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The Mutual Acoustic Effect Between the Open Theater and Public Urban Environment: A Case Study of The Children's Cultural Park

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Abstract Open theaters are crucial for public urban environments, as they require high-quality speech and listening processes. Designers protect open theaters by creating barriers and technical solutions to maintain an appropriate acoustic level. However, the impact of open theaters on the surrounding urban environment is often overlooked. This research aims to understand the mutual influence between open theaters and the surrounding environment to ensure environmental friendliness and noise-free operation. To achieve this, noise levels are measured near the open theater and other noise sources, such as roads, commercial uses, maintenance workshops, and mosques. These levels are then used to predict noise levels in the surrounding areas. The methodology was applied to Children's Cultural Park in Cairo, analyzing acoustic results to increase awareness of selecting the appropriate location for open theaters in urban environments. The noise levels were monitored at 10 different times, divided into three periods: morning (6 am to 12 pm), afternoon (2 pm to 6 pm), and night (8 pm to 12 am). The predicted noise levels were then mapped using satellite images and standard noise models, and the predictions were verified with recorded noise data from the field study.

Keywords Acoustic Comfort, Open Theater, Open Performance Area, Public Urban Environment, Noise Pollution, Noisy Residential Areas, GIS Modeling, Spatial Analysis

1. Introduction

Achieving acoustic comfort in public urban environments is crucial for the success of urban design processes. Open theaters, their activities, and performance areas are affected by the surrounding environment, which can create an uncomfortable and noisy environment for residents. Urban designers, architects, theater arts specialists, and acoustic engineers focus on studying the sound inside the open theater space to protect it from the influence of the surrounding environment. However, the open theater plays a mutual influence on the surrounding environment, as its impact is not more severe than the environment's.

Residential noise from the surrounding urban environment, such as traffic noise, commercial activities, workshops, factories, events, and public celebrations, can

make the public urban environment an annoying and uncomfortable noise environment. This requires technical processing to find solutions. Additionally, loud noise during nighttime can cause physiological changes for humans, such as hearing impairment, and can have psychological hazards [1].

In old Egyptian districts, noise pollution has become dominant, leading many residents to leave their apartments and move to new compounds far from frequent sources of noise, such as open wedding and event areas and 24-hour restaurants and cafeterias [2]. This paper aims to study the mutual influence between the outdoor theater and the surrounding urban environment in terms of acoustics, applying it to the Children's Cultural Garden in Cairo. The goal is to increase awareness of choosing the appropriate location for the open theater in the urban environment, avoiding negative sound effects from the surrounding environment and the open theater, and achieving the required acoustic quality for hearing and speaking processes in the open theater.

2. Materials and Methods

The research methodology for studying the mutual acoustic effect between the open theater and public urban environment is composed of two main parts, as presented in figure 1.

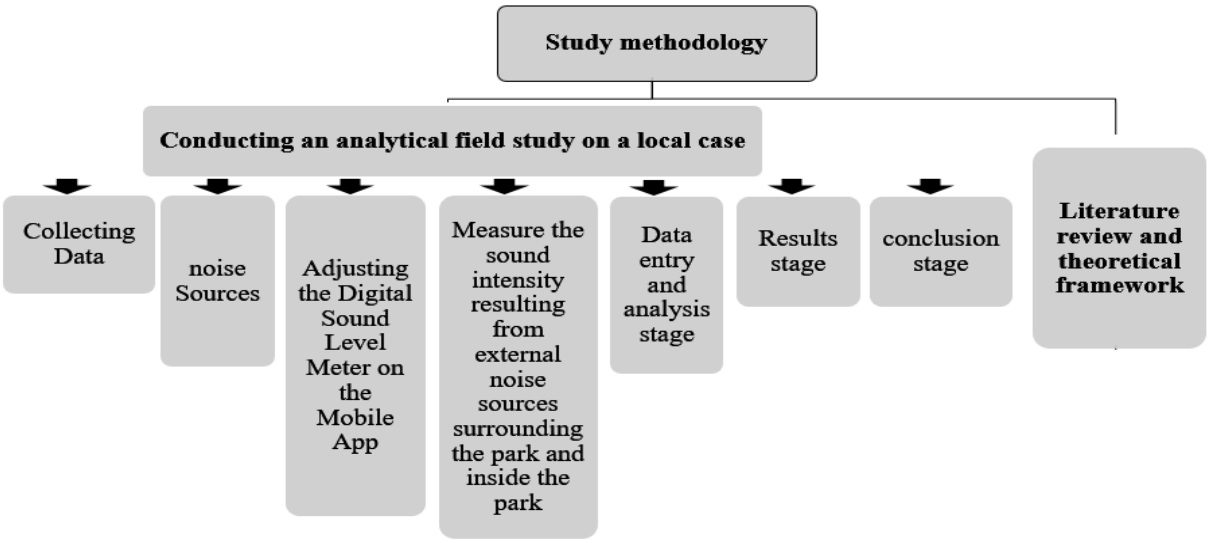
2.1. Part One: Literature Review and Theoretical Framework

Theoretical studies and analysis were conducted covering open theater between supporters and opponents. The studies focus on the integration of its concept and its impact on the urban and cultural dimension of cities, and also the noise pollution that open theater can make in the urban environment. Accordingly, the factor of distance between the open theater and the uses surrounding it was taken into account in the field study.

2.2. Part Two: Conducting an Analytical Field Study on a Local Case

A field study was conducted on a local case and analyzed with the aim of studying the mutual influence between the outdoor theater and the surrounding urban environment, and obtaining results showing the mutual influence in both directions, which can solve the mutual acoustic problems between them, through the following:

- **Collecting Data:** Collecting information about the Children's Cultural Park and the surrounding urban area through the Internet and a field study of the park.
- **The Sources of Noise:** Identifying and studying the sources of noise surrounding the park in terms of:
  - Its types and causes
  - Noise intensity
  - Timing of noise occurrence
  - Degree of control
- **Calibration Process: Adjusting The Digital Sound Level Meter On the Mobile App:** Adjusting the Digital Sound Level Meter on the Mobile App by the device (UNI-T / UT353) decibel meter to measure audio noise volume. The official international standard (UY353) is followed in the construction of the decibel meter sound level reader UT353; it is CE and UKCA certified and conforms with official international standards, including the European Union (EU), European Economic Area (EEA), and the United Kingdom (UK) standards. It works by converting ambient sound into electric signals, processing data, displaying results on an LCD, and constantly monitoring ambient sound. It also can transfer measurement data through Bluetooth to UNI-T's mobile app for further analysis, storage, and export [3, 4].



Source: Author

Figure 1. Research methodology

- **Measure The Sound Intensity Resulting from External Noise Sources Surrounding the Park and Inside the Park (Monitoring Acoustic Measurement Data):** using a sound intensity measuring device (UNI-T / UT353) decibel meter and mobile sound measurement applications (NOISECAPTURE).
- **Data entry & analysis stage:** "creating a database" and preparing a digital map by using geographic information system software tools (ARCGIS APP).
- **Results and Discussion**
- **The Conclusions and Recommendations**

3. Literature Review

3.1. Open Theater Between Supporters and Opponents

Critics argue theaters, both open and closed, can educate and enlighten people, particularly children, by reflecting real-life events, promoting community culture, and fostering artistic expression [5]. Supporters argue that these sounds should dominate the auditory environment, not be blocked by unfavorable sounds [6]. Two approaches to noise management have emerged: the noise control approach, which focuses on reducing noise levels through mechanical design, sound-absorbing materials, and insulating materials, and the soundscape approach, which considers natural and environmental sounds [7]. Recent research has shown that analyses of various sound elements reveal that the type of sound source has a significant impact on the assessment of acoustic comfort; even at very high sound levels, the introduction of a pleasing sound can significantly enhance acoustic comfort [8].

