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Urban Soundscape Ecology: Considering Users Perception

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Abstract: *Public spaces impose an excessive impact on individuals' overall comfort and wellbeing. The acoustic environment in urban outdoor spaces represents, along with users' interaction and improving the public space elements, a fundamental objective of any city planning in order to design spaces that accommodate the complex dynamics of public life.*
As Cairo, Egypt, is considered one of the most overcrowded and largest capitals worldwide, it's soundscape resembles the richest and most diverse that could be experienced. The city's sonic environment is fueled up by the mass of activities and cultural demographic diversity. However, the lack of sufficient urban management observed through the last few years led to the deterioration of this historic city, and a general retrogression in the quality of life of its inhabitants. Recently, it was noticed that during the design and planning processes, architects and urban planners in Egypt, excessively focus on the visual aspects rather than the sensual dimension of public spaces, especially with the expansion of urban populations. A wide-ranging perspective, which includes sonic diversity and acoustic ecology, is still a neglected area of urban design. Therefore, a new and comprehensive planning vision should be considered to assure a completely sustainable way of life.
This paper focuses on the sound as an integration process, considering both urban sound sources and people's quality of lives and satisfaction. An analysis of Cairo`s soundscape was conducted; along with a questionnaire targeting Cairene inhabitants aiming at revealing factors affecting their soundscape and acoustic experience. The paper also outlines important mitigation measures related to the users' perception of the soundscape for Cairene inhabitants in order to underline the overall acoustic comfort of the urban open spaces and its role towards future enhancement of these spaces in Cairo.

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I. INTRODUCTION

"At a time when technological progress is bringing city sounds to the threshold of bedlam, it is no longer sufficient to design environments that satisfy the eye alone" [1]. Generally talking, the soundscape of a city is an important environmental reference to the quality of life in the urban setting. Soundscape concept considers sound mainly as a resource, among other scarce resources such as water, air, and soil. Subsequently, their management aims to rational utilization, protection, and enhancement of these resources with a special focus on individuals and their contribution to the quality of life for both present and future generations. This concept presumes the sound atmosphere as a multi-dimensional entity, based on the complex interaction between sound source, the physical environment, and human beings; and focusing not only on the negative features of the sound environment, but also on the positive aspects: considering physical, social, and psychological factors in human perception of the acoustic environment.

During the last few years, a growing awareness of sound ecology, as a vital aspect of the urban environment that should be considered as important as the visual aspect in a developing city planning and design process, has emerged. While most of the studies focused only on the negative aspect of the urban acoustic environment (using the term "noise"), the consideration of soundscape positive sounds in the planning process, , is usually overlooked. Planners and decision makers' recent researches focused on how to effortlessly apply the soundscape concept into urban planning practices. Therefore, this paper will discuss the impact of soundscape concept on the users' perception to reach the most effective and practical way to realize an improved acoustic environment.

II. URBAN SOUNDSCAPE DEFINITIONS AND BACKGROUND

Multiple communities of scientists and practitioners have identified the "Soundscape" according to their academic background and area of expertise (as shown in Table 1). A standardized definition has only recently been proposed by the "International Standard Organization" in 2014, defining soundscape as ''the acoustic environment as perceived or experienced and/or understood by a person or people, in context''[2]. On

the other hand, nearly all soundscape researches are performed by combining measurements of the acoustic environment concerning the individuals' auditory experience while taking into consideration users' physical environment and mental well-being.

The etymology of the term ‘‘scape’’ in a reference to an ‘‘area, scene, space, or view’’[3], ‘‘Soundscape’’ is thus defined as ‘‘sounds occurring over an area’’. The first use of the term was by Southworth in1969, an urban planner who used ‘‘soundscape’’ to refer to the acoustic properties of cities that help people relate to certain spaces. Southworth tested how blind people used sounds to form a ‘‘sonic identity’’ of unique areas in Boston [1]. While in 1977, in his seminal book ‘‘Tuning of the World’’, Schafer formalized the term ‘‘soundscape’’ as the ‘‘auditory properties of landscapes’’.

Table 1. Definitions of Soundscapes Used in the Literature *(Source: The Authors)*.

Name	Academic Background	Definitions
Schafer, 1994	Urban Planning	‘‘The soundscape is any acoustic field of study. We can isolate an acoustic environment as a field of study just as we can study the characteristics of a given landscape. However, it is less easy to formulate an exact impression of a soundscape then of a landscape.’’ [4]
Krause B., 1987, 2002	Bioacoustics Ecologist	All of the sounds (biophony, geophony, and anthrophony) present in an environment at a given time, soundscape as a finite resource- competing for spectral space. [5] [6]
Farina A., 2006	Eco-field and Environmental Sciences	The collection of sounds associated with a given landscape as perceived by organisms. [7]
Schulte-Fortkamp and Fiebig, 2006.	Fluid Dynamics and Technical Acoustics	Soundscapes can be described as environments of certain sound sources and the way people feel about those sounds contributing to the identity of those residential areas.[8]
Liu et al., 2007	Urban social-ecological systems	It is hypothesized that sound reflects natural and human activities and consequently serves as an exceptional ‘‘universal’’ variable to consider in any study of a coupled natural-human system. [9]
Brown A., 2011.	Environmental Sciences	The totality of all sounds within a location with an emphasis on the relationship between an individual’s or society’s perception of understanding and interaction with the sonic environment. [10]
Pijanowski et al., 2011	Landscape and Soundscape Ecology	Soundscapes are the assembly of biological, geophysical, and anthropogenic sounds that originate from a landscape and which varies over space and time reflecting vital ecosystem processes and human activities. [11]

Generally, researchers focus on narrow conceptualizations of users’ sound environments, overlooking their diversity of meanings. This is shown in researches that concentrate on the negative sound effects, which directly affects the well-being of urban space users. Later, soundscape ecology has become a neglected field with mainstream planning and design practices.

The Soundscape ecology is defined as the entire sonic energy produced by a landscape and is the result of the overlap of three distinct sonic sources: geophones, biophonies, and anthroponies as illustrated in Figure 1, it also identifies the integration of other scientific disciplines such as acoustic ecology, landscape ecology, bioacoustics, urban and environmental acoustics, behavioral ecology, and biosemiotics. Moreover, it is regarded as a dynamic field that investigates the role of the sound environment in maintaining vital functions in animals and humans [12].

