

Restoring Tranquility: Tackling Traffic Noise for Enhanced Comfort in Indonesia Kaya Park, Semarang City, Indonesia

David Suwarno Kusweanto^{1,*}, Natania Nysa Pertiwi N. S.¹,
Eldisya Martha Jebatu²

¹ Department of Urban and Regional Planning, Diponegoro University, Indonesia

² Department of Civil Engineering, Soegijapranata Catholic University, Indonesia

* Corresponding e-mail: davidsuwarno1910@gmail.com

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ABSTRACT

The comfort of a landscape can be seen from the microclimate and traffic noise in the landscape. Traffic noise, including tire and engine noise, is a common disturbance, particularly in cities, and can lead to diseases. Indonesia Kaya Park, located in Mugassari, Semarang City, is an urban park and public space managed by the Djarum Foundation. Despite numerous studies evaluating its accessibility and biophilic elements, the condition of traffic noise nor potential interventions have been considered. The research question aims to understand the traffic noise condition of Indonesia Kaya Park and identify necessary interventions. The study used a mixed methodology, combining quantitative and qualitative methods such as qualitative description, IDW, and I-SIMPA. Indonesia Kaya Park should implement a 1.5-meter buffer using endemic plants and bamboo to reduce traffic noise. The I-SIMPA application was used for a simulation, showing a 6.3 dB reduction by using a buffer. However, further studies are needed to simulate artificial interventions, as I-SIMPA cannot simulate complex structures like twisted bamboo. Further research is needed to improve the park's noise control strategy in terms of the acoustic behavior of each vegetation species. This research recommends placing interventions in high urgency to promote better health and a better experience in Indonesia Kaya Park.

Keywords: traffic noise, noise control, urban parks, I-SIMPA

INTRODUCTION

Landscape design in urban parks is one effort to mitigate climate change and achieve the mission of zero carbon emissions (net zero emissions) in Indonesia. This aims to be realized by providing 20% of quality public Green Open Space (RTH) in urban areas in Indonesia. One form of realizing green open spaces that is currently popular is urban parks. Urban parks can be interpreted as urban green open spaces with the criteria of providing services to users, activity space, meaning, and adequate accessibility (Agustin et al., 2023). The combination of landscape design in an urban park concept can improve the functions of the existence of urban parks, such as sociocultural functions, ecological functions, hydrological functions, and aesthetic functions (Qulubina et al., 2022).

Based on the Regulation of the Minister of Agrarian Affairs and Spatial Planning of the Republic of Indonesia No. 14 of 2022 concerning the Provision and Utilization of Green Open Space (GOS), the four functions of existing GOS can be explained as follows. First, the ecological function of green open space is to produce oxygen (city lungs), provide shade, absorb rainwater, provide vegetation and space for animals, absorb pollution (air, water, and soil), and reduce noise. Second, the hydrological or water absorption function includes providing water absorption areas, recharging groundwater, and controlling floods. Third, the socio-cultural function is a combination of historical aspects, space for community interaction, space for recreational or sports activities, and educational research objects. Fourth, the aesthetic function is to increase environmental comfort, beauty, city landscape, and identity, and to maintain the balance of built and unbuilt areas (Rajagukguk et al., 2019).

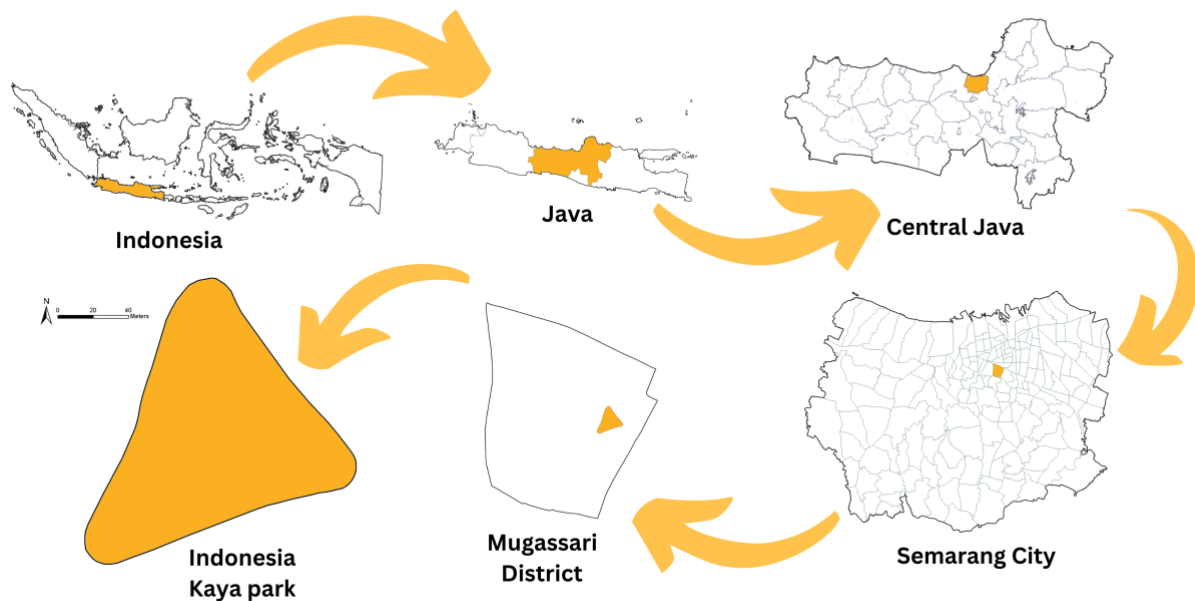
A safe and comfortable landscape design relates to several development challenges, including converting green open space into a built-up area for trade and service activities surrounded by government offices (Saraswati & Yemima, 2020). The comfort of the landscape can be seen from

the microclimate and traffic noise within the landscape (Livania & Marpaung, 2022). A microclimate is a specific type of climate that exists in a smaller region; in other words, it is the existing layer of air above the surface of the planet within that limited scope (Imran, 2013). The sound produced by cars on roads and highways, such as tire and engine noise, horn sounds, and tire contact with the pavement, is referred to as traffic noise. It is a frequent environmental contaminant, especially in cities, and it can harm people's health and well-being in several ways, such as cardiovascular and hormonal diseases (Amalia et al., 2022). The standard limit of the human ear is to hear sounds or sounds with a frequency of 20 to 20,000 Hz. Meanwhile, the acceptable sound loudness level is 0-140 dB (Yüksel et al., 2021). The classification of noise can be divided into three levels, namely: (1) 50-55 dB, which is referred to as noise; (2) an intensity of 90 dB, which can disrupt the autonomic nerves; and (3) an intensity of 140 dB, which causes vibrations in the head, earache, and balance disorders. However, the average human is comfortable with sound when we speak, which is less than 70 dB (Fang et al., 2020).

