

The Difference of the Surrounding Environment's Function Complexity on the Formation of Environmental Sound Character

Nur Rahmawati Syamsiyah*, Rini Hidayati, Dhani Mutiari, Wisnu Setiawan

Department of Architecture, Faculty of Engineering, Universitas Muhammadiyah Surakarta, A. Yani Street, Mendungan, Pabelan, Kartasura, Sukoharjo, Central Java, Indonesia

Received June 5, 2022; Revised September 5, 2022; Accepted October 25, 2022

Cite This Paper in the Following Citation Styles

(a): [1] Nur Rahmawati Syamsiyah, Rini Hidayati, Dhani Mutiari, Wisnu Setiawan, "The Difference of the Surrounding Environment's Function Complexity on the Formation of Environmental Sound Character," *Civil Engineering and Architecture*, Vol. 11, No. 1, pp. 401 - 411, 2023. DOI: 10.13189/cea.2023.110132.

(b): Nur Rahmawati Syamsiyah, Rini Hidayati, Dhani Mutiari, Wisnu Setiawan (2023). *The Difference of the Surrounding Environment's Function Complexity on the Formation of Environmental Sound Character*. *Civil Engineering and Architecture*, 11(1), 401 - 411. DOI: 10.13189/cea.2023.110132.

Copyright©2023 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

Abstract The development of Surakarta has shaped the urban spatial structure into two regions: the north and the south. Every region has royal mosques: the Grand Mosque in the north and the Al Wustho Mosque in the south. The Grand Mosque is located in the middle of the textile trade centre, while the Al Wustho mosque is in the middle of an educational area. This study used the two royal mosques to find the sound or acoustic character. The sound around the building will give the place identity and affect the building design. This study aims to reveal the differences in area character concerning mosques' environmental acoustic character using a soundscape approach. The research employed a sound pressure level measurement method, visitor's behaviour, interview, and descriptive analysis. The data reveal that high environmental function complexity is not always associated with a high noise impact, while low environmental function complexity is associated with a high noise impact. This study's findings highlight the importance of considering outdoor materials as a landscape component with a high noise absorption capacity. One of the research findings is that south beach sand has good acoustic performance in the environmental sound absorption process.

Keywords Acoustic Character, The Grand Mosque, Landscape Component, Soundscape Approach

1. Introduction

1.1. Environmental Sound as a Landscape Identity

Urban planning and sustainable development approach could contribute to shaping physical and non-physical living arrangements, which include environmental, social, and economic factors. Social, economic, and political-administrative processes manifest into patterns of urban spatial structure, land-use, and architectural character of buildings, which depict the image of the city (1). In most cases, land use is a priority that links to a city's sustainability. The land use of a particular part of a city often connects interdependently with other parts. For example, this influences the population's movement pattern regarding the economy, society, and culture, contributing to the area's development.

History has noted that the pattern of urban spatial structure and land use in the past was carefully planned (2), particularly in the context of a traditional city such as Surakarta. Surakarta, informally named Solo, is one of Indonesia's traditional heritage cities belonging to the ancient Mataram Kingdom. The urban structure pattern is divided into two regions, separated by an imaginary west-east axis through the city centre, and divides Surakarta into northern and southern parts. Each part demonstrates a clear land-use pattern, with a palace and a mosque appearing as centres. The south has the Kraton

Kasunanan and the Grand Mosque, while the north has the Mangkunegaran Palace and Al Wustho Mosque. The development of the city of Surakarta was also influenced by colonial development concepts, evidenced by the existence of several educational buildings, offices, and services dating back to the colonial era. The dynamics of the political field, i.e., the transfer of power from the colonial government to the Kraton, also influenced the urban spatial structure (1). In the 1900s, Surakarta became a modern city due to city infrastructure construction.

The intricacy of urban growth in later eras tends to have a negative impact on traditional identity and the natural environment. The city's traditional appearance has changed. For instance, the performance of several conventional structures, including the environmental sound system, has changed. Urban soundscape plays a crucial function in defining landscape identity; it is an integral part of the life of the natural environment (3). On the other hand, modern urban growth frequently disregards the influence of urbanization on the ambient soundscape. On the other hand, green planning development has acknowledged an integrated approach to land-use planning, urban development, urban traffic management, and quality of life, all of which involve noise reduction. This has provided interesting new perspectives for addressing modern urban developments. It is evident that the urban acoustic environment as a whole influences the quality of life of the population, so it is essential to research it in relation to the urbanization and development level of the area being monitored (4).

1.2. Soundscape

The common approach to measuring the quality of the area's sonic environment (soundscapes) involves the people's perceptions of the area (5). Soundscape allows people to better understand a place from the sound of nature that appears. The soundscape approach is important because it shows the relationship between spatial function elements (including ongoing activities), place identity (including building and area characteristics), and local culture (including perceptions and assessment of environmental sounds). Soundscapes can only be understood through people's perceptions (6). Soundscape presents to understand a condition that links to particular feelings and perceptions. The emerging sound heard by people would define the factors of characteristics or identity of a place and whether the continuity of audio comfort can be maintained or not. The soundscape approach's application becomes more challenging when associated with open spaces or public buildings areas, as there are different types of sound sources and sound pressure levels. Similarly, the interpretation of the mosque area's intangible cultural heritage through sound can be made using the soundscape method because it is a mediator between humans and the environment (7). The exploration of the soundscape element in this study focuses on the two

royal mosques in Surakarta, the Grand Mosque and Al Wustho Mosque. Both have distinctive sonic environments, yet they have a significant historical significance in the kingdom. Historical mosques often demonstrate a deep meaning of space, which involves intangible cultural heritage elements, including environmental sounds (8). In the past, mosques and their surroundings were still quiet, and sometimes they created a sacred impression on the mosque building. Nowadays, engine noise distractions and human voices, such as people talking, screaming, and footsteps, contribute to annoying sounds occurrence. The bustle of the city and people's movement is a form of urban spatial development. This situation somehow affects the sonic environment in the area of the two royal mosques.

It is generally understood that a mosque and other religious buildings require places with an excellent audio comfort level. The formation of the sonic environment of the mosque area and religious buildings, in general, starts from an outdoor space that provides a spiritual, relaxing, and calming atmosphere. In turn, this influences the visitors' emotions (9). The sound in the area shapes a sonic environment that gives visitors a distinct impression. The existence of environment around the mosque is very diverse. Moreover, prominent large mosques in the city are generally located in busy areas to be easily recognized and accessed. The environment around a royal mosque can be shaped by an active trading area or a touristic area. Consequently, the sonic environment is influenced by various sound levels and sources.