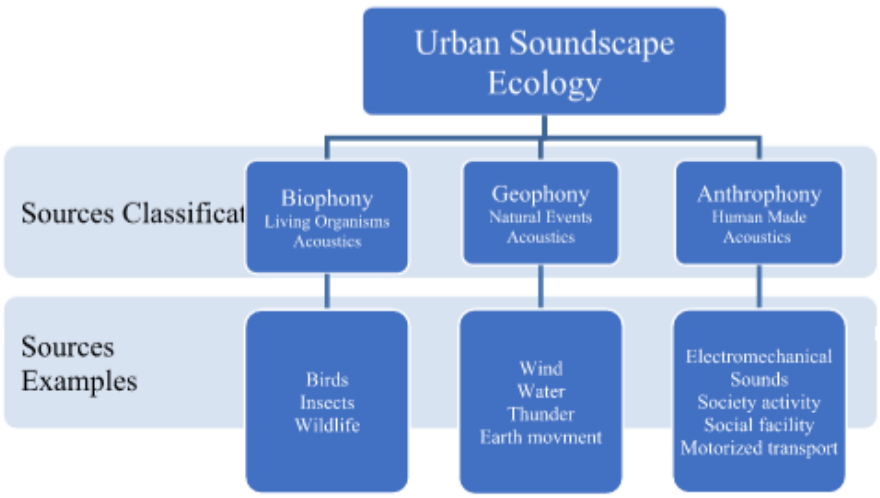

Figure 1: Urban Sound Classification *(Source: The Authors based on Wang, 2003)*.

III. SOUNDSCAPE ECOLOGY AND ITS IMPACT ON SUSTAINABILITY

As more than half of the world's population is now living in urban environments [13], it could be argued that sustainability comprises social, economic, and environmental aspects [14]. Nevertheless, the sustainability concept relates to the design of sound environments as the optical aesthetics, which is, the realization of important factors in providing sustainable settings and well-being [15]. Along with the planning process, sustainability indicates spaces that are planned, designed, and managed to accomplish the "triple bottom line" of being economical, environmentally friendly, and able to improve the quality of life [16]. Many places where we live, work, play, and move through are not characterized only by landscape, cityscapes, or architecture but also by a distinguished soundscape. Hence, the consideration of soundscapes is likely to become one of the most important planning elements as space is used more efficiently.

Future Cities' approaches depend on combining sustainability with planning viability, which requires new urban structures and activities promoting lower energy consumption with respect to the environment and health. Besides, it should be taken into consideration that providing soundscapes, that people judge as having desirable sounds, is not the only goal. It is the consequence of incorporating soundscape quality in the urban design process and creating more attractive and desirable public spaces that matters most.

IV. URBAN SOUND AS A SOURCE OF ANNOYANCE

''Not all urban sounds are pleasant of course; modern society is full of ubiquitous mechanical and engine sounds; cars and airplanes in particular, that serve to destroy and drown out the sounds of nature.'' [17]. The unwanted sound, loud sound, and the disturbance of signals are autonomous factors that possess the potential of leading to emotional responses often demonstrated in frustration. Moreover, some interpreted noise as "unrealized sound" which has the potential of being redesigned or put into a context that makes it more appreciated [18].

The outdoor unintentional sound, that covers acoustic signals and is commonly referred to as urban noise, is also described as community noise, environmental noise, residential noise, or domestic noise. In 1999, Berglund defined the urban noise as a noise formed from all sources except noise at the industrial workplace [19]. While in 2000, the "World Health Organization" defined Noise as "unwanted sound", "annoying sound", "unexpected sound" [20]. On the other hand, "Environmental Noise" consists of all the undesirable sounds in our communities except those initiated in the workplaces which pose a multitude of health and safety concerns on such aspects as productivity, well-being, and functionality [21].

Schafer anticipated four types of Noise definitions, which vary from subjective to objective [22], they are unwanted noise, unmusical sound (defined as non-periodic vibration), any loud sound and disturbance in any signal system.

4.1 Noise as one of the Sources of Environmental Pollution

Noise, as an indicative of patterns of unsustainable living and consumption, can be anticipated as one of the main sources of environmental pollution worldwide, and it is mostly caused by machines and different types of transportation systems [17]. Subsequently, poor urban design and planning can increase noise pollution as industrial buildings can have a considerably negative effect on the residential areas. Numerous sources of noise sound generated by humans can distress a community as shown in Figure 2.

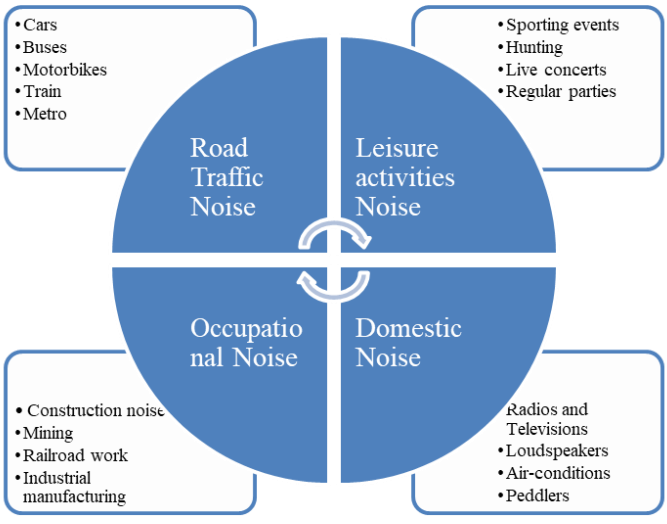

Figure 2: The Main Noise Sources Identified by Users *(Source: The Authors based on Beatley, 2013)*

In an old metropolitan city like Cairo, the soundscape problem has become increasingly annoying. Its negative effects on the lives of Cairenes have become critical causing several harmful drawbacks on the public health, including hearing deterioration, effects on speech intelligibility, sleep disorders, effects on blood pressure, heart rate, other physiological functions, effects on performance and mental health, and behavioural effects. These serious problems could be mitigated by various measures, related to the means of transportation, urban planning, architectural design of buildings, social activities, and governmental regulations and actions.

4.2 Environmental Noise Control Management

Noise management is the current paradigm for the control of an outdoor acoustic environment. It involves knowledge, practice, law, regulations, and control actions. Noise control uses three strategies for action: control at the source, management of the transmission path between source and receiver, and protection of the receiver [15]. For example, trees and other vegetation might play an important role in reducing noise by reflecting and absorbing the surrounding sound.

In order to have a more international interpretation of the Environmental Noise Control, the World Health Organization conducted a comparison between the emission values in various countries (shown in Table 2). It reveals that differences can be up to 15 dB in selected countries [23]. Nevertheless, because of the different degrees of enforcement of the regulations (limiting, guideline, planning, recommended values) and differences in procedures mentioned above, this number must be carefully interpreted.