In addition, reducing the sound level does not always lead to increased satisfaction and pleasure with the auditory environment. Factors such as sound quality, user characteristics, and design elements of external urban spaces play a significant role in improving the acoustic environment of public urban spaces [9]. The soundscape approach considers the material, social, cultural, psychological, and architectural aspects of urban spaces, as well as the environmental aspects [7]. Sound is a crucial community resource, and annoying noises can be mitigated by incorporating positive and preferable sounds for human enjoyment by the soundscape approach [10]. In conclusion, the noise control and soundscape approaches address urban noise pollution, focusing on factors like sound quality, user characteristics, and design elements to improve the acoustic environment (table 1).

These studies indicate that open theater is crucial for culture and entertainment, and governments should support its role by providing suitable locations, spaces, and a good acoustic environment. Barriers, acoustic treatments, and technical solutions can help block city noise, regardless of its nuisance to surroundings.

Table 1. A comparative study between the soundscape & the noise control approaches

	Soundscape Approach	Noise Control Approach
The Sound	It is believed that sound is a resource that needs to be utilized and benefited from; otherwise, it deteriorates and becomes a burden on society.	Sound is viewed as a source of noise and must be eliminated.
Favorite Sound Quality	It focuses on the desired, preferred, and loved auditory environment by individuals and does not ignore unwanted sounds.	Annoying sounds are the sounds that cause individuals to be unable to sleep, and the limits of annoying sounds must depend on the permissible sound intensity levels to reduce the negative effects on individuals without giving any attention to the preferences of individuals in the auditory environment.
Interaction And Response Of Individuals	It is believed that people's preferences for sounds are influenced by both the loudness and quality of the sounds they hear. While total silence and serenity are not goals in and of themselves, it is possible to attain calmness when there is no longer any agitation, excitement, or disruption.	It depends largely on the fact that the interaction and response of individuals in the built environment is related to the level of sound intensity only.
Administration Method	This approach ensures that desirable sounds mask and cover other unwanted sounds. Such as when using the sound of fountain water to mask the noise resulting from the sound of cars.	It focuses on reducing noise levels, and this is done through three dealing strategies: Control noise at the source Controlling noise in its transmission path Noise control at the receiver

Source: Author based on [7,11,12].

3.2. An Open Theater is a Type of Noise Pollution

Open-air theater acts, including singing, music, dancing, and parades, are a major source of noise pollution in urban areas. The loudspeakers emit music and singing sounds exceeding the permissible volume limit, and without proper precautions like soundproof materials or prior licenses, this pollution leads to significant inconvenience and societal crime. This can affect people's sleep, hospital patients', and children's sleep, affecting the comfort of citizens in the surrounding areas. The allowable sound intensity limitations in decibels for each area type are displayed in (Table 2).

3.2.1. Laws and Regulations Pertaining to the Acoustics of Open Urban Theater

Accordingly, Egyptian laws included provisions to criminalize noise pollution resulting from such activities in open spaces. The most important of these laws are as follows:

3.2.1.1. *The Law Controlling Loudspeaker*

This legislation forbids the installation or use of loudspeakers without a license from the appropriate authorities. Violators of this law or the decisions enforcing it risk fines, jail time, and the confiscation of used equipment. [13].

3.2.1.2. *Street Vendors Law*

The Vendors Law stipulates that “It is not permissible for street vendors... to advertise their goods using bells, loudspeakers, or any other method that disturbs the comfort of the public.” Anyone who disobeys the law's provisions or the rulings that carry it out faces consequences. (This is found in Law No. (33) of 1957). [14].

3.2.1.3. *The Egyptian Penal Code*

Article 379 in the Egyptian Penal Code aims to preserve peace and combat noise pollution. It penalizes those who disturb community tranquility. However, the fines do not exceed one hundred Egyptian pounds. The rules have not been updated in over sixty years, requiring a review. The current fine amount is proportionate to the penalty's value, which may be equivalent to a pack of cigarettes. Inflation has decreased the penalty's value, affecting its intended purpose in Egypt. [16]

According to [17], it is best to teach the youngster not to use toys that produce loud noises or to put them too close to his ears, and it is preferable for workers to wear earplugs when using tools in workshops and factories or using a lawn mower or other machines that cause noise. Also, the machines in workshops must be constantly repaired, as this step can reduce or eliminate noise, while tightening control over industries and modifying operations to control noise during the issuance and renewal of work permits [18].

Open-air theaters can disrupt the public urban environment due to their open design, lack of acoustic isolation, spatial configuration, and audience noise. Sound projection, lack of isolation, and audience noise can contribute to noise levels. To mitigate these issues, careful acoustic design and urban planning strategies are needed, including strategic siting, landscaping, and architectural interventions. These techniques aim to control sound

propagation and enhance the soundscape while ensuring the theater's needs are met. Considering the aforementioned, audio planning plays a part in cities [5].

3.3. The Role of Auditory Planning in the Development Process

The National Center for Housing and Building Research suggests that open theaters, night gathering places, and cabarets can control noise pollution from it during planning and implementation stages through audio planning. This involves studying potential audio problems and finding necessary treatments. Buffer zones can be left between the building and the environment to reduce acoustic pollution. Acoustic planning should be part of land use planning projects, especially in large projects like airports and highways. This method predicts potential noise pollution sources, saving treatment costs [19].

Table 2. Maximum allowable sound level in decibels for each area type

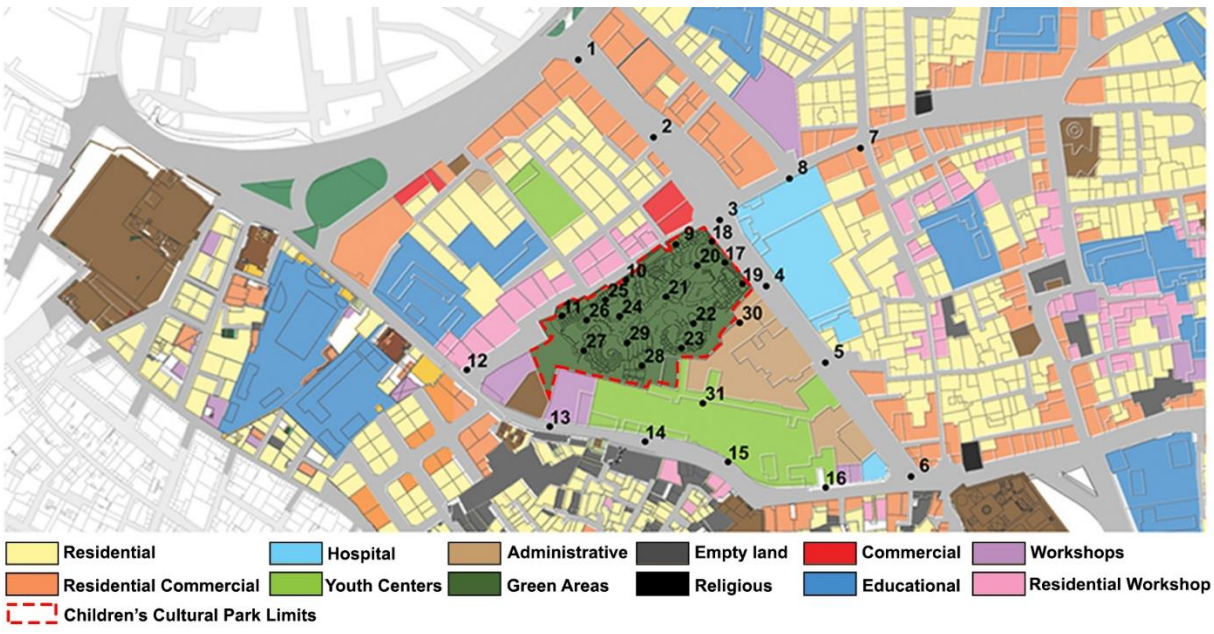
Area type	Maximum Allowable Sound Level (dB)					
	Diurnal Period		Evening Period		Night Period	
	from	to	from	to	from	to
Commercial & administrative areas and downtown	55	65	50	60	45	55
Residential areas with some workshops or businesses or on a public road	50	60	45	55	40	50
Residential areas in the city	45	55	40	50	35	40
Suburban homes with little traffic	40	50	35	45	30	40
Rural residential areas (hospitals - parks)	35	45	30	40	25	35
Industrial areas (heavy industries)	60	70	55	65	50	60

Source: Author based on [15].