In addition to that, audio comfort in mosques is influenced by the geometric design of deep spaces (10), spatial planning, and finishing materials for spatial elements (10), (11). Meanwhile, preliminary research has focused on the comfort of the mosque's indoor audio performance influenced by the sonic environmental conditions outside. A study in the context of the traditional Javanese environment indicates that noise in a traditional mosque's courtyard did not affect the serenity in the mosque room and foyer (12). This phenomenon links to the geometry of the floor, the roof height of the mosque, and the distance between the barrier fence in the mosque yard. The proportion of floor-roof becomes a barrier for noise from the courtyard entering the mosque space. Sound-absorbing landscape components such as vegetation and pond water also provide an additional noise barrier. Even vegetation, namely banana leaf, is a natural landscape component that is effective in environmental absorption or control (13). In line with that finding, there is a strong correlation between the subjective value of environmental noise (listener perception) and the dominant type of sound source (14). The most disturbing sounds emerge from the sounds of machines. Studies in soundscape also acknowledge less disturbing noise from the sounds of nature, such as birds and fountains (12). The studies demonstrate the importance of the relationship between the surrounding physical environment around the mosque and the environment's characteristics. A mosque's physical

environment is formed by the relationship between soundscape elements, spatial functions, and place identity (15). Research focusing on acoustic performance outside the religious building becomes necessary because the sonic comfort and sound quality of the outside/outdoors would contribute to the building's indoor quality.

2. Materials and Methods

This study uses a mixed-method approach. Two different approaches were used to get more comprehensive findings. The mixed method has the advantages of more extensive, valid, reliable, and objective data and has a truth value (16). Qualitative and quantitative data were combined in a balanced manner (concurrent triangulation). The qualitative data provide a deeper understanding and a translator (interpretation) to the quantitative data (17).

The analysis is based on measurements of the dependent variable, sound, and the independent variable, physical environmental conditions. Sound Pressure Level (SPL) is used to measure the soundscape. Soundscape measurement consists of three main techniques: (1) measuring sound pressure levels with a Sound Level Meter (SLM) instrument, (2) recording sound and analyzing it along with environmental observation (recording sound with the spectrum analyzer H6Zoom instrument), and (3) measuring the visitor's subjective perception through questionnaires. Among the qualitative methods were the observation of landscape characteristics and activities, the documentation of historical evidence and urban development aspects, and the administration of a number of casual interviews. Figure 1 displays the whole data and its contribution to the research of soundscapes.

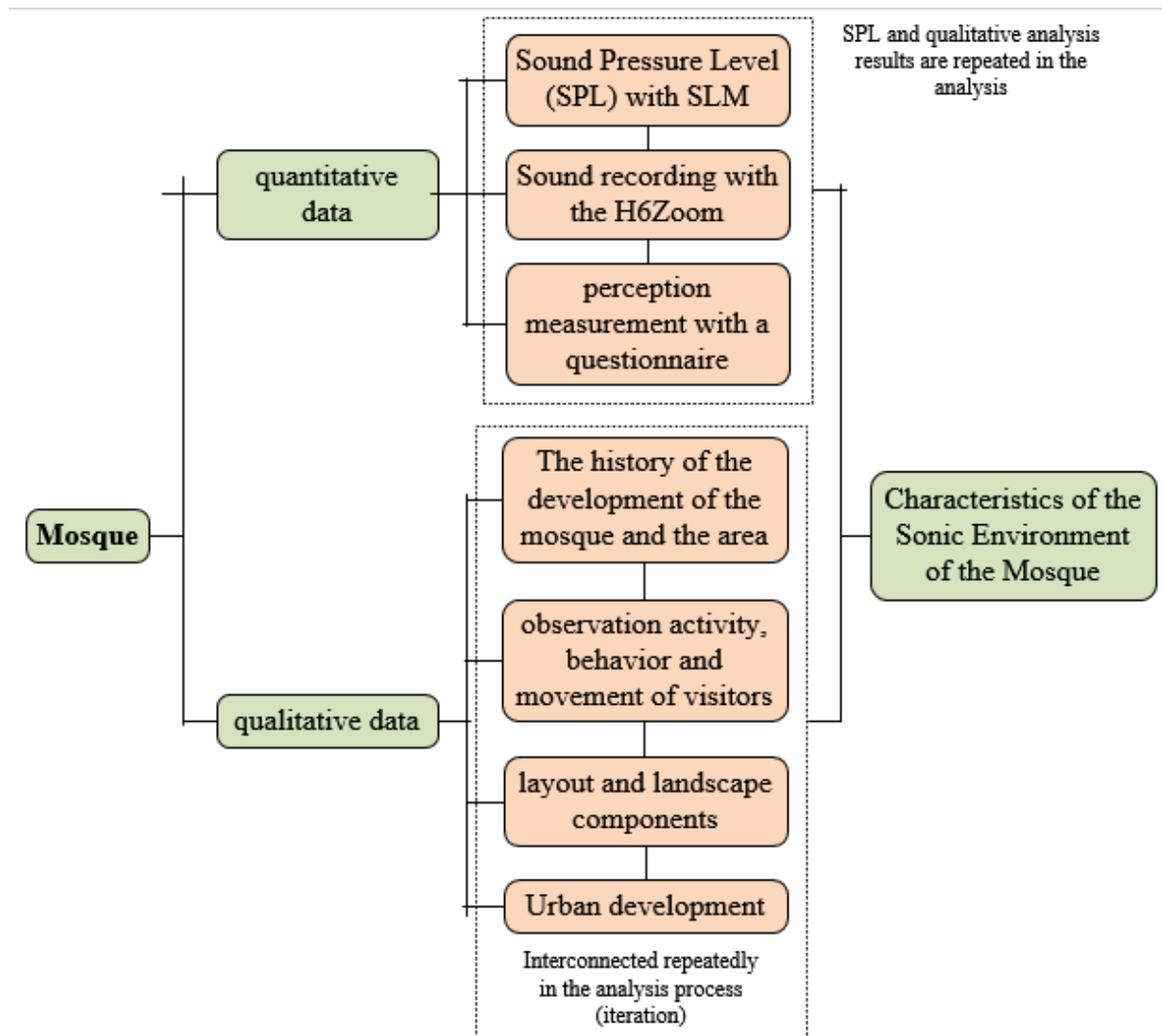


Figure 1. Schematic of research steps using qualitative and quantitative methods

Over the period of one week, from early morning to the late evening, quantitative data was collected using tools such as a sound level meter, anemometer, thermal hygrometer, and spectrum analyzer, and qualitative data were obtained using a questionnaire measuring instrument. The study limits the respondents from the age of 17 to 55 years. This age presumably has hearing ability in normal conditions (18). The study compared the data into two groups: 17-45 years old and 46-55. The ability to distinguish between age groups is based on the ability to hear sounds clearly. The questionnaire responses from both groups were then combined and averaged. The respondents' minimum educational background is high school and equivalent; they presumably can understand the research context. Since this study requires respondents to have good perceptual and spatial abilities in the context of a soundscape, the number of men and women respondents was balanced. Women respondents might have better fine motor coordination and perceptual capabilities than men; on the other hand, men have more capabilities than women in terms of spatial and scientific reasoning (19).