Table 2: The Sound Emission Values in Various Countries *(Source: The Authors based on WHO and Nadaraja)*

Regions	Noise Level Standards	Noise level (dB)	
		Day time	**Night time**
International	**WHO (recommended health criteria)**	55	45
Regional	**European Region**	54	45
Examples of several countries	**Germany (noise level guidelines)**	45	35
	Australia (recommended outdoor noise level)	45	35
	Japan (environmental quality standards)	45	35
	Korea (environmental quality goal)	50	45
	Philippines (environmental quality noise standards)	50	40
	Malaysia (planning guidelines for noise limits)	**65**	**60**

Similarly, in Cairo, the Egyptian Environmental Affairs Agency (Ministry of Environment), gathered data for Sound Pressure Levels (SPL) in several zones in Cairo during day and night [24]. The Agency chose several noise monitoring stations located in different sites in Cairo as shown in Figure 3.

The results deduced from the chosen sites showed that the Yearly Average of Sound Pressure Levels (SPL) in several areas in Cairo exceeds the Egyptian regulations approved permissible levels collectively during the day and night [25]. Several predefined areas' decibel level (dB) was significantly higher than the permissible Sound Pressure Levels (SPL) stated in the national regulations as shown in Figure 4. For example, the three squares of El-Tahrir, Ramses, and El-Opera, which are well-known squares characterized by heavy traffic and mixed-use buildings. The same case applies to El Katamia district, which is famous for the Marble industry and El Amiriya where many medicine factories are located. On the other hand, El Maadi and Zamalek are quiet districts known for their leafy streets which makes them popular to expats crowd and where various embassies are located. Thus, their decibel levels (dB) were lower than the permissible Sound Pressure Levels (SPL) stated in the national regulations.

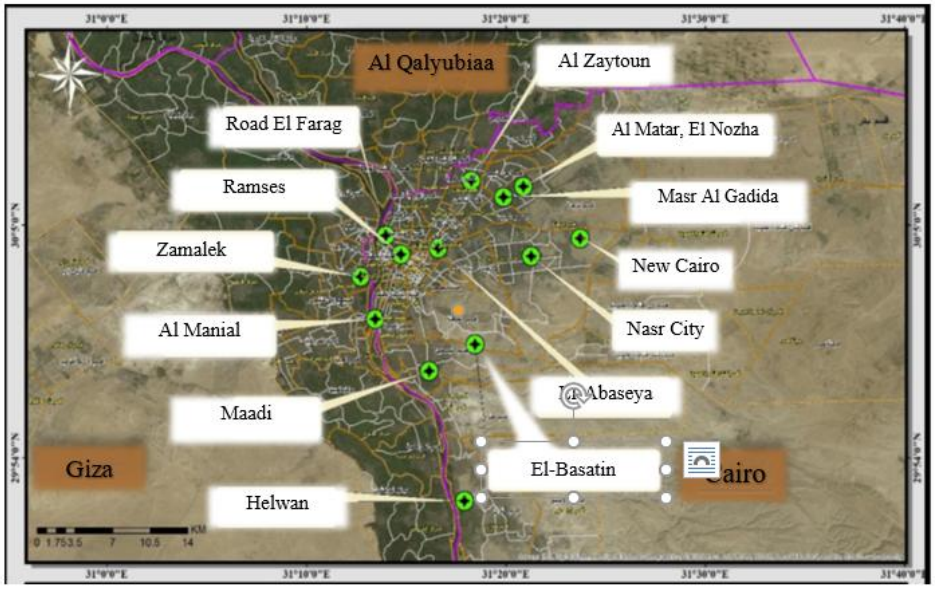

Figure 3: Map for Noise Monitoring Stations in Cairo. ***(Source: The Authors based on the Egyptian Environmental Affairs Agency)***

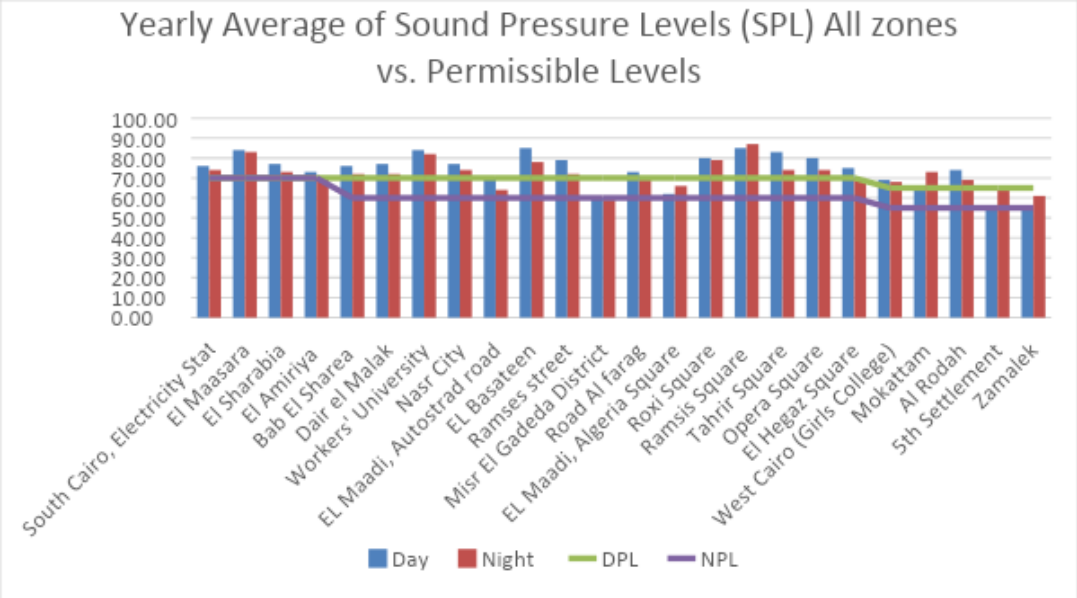

Figure 4: Yearly Average SPL in several areas in Cairo and Permissible Levels ***(Source: The Authors based on Environmental Protection Law [25])***

V. IMPROVING URBAN SOUNDSCAPE APPROACH

In terms of improving the soundscape, it is not only the undesirable aspects of sounds that need to be considered but the preservation or restoration of desirable sounds that are covered up or masked by undesirable sounds. If our living spaces are to provide the 'triple bottom line', of being economical, environmentally friendly, and improving the quality of life [16], the full panoply of sounds we experience needs to be managed to preserve or restore desirable soundscapes.