Table 3. The sources of noise pollution

Sources of noise pollution					
External noise sources					Internal noise sources
Transportation			Industrial areas	Construction works	Local noise and noise resulting from recreational activities	All sounds coming from inside the residential units
traffic movement	Railway traffic	Movement of airports and ports				

Source: Author based on [19].



Source: Author based on the field study

Figure 2. Land use plan for the area surrounding the Children's Cultural Park

4. Collecting Data

4.1. About the Park

The Children's Cultural Park, designed by Dr. Abdel Halim Ibrahim, won the Aga Khan Award for Islamic Architecture in 1992. Located in Cairo's Sayyida Zeinab district, the park, which occupies a historical garden dating back to the Mamluk era, is a prominent urban feature serving the Arab world. Despite the city's crowding, the park occupies 12,000 square meters, making it a significant urban project.

4.2. Contents of the Park

The cultural park is a knowledge park for children that contains exhibition halls and a building for museum activities (located in the area around point 19), a large open theater (points 22, 23), a small open theater (points 24, 25, 26), a closed theater (point 27), a library (next to point 17), amusement (point 29), and a nursery (point 19). (Figure 2)

4.3. About the Study Area in AL-Sayyida Zeinab District

The Sayyida Zeinab area, in which the Children's Cultural Garden is located, is considered the downtown area.

This area is considered a mixed-use residential area, with

- Commercial uses such as shops, restaurants, cafeterias, and markets
- Government administrative uses and buildings, such as the presidency building of the Sayyida Zeinab district and the Khalifa district
- Religious buildings, such as the Sayyida Zeinab Mosque, the Ahmed Ibn Tulun Mosque, and the Lashin al-seifi Mosque
- Sports and recreational areas such as the Sayyida Zeinab Youth Center, gyms, and the Children's park
- Educational buildings such as nurseries and primary schools such as Najm Al-Din Primary School, Al-Suniya Girls School, and the Sayyida Zeinab Youth Center Nursery
- Hospitals such as Al-Hawd Al-Marsoud Hospital for Dermatology and Venereology and Sayyida Zeinab General Clinic
- Workshops and maintenance places, car maintenance and repair workshops, carpentry and blacksmithing workshops, and electrical appliance repair.

All of these uses make the area a lively residential service area, and it is noisy most of the time as a result of the crowding and sounds resulting from these uses at different times throughout the day and sometimes at the same time.

5. The Sources of Noise

Noise sources around the study area were identified as shown in (Figure 2) (Tables 4,5).

5.1. Monitoring Points in the Area

According that, (31) points were identified in the study area within the Sayyida Zeinab District (Table 5, Figure 2).

5.2. Calibration Process: Adjusting the Digital Sound Level Meter on the Mobile App

Adjusting the Digital Sound Level Meter on the Mobile App by the device (UNI-T / UT353) decibel meter to measure audio noise volume. The official standard UY353 is followed in the construction of the decibel meter sound level reader UT353, a sound measurement instrument that complies with international standards. The SPL (Sound Pressure Level) calibration approach was employed by the authors in accordance with [20].

Table 4. Sources of Noise surrounding the study area

Sources of Noise	Type	Noise Intensity (Average during day) (dB)	Timing of noise occurrence	Degree of control
Al-Hawd Al-Marsoud Hospital (Area from point 3 to point 8)	Hospital Noise (crowd noise of hospital)	88.05	Every day except Friday from 6 am to 3 pm	weak
Presidency building of the Sayyida Zeinab & Al-Khalifa Districts (Area from point 4 to point 5)	Parking noise & Transportation and road noise	86.6	Every day from 7 am to 2 pm	weak
The old Rashidi Al-Mizan factory building (Area from point 2 to point 3)	street vendor's noise	83.2	Every day from 10 am to 2 pm and From 8 pm to 12 am	medium
The Sayyida Zeinab Youth Center (Area from point 14 to point 15)	social & youth sports activities' noise	80	Every day from 8 am to 8 pm	medium
Car maintenance, carpentry & blacksmith workshops (Area from point 9 & 10 to 11)	Workshop noise	83.7	Every day from 10 am to 6 pm	weak
Ahmed Ibn Tulun Mosque (Area around point 6)	Call to prayer and iqama noise Microbus stop	86.7	Every day during prayer times for Muslims	weak

Source: Author based on the field study

Table 5. Detailed description of the points location

NO.	Description of the point's location	Type	Noise Intensity: day Average (dB)	Timing of noise occurrence	Planting situation	Noise source control degree
1	The main bus station & the main microbus stop on Qadri Street	Traffic noise	87	Daily from 6 am to 12 am	No planting	Weak
2	The old Rashidi Al-Mizan factory building	Street vendor's noise	83	Daily from 10 am to 2 pm & from 8 pm to 11 pm	No planting	Medium
3	The intersection of Qadri St. with Al-Marsoud St., where the entrance no.2 of Al-Marsoud Hospital & the temporary microbus stop are.	Long, crowded lines' noise from entering the hospital & traffic noise of the temporary microbus stop	91	Daily from 6 am to 3 pm, except on Fridays due to hospital closure & clinic remains open only	Some trees on one side of the road	Weak
4	The point that The Children's Cultural Garden's exterior fence ends at the Sayyida Zeinab District Presidency Building.	Parking noise, transportation and road noise	87	Daily from 7 am to 2 pm	Some trees on one side of the road	Weak
5	The front area of the Egyptian Child Welfare Association building	Street vendor's noise	81	Daily from 10 am to 2 pm and From 8 pm to 11 pm	Some trees on one side of the road	Medium
6	Ahmed Ibn Tulun Mosque building	Call to prayer and iqama sounds & Microbus stop	87	Daily during prayer times for Muslims	Some trees on one side of the road	Weak

Table 5 continued

7	The intersection of Al-Hawd Al-Marsoud St. with Salama Hegazy St. where the vegetable market zone and the entrance to the Birkat Al-Fil residential area are.	Street vendor's noise The street is home to a vegetable market	81	Daily from 8 am to 8 pm	Some trees on both sides of the road	Medium
8	The entrance no. 1 to Al-Hawd Al-Marsoud Hospital	Long, crowded lines' noise from entering the hospital	85	Daily from 6 am to 3 pm, except on Fridays due to hospital closure & clinic remains open only	Some trees on both sides of the road	Weak
9	Entrance point of Abu Al-Dahab Street to the nearby residential area & the area for workshops	Workshop noise	83	Daily from 10 am to 6 pm, except Friday prayer timing	Some trees on both sides of the road	Weak
10	From within the park, close to the Children's Cultural Park's small open theater entrance	Workshop noise	84	Daily from 10 am to 6 pm, except Friday prayer timing	Some trees on one side of the road	Weak
11	The point that The Children's Cultural Garden's exterior fence ends at the Public Transport Authority car garage building	Parking & traffic noise	81	Daily from 6 am to 10 pm	Some trees on both sides of the road	Weak
12	The intersection of Abu Al-Dahab St. with Abdul Majeed Al-Labban St. (Marsina)	Normal street sounds	78	Daily	Some trees on one side of the road	Medium
13	Lashin Al-Seifi Mosque	Call to prayer and iqama sounds	78	Daily during prayer times for Muslims	Some trees on one side of the road	Weak
14	The maintenance building and its cars and buses yard of the Transport Authority (beginning of the Kabsh Castle Area)	Parking & Transportation & road noise	78	Daily from 7 am to 2 pm	Some trees on one side of the road	Weak
15	Sayyida Zeinab Youth Center building	Social & youth sports activities' noise	80	Daily from 8 am to 8 pm	No planting	Medium
16	The historic Sanjar Al-Jawli Mosque building	Normal street & Call to prayer and iqama sounds	84	Daily and during prayer times for Muslims	Some trees on one side of the road	Medium
17	The main entrance to the Children's Cultural Park	Parking, transportation, road noise & street vendor's noise	75	Daily from 7 am to 10 pm	Some trees on one side of the road	Weak
18	The beginning of the garden fence on the side of Qadri Street	Parking noise, transportation and road noise	73	Daily from 7 am to 10 pm	Some trees on one side of the road	Weak
19	The garden fence's endpoint on the side of Qadri Street	Parking noise, transportation and road noise	75	Daily from 7 am to 10 pm	Some trees on one side of the road	Weak
20	The start point of the main path in the park	Social activities' noise from children	67	Friday & Saturday from 2 pm to 10 pm	High density of trees and vegetation	Medium
21	The middle point of the main path in the park	It's kind of quiet	65	Daily except Friday and Saturday due to the park's weekend festivities	High density of trees and vegetation	Medium

