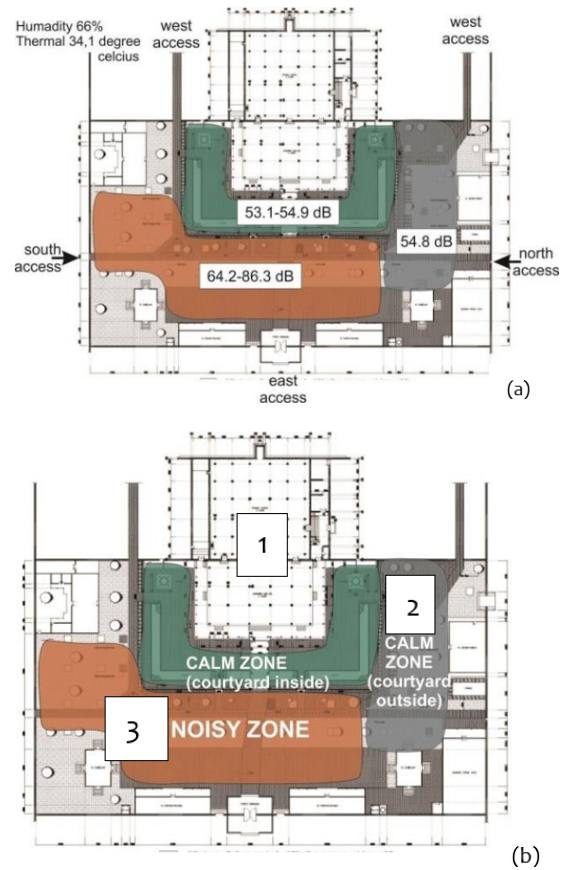
**RESULT AND DISCUSSION**

**ACOUSTIC CHARACTERISTICS**

The outside space of the mosque has background noise or SPL value exceeding the noise tolerance of 55.0 dB, which reaches 64.7-68.1 dB; even during the day when school is over, the noise reaches 86.3 dB. The noisy zone is on the southeast side of the mosque. Meanwhile, the north side of the mosque is still below the noise limit, which is a quiet zone, 54.8 dB. According to the requirements, the mosque's inside courtyard in all parts is a quiet zone, below the noise limit, of 53.1-54.9 dB (see figure 4). Noise in the courtyard of the mosque was reduced by the presence of fences, the distance between noise sources and receivers, the presence of vegetation, and the shape of the porch proportion that seemed to be closed, so the noise reduction was very significant, reaching 27.5 dB [22].

The highest noise comes from students running while screaming when they get school over. Parents also participate in creating noise by sounding the motor brakes and honking. The crowded atmosphere outside the mosque fence is interesting to study because there is exciting social interaction. Some students buy food and drinks; they joke; some traders hit the plates as a sign of peddling their wares; there are mothers gathered in one of the stalls, and they use the time waiting for social gatherings. There are also students running around playing ball while waiting for the pickers-up. Noise is concentrated on the southeast

side of the mosque because the access to pick up students or people who pass in the yard is on the south side of the mosque. The other three sides of the high wall surrounding the mosque complex also have doors (see figure 5). Access to and from the mosque courtyard is one of the causes of noise and local acoustic character.



- 1. Private zone (calm zone at a mosque inside)
- 2. Semi-public zone (calm zone courtyard inside and porch)
- 3. Public zone (noisy zone courtyard outside)

Figure 4. (a) Value of background noise, and (b) the zoning of the mosque based on SPL value or background noise value

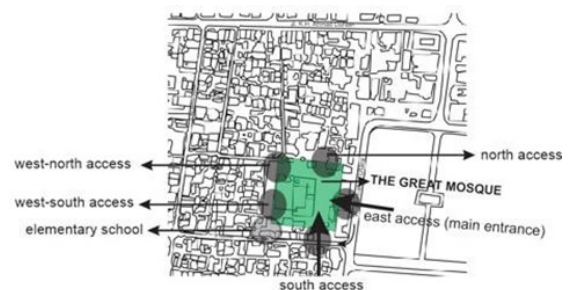


Figure 5. Access to the mosque courtyard from the five sides of the mosque wall fence

### MOSQUE ARCHITECTURAL LOCALITY

Mosque architecture must provide awareness for worshipers in glorifying God, individually and communally. The creation of a meditative atmosphere in the process of praising God can be formed by traditional Javanese architecture. The main prayer room of Javanese architecture has many poles, which creates personal space. The pole in the mosque is not just a reinforcing structure but also a place for worshipers or a permanent center of space for individual worshipers that can personally form the human spatial to perform worship activities more fervently [5]. Worshiper shows behavior that the pillar and its surroundings become his territorial space.