5.1 Sound Design Using Acoustic Masking Elements

Generally talking, urban planners often seek to control undesirable urban sound by keeping residential development out of noisy areas, while architects use elements' design such as windows, building materials, interior room layout, to reduce the decibel levels of the noises around us [26]. Using natural sound sources in urban planning and design, such as water and vegetation, has also proved to be efficient and attractive for the public areas such as green walls which can reduce up to 40 dB of outdoor noise and vibration [27]. These

different strategies can be beneficial for designing quiet areas, taking in consideration the acoustic comfort characteristics of the place to enhance the quality of life of its inhabitants.
In terms of soundscape planning, noise reduction through sound design, using acoustic masking elements, can be accomplished by numerous methods as demonstrated in Figure 5.

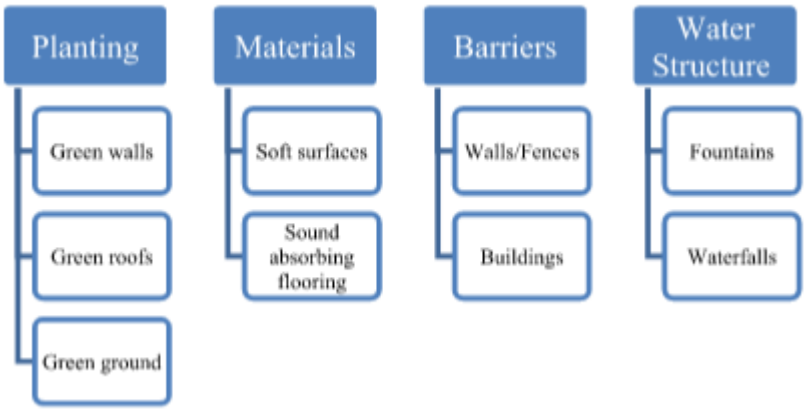

Figure 5: Noise reduction proposed methods in planning and design *(Source: The Authors based on Elmqvist, 2013)*

5.2 Setting the Soundscape Planning Objective

The acoustic environment, as it is perceived and understood by an individual or society within a certain context, must be considered inside a wider context of urban design. Aspects such as the visual context, the distinctive use of the space (shopping, relaxing, retiring at night, etc.) and its typical users, cultural and climatological context, reproduce the process of creating a vision on the soundscape and setting the objectives [2].

The urban soundscape design should address both subjective and objective measures of soundscapes, which can be a portion of a wider intervention comprising different fields such as urbanism, community affairs, or environmental fortification. The objectives should be compatible with a set of universal objectives for the specified areas. Besides, the planning of these objectives must contain the active involvement of the stakeholders from the outset of the decision-making process.

Several methodologies could be conceived to develop soundscape objectives such as the co-creation of the public space, considering its soundscape, by some stakeholders. The accomplishments of these objectives at the soundscape scale can lead to meet the comprehensive goals of achieving the overall comfort that influences people's attitude, behavior, and quality of life. Soundscape design's methodologies have been mostly applied to open outdoor public spaces with typical use such as parks and squares. The literature on sound preferences has identified different varieties of unwanted sound (mechanical and technological sounds) and wanted sound sources, such as:
A) Natural sound (rustling leaves, water sounds, wind, birds twitting, …)
B) Cultural sounds (Azan, bells, traditional festival sounds, sound marks, …)
Although soundscapes should connect different functions of the city, the feeling of being in control of the sound environment became particularly challenging.

5.3 Considering Human Perception

The soundscape is an acoustic environment as perceived and/or understood by a person or a group of people in a certain context. Therefore, soundscape researches represent a paradigm shift in the field of sound evaluation. Firstly, it improves human perception, and secondly, it expands on classical physical measurements and refers to the use of different investigative measurement methods. In 2014, the "International Organization for Standardization" [2] provided a clear definition of understanding this innovation in acoustics.

Implementing soundscape objectives is indispensable, along with the different deviations in a sound environment that directly affect human perception. Although soundscape characteristics in urban areas need to be analyzed on a large scale, many queries must be discussed to reveal more general and comprehensive characteristics of urban soundscapes in terms of human perception. For example, how could the urban soundscape composition be classified? What are the relationships among different soundscape elements? How do different soundscape elements contribute to the overall soundscape? How do these soundscape elements affect the overall soundscape quality as perceived by a human? Furthermore, how could the characteristics of urban soundscapes be observed more directly or how could the soundscape information be visualized?

Consequently, the soundscape implementation objectives must consider the characteristics of the sound sources and how much would they attract human attention.

VI. SOUNDSCAPE DATA COLLECTION AND STATISTICAL ANALYSIS

As the number of vehicles has significantly increased in Cairo, the sound triggered by these vehicles is considered one of the main sources of noise in Cairo. Besides, the on-street Vendors are obstructing the traffic flow causing unjustified chaos. Moreover, there are many industrial areas, garages, workshops, mixed-use buildings in close vicinity of residential areas generating discomfort sounds.

In order to fully investigate and analyze the problem, the paper will use two techniques for data collection which are the "On-site survey" and "Users Questionnaires". The authors have classified the onsite survey time parameters to Day and Night in accordance with the Egyptian Environmental Affairs Agency [24]. Simultaneously, the collected dataset has been analyzed and demonstrated with reference to the permissible noise levels identified by Egyptians' regulation. Three main residential-commercial squares corresponding to three dB category levels of high, medium, and low have been selected for further analysis in the form of a questionnaire. Nevertheless, the questionnaire has been designed and distributed targeting users in the predefined three squares to understand their soundscape perception about the places in which they live/visit.

6.1 Parameters Identification and Sampling

Two parameters have been identified as follow:

Day: represents the average Noise level during day time from 7:00 to 22:00, while Night: represents the average Noise level during night time from 22:00 to 07:00

The research's dataset has been collected based on the predefined areas' classification stated with the Egyptian Environmental Affairs Agency [24] in (Table 3) of the Executive Regulations of Law 4/1994, and the amendments 9/2009 [25]. The areas were classified by the agency into Industrial Areas, Commercial Areas, Residential - Commercial, and Residential Areas.

6.2 Statistical Data Analysis

As demonstrated in (Table 3), the collected values have been examined against the permissible noise levels identified by Egyptians' regulation as stated in environmental Law number 4/1994, and the amendments 9/2009[25]. While Figure 6 illustrates the combined yearly Average of Sound Pressure Levels (SPL) in several locations corresponding to the predefined four classified areas in Cairo.