Table 5 continued

22	Main open theater (audience Places point)	It's extremely quiet except on Friday and Saturday due to the amusement park's noise & the park's festivities	55	Daily except Friday and Saturday due to the park's weekend festivities	High density of trees and vegetation & stone walls as barriers	Strong
23	Main open theater (performance stage)	It's extremely quiet except on Friday and Saturday due to the amusement park's noise and the park's festivities	50	Daily except Friday and Saturday due to the park's weekend festivities	High density of trees and vegetation & stone walls as barriers	Strong
24	Small open theater (stage)	Children's social activities noise	76	Friday & Saturday from 2 pm to 10 pm	High density of trees and vegetation and the barriers of children's book outlets	Medium
25	The children's book outlets fence from Muhammad Abu Al-Dahab Street	Children's social activities noise & Workshops noise	75	Friday & Saturday from 2 pm to 8 pm	High density of trees and vegetation and the barriers of children's book outlets	Medium
26	The small open theater entrance of the Park from Muhammed Abu Al-Dahab Street	Children's social activities noise & Workshops noise	70	Friday & Saturday from 2 pm to 8 pm	High density of trees and vegetation and the barriers of children's book outlets	Medium
27	Closed theater building	Children's social activities noise & amusement park noise	70	Friday & Saturday from 2 pm to 8 pm	High density of trees and vegetation	Strong
28	The end point of the park's main path, nearby Public Transport Authority's bus yard	Children's social activities noise & Parking noise & Transportation and road noise	77	Daily from 7 am to 10 pm	High density of trees and vegetation	Weak
29	Children's play amusement park	Children's social activities noise & amusement park noise	84	Friday & Saturday from 2 pm to 8 pm	High density of trees and vegetation	Weak
30	Children's library building near the fence of Sayyida Zeinab district presidency building	Children's social activities noise and Parking noise	74	Daily from 7 am to 2 pm	Some trees and concrete wall as a barrier	Weak
31	Out of the park, In the Sayyida Zeinab Youth Center area, near the garden fence	Social & youth sports activities' noise	70	Daily from 10 am to 8 pm	Some trees and concrete wall as a barrier	Medium

Source: Author based on the field study

The literature that they reviewed indicated that they could readily predict the Sound Level by using an iPhone and flagship Samsung phones, such as the Note8, Note9, A30, A50, etc., would produce better results than using other phones with decent microphone quality. The un-calibrated smartphone was set up next to the calibrated SPL at a distance of one meter from the source after the study's tonal sounds and white noise were played continuously from a reliable source. The fluctuations or variations along the octave bands were produced by continuously adjusting the tonal sounds using the smartphone and SPL meter (in music, one note is higher than another note at twice the frequency; the space between them is an octave). Using a sound pressure level meter (UNI-T UT353) to calibrate a noise app named (NOISECAPTURE), the current study recorded sound levels at specific points on the app with ease for future reference.

For note: most smartphones have high amplitude dynamic operation noise, which was not taken into consideration while the program is used to collect noise data and measurements, so this necessitated calibration using a standard sound pressure level meter (noise meter) and basing the analysis on its measurements in order to eliminate the possibility that the noise levels recorded via the mobile phone application may be inaccurate and to guarantee the highest level of accuracy in the measurements. The comparative analysis of the measurements revealed that the predictions' accuracy was ±3.0 dB.

6. The Measuring Sound Intensity Process (Monitoring Acoustic Measurement Data)

After the calibration process, the intensity of sound resulting from external noise sources surrounding the park and inside the park was measured at the times from 6 am to 12 am on Saturday (06/08/2024). Saturday was chosen for the following:

- Saturday is the day when all noise sources gather, whether it is the noise of the surrounding environment from the hospital, workshops, factories, the public transportation system, restaurants, and cafeterias, or park activities from amusement park activities and celebrations in large and small theaters.
- This is due to the Egyptian vacation system. In Egypt, Saturday is a working day for some institutions and a weekend for other institutions. It is an additional day after Friday, but most activities stop on Friday, except for mosques and entertainment places, because it is a day associated with religious rituals for Muslims.
- Therefore, choosing Saturday allows for a comprehensive study of the impact of events surrounding the park, ensuring that all surrounding activities affect each other simultaneously.

So the intensity of sound was measured for 31 points with determining the power for each point and each time according to the importance and occupancy rate for each time during the measurement times.

- Occupancy rate:
  - Very low occupancy = 1
  - Low occupancy = 2
  - High occupancy = 3
  - Very high occupancy = 4
- Point power
  - The point that has a high impact
  - (Strong point) = 3
  - The point that has a medium impact
  - (Medium point) = 2
  - The point that has a low impact
  - (Normal Point) = 1

And the results were as follows: (Table 6)

Table 6. Monitoring acoustic measurement data

Street name	Point number	Score point	Point power	Occupancy Rate	The Sounds level at the timing of 6 am : 12 pm (dB)				The Sounds level at the timing of 2 pm : 6 pm (dB)			The Sounds level at the timing of 8 pm : 12 am (dB)		
					6:00 AM	8:00 AM	10:00 AM	12:00 PM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 AM
					Very low Occupancy		Low Occupancy		Very low Occupancy	High Occupancy		Very high Occupancy		Very low Occupancy
					1	1	2	2	1	3	3	4	4	1
Mohamed Qadri Pasha Street	1	1	Normal		65	80	89	90	105	103	95	93	85	65
	2	1	Normal		63	75	85	90	95	100	90	90	80	64
	3	3	Strong		70	85	90	105	105	110	100	86	83	75
	4	2	Medium		70	75	87	90	100	105	95	85	84	75
	5	1	Normal		65	70	80	85	96	92	90	87	83	66
	6	2	Medium		75	80	85	95	100	98	94	90	80	70
Al-Hawd Al-Marsoud Street	7	1	Normal		60	68	77	82	90	94	90	90	80	80
	8	1	Normal		65	73	84	95	99	99	95	90	77	75
Abu Al-Dahab Street	9	1	Strong		61	75	82	98	101	90	90	80	77	72
	10	1	Strong		62	77	85	96	105	95	95	85	75	62
	11	1	Medium		58	73	83	93	97	99	92	87	75	55
	12	1	Normal		58	70	79	90	95	85	90	80	71	63
Abdul Majeed Al Laban Street (Marsina)	13	1	Normal		60	73	85	87	90	75	77	97	79	60
	14	1	Normal		62	75	88	90	85	85	75	84	79	56
	15	1	Normal		65	75	85	92	89	85	80	85	82	62
	16	1	Normal		65	77	83	94	97	90	85	100	83	65
Inside the Children's Cultural Park	17	3	Strong		The park is closed at this time		58	62	65	80	85	90	90	66
	18	3	Strong				56	59	62	75	80	88	93	69
	19	3	Strong				60	62	67	85	87	93	89	60
	20	1	Normal				55	58	60	72	67	72	86	63