The conical roof of the mosque symbolizes a symbol of grandeur. The presence of symbols can help humans to realize the presence of something sacred [24]. Acoustically the conical shape of the roof results in a long reverberation time of  $T_{30}$ . Kasim counts  $T_{30}$  for up to 5 seconds when the room is empty [9]. Kavraz has the same opinion [10]. However, the Great Mosque of Yogyakarta has a value of  $T_{30}$  1.49. The acquisition of a short period is greatly assisted by the carpet of the floor and wooden ceiling. An area of 34.4% floors and 53.2% ceilings helps absorption [22]. Floor material made of marble covered with carpet. Orfali proposes that it is coated with foam rubber to have high absorption [25]. However, the Great Mosque of Yogyakarta uses carpet without a layer of foam rubber, providing reverberation time to meet the ideal standards. Likewise, the presence of mihrab inside the mosque does not affect the value of acoustic parameters. The finding research on mihrab conducted by Othman said there is no effect of different forms of mihrab toward an acoustic quality in traditional mosques in Malaysia [14].

### SPACE AND ACTIVITY CONFIGURATION

Mosque space is a means to transmit 'something' through the media between humans and the environment. The activity begins with the gate entering the mosque area, and Bollnow calls it a landscape [5]. Starting from here, the religious atmosphere is felt as a medium that will make the heart and soul solemn. Continued activities related to open space in the inner court and terrace are called the environment. The meditative atmosphere has begun to form here. The surrounding noise will not sway the heart and soul power of the solemn. It is very much in accordance with the spatial configuration of the mosque according to B. M. Reza, J. Matin, and A. Samira [21], where the level of connectivity and level of control of the Great Mosque is high, and the constituents in the depth of space are low. The mosque has a very simple space, like traditional mosques in general. The simple spatial arrangement, where there is the main room, is sacred. A profane supporting space is in the north and south of the main room and on the east side. The entire room can be accessed by pilgrims easily. The connectivity of pilgrims with all parts of the mosque space is high. All spaces are open, so the level of control is high. The activities'

connectivity and the pilgrims' perception of space make each pilgrim can form their religious atmosphere in all rooms in the mosque, inside and outside. Pilgrims can pray in all parts of the mosque, the main hall, the porch, and even the yard, as long as the place of prostration is clean and sacred. Even though all parts can be used for prayer, the mosque's main room is where the human senses and human sensors function optimally because, according to Bollnow [5], that's where the human body is the main domain.

Bollnow further interpreted space and place in the traditional concept as a kind of 'flowing quality' [5]. Something that 'flows' can be tangible or not can be activities and objects that are observed or the form of sounds or not observed, but it can be felt/heard. This understanding gives meaning to the mosque in this study, namely that people who will perform worship activities in traditional architecture mosques will experience an activity that is flowing and patterned. Space or form of objects as a container of activity is a means to transmit 'something' through the media between humans and the environment. The activity starts from the gate entering the mosque area, or Bollnow calls it a landscape [5]. Starting from here, the religious atmosphere is felt as a medium that will shape the heart and soul to become solemn. He continued activities related to open space in the inner court and porch, which he called the environment. The meditative atmosphere has begun to form here. The power of the heart and soul fervently will not be swayed by the surrounding noise. Finally, the mosque's main room is where the human senses and sensors function because, according to Bollnow, the place is where the human body is the main domain. The connectivity of activities flows and is patterned to all parts of the mosque's space and cones towards a central point in the main hall of the mosque, as illustrated in Figures 6 and 7.



Figure 6. Spatial concept by Bollnow: place, environment, and landscape

Based on the acoustic characteristics shown in Figure 4 and the zone categorization analysis according to Figure 7, as a place, environment, and landscape zone, it can be seen that there is an accordance between the configuration of the space and the connectivity of the activity with the existing space. All activities, whether public, semi-public or especially private, have an orientation to space in the mosque. Whoever comes to the mosque they have prepared themselves physically and mentally to worship God. Suppose the worshiper's activities are traced from the beginning of entering the yard to

reach the main room. There will be an order and continuity of all activity and spatial in the meditative atmosphere in the outside space (the courtyard of the mosque) and the mosque's interior, which is expressed in hierarchies or levels based on spatial function, the form of activity, the principle of worship activity, traditional architecture, and nature of space (see Figure 8):

- a. Spatial functions: (1) public zones, (2) semi-public zones, and (3) private zones
- b. Forms of activity: (1) communal zones, (2) transition zones, and (3) personal zones
- c. The principle of worship activities: (1) worship is social and communal, (2) worship is individual and communal, (3) worship is individual worship to God
- d. The traditional architectural form of the mosque:
- e. The outside courtyard of the fence and inside the fence, (2) the mosque's terrace, and (3) the mosque's main hall.
- f. The nature of mosque spaces: (1) open, (2) semi-open, and (3) closed.