Table 3: Yearly Average of Sound Pressure Permissible Levels in four classified areas in Cairo at Different Day Timing *(Source: The Authors based on the Egyptian Executive Regulations of Law 4/1994)*

Area	Day	DPL	Night	NPL
Industrial Aera	85.00	70.00	75.00	70.00
Commercial Areas	79.00	70.00	75.33	60.00
Residential - Commercial areas	75.75	70.00	69.33	60.00
Residential Areas	63.40	65.00	67.00	55.00

DPL: Day Permissable Level; NPL: Night Permissable Level

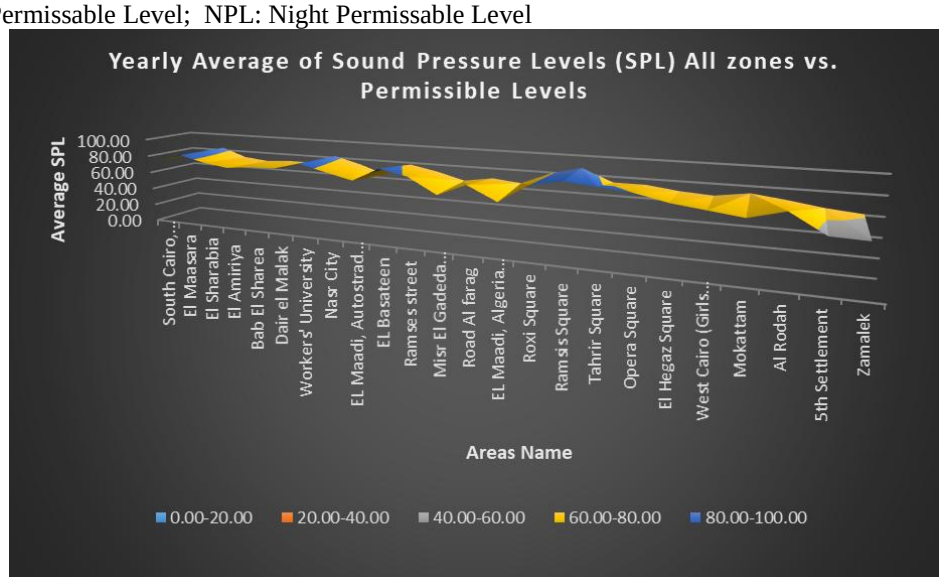

Figure 6: Yearly Average of Sound Pressure Levels and the approved Regulation Permissible Levels in several areas in Cairo *(Source: The Authors based on The Egyptian Environmental Protection Law, 2009)*

Figure 7 establishes the Sound Pressure Levels (SPL) of different areas in Cairo against the government-approved permissible levels, collectively during the day and night. A comprehensive analysis has been conducted on the collected data which revealed that the yearly average of (SPL) for some of the Residential - Commercial areas that are part of this research's sample is above the permissible level defined by the national regulations [25]. To demonstrate, the acceptable SPL in Residential - Commercial Areas is 70 dB during the day and 60 dB during the night. However; the calculated SPLs for the selected Residential - Commercial ranging from 86 dB as the highest during the day (16 dB above the Permissible Level) to 64 dB as the lowest during the night (4 dB above the Permissible Level for commercial areas during the night).

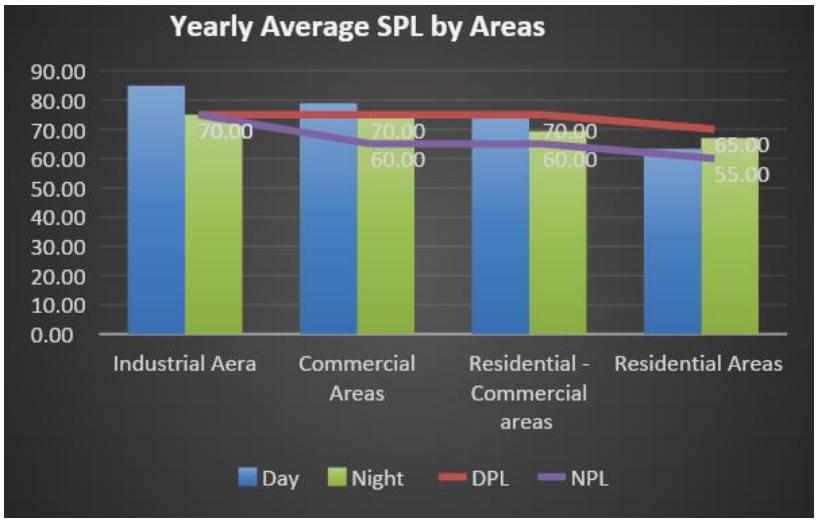

Figure 7: Yearly Average of Sound Pressure Permissible Levels (SPL) in several areas in Cairo ***(Source: The Authors based on The Egyptian Environmental Protection Law 4/1994, 2009)***

6.2.1 Discussions and Evaluation

Based on the above-verified analysis, five urban areas in Cairo have evaluated as having a severe acoustical problem: It has been noticed that the decibel (dB) levels in Ramis Square, Tahrir Square, Opera, Roxi, and El Basateen areas were significantly higher than the permissible Sound Pressure Levels (SPL) stated in the national regulations [25]. While Al Gazaer Square, Misr Al Gadeda, and Al Mokattam were ranked as a minimum dB level; however still higher than the permissible levels. Eventually, El Hegaz square, EL Maadi, Autostrad Road, and Nasr City were found to be classified as intermediate. Consequently, a further detailed study in the form of a questionnaire will be conducted focusing on specific areas that are part of the Residential - Commercial areas to identify the source of the problem and contributory factors.

6.3 Questionnaire

A questionnaire targeting Cairene inhabitants/visitors in three Residential-Commercial Areas was conducted with the aim of revealing main factors affecting their soundscape and aural experience, as well as psychological and physical parameters affecting the perceptual experience. Still classified as Residential-Commercial Areas, the three targeted locations are a downtown area, a northeastern suburb site, and finally a southern suburb site. A brief description of each site is given below before explaining the questionnaire's design:

Ramses Square: Located in downtown Cairo, the square is dominated by numerous noise sources from traffic congestion, unwanted sounds from trains in the railway station, shouting of vendors, in addition to the sounds from the traffic overcrowding of "6 of October" Bridge (Elevated Highway) that passes the square. Consequently, it was classified as a high sound intensity area.

El Hegaz Square: One of the more affluent areas of Cairo which is located between Cairo International Airport and central Cairo. Recognized by its crowdedness and noisiness, as many commercial buildings, restaurants, educational buildings, schools, and hospitals are surrounding the square, it is classified as a medium sound intensity area.

Al Gazaer Square: Located in El Maadi, a suburban district south of Cairo, where the Nile is paralleled by the Corniche. The district is recognized by green vegetation as it is home to many embassies, as well as major international schools, sporting clubs, and cultural institutions. Thus, it was classified as a low sound intensity area.