Indonesia Kaya Park, Mugassari, Semarang City, can be described as an urban park and public space, as seen in Figure 1. It is located on Menteri Supeno Street near the city center. The Djarum Foundation's Indonesia Kaya Park is an example of corporate social responsibility (CSR), where administration is shared between public and private sectors (Widyonarso & Mardiansjah, 2020). Indonesia Kaya Park was built from 1973 to 1975 and carries the concept of family welfare. Because of this, this park is known as the Family Planning Park. It was renamed into Indonesia Kaya Park to revitalize the park (Konian, 2022). Indonesian Kaya Park landscape design expresses two concepts of public space, namely cultural education and artistic creativity space. Currently, Indonesia Kaya Park is the first outdoor cultural park in Central Java. Some of the activities held include art performances, theater stages, and cultural events in Central Java (Nursanty & Wulandari, 2021).

Figure 1

Location of Indonesia Kaya Park



Note. This figure demonstrates the location of Indonesia Kaya Park.

Several studies have been carried out to analyze and evaluate the existence of Indonesia Kaya Park. Machfud and Harsitanto (2020) conducted research on the accessibility of Indonesia Kaya Park. The research results concluded that 62% of building and environmental access complies with applicable standards in Indonesia. This is supported by the results of research conducted by Qulubina et al., (2022) from an anthropometric point of view, namely that all complex elements meet ergonomic values. This shows that Indonesia Kaya Park provides comfortable and safe facilities for visitors and public space activities, and has a good maintenance process. Research by Ristianti et al., (2024) discusses that in terms of biophilic and ESG, Indonesia Kaya Park can still be mitigated to provide more temperature comfort for its users. However, these three studies have not looked at Indonesia Kaya Park from a noise perspective or how it can be intervened. Therefore, the research question from this article concerns what is the noise condition of Indonesia Kaya Park and what interventions are needed.

LITERATURE REVIEW

Comfortable Landscape

Human activities create urban landscapes intentionally to manage the environment to meet living needs. Since it is harder to record and study human behavior and activities, there is less research in terms of human behavior than the physics of a building (Sargazi & Tahbaz, 2022). Urban landscapes reflect urban patterns, which can include green spaces at the building level, such as balconies, green roofs, and vertical gardens. However, urban landscapes (gardens) are also heterogeneous. Namely, they can also take the form of residential gardens, playgrounds, gardens, institutional building gardens, planting areas on roads and highways, cemeteries, sports fields, and hobby parks (Lyon, 2021). An urban landscape must be managed, which consists of planning and utilizing, maintaining, preserving, controlling, and developing the environment to create an urban landscape that is beneficial for all living things. Landscape management includes: planning a park with simple patterns so that physical

maintenance is easy; creating clear and rational traffic or circulation patterns so that the flow of activities in it will always run smoothly; choosing a strong building/object structural system; choosing appropriate pavement materials; and equipping the park with adequate facilities such as lighting and utility networks (Indah et al., 2014).

The landscape in a city park consists of hard elements in the form of garden pedestrian paths and soft elements in the form of plants.

Meanwhile, the supporting elements include toilets, rubbish bins, notice boards, playgrounds, and landmarks. According to Carr, a city park landscape must have several aspects that form the quality of the space itself, namely consisting of (1) the needs aspect, (2) the right aspect, and (3) the meanings aspect (Pratomo et al., 2019). (1) The needs aspect includes comfort, which refers to the comfort of visitors when in the room, which can be measured based on the comfort of seating facilities, garden lights, and public telephones. Even though discomfort was considered an accepted condition (Janpathompong & Murakami, 2021), it should not be viewed in that way. Lighting is also a criterion for creating a comfortable city park landscape. Good lighting is formed from good design, too. Not many parks are designed with this in mind. Limited lighting, both from lighting and sunlight, causes a park to have an uncomfortable atmosphere for visitors. The high intensity of trees, such as trees that are too dense and tall, and limited lighting at night creates an atmosphere in the park that most visitors wish to avoid. The park needs to be a place for recreation and a place to reduce a person's stress level when visiting (Bachtiar et al., 2021). Next, cleanliness refers to trash cans and public toilets, health related to the air quality that users feel when they are in city parks, and security and safety related to gazebos and park lights. (2) The right aspect refers to the ability or function of the park for activities and can be assessed from the level of freedom of users to carry out activities. In general, this can be seen physically, such as the availability of play facilities such as playgrounds or other facilities that support the activities of park users. (3) The meanings aspect refers to the ease of the park being recognized by users, such as the presence of signage. Apart from these three aspects, a city

park must have easy access, such as the availability of roads that are easily accessible by public transportation, private transportation, and pedestrians to get to the city park. Consequently, it is essential to enhance and upgrade urban green spaces by incorporating basic amenities and green infrastructure. This improvement will not only elevate the appeal of these urban areas but also attract more visitors, ultimately increasing the social benefits they provide (Rai et al., 2022).

Landscape and Noise

As a space for people to rest and do activities, a comfortable landscape is connected to sound. The location of a park is generally right in the middle of a dense urban area with sounds from various human activities rather than natural sounds. This condition will be even less ideal if it is not balanced with good management because the park's function is as a community place for various activities, such as recreation, simply relaxing, or looking for inspiration; without the appropriate sound, the function of the city park as a social space will not be successful. Based on ISO12913, 2018 concerning soundscape, urban sound consists of (1) Motorized transport, (2) Human movement, (3) Electromechanical activities such as construction and industrial activities, (4) Social/communal activities such as fireworks, alarms, and (5) other. Various urban activities cause the phenomenon of noise pollution. Urban road noise is usually defined as the sound of oncoming vehicles and exceeds national standard measurements of 70dB during the day and 55dB at night. Noise is divided into three levels. Namely, an intensity of 50-55 dB is called noise, an intensity of 90 dB can disturb the autonomic nerves, and an intensity of 140 dB can cause vibrations in the head, earache, and balance problems. However, the average human feels comfortable with 70dB sound (Oquendo-Di Cosola et al., 2022). Based on the Decree of the Minister of the Environment No. 48, the noise in a Green Open Space (RTH) is 50 dBA (Keputusan Menteri Negara Lingkungan Hidup, 1996).