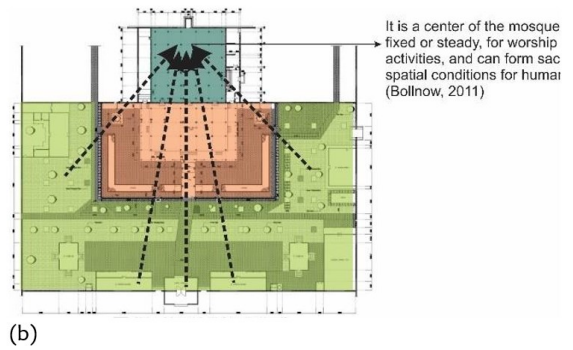
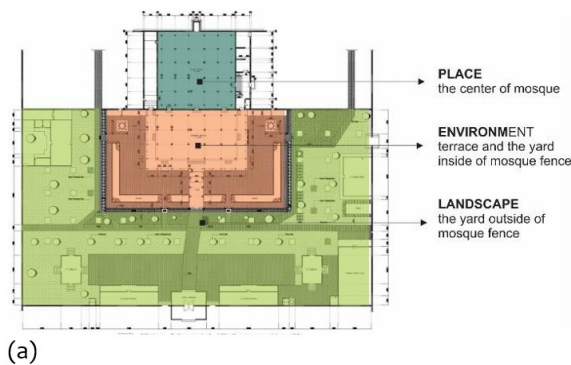


Figure 7. (a) Place, Environment, and Landscape at the Great Mosque of Yogyakarta; (b) main room of the mosque is the center of the configuration of space

The hierarchy or level is reflected in the height of the floor and its environment. The hierarchy reflects the regularity and continuity of spatial configurations, activities, and locality forms of traditional Javanese architecture, which are in accordance with acoustic characteristics. Regularity forms the concept of spatial continuity of the Great Mosque of Yogyakarta, assessed with a linear spatial pattern leading to the center of space in the mosque's main hall. The room's breadth and shape depend on the activities contained and traditional architectural design. It is very different from the Ottoman mosque, where the dome shape and construction system was an essential element in the spatial design during the 13th to 15th centuries. Dome construction can create a wide interior and diverse volume of space. The connectivity of pilgrims' activities and mosque space forms spatial configurations with circular and turning patterns. It is very different from the traditional Javanese mosque, like the Great Mosque of Yogyakarta. Spatial configuration forms a linear hierarchical pattern, and there is order and harmony between the acoustic characteristics in each space and the contained activities. The hierarchical pattern can be seen in figure 9.



(a)

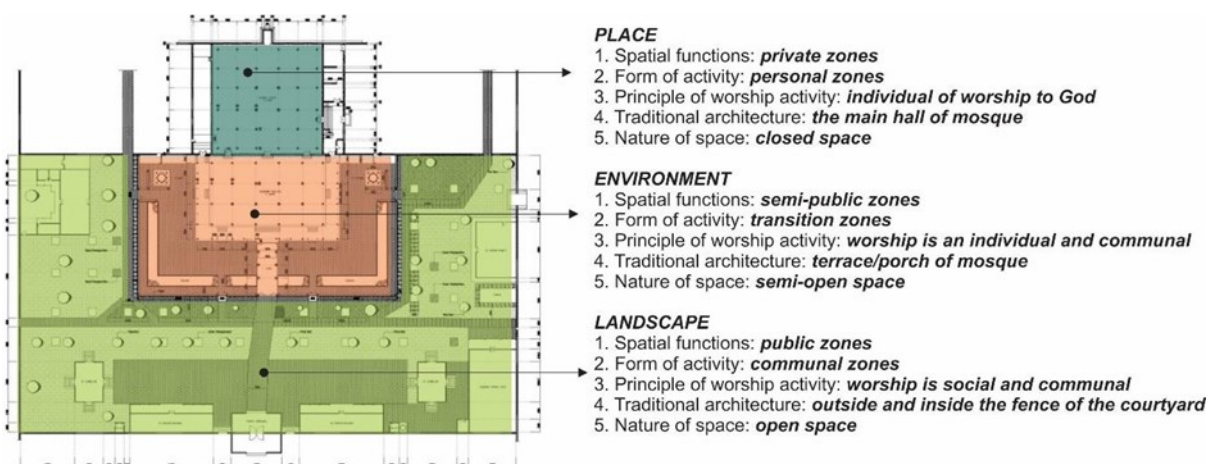


Figure 8. Spatial configuration and connectivity between activity and space of the mosque