Soundscape measurements were carried out in the outdoor mosque area up to the yard fence. The courtyard area of the Grand Mosque is 7,644 m², and the courtyard area of the Al Wustho Mosque is 1,281 m² (20). The measuring point followed a grid pattern ten meters away from point to point at the Grand Mosque and a measuring point distance of 7.5 meters in the courtyard of the Al Wustho Mosque.

3. Result and Discussion

3.1. The Urban Soundscape around the Grand Mosque

The area surrounding the Grand Mosque could be considered to be a miniature of a city because it is surrounded by a government area (Kraton Kasunanan, the Palace), an economic area (three textile markets: Klewer, Solo Wholesale Center, and Beteng Trade Center), a religious area (Grand Mosque), and residential areas (Kauman Kampong). The contemporary development began in 1947; it grew into a clothing or textile trade centre integrated with the Kraton Kasunanan tourist area. This situation brings on the conditions of dense transportation movement and the people movement related to socio-cultural-economic activities. According to observations, the Great Mosque of Surakarta has become the centre of urban interaction. Architecturally, this is a unique urban spatial structure that develops based on socio-economic influences, technological developments, and the needs that arise from the population and the environment (21). Figure 2 shows the Great Mosque of Surakarta's existing condition within a radius of 300 meters, where commercial function buildings surround the Grand Mosque.

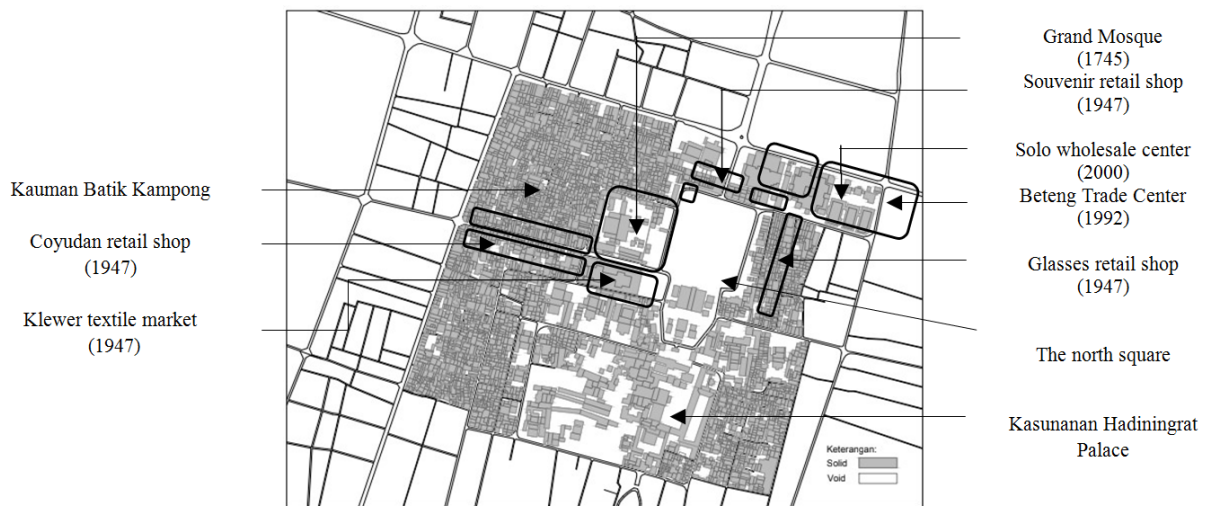
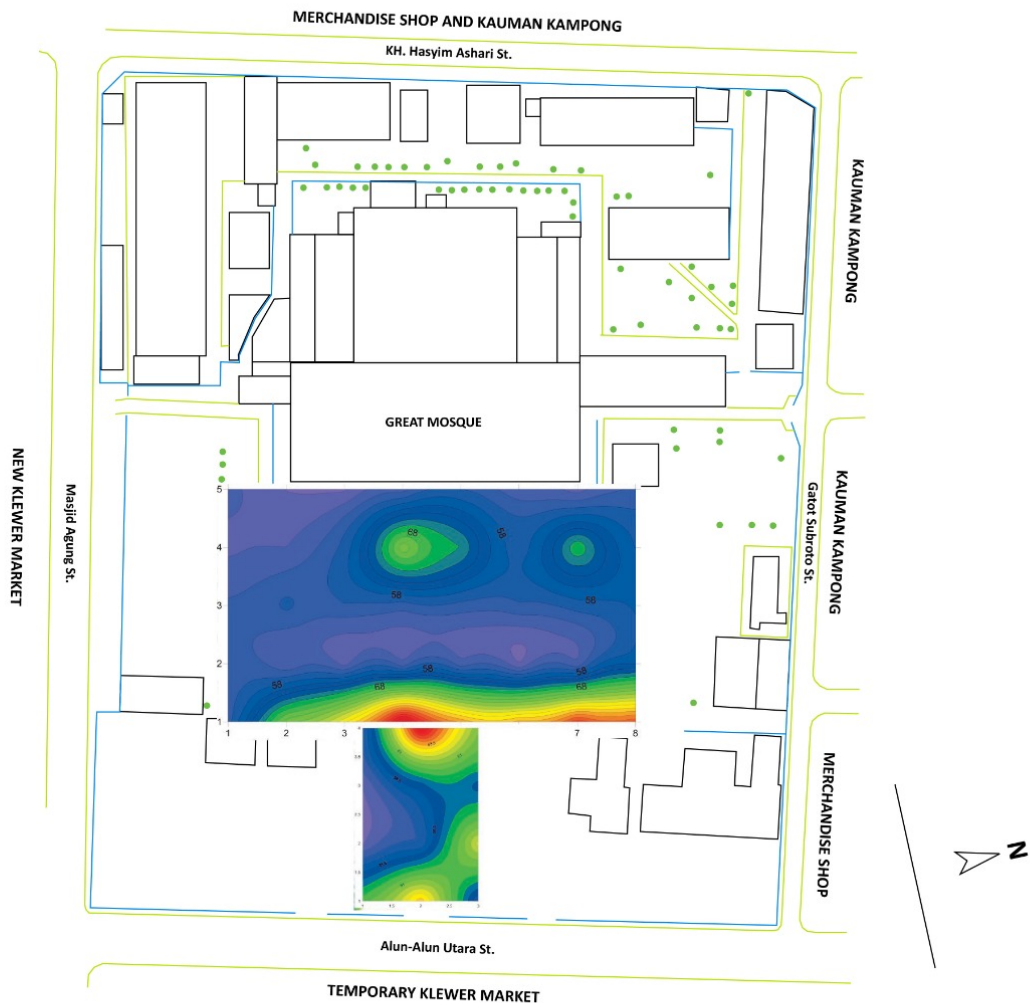
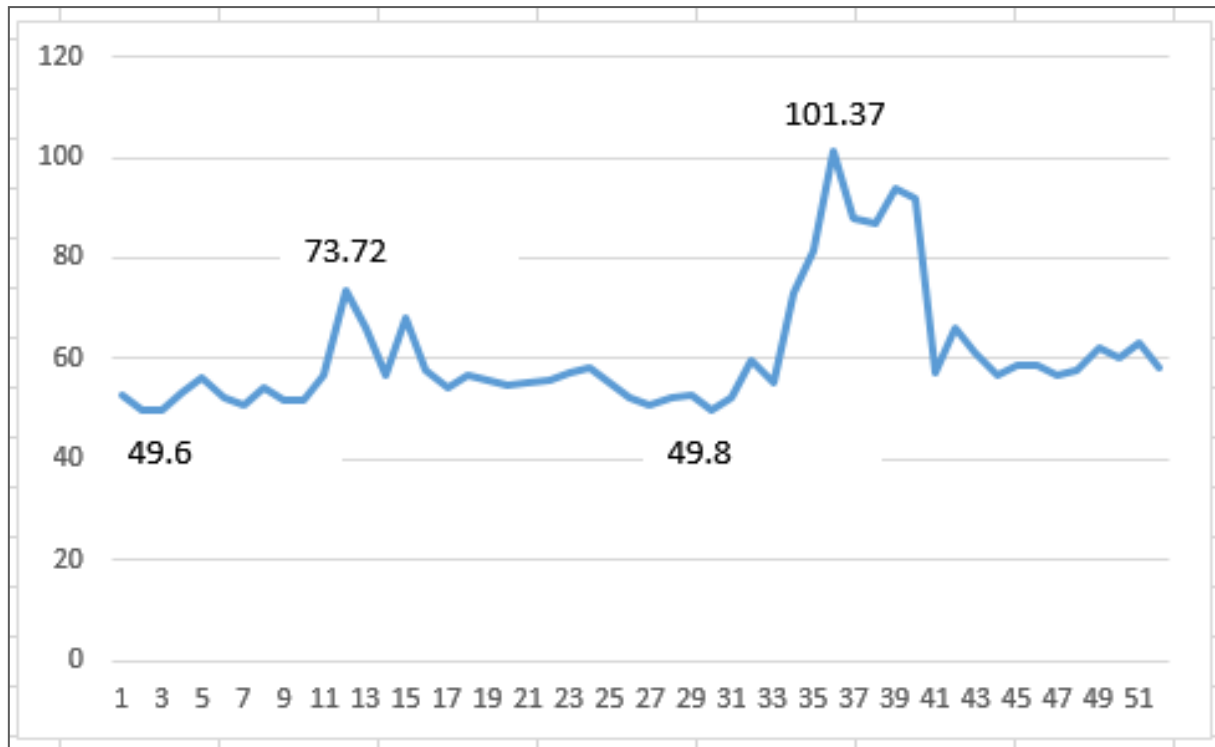