In general, motor vehicle noise is a source of urban traffic noise. Noise is influenced by traffic volume, vehicle type, speed, road type, and slope. Noise tends to increase with traffic volume.

Noise pollution resulting from vehicle noise disturbs environmental comfort and poses a major threat to public health. Moreover, noise hurts human health. It affects mental stability and psychological reactions, such as worry, irritation, stress, and disturbed sleep patterns, and it can also trigger diseases such as heart disease, learning disabilities, and so on (Daniaty Malau & Delviani Jehadun, 2018; Fang et al., 2020). This has sufficiently increased the awareness among researchers, planners, and governments, resulting in environmental development decisions and guidelines that must consider noise regarding community comfort and well-being (Oquendo-Di Cosola et al., 2022; Sami & Sara, 2023). Noise pollution can be reduced through planning and architectural design techniques, dividing zones to form comfortable spaces for all activities. Moreover, understanding the cultural context and urban community values is essential for meaningful, sound environments (Sami & Sara, 2023). A comfortable landscape is assessed by a balanced soundscape, reflecting the landscape itself, not eliminating it or the landscape (Chitra et al., 2020).

According to Cerwén et al., (2017), several steps can be taken to create a good soundscape. These include (1) Localization of functions, (2) Reduction of unwanted sounds by considering noise filtering with acoustic properties of materials, and (3) Introduction of wanted sounds by trying to present sounds that are desired through water, plants, birds, and other materials. In forming a comfortable urban landscape, an ecological approach can be taken, such as by using vegetation and water bodies, especially trees, as noise absorbers, temperature stabilizers, air humidity controllers, and wind barriers (Chitra et al., 2020; Wang, 2004). Using a buffer zone can also be utilized as a way to reduce noise pollution; however, practically, it is unknown how effective this intervention is (Judphol, 2023).

By transferring the kinetic energy of vibrating air molecules in a sound field to the vibration pattern of the leaves, plant leaves absorb sound energy. Because leaf friction occurs in a vibrating plant, vibration energy is therefore extracted from the acoustic environment, and some of this energy is lost through heat transfer (Samara & Tsitsoni, 2011). The first 10 to 20 meters of vegetation's absorption of road noise is the most effective,

and as one gets farther away from the road, the rate of attenuation declines (Peng et al., 2014). If there is sufficient depth and density of foliage cover, noise attenuation can be achieved. The more noise that can be absorbed by plants, the denser it is (Zia et al., 2021).

Noise Control Best Practice in Urban Parks

Several urban garden best practices consider balanced soundscape noise control strategies to create a comfortable landscape, which are listed as follows:

1. Washington Square Park, located in Greenwich Village, New York, is a city park surrounded by tall and dense buildings, yet it has a design that creates a good soundscape. The park is surrounded by motorways, with an average decibel range of around 80 dB and construction noise. This park has large, canopied trees with a wide expanse of green grass. Equipped with a playground and open plaza space, it provides an atmosphere of free activity for users to practice drama, singing, public meetings, and impromptu music events. Apart from the canopy trees, the water element in the form of a fountain in the middle of the park acts as a noise reducer and fills the soundscape of the park well, where the sound produced is 30-40 dB (Counts & Newman, 2019).

2. The High Line, a New York City park that uses railroad lines, was transformed into a busy park and is sought after by many people. The strategy implemented by this park is the use of materials that can reduce pollution. The seating is strategically placed and has a mix of nature, art, and urbanism. Designers utilize acoustic panels and tiles to combat sound pollution and sound-absorbing materials such as wooden decks to reduce sound pollution, thereby improving the quality of the landscape. Moreover, plants are placed near noise sources, such as roads or construction zones, to reduce noise. It presents water elements to reduce annoying sounds and create calm, well-being, and rhythmic hearing, and it provides psychological benefits to the user, such as relaxation and reduced stress levels (Sami & Sara, 2023).

3. Bungkul Park, Surabaya, Indonesia, is a city park with an area of 16,800 m² and 80% of the land composed of vegetation. This park was designed to be friendly to Indonesia's tropical climate, with trees to protect it from direct sunlight. It was also designed based on zones to form a soundscape that is balanced and does not interfere with activities in the park. The five zones are a front sitting area, an amphitheater plaza, a skate park, fountains and playground, toilet facilities, a security post, and a prayer room. Dividing zones and vegetation provide a belt between spaces that provides calm and comfort for all users with their various activities in the park (Mediastika et al., 2020).

A Previous Study of Indonesia Kaya Park

The primary goal of Indonesia Kaya Park's establishment was to serve as a bustling public urban park that would facilitate neighborhood social events. Thus, practically every area in this park—such as the paving grounds, walkways, green areas, and cultural stages—can serve as a place for socializing. Indonesia Kaya Park was also temporarily closed during the pandemic to prevent the growing SARS-CoV2 infection in the neighborhood. It is also easily accessible and situated in a prime area in the city center. There is a culinary center on the west side of the park, street vendors on the east, and rather extensive amenities in addition to a cozy garden setting (Hetyorini & Ekawati, 2022).

The park has a paving field in the center that may be utilized for gatherings in addition to viewing performances. The park is laid up like a grandstand. In addition to being large and having park benches on either side, the sidewalks that serve as a pedestrian facility may also be used as a place for socializing. This allows people to use it for group conversations (Harjanti, 2020). However, the thermal comfort of Indonesia Kaya Park can still be improved through biophilic elements (Ristianti et al., 2024). In terms of being child-friendly, Indonesia Kaya Park is in the category of being less friendly to children. Freedom of access results in uncontrolled behavior and a large number of visitors. Visits to the Indonesia Kaya Park fluctuate in direct proportion to the diversity of play facilities and

natural conditions that add to the attraction for visitors amidst the hustle and bustle of the city center. The peak number of visitors occurs on Sundays because there are weekly market activities as an additional attraction. Moreover, congestion or density is caused by the available facilities not being able to accommodate the number of visitors (Prihantinia & Kurniawatib, 2019).