6.3.1 Questionnaire Design

A designed questionnaire has been distributed to inhabitants and visitors in the previously selected three locations, to understand their perception about the places in which they live/visit.

The aim was to create a rating for each neighborhood census area and to identify aspects that present the greatest problems for each area, after which planners can design interventions aimed at upgrade the neighborhood's environmental auditory quality.

An online/onsite questionnaire was distributed to users who are living/visiting in the targeted residential-commercial areas. The questionnaire has covered the following concerns:

A) General questions about the respondent such as age, gender, and education, sounds they like or dislike. B) The assessment of several comfortable and annoying sounds found in these residential-commercial areas.

C) Questions that examine the reaction of Cairenes to the soundscape as well as allowing them to suggest solutions for the soundscape problem within their area.

6.3.2 Factual Information on Questionnaire Responders

The questionnaire was answered by 380 persons part of 500 questionnaire recipients of Cairenes living in different districts in Cairo, 55% males, and 45% females. A percentage of 87.5% of the respondents fall in the age range of 20-29 years, consequently the questionnaire will be assessing the perception of Cairo's young adults. A percentage of 93% of respondents have completed or are pursuing their higher education level, which shows that they have the capabilities to understand and answer the questionnaire accurately. Moreover, 64.9% of the respondents spend more than two hours per day in residential-commercial areas of Cairo, which is too much given the tight fabric of Cairo. When asked about the sound evaluation of Cairo's soundscape, 80% responded that it is unacceptable which shows the poor quality of the soundscape of the selected area. Nevertheless, the code of ethics and conduction was taken into consideration, in which the importance of the respondents' protection of human rights and privacy are clearly described when conducting social surveys.

6.3.3 Questionnaire Data Analysis

The analysis of the respondents to the annoyance assessment questions relative to several specific noise sources (voices, road traffic, and natural sources) that have the nature of *Inaudible, Audible - Not Annoying, Annoying* sounds in predefined Cairo's streets, and squares were the following:

Ramses Square:

Ramses square is one of the most famous and historical squares in downtown Cairo; it is an overcrowded and noisy place. The square is surrounding the railway station building and the railway museum. To the west, the tallest minaret of Cairo from el-Fath Mosque is dominating the whole area as illustrated in Figure 8 (a).

The square is dominated by noises from the traffic congestion as well as unwanted sound from trains in the railway station. There are almost no sidewalks for pedestrians which increase the chance of overcrowding and noise from the shouting of vendors as seen in Figure 8 (b). Consequently, there are no natural clear sounds that can be identified.

Figure 8: (a) Satellite View of Ramses Square *(*b) Ramses square street vendors *(Source: http://www.google earth.com and The Author)*

As shown in Figure 9, respondents' soundscape evaluation indicates the annoyance levels from combined noise sources. The majority of the questionnaire's respondents in Ramses Square have close to a similar perception of the audible soundscape preferences. For instance, 95% of questionnaire respondents found that the vehicle horns and road traffic noise are the main sources of annoyance. Besides, 87% responded that the

train noise is one of the discomfort sounds. The street vendors' noise was considered one of the most distressing sounds by 87% of the respondents. On the other hand, 84% of the questionnaire respondents' counts found the Call for prayer sound (i.e. Muslim Azan) is Audible but Not Annoying.

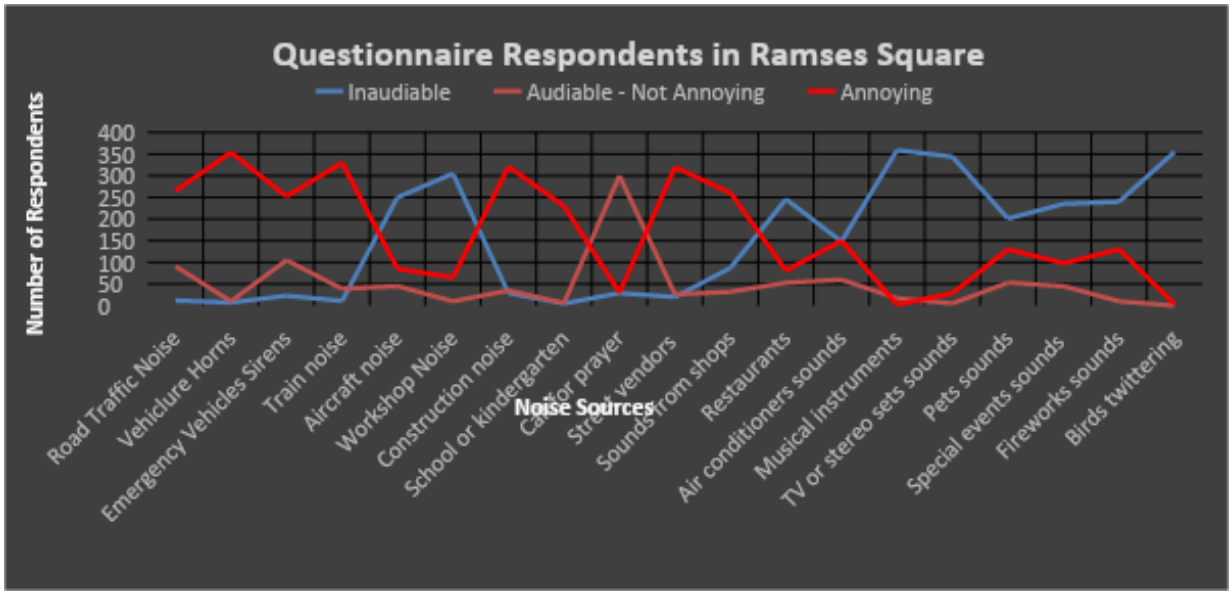

Figure 9: Demonstration for the questionnaire respondents in Ramses Square *(Source: The Authors)*

El Hegaz Square:

El Hegaz square is one of the most famous and affluent areas of Heliopolis district in Cairo. Many commercial buildings and restaurants surround the square, while to the east, three schools predominant the whole area in addition to several administration buildings, churches, and hospitals. Even though traffic congestion is one of the main noise sources in the square because of school buses and undesignated parking spaces, there are multiple sources of sound including, unwanted sound from school students, the call for prayers, and bus stations as shown in Figure 10. Moreover, aircraft sounds and temporary construction activities' sounds. Accordingly, the least possible natural clear sounds can be identified.