Figure 2. The current condition of the area around the Great Mosque of Surakarta, and the year of its establishment

Textile trading activities also use the mosque's front yard for traders' and buyers' movement routes. The circulation path that crosses the courtyard is the shortest route chosen by traders when they move supplies from one textile market to another. The large yard, shady trees, and the gurgling of water in the front of the mosque's terrace are attributes of the mosque's landscape that makes anyone feel comfortable and welcomed (22). The courtyard of the mosque has a shady sapodilla tree. The sapodilla tree is usually planted in the palace yard as a symbol of goodness. This plant's ecological characteristics provide an effective noise absorber; it has a wide canopy, thick leaf mass, dense leaves, large branches and stems, dense twigs, and thick yet

light leaves (23). Meanwhile, sand from the south beach covers the mosque's yard, contributing to the relaxing and serene condition. The nature of south beach sand contains magnesium (Mg) and iron ore (Fe) (24), whereas magnesium is obtained from saltwater (seawater). Several studies state magnesium has good sound-absorbing properties (25). Figure 3 shows the measurement results, where the measuring point 1-40 (inside the fence of the mosque yard) tends to have a flat graph line compared to the fluctuating measuring points of 41-52 (outside the mosque fence).





(b)

Figure 3. (a) SPL mapping in the courtyard of the Grand Mosque, (b) The graph of SPL value

The graph forms a horizontal line indicating the measurement area has a stable background noise condition. There are only a few measuring points that show fluctuating SPL values. At these points, the noise comes from the voices of elementary school students exercising. Although human movement activities cause noise, landscape components can reduce it. In contrast to measuring points 41-52, the landscape components reflect sound rather than absorb sound. It is indicated by a graph line that is peaking and decreasing significantly.

The complexity of the mosque area's function as a trade centre with the hustle and bustle of traffic jams around it, parking areas, and on-street food stalls produces disturbing noise reaching 101.37 decibels. Even the footsteps sound on the pedestrian path of the mosque yard recorded by the H6zoom instrument has a high intensity; this creates an apparent audible noise. Figure 4 presents the types of noise sources and their level of appearance.

As many as 80% of respondents rated noise that exceeded the standard as not disturbing. The condition of the terrace and courtyard of the mosque remains calm.