Semarang Local Vegetation

Before Semarang became a city, it was a riparian area with a riparian forest, swamp, river, and coast. In the coastal area, five mangrove species are endemic to Semarang, namely *R. mucronata*, *A. marina*, *Excoecaria aghalloca*, *B. cylindrical*, and *Xylocarpus mocullensis* (Suedy et al., 2015). During the city building period, a lot of vegetation started to disappear, but a lot of endemic vegetation was still able to be found. Trees that were endemic to the city of Semarang during this time were *Cupressus sempervirens*, *Pterocarpus indicus*, and *Tamarindus indicus*. Bushes that are endemic to the city of Semarang are *Pandanus amaryllifolius* and *Acalypha siamensis*.

Decorative vegetation in Semarang City is *Piper ornatum*, *Luffa acutangular*, *Luffa aegyptiaca*, and *Allamanda cathartica*. Currently, most of the vegetation that is grown in Semarang is called instant vegetation or vegetation that is used purely as aesthetic without any ecological consideration (Roesmanto, 2012). The disappearance of endemic plants was so severe that in some cases, there was no longer any endemic vegetation to be found in some areas (Rahmani & Caesarina, 2020).

METHODOLOGY

Research Method

The method used in research is mixed methodology or quantitative and qualitative research, by using qualitative description, IDW, and I-SIMPA. This research lasted for three months; one month was used for data preparation and collection, and two months was used for analysis. Quantitative analysis was used

to determine traffic noise in Indonesia Kaya Park and the effectiveness of the interventions to be used, while qualitative analysis was used to determine the interventions needed.

Data Collection Techniques

In measuring the noise in Indonesia Kaya Park, researchers used a decibel meter at 24 points in the park and its surroundings for 10 minutes. Those 24 points were chosen because of the requirement from the IDW analysis. Each location has a distance of 10 to 20 meters from each other. Some of the points were located outside the park to provide more data for the IDW to calculate the approximation of traffic noise of the whole park. To create an accurate picture, it was suggested that the amount of data points should be increased, but due to time limitations, only 24

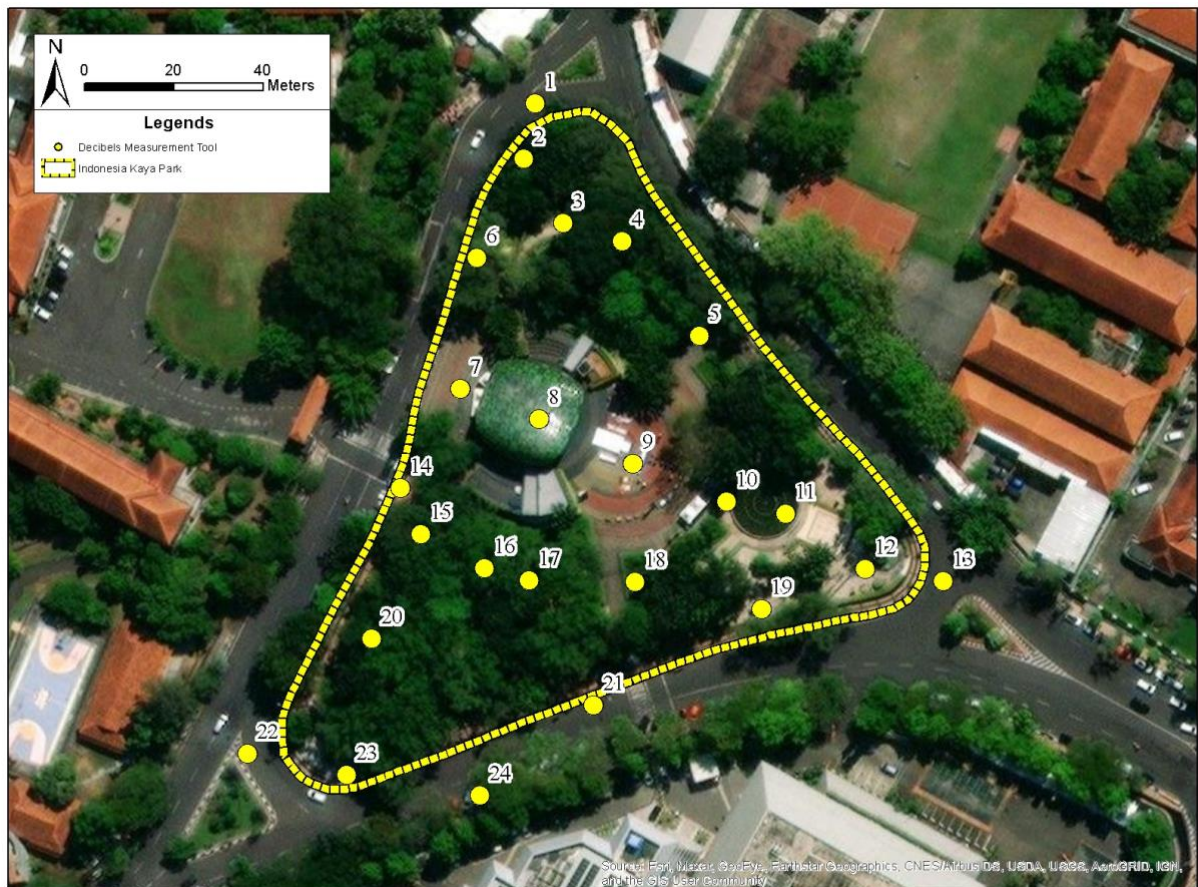
could be recorded in this research. Decibel measurements focus on the average and highest decibel values for 10 minutes. These measurements can be seen in Figure 2. The results of these measurements are entered into the GIS in the form of data points.