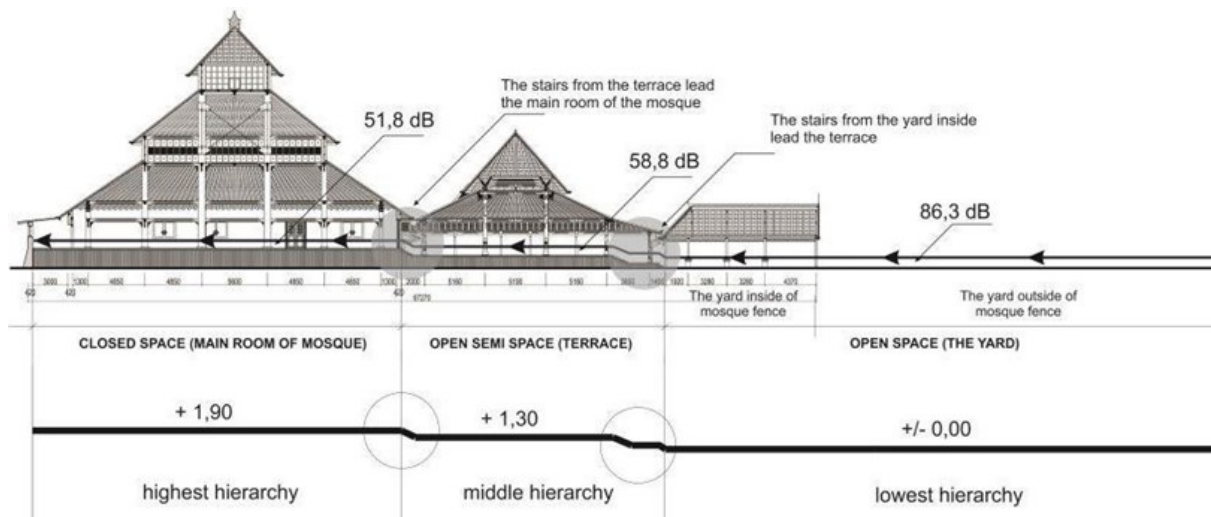


Figure 9. Continuity and hierarchy of space as the value of mosque space

## CONCLUSION

The spatial configuration of the Yogyakarta Great Mosque based on acoustic characteristics is the regularity of patterns, a form of gradual and continuous linear patterns. The outer space position of the mosque against the position of the space inside the mosque has openness. Activities in it are communal in the yard and terrace, and more social and cultural interaction takes place between mosque visitors. Meanwhile, the space in the mosque is a closed room and only for prayer. The activities in it are individual. Configuration of spatial patterns forms the continuity of space.

The variables that make up the spatial pattern continuity value of the Yogyakarta Great Mosque are sound variables and space variable. In sound variable, there is an acoustic zone of background noise or gradual of sound pressure level (SPL) starting from the courtyard of the mosque, around 86.3dB, inner court and terrace, around 58.8 dB, and the mosque's space, with a value of 51.8 dB. In the space variable, there is a gradual and sequential zonation on a regular basis (hierarchy) based on the nature of the activity (communal, communal and personal, and personal), function space (public, semi-public, and private), architectural characteristics of the mosque (open, semi-open, and closed), and the locality of the spatial pattern of the mosque area (outside the courtyard of the mosque, inner court and terrace, and main room in the mosque). The concept of continuity in the configuration of mosque spaces indicates the level of spatial, visual, and audial quality that can be implemented in acoustic space indoors and environmental planning outdoors.

Mosques with similar spatial layouts and environments, such as the Great Mosque of Yogyakarta, can be found throughout Indonesia. After learning from the Great Mosque of Yogyakarta, it can be followed by other traditional mosques to obtain the spatial pattern of mosques based on acoustic

sustainability characteristics. Further research will yield guidelines for mosque planning in the archipelago context.

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