Sounds arising from people moving around in the mosque's courtyard, whether using motorbikes or not, are considered normal sounds and entirely unobtrusive. Even people use some parts of the mosque foyer to take a short nap awaiting the midday prayer or Asr. Traffic noise or the sound of sales trolleys crossing the courtyard of the mosque, or the sound of people running and screaming can only be heard on the mosque's porch with an intensity of 51.0 decibels. The landscape component apparently plays an essential role in this noise reduction. This study's results align with research at the Great Mosque of Yogyakarta, where water gurgling affects the congregation's perception of the serenity of the atmosphere (12). The gurgling of water as the sound of nature has a significant role in reducing noise (26). Sounds picked up by SLM (Sound Level Meter) and spectrum analyzer H6zoom at the Grand Mosque reach an average of 60.8 decibels, below the standard 70 decibels. In addition, the biophonic sound, for example, the sound of birds chirping from the trees, makes the courtyard of the mosque sound more tranquil.

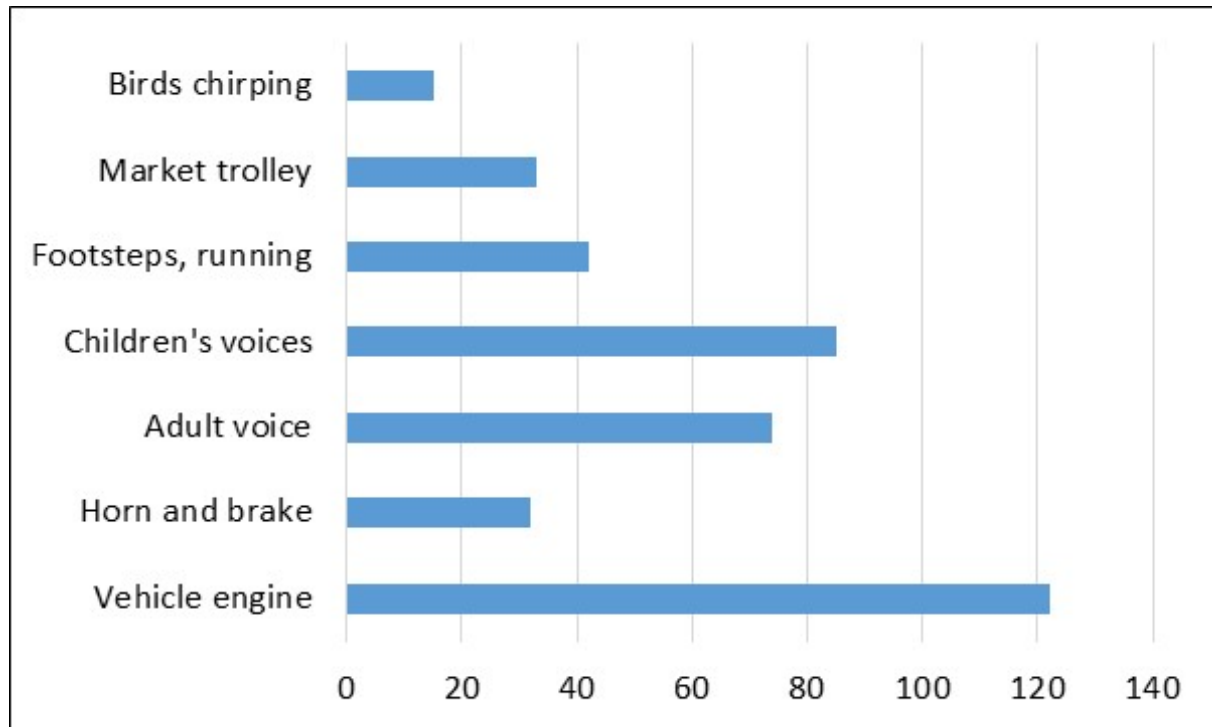


Figure 4. Kinds of noise sources in the courtyard of the Grand Mosque

3.2. The Urban Soundscape around the Al Wustho Mosque

The Al Wustho Mangkunegaran Mosque is located west of the Mangkunegaran Palace, separated from the secondary city road. This mosque is located between the Muhammadiyah Elementary School, the Muhammadiyah High School, the Ketelan Elementary School, and the Bustanul Athfal Playgroup, all of which were established about 1935. Originally constructed between 1878 and 1918, the Al Wustho Mosque served as the royal family's place of prayer. The mosque is now also accessible to the public. With the inclusion of a secondary function, the use becomes more complex, especially in the case of educational buildings, ranging from preschools to universities.

The mosque welcomes the schools around it to use the facility for religious teaching and practices. The mosque provides the practice of ablution and prayer for elementary and kindergarten students and also routine Quran recitation activities for the parents of SD Muhammadiyah students in

the morning from 9 to 10. Meanwhile, high school kids park their motorcycles in the mosque's courtyard. Visitors perceive the sound of students passing by in the courtyard and adjacent areas of the mosque to be inconspicuous, and morning and evening motorbike traffic does not disturb them. Students typically turn off their cars when approaching the mosque yard to park their motorbikes. The intensification of the anthrophonic soundscape, including passing automobiles, people conversing, and footsteps, was caused by the urbanization of the region and the turning of the mosque's courtyard into a motorbike parking lot for school students.

The noise picked up by the H6Zoom recorder and sound pressure level meter reaches 78.9 decibels (see Figure 5). About 60% of respondents feel anthrophonic sounds. Vehicle noise does not only come from the motorcycle parking space but also from the secondary road in front of the mosque. High-intensity vehicle sound frequency reaches 150 times in 4 hours and appears during the day (see Figure 6).

