



The Role of Urban Form in Delivering a High-Quality Acoustic Environment

Sami Gamal Elboushi^{1*}, Soad Youssef Bashandy¹, Mostafa Refat Ismail², Abdullah Farouk Al-Attar¹

¹ Faculty of Urban and Regional Planning, Cairo University, Giza 12613, Egypt

² Department of Architecture Engineering, Faculty of Engineering, Ain Shams University, Cairo 11517, Egypt

Corresponding Author Email: s_elboushi09@cu.edu.eg

Copyright: ©2026 The authors. This article is published by IETA and is licensed under the CC BY 4.0 license (<http://creativecommons.org/licenses/by/4.0/>).

<https://doi.org/10.18280/ijstdp.210801>

ABSTRACT

Received: 7 May 2026

Revised: 3 July 2026

Accepted: 10 July 2026

Available online: 31 August 2026

Keywords:

acoustic environment, built environment, density, land use, user perception, noise levels, soundscape, urban form

Acoustic environment acts as an essential aspect that affects the urban quality of life. It is not formed only by sound intensity but also by building configuration and functional traits of the built environment. The present study investigates the relationship between urban form and urban soundscape quality in regard to the properties of physical sound and the users' perceptual evaluation. Furthermore, the study aims to identify the characteristics of urban form that impacts soundscape quality in residential areas. The study adopts a mixed-method approach, combining spatial analysis, field measurements of sound levels, and questionnaire surveys to assess users' perceptions. The study provides an analysis of five case studies conducted in Greater Cairo to represent a range of densities that span from very high-density areas to high-density areas, and down to moderate density areas. The findings of the study indicate that urban form and acoustic conditions are strongly correlated. Increased noise levels and less perceived quality are detected in highly densely inhabited areas with intensive mixed use and high traffic congestion, commonly known as over-compacting development. Conversely, improved acoustic conditions are detected in areas with moderate density, moderate mixed-use concentration and greater green coverage. However, users' perception is significantly affected by demographic factors. Therefore, the study highlights the inevitability of integrating soundscape factors into urban planning and design techniques to improve environmental quality and enhance user well-being in urban areas.

1. INTRODUCTION

Over recent decades, cities have witnessed a rapid expansion and a noticeable growth in urban activities. Consequently, travel demand has increased significantly, relying mainly on private cars, which in turn has increased the number of vehicles and raised the levels of noise pollution in cities [1].

According to the World Health Organization (WHO), besides air and water pollution, urban noise acts as one of the top environmental threats in big cities. WHO defined community noise (environmental noise) as "noise produced from all sources except noise at the industrial workplace" [2].

Environmental noise poses a significant threat to public health all over the world. Furthermore, environmental noise is linked to adverse health conditions, such as cardiovascular diseases, sleep disorders, mental health problems, annoyance, and cognitive dysfunction [3-5]. In addition to its health problems, environmental noise greatly influences the social and economic level of the inhabitants. It adversely affects residential satisfaction, property values [6, 7], workers' productivity [7], and the overall quality of urban life.

1.1 Environmental noise: Historical background

Historically, the evolution of early cities has paved the way

for environmental noise. Nonetheless, modern cities suffer from higher noise levels and more people are exposed to increased daily noise. In the past, sound played a pivotal role in determining the relationship between people and their environment and affected the formation of place identity [8]. Nowadays, sound is commonly perceived as an undesirable object that needs to be controlled and restricted.

During the late twentieth century, a wider international concern first emerged over noise pollution. In 1972, the United States Environmental Protection Agency (EPA) officially considered noise as a major source of environmental pollution causing adverse impacts on urban quality of life. Later, in 1980, regulatory standards were issued aiming to safeguard public health. During this period, and in 1977, greater attention was given to the concept of the urban soundscape through the work of Schafer [9], which enhanced human perception of acoustic environments. Afterwards, institutional developments such as the establishment of the World Forum for Acoustic Ecology in 1993 and WHO initiatives on community noise have grown to set international guidelines regarding noise pollution. With the EU Environmental Noise Directive (2002/49/EC), Further reinforcement introduced noise mapping and management strategies for urban areas.

1.2 Environmental noise in the local context

Based on recent population estimates, Egypt's population has grown beyond 107 million in January 2025, with approximately 43% of the inhabitants in urban areas. Nearly 40% of Egypt's urban population resides mainly in Greater

Cairo [10]. Therefore, it serves as the largest urban agglomeration and the main center for economic and service activities. Consequently, the region of Greater Cairo faces several social, economic, and environmental challenges, particularly urban noise, which negatively affects the quality of life.

Table 1. Impact of local authorities' traffic congestion mitigation on urban noise

Intervention	Urban/Transport Characteristics	Positive Impacts	Negative Impacts
Public transport expansion (metro/BRT)	High-capacity transit infrastructure supports daily urban mobility	Reduces dependence on private cars Lowers traffic noise levels	Operational noise along corridors Increased density around stations
New roads and urban axes	Radial and ring road networks High traffic capacity corridors	Reduces congestion in some areas Shorter travel time	Continuous traffic noise sources Higher exposure of nearby residents
Existing roads widening	Increased road capacity Reduction of pedestrian and green areas	Temporary traffic flow improvement Less congestion noise	Higher traffic speed Loss of green areas, increased noise exposure Facilitating private car ownership
Public transport modernization (tram/monorail)	Modern low-emission vehicles Improved operational efficiency	Reduced engine noise Potential shift from private cars	Limited impact without modal shift
Taxi fleet renewal	Replacement with newer vehicles	Lower mechanical noise	
Cycling promotion	Limited cycling infrastructure Weak integration with transit	Reduces short car trips Improves urban acoustic quality	Limited impact due to low adoption

Source: The researcher.