Figure 10: (a) Satellite View of El Hegaz Square *(*b) El Hegaz Square *(Source: http://www.google earth.com and The Author, 2020)*

The annoyance assessment relative to several noise sources in Figure 11 shows that 74% of the questionnaire respondents' counts form El Hegaz square found the vehicle horns and traffic noise Annoying. Due to the location of the square in close vicinity to Cairo international Airport as well as Almaza Airport, a percentage of 81% classified the aircraft sounds as discomfortable. Despite the convenience of having a diversity of restaurants on the door-front, 58% of the inhabitants who have responded to the questionnaire found the restaurants sound noisy. A notable number of inhabitants/visitors described the construction noise as inconvenient. However, keeping in mind that it is a temporary noise that will vanish in the near future reduced the dissatisfaction feeling of the inhabitants. 72% found the sound of birds twittering is audible but not annoying.

Nevertheless, some other elements have proved the reflection of human audible preferred diversity. To demonstrate, concerning firework sound, 26% of the defendants liked it, 30% disliked it, 32% have reported inaudible. Moreover, 32% of the questionnaire sample stated that the Pets sounds are Annoying; yet, 15% found it audible- not annoying. Such a contradiction is justified by the individuals' personnel preferences.

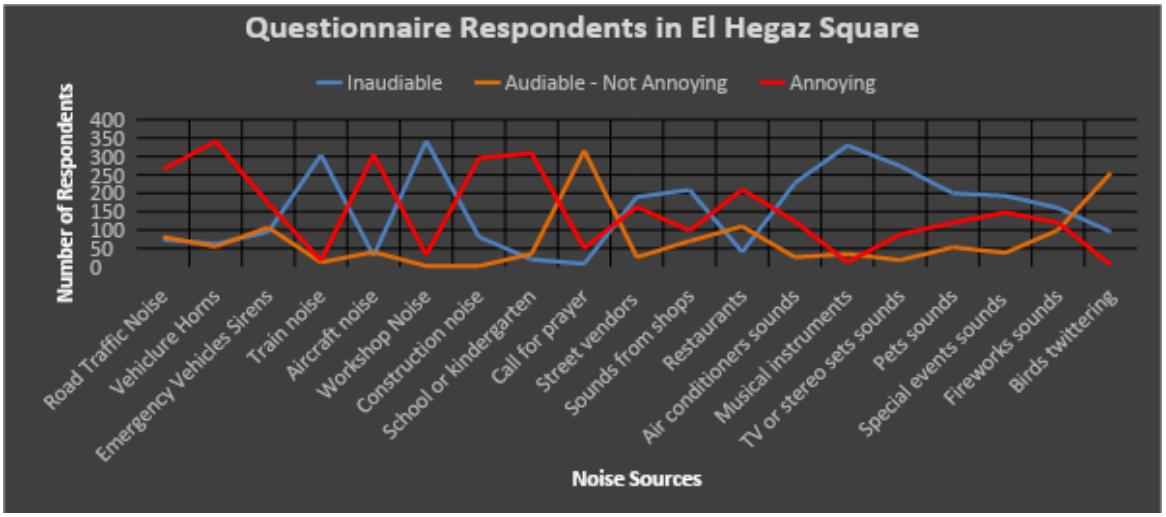

Figure 11: Demonstration for the questionnaire respondents in El Hegaz square *(Source: The Author)*

A. Al Gazaer Square, Maadi:

It's one of the most lively areas in El Maadi, Cairo; The district is popular with international expatriates as well as Egyptians and many embassies, international schools, sporting clubs, and cultural institutions such as the Supreme Constitutional Court of Egypt and the national Egyptian Geological Museum. Al Gazaer Square is recognized by green parks and a planted trees strip that provides a partial visual separation for pedestrian and vehicular areas. Many commercial buildings, restaurants, and educational buildings surround the square, in addition to several administration buildings and hospitals as seen in Figure 12. Even though there are multiple sources of noise almost entirely from traffic, natural clear sounds can be identified.

Figure 12: (a) Satellite View of Al Gazaer Square, Maadi (b) Al Gazaer Square, Maadi *(Source: http://www.google earth.com and The Authors)*

Figure 13 demonstrates that 68 % of the questionnaire respondents found the sound of schools or kindergarten is the main source of noise in their area. Secondly, 53% of the respondents reported that the construction noise in the neighborhood is the most annoying sound. While 48% found that the pet's sound is discomfort. Lastly, 47% said that the sounds from the shops are inconvenient.

On the other hand, even though 72% of the inhabitants classified the birds twittering as audible and maybe has the highest dB level among other sounds in the district; however, they found it relaxing. Call for prayer was found as audible but not annoying by 69% of the questionnaire respondents. Furthermore, 66% found the Emergency Vehicles Sirens audible but not annoying.

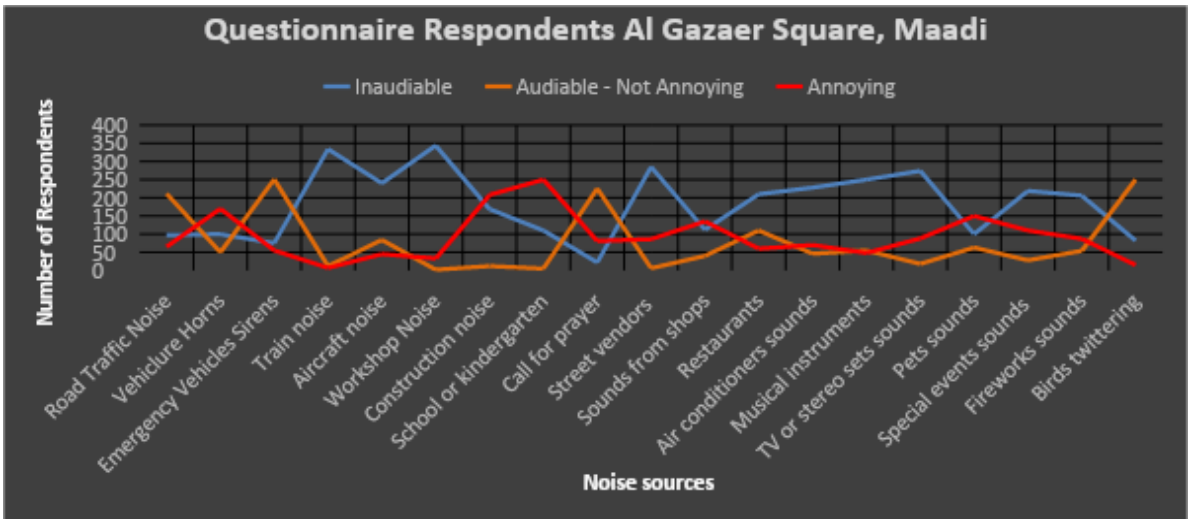

Figure 13: Demonstration for the questionnaire respondents in Al Gazaer Square, Maadi *(Source: The Author)*

The multiplicity of the number sometimes is justified by the distances from different sound sources. For example, inhabitants who are living in compounds, where the commercial, industrial, education, shopping, and events facilities are separated from the residential zones have reported that the shops, restaurants, schools' noises are unrecognized. Nevertheless, it could be unreasonable to eliminate all the annoying sounds since the classification for annoying, not-annoying sounds are not definite. Though, controlling the sound to be acceptable by the majority could be the solution.