IDW

The existing data was then interpolated using Inverse Distance Weighting (IDW) interpolation, where the interpolation results are not higher or lower than the existing dataset. With this interpolation technique, observation points were weighted during the process such that, as the distance from the new location increases, the relative importance of each point decreases. A weighting power that regulates how weighting factors decrease with increasing distance from

Figure 2

Measurements of Noise in Indonesia Kaya Park



Note. This figure demonstrates all the observation points and boundaries of Indonesia Kaya Park. Adapted from *Indonesia Kaya Park*, by Google Map, 2024, Google LLC (<https://maps.app.goo.gl/UPKN7QSoBTDpPwsE9>). Copyright 2024 by Google LLC.

a new point was used to assign weights to observation locations. The fewer influence points remote from the new point during interpolation, the bigger the weighting powers (Ibrahim & Nasser, 2017). The general formula of IDW can be seen in Equations 1 and 2. The IDW approach assumes that the distance between neighbors, which may be defined as the distance reverse function of each point from surrounding points—determines the rate of correlations and similarities between them (Masoudi, 2021). The current data point, which is 24, is sufficient to meet the method's minimum requirement of 14 (Setianto & Triandini, 2013).

$$Z(X_0) = \sum_{i=1}^N \lambda_i \cdot Z(X_i) \quad (1)$$

Where,

N is number of observation points,

$Z(X_i)$ is Scattered observation values points; $i=1, 2 \dots N$, and

λ_i is weights in observation points

$$\lambda_i = \frac{d_{ij}^{-p}}{\sum_{i=1}^N d_{ij}^{-p}} \quad (2)$$

Where,

P is weight power,

d_{ij} is distance between grid node i and neighboring point j

Determining Urgent Intervention Locations

The interpolation results were then classified into two groups, namely above 70 dB and below 70 dB, which are based on the noise tolerance limit that can be accepted by humans (Fang et al., 2020). Since the results of IDW are in the form of a raster, the researcher needed to change it into a polygon for easier data management. An overlay was carried out on the results of these two classifications to determine which parts require urgent intervention and which do not. Areas with average noise above 70 dB are included in urgent intervention, while areas with the highest noise above 70 dB are included in non-urgent intervention.

Qualitative Descriptions

Responses to noise that require intervention are based on literature review and qualitative descriptive methods. The literature review results were realized with several options shown in 2D and 3D designs accompanied by qualitative descriptions to provide a noise intervention design in Indonesia Kaya Park.

I-SIMPA

In order to compare the effectiveness of noise reduction, the authors used the I-SIMPA acoustic application to see the difference. Initiated during a research project funded by the French Environment and Energy Management Agency (ADEME), I-SIMPA was part of a collaboration between the French Engineering Department SerdB, the University of Poitiers, the French Institute of Sciences and Technology for Transport, Development and Networks (Ifsttar), and the University of La Rochelle. The primary goal was to create a novel prediction model for the transmission of sound in intricate settings, both indoors and outdoors (Picaut & Fortin, 2012). The leaves in the model have a reduction of noise value of 80% (Baruah et al., 2019). The sound source was placed one meter off the ground, just like the sound source from a car or motorcycle. Since I-SIMPA could not import SKP files from SketchUp, the model had to be converted into 3ds format before being imported into I-SIMPA.

RESULTS

From the decibel meter, the researcher managed to collect the highest, lowest, and LaEq (the average decibel) around the area. Based on the numbering of points, which can be seen in Figure 2., the value of each noise point can be seen in Table 1.

Based on IDW's interpretation of the average decibel value in Indonesia Kaya Park, most of this park falls into the tolerable range, namely below 70 dB. Several park areas in the north have high traffic noise. This is because the northern road tends to be more congested with

Table 1*Results From the Decibel Meter Data Collection*

No	Sound Pressure Level (dBA)		
	Lowest	Highest	LaEq
1	58.2	82.3	79.31
2	53.9	82.4	79.4
3	56.7	75.2	72.25
4	61.2	71.5	68.88
5	56.5	78.5	75.52
6	62.1	71.7	69.14
7	56.8	67.8	65.12
8	54.9	65	62.39
9	54.1	67.8	64.97
10	56	68.5	65.73
11	51.1	69.1	66.16
12	60.1	76.2	73.3
13	65.3	74.2	71.72
14	57.4	77.1	74.14
15	54.2	61.4	59.15
16	53.2	60.3	58.06
17	54.7	67.5	64.71
18	53.4	66.4	63.6
19	55.9	68.7	65.91
20	56.9	62.1	60.24
21	54.2	69.2	66.32
22	62.1	74.2	71.45
23	58.2	71.2	68.4
24	56.4	70.8	67.94

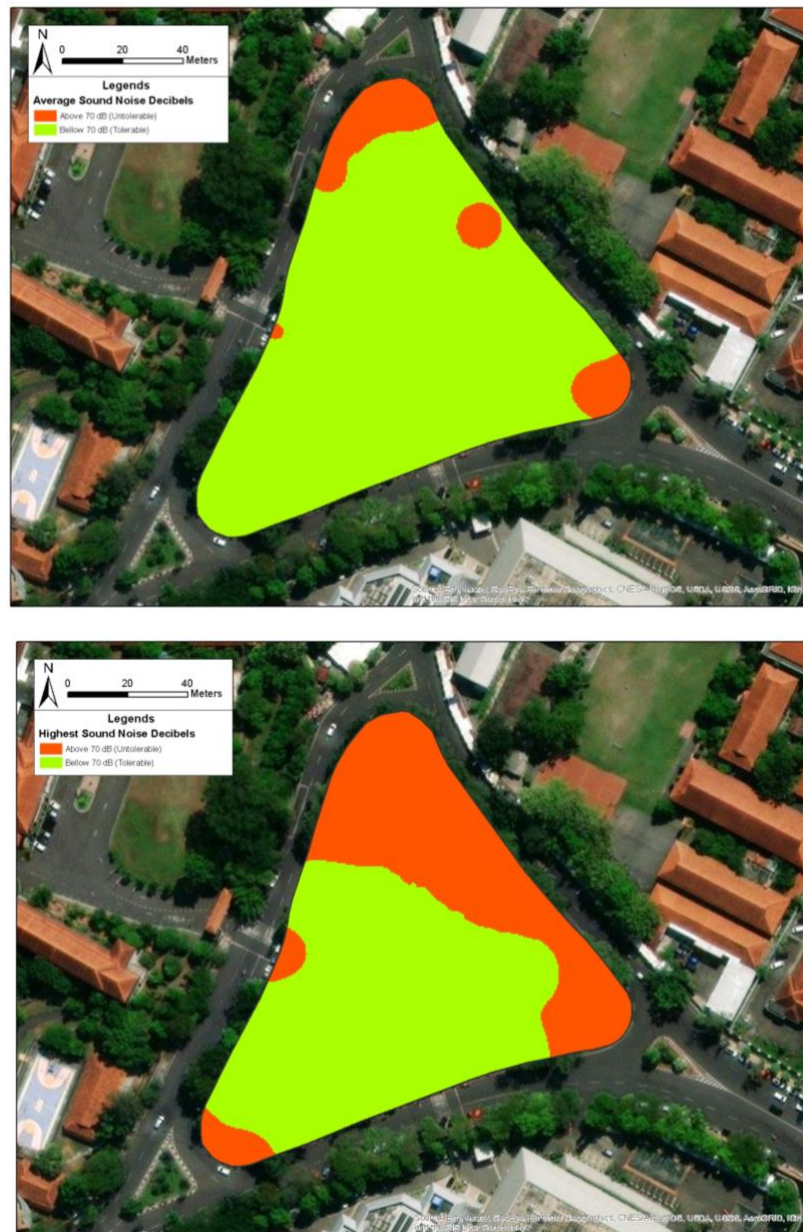
Note. This table demonstrates the highest, lowest, and average of sound pressure level captured from the decibel meter. The number here corresponds to the number of the point in Figure 2.