Table 6 continued

	21	1	Normal		52	55	58	70	60	65	89	72
	22	2	Medium		50	51	55	65	53	55	65	45
	23	3	Strong		45	44	50	60	50	51	60	42
	24	3	Strong		49	53	60	75	85	105	110	73
	25	1	Normal		52	56	59	78	85	97	101	70
	26	3	Strong		55	58	59	82	70	80	89	68
	27	1	Normal		58	58	63	77	72	86	82	66
	28	1	Normal		62	65	65	85	95	97	93	57
	29	3	Strong		59	59	67	105	110	109	105	56
	30	1	Normal		62	67	69	82	85	89	83	56
Inside the Sayyida Zeinab Youth Center	31	2	Medium		55	63	65	75	77	82	80	60

Source: Author based on the field study

7. Data Entry & Analysis Stage (Modeling Using GIS)

- Creating a database in (ARCGIS) using (X, Y) coordinates for survey points to add data for each time as it got collected from the field. (Table 7)
- Using the join tool to add the survey data to the database for the time and measurement of the sound level.
- Adding the base map of the Action Area (Children's Cultural Park) to the database to use the building as the barrier of the sound level.
- Using the IDW tool (inverse distance weighted) to interpolate a raster surface from survey points data for each time collected as per the table. 6.
- IDW parameters (cell size = 1, power = 3, search points = 4, barriers = building). For each time.
- Cell size: The cell size at which the output raster will be created.
- Power: Controls the significance of surrounding points on the interpolated value. A higher power value results in less influence from distant points, and a lower power value is a high influence from distant points.
- Search points: Defines which of the input points will be used to interpolate the value for each cell in the output raster.
- Barriers: Polyline features to be used as a break or limit in searching for the input sample points for sound level as building or structure furniture.
- Generating 10 raster surfaces for each time from survey data.
- Using Weighted Sum tool that uses Overlays several raster, multiplying each by their given weight and summing them together.
- Weighted Sum tool to generate an overall map with score for each time Wight with a score as the method used, and generate an overall map for 3 time zones (6AM:12PM, 2PM:6PM, 8PM:12AM).

Table 7. Coordinates of monitoring points

Point no	X (m)	Y (m)	Point no	X (m)	Y (m)	Point no	X (m)	Y (m)
1	330854.7309	3323734.366	**11**	330835.7851	3323522.811	**21**	330920.3066	3323538.498
2	330910.853	3323668.214	**12**	330758.4615	3323480.117	**22**	330940.9557	3323515.721
3	330963.3056	3323600.109	**13**	330826.4187	3323433.86	**23**	330932.7701	3323498.674
4	331001.2403	3323547.057	**14**	330902.8584	3323421.162	**24**	330880.4915	3323525.514
5	331048.5429	3323485.869	**15**	330969.0539	3323404.395	**25**	330872.2997	3323535.949
6	331117.8088	3323393.635	**16**	331045.7955	3323384.704	**26**	330858.0737	3323523.742
7	331077.4443	3323658.386	**17**	330967.2569	3323565.533	**27**	330853.3693	3323493.91
8	331019.8537	3323633.214	**18**	330956.4544	3323584.091	**28**	330899.2655	3323481.739
9	330928.7483	3323580.949	**19**	330981.6061	3323548.642	**29**	330888.7418	3323500.019
10	330886.6814	3323550.411	**20**	330945.2831	3323563.566	**30**	330978.4525	3323517.158
						31	330948.8239	3323452.003

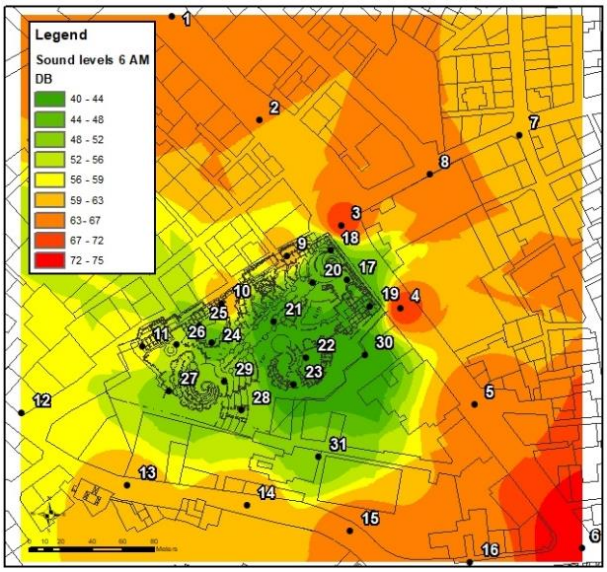
Source: Author based on Google Earth

8. Results & Discussion

Acoustic maps were extracted from GIS for each time of the study area, and the results were as follows:

- **Sound levels at 6 am:**

The study area has been experiencing high sound levels exceeding permissible limits for residential areas, indicating a lively and noisy environment. (Figure 3)



Source: Author based on GIS

Figure 3. The noise map of study area at (6 am)

The northern, eastern, and southern areas surrounding the park have the highest sound levels, ranging from 67 to 75 decibels, while the western area has lower levels.

The northern parts, particularly at point (1), are affected by the noise from the two official bus and microbus stations, causing a noise level of (65) decibels.

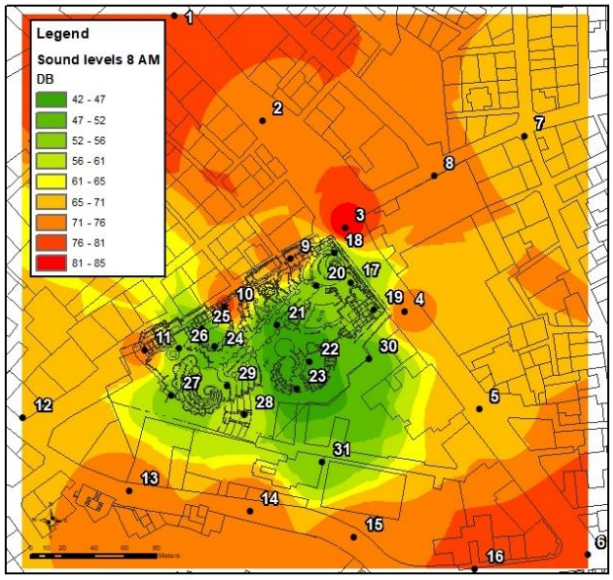
The eastern parts, especially at points (3 & 4) and (4 & 5) are also noisier, reaching 70 decibels due to crowding at the entrances to Al-Hawd Al-Marsoud Hospital and the temporary parking of microbuses at this point. The main direction of these microbuses is to leave the station at Sayyida Zeinab metro station and head to Sayyida Aisha Square or Ahmed Maher Hospital, but this temporary stop ends at the end of hospital working hours, causing severe crowding.

The southern parts, at points (6) and (15), have high sound levels due to the secondary microbus station and the children's nursery in the youth center.

- **Sound levels at 8 am:**

The overall pattern is approximately similar to the 6AM map, with the northern, eastern, and southern areas surrounding the park having the highest sound levels, reaching (75-80) dB. The western area still shows lower sound levels, primarily in the (70-75) dB range.

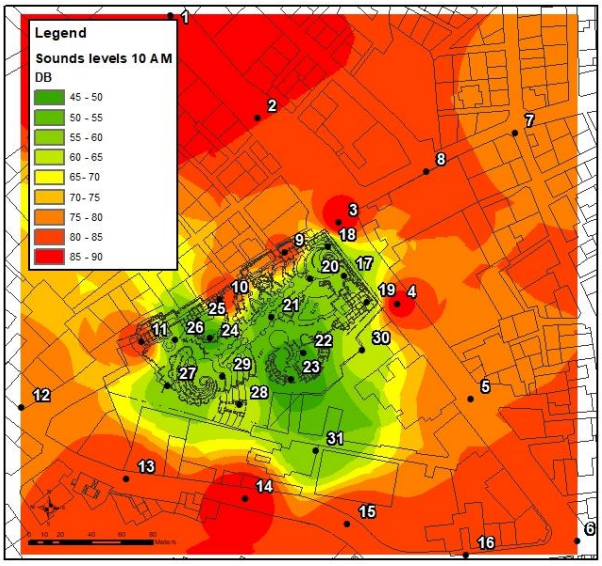
This indicates that the high noise levels persist in the northern, eastern, and southern parts as the day progresses. (Figure 4)



Source: Author based on GIS

Figure 4. The noise map of study area at (8 am)

- **Sound levels at 10 am:**



Source: Author based on GIS

Figure 5. The noise map of study area at (10 am)

Noise levels in the park have significantly increased, with northern, eastern, and southern areas experiencing (80-90) dB levels.