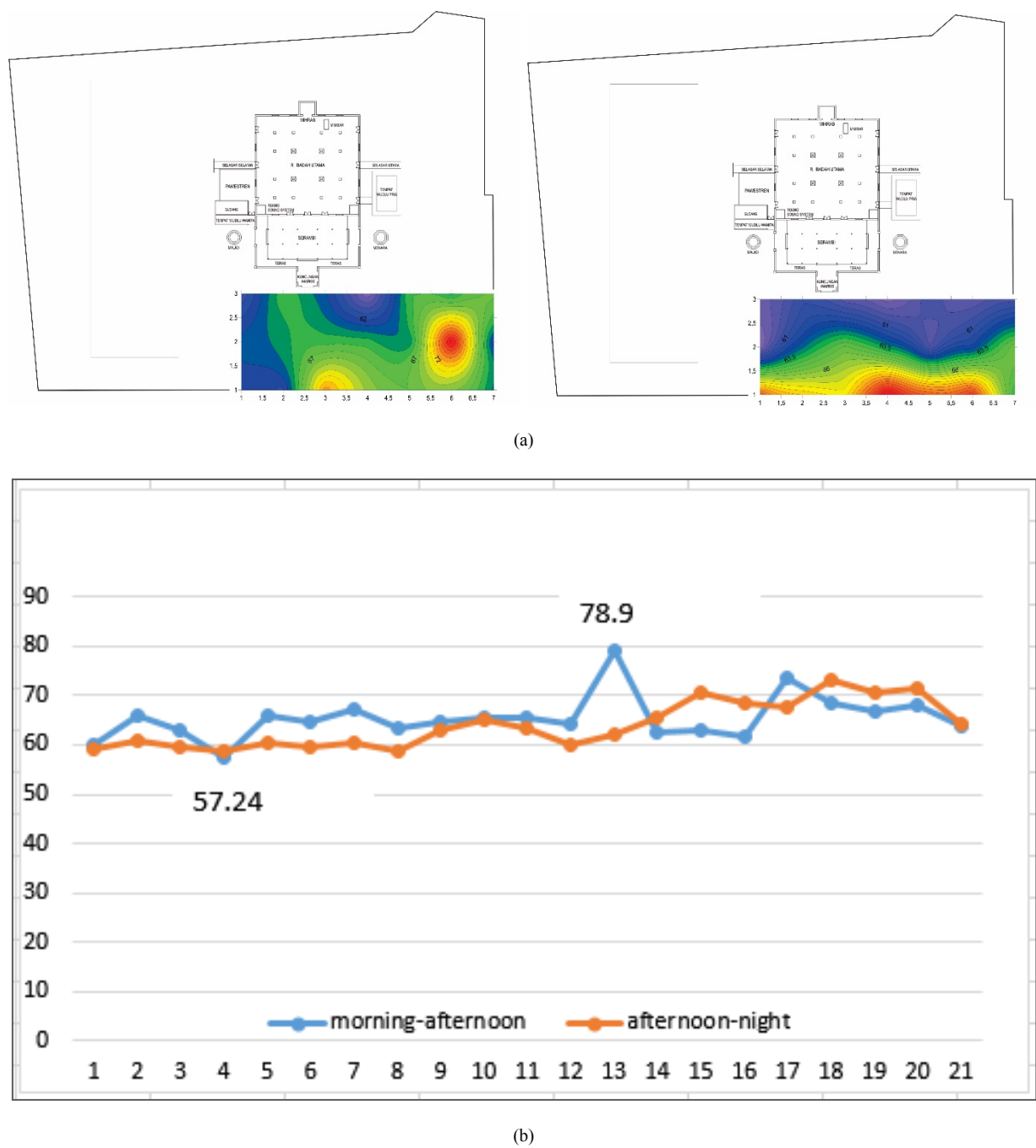


Figure 5. (a) SPL mapping (morning-afternoon) in the courtyard of Al Wustho Mosque, (b) The SPL value in the courtyard of Al Wustho Mosque