VII. GENERAL RESULTS AND CONCLUSIONS

This paper has concluded that the users' perceptions of sound annoyance differ based on several aspects such as the user cultural background and personnel preferences. Based on the questionnaire analysis, the soundscape problem is a cultural behavioral issue that requires active intervention and awareness campaigns targeting different social levels in the community. Furthermore, the traffic dilemma also contributes to the soundscape problem, as traffic congestion is a significant challenge in Cairo that needs to be further studied in order to present further suggestions to the concerned authorities. Moreover, the lack of law enforcement and governmental control on traffic and behavior of drivers in streets and squares are major contributors.

The following section will summarize the research comprehensive conclusions that are extracted from the questionnaire and the onsite survey assumptions of the selected residential- commercial areas.

7.1 Onsite Survey & Questionnaire Conclusion

The perception of the annoyance of urban soundscape is an essential aspect of urban soundscape design. Based on the comparison of annoying sounds assessment graphs and in reference to the factors that affect the annoyance perception, it was noticed that some sounds have a similar audible range such as 'Loud People and Crowds' and 'Street Vendors'. This similarity might be a result of the presence of the human factor in the generated sound. Moreover, a similarity was noticed in the graphs of 'Car Horns', 'Motorbikes', and 'Microbus Drivers', which might be a result of the presence of the mechanical factor in the generated sound.

The onsite survey has concluded the exact noise sources on the selected Residential- Commercial areas as follows:

- Vehicular traffic e.g. buses, private vehicles, motorbikes, wrongly parked/stopping vehicles.
- Employees, and students' movements
- On-street peddlers
- Bus stops
- Unauthorized Markets

The above-presented questionnaire targeted Residential-Commercial Areas' inhabitants/visitors in Cairo, Egypt, with the aim of uncovering factors affecting the acoustic convenience, as well as psychological and physical parameters influencing the perceptual experience. Several factors contributed to the soundscape problem; however, the soundscape challenge in the Residential- Commercial areas in Cairo is the result of other greater complications that require attention in order to improve Cairo's soundscape.

To summarize, the vehicle horns and road traffic noise were classified by the questionnaire respondents as the main source of noise in the three predefined locations i.e. Ramses Square, Al Gazaer Square, and El

Hegaz square. However, other location-based noise elements were concluded depending on the characteristics of each place. For instance, as Ramses Main Train Station is located in close proximity to Ramses Square, inhabitants/visitors reported that train sound was considered as a significant source of inconvenience sounds. Similarly, Questionnaire respondents in El Hegaz square reported that the aircraft noise is a considerable factor. The reason is that El Hegaz square is located in the vicinity of two busy civilian and military airports. On the other hand, the two main sources of noise in Al Gazaer Square were Schools & kindergartens and construction noise which is also relatively based on the location of nearby education facilities.

VIII. RECOMMENDATIONS

Soundscape designers in collaboration with an Urban designer should focus on the factors that affect the perception of the annoyance of the soundscape as well as the different aspects of the sounds present in the urban soundscape such as human aspects, natural aspects, and mechanical aspects of sounds. Based on the analysis, the presence of the natural aspect in the generated sounds is the most preferable while the presence of the mechanical aspect is the least preferable.

In order to control the generated noise and to minimize the SPL as low as permitted by the environmental authorities, a number of considerations, depending on the proposed mitigations measures as part of soundscape design during the initial planning of new districts as well as for enhancing the wellbeing and minimizing the inconvenience in the old settlements, is advisable. These measures are aiming to reduce the negative sounds as well as emphasizing the positive desirable sounds. To demonstrate, urban planners should consider soundscape by including more positive sounds which could form an acoustic comfort environment to minimize noise and to reduce the decibel (dB) levels of surrounded noises.

8.1 Questionnaire Recommendation

As a result of the questionnaire conclusions, the below recommendations are suggested for the upgrading projects of city planning:

- While planning for similar new urban projects or the rehabilitation of existing ones, users' perceptions should be taken into consideration along with their cultural background. In addition, an assessment of the environmental impact should be a prerequisite for zoning particularly for possibly noisy establishments.
- For the cultural behavior problem, awareness campaigns to be conducted through social media as well as the national TV channel targeting different social levels to emphasize soundscape and its effect on public welfare and wellbeing.
- For the poor soundscape quality, the following solutions are suggested concerning future city planning:
- Increase the green areas in urban public spaces in the city.
- Enhance pedestrian areas by using a well-designed water structure.
- City planning should contribute to the visual qualities of the area by utilizing noise barriers such as walls and buildings.
- Several materials can be used as road-side noise barriers and acoustic screens; including concrete, glass, metals, and mixes of recycled materials that can absorb and decrease sound reflections.

8.2 Onsite Survey Recommendations

While a car-free urban district is a potential design strategy to protect and celebrate the natural sounds present in cities, especially in Residential-Commercial areas, the below measures should be considered:

- Planting trees and green vegetation on both sides of the road for Sound absorption.
- Applying green roof systems which have the ability to reduce noise reflection by up to 3dB.
- Using finishing materials that can absorb and decrease sound reflections and noise reduction /isolation design of building structures (windows, building materials, interior layout, etc.)
- Restricting vehicular traffic movements specifically lorries and loud engine vehicles
- Land-use-planning by keeping residential areas away from noisy areas e.g. industrial and commercial areas.
- Enforcing Strict violation from the district's municipality against any shop or personnel using microphones and the unjustifiable use of vehicles' horns.

Moving street vendors to alternative/temporary markets.

IX. RECOMMENDED FUTURE STUDIES AND RESEARCHES

Further researches could be carried out in different districts in Cairo that have diverse soundscape qualities and users' composition such as Zamalek, Nasr City, Mokattam, and Mohandeseen. Additionally, a deeper analysis of the aspects of annoying urban sounds is needed. It is also recommended to excessively study the urban planning and roads network of Cairo to try and find a more effective solution for the traffic problems in Residential-Commercial areas. Furthermore, studies could be carried out on the soundscape quality inside

Cairo's urban parks and gardens to investigate the acceptability of the soundscape. Moreover, comparative Soundwalk exercises may possibly be carried out to reach a mitigation technique to decrease annoyance.

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