The western area has higher levels (79-85) dB due to car maintenance, carpentry, and blacksmithing workshops. The lowest sound intensity was recorded at 10 am inside the park, ranging between (45-62) decibels.

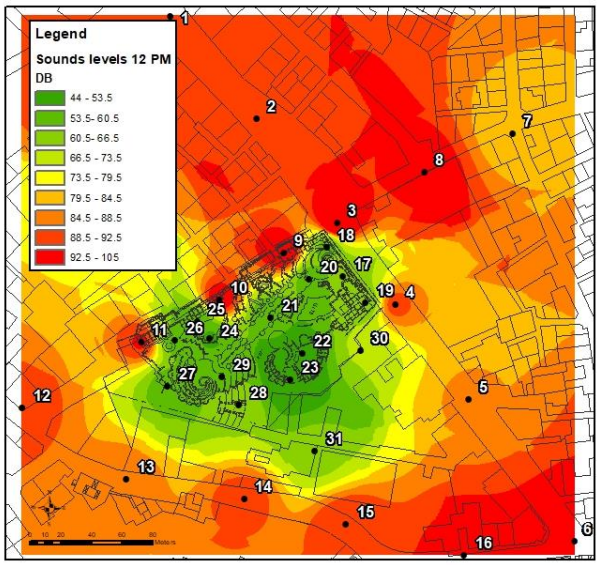
This increase is attributed to increased human activity, traffic during late morning hours, and workshop operations. (Figure 5)

- **Sound levels at 12 pm:**

The park experiences high noise levels, with northern,

eastern, and southern areas reaching 85-105 dB, and the western area exhibiting elevated levels in the 93-98 dB range. The park also experiences an increase in sound intensity, with measurements ranging from 44-67 decibels.

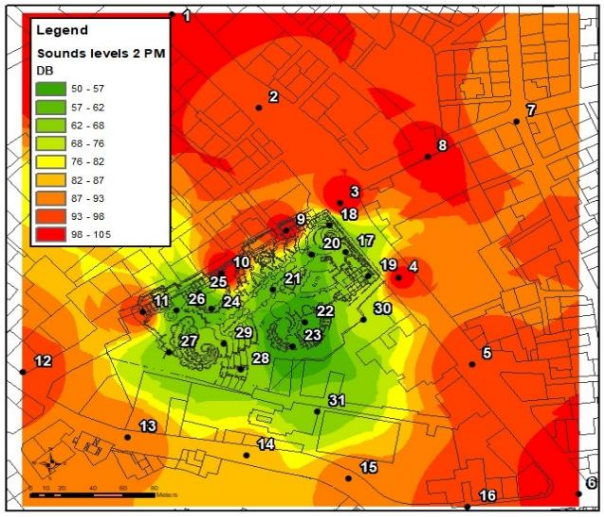
These high noise levels suggest a peak in activity and urban/workshop operations during midday. (Figure 6)



Source: Author based on GIS

Figure 6. The noise map of study area at (12 pm)

- **Sound levels at 2 pm:**



Source: Author based on GIS

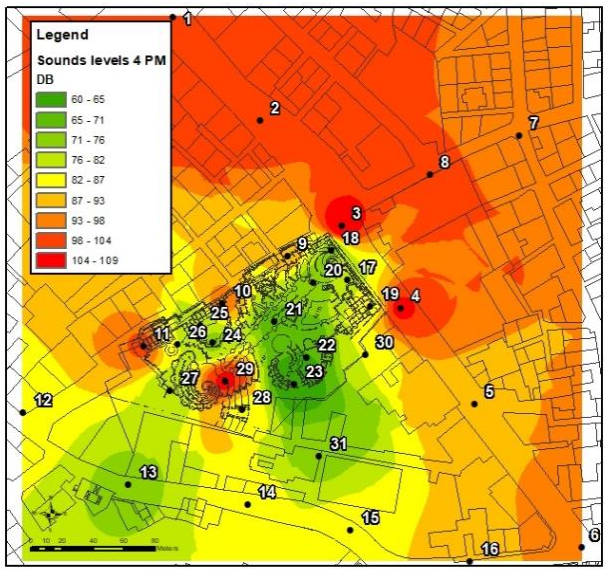
Figure 7. The noise map of study area at (2 pm)

The 2 PM map shows high sound levels in all areas surrounding and inside the park, reaching 90-105 dB. This indicates a peak in activity, with a slight increase at points 22 and 23 of the main theater. This is due to rock-made parallel barriers acting as a sound barrier, protecting the main theater from surrounding noise.

The noise levels persist throughout the day, indicating a peak in activity. (Figure 7)

- **Sound levels at 4 pm:**

The situation on the map differs at 4 p.m. A high level of noise appears inside the park, much louder than outside, and the reason is due to the start of the children's amusement park at point (29), which works from (4 p.m. to 8 p.m.) on Fridays and Saturdays, due to the main theater and the small theater starting their shows on these two days from (8 p.m. to 10 p.m.). As for the weekdays, the two theaters do not work, and the amusement continues to work until (10 p.m.) and sometimes until the hour (12 a.m.), which recorded a higher sound intensity of up to (105) decibels, which in turn affected the transmission of sound to the inner surroundings of the park, and the rest of the external areas recorded (90-110) decibels, due to the increase in noise sources, an additional source, which is the children's amusement. (Figure 8)

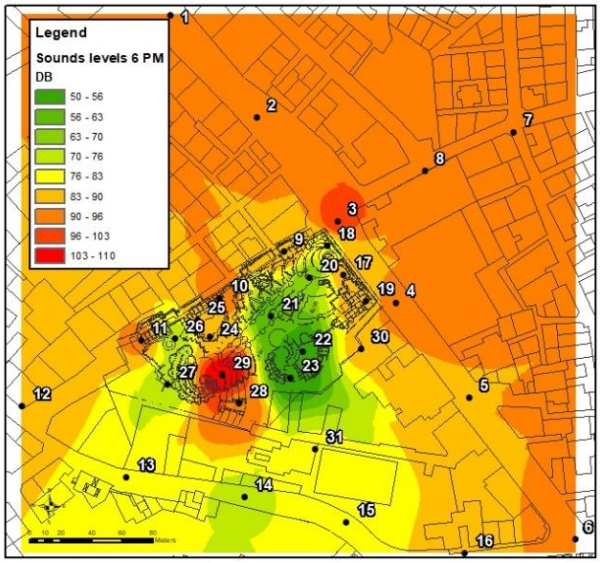


Source: Author based on GIS

Figure 8. The noise map of study area at (4 pm)

- **Sound levels at 6 pm:**

The rate of sound intensity increased in the amusement park area inside the park, and the surrounding area continued to increase, even though it was the time when the workshops were closed, but the area surrounding the workshops still recorded higher sound points due to its being affected by the sound produced by the amusement area. Sound levels in the northern, eastern and southern regions were also lower than before, as a result of the end of the deadline for receiving medical examination cases at the hospital, and the end of the timing of nurseries and schools. (Figure 9)