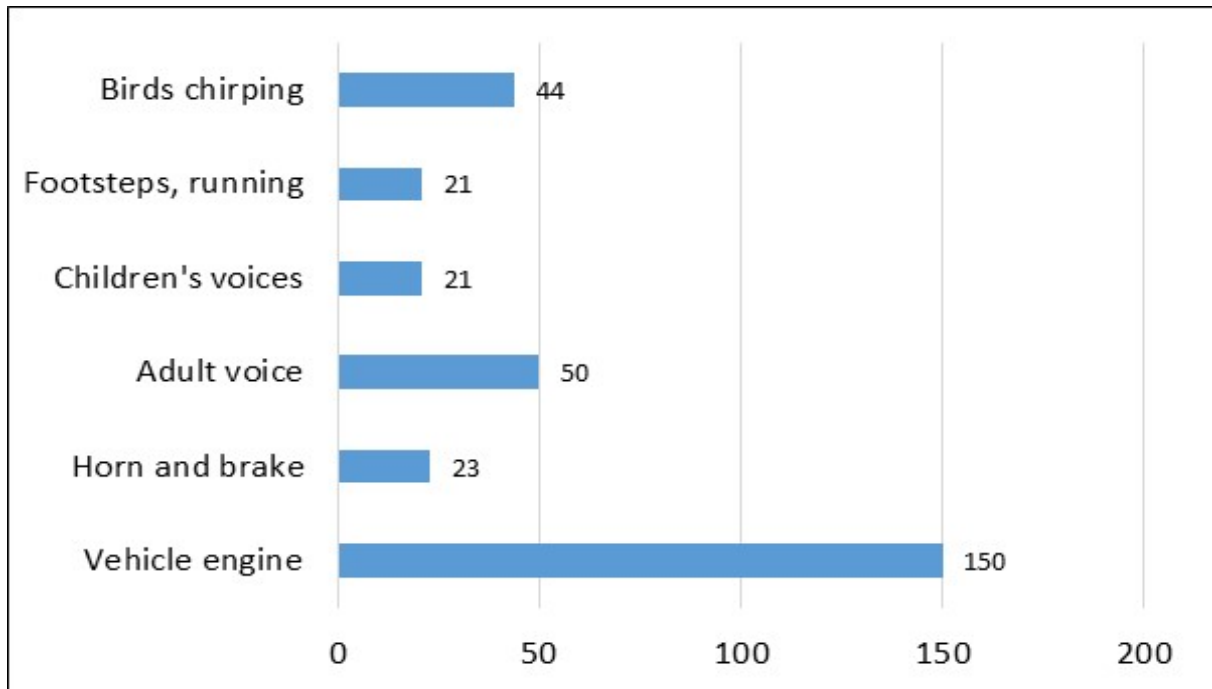


Figure 6. Kinds of noise sources in the courtyard of Al Wustho Mosque

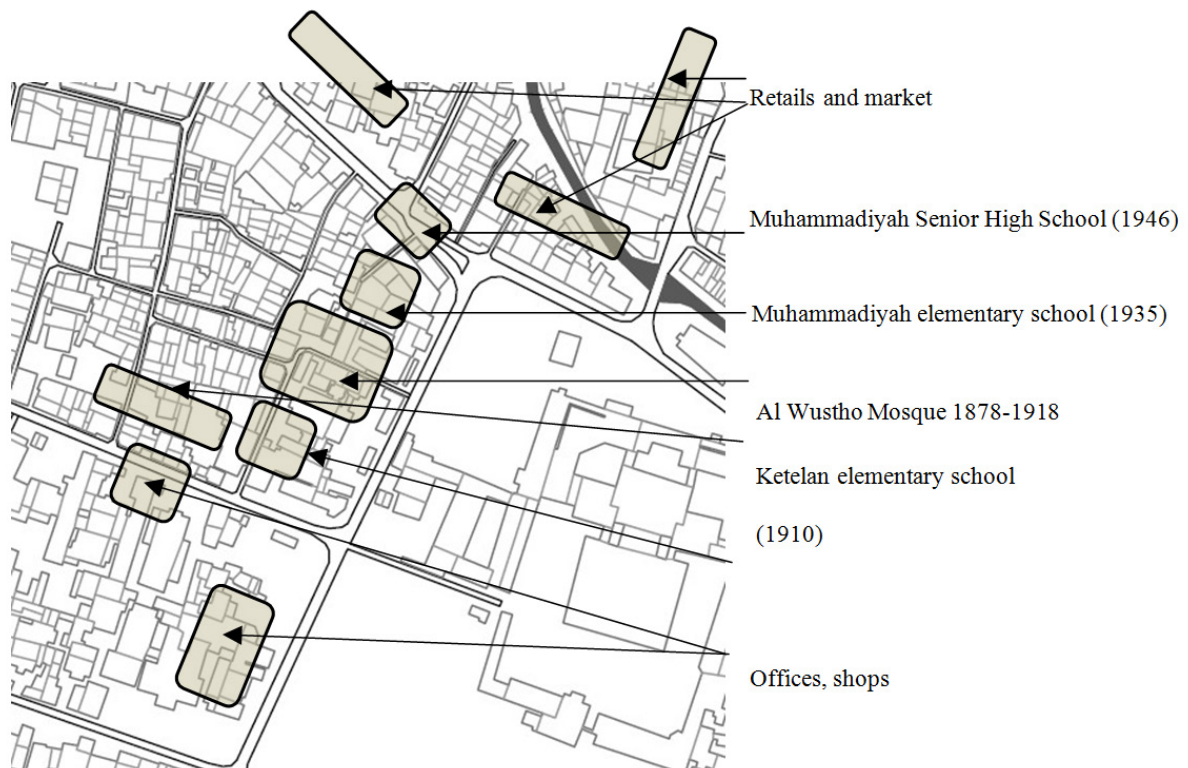


Figure 7. The current condition of the area around Masjid Al Wustho, and the year of its establishment

Traffic movement comes from south to north through connecting roads between education, economic (shops and markets), offices, and tourism areas. Figure 7 shows the location of the Al Wustho Mosque and several educational function buildings around it.

Most buildings around the al Wustho mosque are formal

buildings such as schools and offices. This building affects the formation of a sonic environment; at certain times, the sound intensity increases (into crowds), and there are times that the sound intensity decreases (silent). However, the situation is usually complicated all day long, specifically in the mornings and afternoons, due to students' and office

employees' movement. During the day, the situation is also complicated due to the general public's movement going to the mosque or just looking for shortcuts. The sound pressure level captured by the SLM and H6zoom reached an average of 63.8 dB, even though this value is still below the noise limit of 70 dB. This observation raises the question of why the instrument can only detect a noise level of 60.8 dB in the Grand Mosque (101.37 dB) whereas it can detect a noise level of 63.8 dB at Masjid Al Wustho (78.9 dB). According to the notion of soundscape, a louder sound source will be accepted by the listener in order to reach a higher value (6). This may not be the case in this investigation. The listener perceived the high SPL value of 101.37dB at the Grand Mosque to be a lower (quieter) 60.8dB. At the Al Wustho Mosque, the SPL was 78.9 dB lower, yet the listeners perceived it as being 63.8 dB louder.

The landscape of the Great Mosque of Surakarta was designed starting from the entrance to the mosque gate. The landscape was designed using a building-site scale and proportions (22). Since entering the courtyard, the proportions of the mosque building look monumental in scale. The roof appears to dominate the overall shape of the mosque, which is two-thirds of the mosque's total height (22). The mosque sits in the middle of a large courtyard, while the expansive space around it makes people feel small; the outdoor area has an essential role in this case. It can be said that the landscape of the Great Mosque appears as the main design element that has embedded meaning and functional spaces for the community, including presenting a sense of sequences that lead to the solemnity of the mosque (27). Even though this mosque is in the middle of busy economic activity throughout the day, the noise does not significantly affect the solemn atmosphere, thanks to the landscape elements. Unlike the Grand Mosque, Al Wustho Mosque does not have a large courtyard, and the landscape design on a monumental scale is less successful. The order to reference is not found in this mosque. A person who enters the gate and walks into the mosque does not feel a solemn atmosphere. This phenomenon could be associated with the mosque's courtyard, which has been turned into a parking space. This might have happened due to the community space development developed without supervision from the local government (28).

Acoustic issues have become a hot topic in Indonesia, particularly religious buildings and their surroundings. Acoustic properties exist in every environment. Even though they are part of the same cultural heritage, the two royal mosques in Surakarta have different acoustic characteristics. This character becomes more prominent when combined with other functions, such as religious tourism. In the mosque object, the combination of religious tourism and natural tourism is the most in-demand kind of tourism development.

This tourism development connects tourist attractions by making them more accessible and improving the landscape quality (29). Every kingdom in Indonesia has always left a

record of the mosque's existence. Several old mosques, including these two royal mosques in Surakarta, are still functional, although their surroundings have altered their purpose. Changes in the function of the surroundings surrounding the mosque, such as commercial or other functions, do not always affect the calming acoustics of the mosque. Because the majority of mosques no longer have a culture, their function and appearance do not change (30).

4. Conclusion

The spatial arrangement as part of the urban development strategy should pay more attention to the welfare of the community, including consideration of environmental protection and utilization and its impact on social, cultural, and economic activities. Urban planning is considered an interdisciplinary field involving many disciplines, including designing roads, parks, building layouts, and other urban areas. However, the current urban development has paid little attention to soundscape design, which is essential for the built environment. Soundscapes should not be ignored; instead, they should be considered as resources. Urban development must take more serious efforts to create a built environment supporting activities. The landscape design of the Great Mosque and Al Wustho Mosques in Surakarta demonstrates the example of how the development of the area around the two mosques has become very noisy, especially from motorized vehicles. The layout of the mosque landscape and its components play an important role in reducing noise. The landscape could anticipate the disturbing noise from the situation, created mainly by people's movement around it. The monumental scale, the expanse of sand on the ground, the vegetation, and the sound of the water are present as important landscape attributes that contribute to creating a serene atmosphere in the mosque's courtyard.