vehicles than the southern road, which is due to government and educational activities on the northern part of the road. A few areas close to the zebra crossing have high traffic noise because cars often stop and brake. IDW's interpretation of the highest traffic noise value

shows that areas with high decibels are near the road. The three corners of the park have areas with high decibels because, in this area, there tend to be more vehicles passing by due to its position as a road junction. The average and highest traffic noise map can be seen in Figure 2.

Figure 2

IDW Results of Traffic Noise in Indonesia Kaya Park



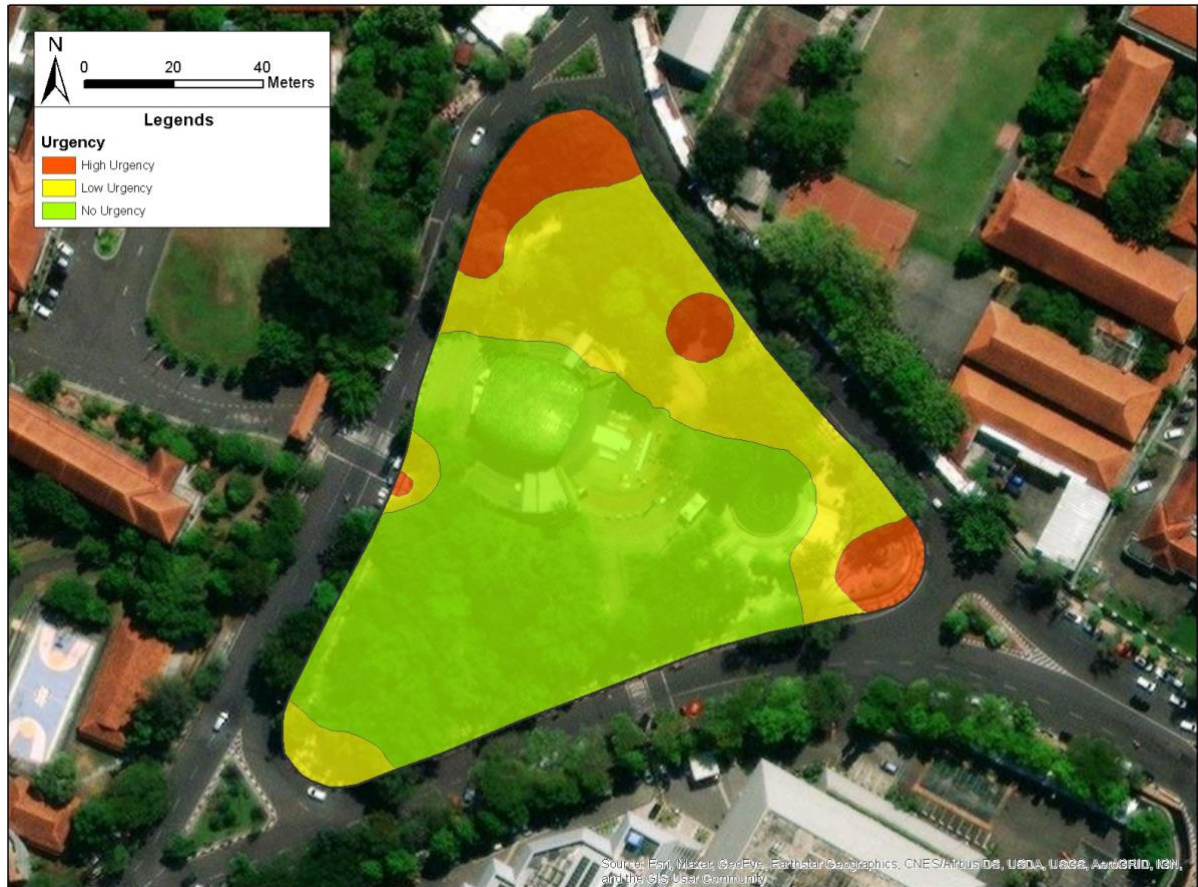
Note. This figure demonstrates all the average and highest traffic noise in decibels. The figure on the left shows the average traffic noise, while the one on the right shows the highest traffic noise in Indonesia Kaya Park. The red color represents noise above 70 dB, which is intolerable, and the green color represents noise below 70 dB, which is still tolerable. Adapted from *Indonesia Kaya Park*, by Google Map, 2024, Google LLC (<https://maps.app.goo.gl/UPkN7QSoBTDpPwsE9>). Copyright 2024 by Google LLC.

The overlay results of the two maps show that urgent intervention is needed on the northern part of the road. If the average noise of an area is above 70 dB, that place is considered a highly urgent location for intervention. If the highest traffic noise is below 70 dB, that place is considered an urgent location. If it was in

between, then that area is considered as low urgency. Two street corners and two park edges right in the center of the crossing area of the road require urgent traffic noise intervention. Details of the degree of intervention can be seen in Figure 3.

Figure 3

Traffic Noise Intervention Urgency



Note. This figure shows the urgency of traffic noise intervention. It is divided into three categories: no urgency, low urgency, and high urgency. Adapted from *Indonesia Kaya Park*, by Google Map, 2024, Google LLC (<https://maps.app.goo.gl/UPkN7QSoBTDpPwSE9>). Copyright 2024 by Google LLC.

DISCUSSION

Natural and Artificial Interventions

Two types of intervention can be carried out to reduce traffic noise, either in the form of vegetation or artificial intervention. These two interventions should be used simultaneously to obtain optimal results. Vegetation intervention can reduce noise by up to 12 dB. Plant density influences how much noise is reduced, where the denser the plants, the greater the noise that can be reduced. Another factor to consider is the height of the vegetation. The higher the vegetation, the greater the traffic noise that can be reduced (Raihan, 2023; Sami & Sara, 2023). The vegetation that can be used is not only

conventional but green walls can also be used to reduce traffic noise (Oquendo-Di Cosola et al., 2022). The application of a green wall can also be made in the form of bamboo poles provided with vines to provide shape to the green wall. Providing this vegetation has a higher aesthetic value and provides identity to an area rather than just providing boundaries (Xing & Brimblecombe, 2020).