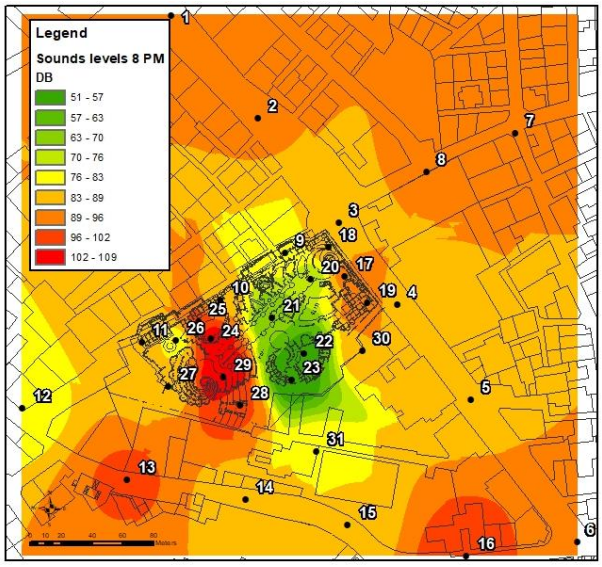


Source: Author based on GIS

Figure 9. The noise map of study area at (6 pm)

- **Sound levels at 8 pm:**

It did not differ much from the map at 6 p.m., except that the average sound intensity increased to the highest degree in the amusement park area in the park, and this led to an increase in the sound intensity in the residential area near the workshops, despite the workshops finishing their work at this time. (Figure 10)

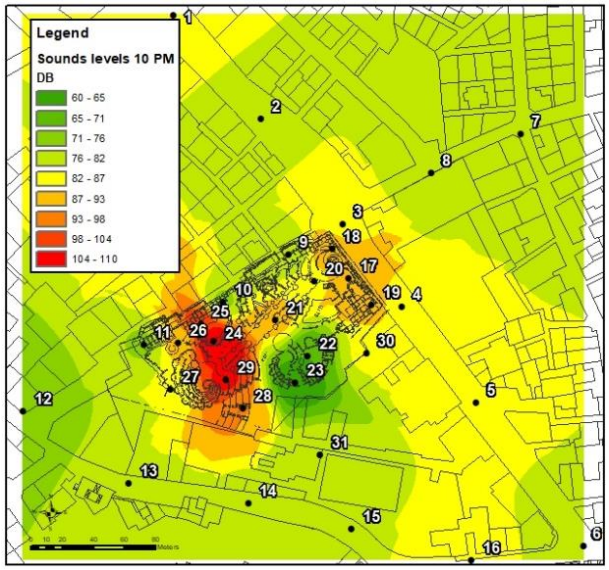


Source: Author based on GIS

Figure 10. The noise map of study area at (8 pm)

- **Sound levels at 10 pm:**

The area shows lower rates of sound intensity than before, ranging from approximately (70 to 83) decibels, as a result of the noise of the coffee shops and gym areas at points (3, 8, 7), while the park records the highest level of sound intensity inside it in the two amusement areas (105) decibels, and the small theater (110) decibels. (Figure 11)

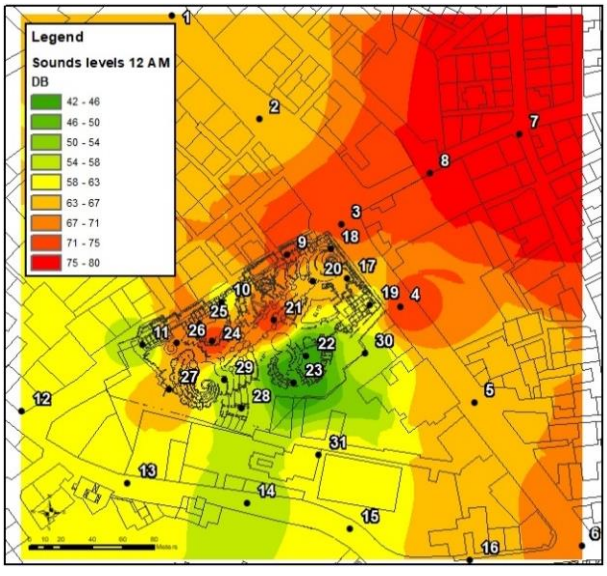


Source: Author based on GIS

Figure 11. The noise map of study area at (10 pm)

- **Sound levels at 12 am:**

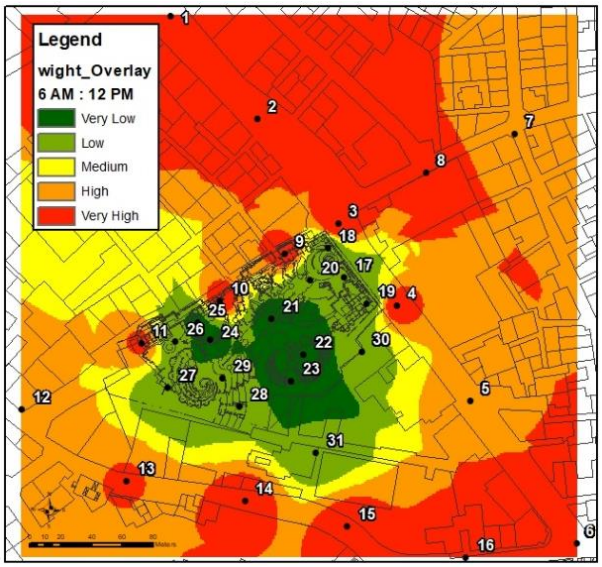
Sound levels inside the park are still high, but they decreased from the map at 10 p.m., ranging between (60 to 73) decibels, while the exit of users affected the park entrance area, and sound levels increased inside the eastern area at points (8, 7) due to the presence of the gym and a food store in front of it are called Baba-Abdo. It is one of the most famous restaurants and food stores in this area, and has been associated with the place for more than 50 years. This store is open from after 12 a.m. to 6 a.m., where the points (8, 7) were recorded for sound intensity ranging from (75 to 80) decibels. (Figure 12)



Source: Author based on GIS

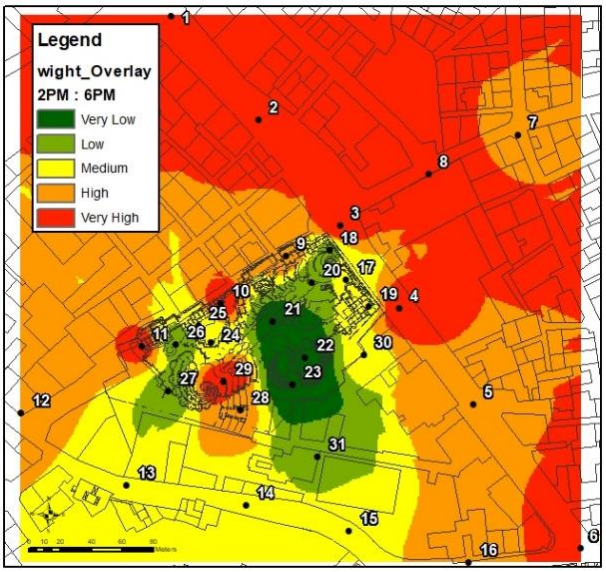
Figure 12. The noise map of study area at (12 am)

- **Collected sound maps were produced for 3 periods throughout the day, and a total sound map was collected to obtain final conclusions from them.** (Figures 13, 14, 15, 16)



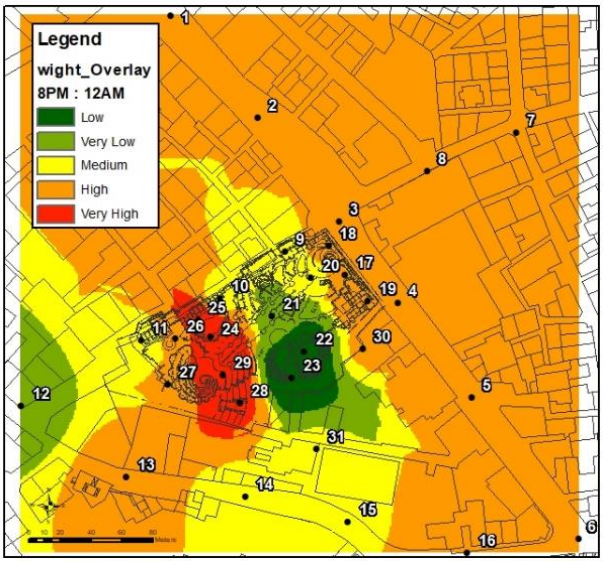
Source: Author based on GIS

Figure 13. The noise map of the study area at the early morning period from (6 am to 12 pm)