This circumstance exists in the Great Mosque of Surakarta, despite the fact that numerically it demonstrates noise, but the sense of mosque visitors is that they are not troubled by any sound. In contrast, the environment of the Al Wustho Mosque, which is quieter than the Grand Mosque, has an unsettling sound quality. The variation in the landscape component between the Great Mosque and the Al Wustho Mosque is one of the factors for the distinction in the acoustic characteristics of the two mosques.

Acknowledgment

We would like to convey our appreciation for the outstanding research conducted by the study program at LPPM Universitas Muhammadiyah Surakarta (UMS). The Building Science Laboratory students who assisted with the acoustics measurements are also appreciated.

REFERENCES

- [1] Kusumastuti. Proses Dan Bentuk “Mewujudnya” Kota Solo Berdasarkan Teori City Shaped Spiro Kostof. Reg J Pembang Wil dan Perenc Partisipatif. 2017;7(1):33.
- [2] Adrisinjati I. Arkeologi Perkotaan Mataram Islam. Jendela. 2000;345.
- [3] Chitra B, Jain M, Chundelli FA. Impact of Landscape Elements in The Selected Soundscape of Urban Parks. Int J Recent Technol Eng. 2020;8(6):1507–11.
- [4] Laurie M. An Introduction to Landscape Architecture. Am Elsevier. 2009;3:203–6.
- [5] Brooks MB, Fortkamp BS, Voigt KS, Case AU. Exploring Our Sonic Environment Through Soundscape Research & Theory. Anal Lett. 2014;39(9):2073–83.
- [6] Miller N. Understanding Soundscape. Buildings. 2013;3:728–38.
- [7] Fowler MD. Soundscape as a design strategy for landscape architectural praxis. Am Elsevier. 2013;34(1):111–28.
- [8] Brezina P. Acoustics of Historic Spaces as a Form of Intangible Cultural Heritage. Antiq Journals. 2013;87(336):574–80.
- [9] Zhang D, Zhang M, Liu D, Kang J. Soundscape evaluation in Han Chinese Buddhist temples. Appl Acoust. 2016;111:188–97.
- [10] Kutturff H. Acoustics An Introduction. Taylor Fr. 1st ed. 2006;480.
- [11] Kamalipour H, Faizi M, Memarian G. Safe Place by Design: Urban Crime in Relation to Spatiality and Sociality. Curr Urban Stud. 2014;2(2).
- [12] Syamsiyah NR, Dharoko A, Utami SS. Sound preservation at the Grand Mosque of Yogyakarta in Indonesia: The Acoustic Performance of The Traditional Architecture. AIP Conf Proc. 2018;1977(June 2018).
- [13] Suharyani and D. Mutiari, "Limbah Pelepah Pisang Raja Susu Sebagai Alternatif Bahan Dinding Kedap Suara," *Sinektika Jurnal Arsitektur* DOI.10.23917/sinektika.v13i1.747, vol. 13, no. 1, pp. 62-68, 2013
- [14] Damaranti NH. Karakterisasi Lingkungan Sonik Masjid Multifungsi: Studi Kasus Masjid Gedhe Kauman Yogyakarta. Repos UGM. 2017;1:28–60.
- [15] Yilmazer S, Acun V. A grounded theory approach to assess indoor soundscape in historic religious spaces of Anatolian culture: A case study on Hacı Bayram Mosque. Build Acoust. 2018;25:137–50.
- [16] Sugiyono. Metode Penelitian Kuantitatif Kualitatif dan R&D. Bandung Alf. 2011. p. 143.
- [17] Creswell JW. Penelitian Kualitatif & Desain Riset. Mycol Res. 2015;94(4):522.
- [18] Janusik LA. Listening and Human Communication in the 21st Century. Wiley Blackwell. 2010. 193–224 p.
- [19] Papalia DE, Wendkos S, Feldman RD. Human Development. Selemba Humanika. 2013;800.
- [20] Syamsiyah NR, Mutiari D, Hidayati R, Setiawan W. Karakteristik Lingkungan Sonik Kawasan Masjid Kerajaan Di Surakarta. Langkau Betang J Arsit. 2020;7(2):175.
- [21] Asif N, Utaberta N, Sarram A. Urban Mosque in The Compact City of Kuala Lumpur: Suitability and Design Considerations. Geogr Tech. 2016;11(2):39–50.
- [22] Syamsiyah NR. Pola Spasial Masjid Agung Yogyakarta Berdasarkan Karakteristik Akustik. Gajah Mada Univ Press. 2019;1–3.
- [23] Nurnovita C. Evaluasi Fungsi Ekologis Pohon Pada RTH Lanskap Permukiman Sentul City, Bogor (Studi Kasus: Cluster Bukit Golf Hijau). Arsit Lanskap Fak Pertan IPB. 2011;
- [24] M, A Lusiyana, Rohman F. Uji Sifat Magnetik Pasir Pantai Melalui Penentuan Permeabilitas Relatif Menggunakan Logger Pro. J Fis. 2014;4(2):78–82.
- [25] Kurniawan FA, Isranuri I. Penyelidikan Karakteristik Mekanik Tarik Paduan Aluminium Magnesium (Al-Mg) Dengan Metode Pengecoran Konvensional. J Inotera. 2016;1(1):1.
- [26] Rehan RM. The phonic identity of the city urban soundscape for sustainable spaces. HBRC J. 2016;12(3):337–49.
- [27] Hendola F, Safitri R, Purisari R. Peran Elemen Alam Pada Sequence Ruang Ibadah Studi Kasus Masjid Bahrul Ulum, Tangerang Selatan. J Arsit KOMPOSISI. 2019;12(2):129.
- [28] Desiyana I. Urban Sprawl Dan Dampaknya Pada Kualitas Lingkungan : Studi Kasus Di Dki Jakarta Dan Depok, Jawa Barat. J Komun Vis Ultim [Internet]. 2017;9(2):16–24. Available from: <https://ejournals.umn.ac.id/index.php/FSD/article/view/745>
- [29] R. Hidayati, Sudaryono, D. Wijono and B. Prayitno, "Tourism development of historical riverbanks in Jatinom Village," *Procedia: Social and Behavioral Sciences*, vol. 227, pp. 650-655, 2016
- [30] R. Hidayati and W. Setiawan, "The architectural transformation of historic mosques in Javanese rural settlements," *IOP Conference Series: Earth and Environmental Science*, vol. 447, no. doi:10.1088/1755-1315/447/1/012043, 2020.