The type of vegetation planted also needs to be considered (Ferrini et al., 2020). Native vegetation does not need excessive adaptation to tropical environments such as Indonesia Kaya Park. This advantage means it does not require excessive maintenance, which means less energy is required to maintain park vegetation, resulting in higher sustainability. Native vegetation is also not prone to causing issues such as invasive species, which can threaten

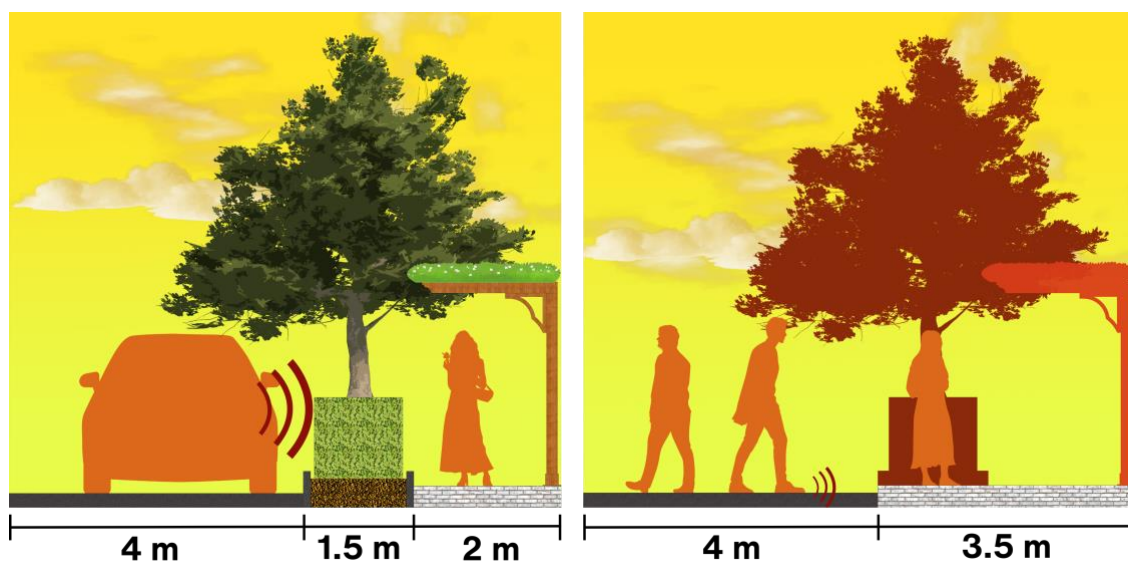
local species in Semarang City. The city of Semarang has lost various types of vegetation over time due to the use of external vegetation, which is often used to create parks. This use of external vegetation also has occurred in Indonesia Kaya Park, where Acacia trees and redbud flowers are used, even though they are not endemic vegetation. Trees that are endemic to the city of Semarang are *Cupressus sempervirens*, *Pterocarpus indicus*, and *Tamarindus indicus*. Bushes that are endemic to the city of Semarang are *Pandanus amaryllifolius* and *Acalypha siamensis*. Decorative vegetation in Semarang City includes *Piper ornatum*, *Luffa acutangular*, *Luffa aegyptiaca*, and *Allamanda cathartica* (Roesmanto, 2012).

Indonesia Kaya Park has a three-and-a-half-meter-wide space to be used as a buffer zone between the road and the park. In this buffer, a combination of endemic plants will reduce noise from the road and increase public comfort. The use of various types of vegetation is essential to support the biodiversity of Semarang City. Vegetation will be provided 1.5 meters wide from the road border. Providing vegetation on road borders also protects pedestrians from the dangers of traffic accidents. Street furniture such as chairs and trash cans will remain in the buffer area as part of Indonesia Kaya Park's utilities.

Acalypha siamensis and *Pandanus amaryllifolius* plants can be used as borders around the park. The trees will be placed every four meters and right next to the road. The reason for the placement is that the closer it is to the noise source, the better it is at controlling the noise (Peng et al., 2014). The trees used are an alternation of *Tamarindus indicus* and *Cupressus sempervirens*. These two trees were chosen because they are easily found and possess the characteristics of the city of Semarang itself with *Tamarindus indicus* having the local name Asam Tree. Before the city of Semarang got its name, the tree was nicknamed Asam Arang and that eventually merged into Semarang. There is a pergola provided with the vines used, namely *Luffa acutangular* and *Luffa aegyptiaca*, which are vines that have existed for a long time in the city of Semarang. Vines are also allowed to propagate on the pergola's upholding poles to bind the artificial elements of the pergola to the existing vegetation. Providing a pergola also provides its own coolness amidst the weather in Semarang City, which tends to be hot. The presence of this vegetation will absorb vehicle noise and reduce noise in Indonesia Kaya Park. The cross-section of the buffer can be seen in Figure 4.

Figure 4

Traffic Noise Buffer Section



Note. The figure on the left demonstrates a closed buffer section separate from the road while the one on the right shows a buffer section along the zebra crossing. The main sound source of traffic noise is motorized vehicles.

Artificial interventions to reduce traffic noise were carried out at the entrance to the park center. The materials used in this intervention must have sound insulation properties and should also be sustainable. One material that can be used as an intervention to reduce traffic noise is bamboo. Bamboo is a material that has acoustic properties similar to rockwool and it has good sound-absorbing properties (Zubir & Rahman, 2021). The flexible nature of bamboo makes it suitable as a construction material, especially in Asia (Borowski et al., 2022). Bamboo is also considered to be highly sustainable because it can be harvested every year after 3-4 years of planting. Bamboo also has a fast growth rate and can be planted together with other plants. To produce bamboo, the energy required is only 0.5 MJ/Kg, lower than concrete (0.8 MJ/Kg) and steel (30 MJ/Kg) (Manandhar et al., 2019).