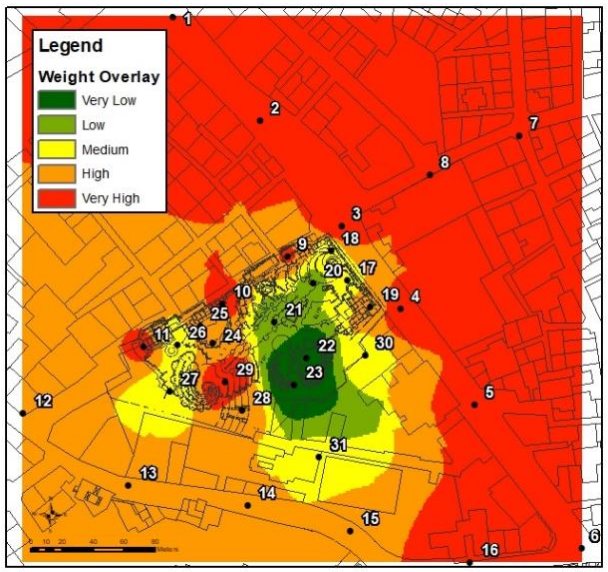
Source: Author based on GIS

Figure 14. The noise map of the study area in the evening period from (2 pm to 6 pm)



Source: Author based on GIS

Figure 15. The noise map of the study area during the night period from (8 pm to 12 am)



Source: Author based on GIS

Figure 16. The noise map of the study area during all hours of the day

9. Conclusions

Acoustically the mutual influence between the open theater and the surrounding urban environment appears as follows:

- **Regarding the surrounding urban environment:**

1- The study area suffers from traffic congestion and overcrowding in its streets, which results in a high level of noise pollution along the city's street network.
2- Noise pollution levels increase in intersection areas, especially the intersection of Al-Hawd Al-Marsoud Hospital Street with Qadri Street, and Qadri Street Square (the main bus stop), at most times of the day.
3- Noise levels rise at peak times and morning times beyond the permissible limits in the streets of the study area. It rises to a maximum in the evening, as a result of it being affected by the level of noise produced at night from the loudspeakers of cafeterias and coffee shops, in addition to open theater activities, such as children's amusement parks and various performances.
4- Noise levels increase at the microbus stops, which are spread randomly and unofficially in the streets of the study area, such as the temporary stop of the microbuses at Al-Hawd Al-Marsoud Hospital and the temporary stop of Sayyida Aisha at the Ahmed Ibn Tulun Mosque.
5- Workshops are spread within residential buildings and along Muhammad Abu Al-Dahab Street, which leads to a high level of noise in the neighboring residential area.
6- Sound levels increase in the areas surrounding mosques, as the loudspeakers used for the call to prayer increase the intensity level of the sound produced during prayer times only and return to their normal level for the area after the end of the call to prayer and the iqama.
7- Building facades are affected by the noise outside in a way that causes residents to have sleep disturbances.
8- The study area contains many incorrect behaviors that have a serious role in increasing the level of noise, such as operating loudspeakers and music players (DG) for shop and cafe owners repeatedly, day and night, and using the horns of cars and microbuses in an inappropriate, permanent, and repetitive manner.
9- There are many sources of noise pollution in the study area, the most prominent of which are the sounds of cars, crowding, street vendors, and workshops.

- **For the children's cultural park:**

1. The main open theater in the park:

Despite all the sources of noise pollution surrounding the place, the design of the park includes a group of parallel rock barriers behind each other, especially for the location of the main theater in the park, each of which works to protect the large theater from being affected by the noise resulting from the surrounding environment.

At the highest noise levels in the surrounding area (110) decibels, the main open theater recorded only (60) decibels at times (4 p.m., 10 p.m.), as a result of it being affected by the noise of the park from within (the noise of the amusement park and small theater performances) and not the noise resulting from the surrounding urban environment, and its measurements were limited to (44: 51 decibels) at all times of the day.

During the field study, the organizers of the performance celebrated with rockets, firecrackers, and fireworks with the children and their families and launched fireworks from the area of the main open theater in the park. The measurements at that time recorded (120) decibels in the main open theater and (95) decibels outside the park inside the residential area opposite it at (10) PM, and we expect that if there is a performance inside the main open theater, its impact will be more severe and stronger than the impact of the urban environment on it.

2. The small theater in the park:

The small theater in the park was not greatly affected by the surrounding urban environment. Despite its proximity to the workshop area in the study area, the park fence from this side is considered a very strong sound insulator to block the noise of the external workshops from the small theater. The fence in this area was designed from a group of small rooms, the dimensions of which are (2.5 * 3.5) square meters, used as outlets for selling children's books, and works to block the sound coming from the workshops, which could affect the small theater in the park. The small theater recorded its highest reading affected by the surrounding area (60) decibels, at the time of Zuhr prayer, and the area outside recorded (95) decibels.

The small theater had a negative impact on the residential area adjacent to it. Measurements of the residential area were recorded at 10 p.m., that is, at the time at which the performance in the small theater takes place (from 75 to 85 decibels), while the small theater was recorded at the same time. (110 dB). This negatively affects the residents' ability to sleep, as it causes an increase in the source of noise pollution in this area. Despite the strong insulation resulting from the fence, when the noise level increased to higher than (110) decibels at the small theater, this increased the measurements of the external residential area, while it was recorded after the end of the show at (12) AM, (from 55 to 62) decibels.

3. Children's amusement park inside the park:

Children's amusement parks affected the sound intensity level of the outdoor area of the park much more than they affected the amusement parks, as measurements were recorded at 6 p.m. The noise in the amusement park was (110) decibels; in contrast, the outdoor area was (90-95) decibels. It was recorded immediately after the

amusement park noise stopped (80-85 decibels).

4. Rest of the park:

It was affected by the urban environment according to each time monitored, whether it increased or decreased according to the timing of the noise sources and their intensity, such as their effect on the sounds of the call to prayer and the Iqama.

10. Recommendations

From the above, it is clear that the effect that the open theater has on the surrounding urban environment is a mutual effect, and in most cases the effect of the open theater is more severe and violent than the effect of the surrounding environment on it, and therefore it.

- **Recommendations for decision makers:**

Authors recommend that the state and private investment institutions develop such open theatrical urban spaces (open theater), which help build cultural and enlightenment awareness for individuals and children in society. And choosing appropriate locations for such spaces and providing them with the appropriate acoustic environment for the success of their function. This will ensure their great popularity throughout the year and achieve the required financial and cultural profit. Reconsidering the value of the penalty for noise pollution under current laws and enacting new laws and regulations or amending them in line with the current extent of the crime itself.

- **Recommendations for the urban designer and architect:**

It is necessary for the urban designer and architect to be familiar with the elements affecting the design of such spaces, and how to calculate their influence, and to cooperate in the various stages of work between him and the rest of the specialists, and identifying what is new in the world of urban and architectural treatments and the materials that can be used to provide an audio environment suitable for all uses. It is necessary to protect the surrounding urban environment of open theaters from the influence of open theaters on them, as is the case in protecting theaters and isolating them acoustically to reduce the noise of the surrounding urban environment, by creating soundproof barriers or changing the terrain level of the open theater, etc. And the distance element can be taken into consideration at the beginning of the design process for open theater areas and work to provide large spaces between them and residential and urban areas used for landscaping, which in turn act as sound insulation areas for these uses within cities.

- **Recommendations for specialists in open theater science:**

It is necessary to realize the impact resulting from open theaters on the surrounding urban environment and take it into consideration in order to deal with it in a way that is proportional to both directions and does not harm any of the parties.

- **Recommendations for managing open theaters:**

Determine time schedules for the performances presented inside the open theater so that they are compatible with the needs of the residents of the surrounding area, without harm.

- **General recommendations:**

It is necessary to plant trees on the streets because they play a major role in absorbing a large portion of the noise level. And organizing traffic movement, especially at the most crowded road intersections, especially during peak times and on holiday evenings.

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