The placement of artificial interventions at the entrance is made to form a kind of tunnel with a frame made of bamboo. The color of bamboo has natural properties and can easily be integrated with the surrounding vegetation. The use of this material will add its own characteristics to Indonesia Kaya Park because this material is still rarely used in parks in Semarang City. The frames are then connected to each other with woven bamboo to provide protection from sunlight and excessive vehicle noise. The form of bamboo used will affect the acoustic properties of the bamboo. An object's twisted shape can reduce sound better than its normal condition (Rose et al., 2020). From here,

the bamboo used as a frame is twisted to provide better acoustic properties. The size of the bamboo used as a frame should have a diameter of 8 cm because this is the minimum size for bamboo to be used as a construction material (Correal, 2020). The application of this artificial intervention can be seen in Figure 5.

Before and After

A simulation was carried out using the I-SIMPA application, and the sound source entered was 82.39 dB, which is the highest decibel value measured using a decibel meter. The sound source was placed 3 meters from the park boundary on the outside of the park, and the receiver was placed 1.5 meters from the park boundary on the inside of the park. The simulation shows a noise reduction of 6.3 dB from 56.5 dB to 50.2 dB. This result is less than Raihan (2023) stated, but it still has significant value in reducing park noise. The results of this simulation can be seen in Figure 6.

Even though this research focuses on reducing traffic noise in Indonesia Kaya Park, there are still additional benefits provided by both interventions in other respects, including aesthetics. The aesthetics provided by this intervention enrich the impression of a monotonous park and add a more clearly visible sense of place to the park area. The visualization before and after natural and artificial interventions can be seen in Figure 7.

Figure 5

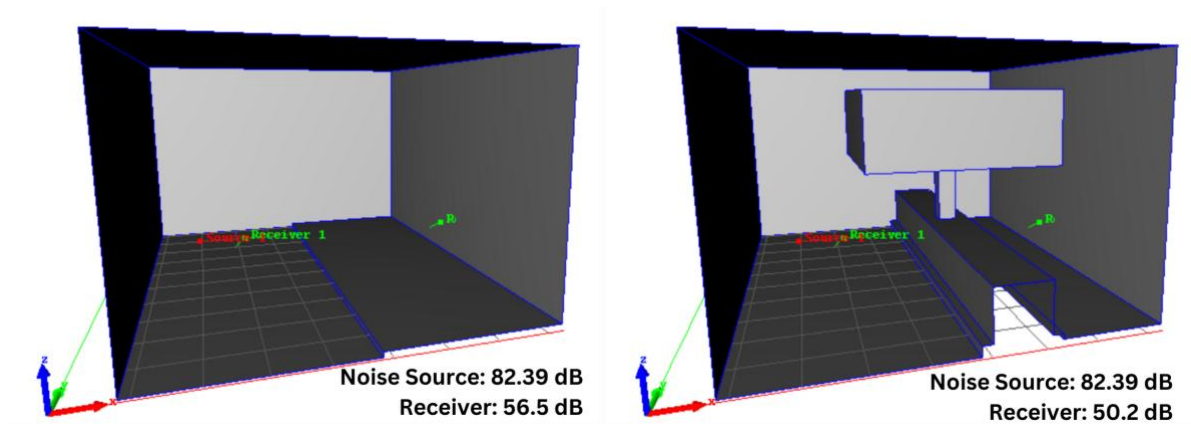
Artificial Intervention in Indonesia Kaya Park



Note. This figure shows the material and form of the artificial intervention in Indonesia Kaya Park.

Figure 6

Traffic Noise Before and After Natural Intervention



Note. This figure shows the simulation of the intervention in Indonesia Kaya Park. The left image shows the condition before natural intervention while the right shows the condition after natural intervention.

Figure 7

Indonesia Kaya Park Before and After Intervention Visualization



Note. This figure visualized Indonesia Kaya Park's condition in concept, before and after traffic noise intervention.

CONCLUSION

Indonesia Kaya Park's average decibel value is below 70 dB, with high traffic noise in the north due to congested roads and government and educational activities. High decibels are registered near the road, with three corners having high decibels due to road junctions. Urgent intervention is needed on the northern part of the road, as well as two street corners and park edges in the crossing area. Vegetation and artificial interventions can be used to reduce traffic noise in Semarang City. Vegetation can reduce noise by up to 12 dB, with plant density and height influencing the reduction. Green walls and bamboo poles with vines can also be used. Native vegetation requires less maintenance and is less prone to invasive species. External vegetation, such as Acacia trees and redbud flowers, is often used in parks, causing a loss of various types of vegetation. Decorative vegetation like *Piper ornatum*, *Luffa acutangular*, *Luffa aegyptiaca*, and *Allamanda cathartica* can also be used to provide aesthetic value and identity. Indonesia Kaya Park in Semarang City is constructing a buffer between the road and the park, using endemic plants to reduce noise and increase public comfort. The buffer is 1.5 meters wide from the road border, protecting pedestrians from traffic accidents. Trees, such as *Acalypha siamensis* and *Pandanus amaryllifolius*, are placed every four meters, with *Tamarindus indicus* and *Cupressus sempervirens* chosen for their unique characteristics. A pergola with vines, *Luffa acutangular*, and *Luffa aegyptiaca* is also provided to absorb vehicle noise and provide coolness in Semarang City. Indonesia Kaya Park in Semarang City has created a buffer between the road and the park, using endemic plants and vegetation to reduce noise and increase public comfort. The buffer area will be 1.5 meters wide from the road border, protecting pedestrians from traffic accidents. Bamboo, a sustainable material with acoustic properties similar to rockwool, will be used as an intervention to reduce traffic noise. The bamboo frame, connected to woven bamboo, provides protection from sunlight and excessive vehicle noise. The twisted shape of the bamboo reduces sound better than its normal condition. The bamboo's diameter should be 8 cm, as this is the minimum size for construction materials. The bamboo's natural properties and sustainability make it an attractive choice for the

park. The I-SIMPA application was used to create a simulation of park noise reduction, with a sound source of 82.39 dB and a receiver of 1.5 meters from the park boundary. The simulation showed a 6.3 dB reduction in terms of natural intervention, less than the previous estimate, but still achieving a significant value in reducing park noise.

Further studies need to be done on simulation in artificial intervention, as currently, I-SIMPA cannot simulate complex structures such as twisted bamboo. Limitations in simulation also caused generalization in the model's shape, causing inaccuracy in the results; hence, a study precisely simulating the acoustic behavior of each species of vegetation suggested in this study would be helpful in terms of identifying the best vegetation to plant according to acoustic behavior. The research recommends placing interventions in areas of high urgency to promote better health and user experience in Indonesia Kaya Park.

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