Since the 1970s, problems of traffic noise have increasingly grown as a result of several reasons, including the rapid growth of population, increased urban activities, higher rates of urban expansion and internal migration, and the rising number of private vehicles [11]. During the period between September and October 2001, noise measurements of traffic flow indicated that sound levels surpassed the permissible limit for residential areas (65 dB), reaching 80 dB or higher in different places [12]. Furthermore, 60–80% of urban noise is reported to be directly produced by traffic movement, particularly in densely populated cities such as Cairo, where noise levels during peak hours may range between 95 and 120 dB [12, 13].

Local authorities have established measures to enhance traffic flow and mobility in response to congestion and air pollution, which has a direct impact on the acoustic environment. The following section provides an evaluation of these measures and their consequences.

Based on Table 1, although governments and local authorities exert great efforts to control noise levels, they continue to rise in big cities, such as Cairo, as a result of the limited focus of current policies on lowering noise levels rather than improving the overall acoustic quality. Therefore, the problem of urban noise requires broader techniques that consider all of the factors affecting the acoustic environment.

1.3 Noise environment management approach

Literature specifies two key approaches to environmental noise Management: the traditional noise control approach and the Soundscape approach [13]. These approaches differ in their perception of sound, human response, management strategies, and design tools.

1.3.1 Noise control approach

Noise control approach is a commonly used technique for the management of environmental noise. It focuses on

reducing sound pressure levels (SPL) to meet regulatory standards, without differentiating between undesirable and desirable sounds. Although this approach focuses on noise reduction, it does not always manage to meet the regulatory limits. Nonetheless, studies indicate that residents' satisfaction is not necessarily achieved by way of lowering sound levels within the acoustic environment [8]. Therefore, it is advisable to implement more comprehensive strategies rather than traditional noise control approaches to achieve a better acoustic experience.

1.3.2 Soundscape approach

The term "soundscape" was first introduced by Southworth [14] in 1969 in his study *The Sonic Environment of Cities*. However, the term later became strongly associated with Schafer [9], who is considered the pioneer of soundscape studies, particularly through his influential book *The Tuning of the World*.

The soundscape of a place is defined as its sonic or acoustic environment, with the receiver or listener at the center of the sonic landscape [15]. It was also defined as "An environment of sounds (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society" [16]. Recently, ISO in 2014 defined soundscape as "acoustic environment as perceived or experienced and/or understood by one person or a group of people, in context" [17].

As shown in Figure 1, soundscape serves as a product of the interaction between several variables that can be summarized into three main elements:

Sound element: it includes the physical characteristics such as sound levels, as well as the qualitative characteristics corresponding to the nature of sounds present in the urban environment and their semantic meanings.

Environmental context: it serves as a mediator between the sources of sound and the human receiver, including both

natural factors (e.g., climate) and the characteristics of the built environment (e.g., density, land use, and street networks), which shape the acoustic environment.

Human: they serve as the receiver of the acoustic environment, where demographic features, the nature of activities, hearing conditions, and individual preferences all contribute to how people evaluate the acoustic environment and determine quality.

Although soundscape is produced from the interaction of these three elements, most traditional policies largely focus on the element of sound, specifically sound levels, to conform to regulations. However, this approach did not improve the acoustic conditions, especially in big cities. Rather, it ignored other significant factors leading to worse acoustic conditions. Therefore, the improvement of the acoustic environment relies on both reducing noise levels and enhancing the urban form, social context, and user preferences. In the following, Table 2

presents a comparison between noise control and soundscape approaches.

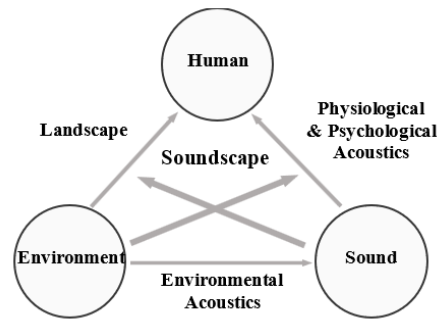


Figure 1. Soundscape perception model
Source: Qin Youguo, reproduced in Ge et al. [18].

Table 2. A comparison between noise control approach and soundscape approach

Aspect	Noise Control Approach	Soundscape Approach
Approach Mechanism	Focus on addressing noise problems after they occur	Integrated into the planning process from the early stages
Sound	Perceived as a waste element	Perceived as a resource that should be invested
Type of Sounds Considered	Focuses primarily on unwanted sounds	Focuses on preferred sounds
Human Response	Related only to sound pressure levels (SPL)	Related to both sound levels, nature and individual perception
Management Strategy	Focuses on reducing noise levels	Focuses on enhancing preferred sounds and masking unwanted sounds
Measurement Method	Quantitative Measurement like SPL as the main indicator	Qualitative Measurement that distinguishes between different types of sounds

Source: The researcher based on previous studies [13, 19, 20].

1.4 Establishing a new approach: Urban form and acoustic environment

When compared to other forms of environmental pollution, environmental noise acts as a localized phenomenon where noise levels can differ significantly from one place to another even within a relatively small-sized area. The reason behind this variation lies in the impact of the local urban form, including building arrangement, land use pattern and transportation infrastructure. Thus, enhancing soundscape in big cities is closely linked to studying the pivotal role of urban form elements play in lowering noise levels.

The quality of life, including public health and environmental conditions, is greatly influenced by decisions regarding the development of the urban community, particularly those relevant to the built environment. Urban problems, such as environmental noise, result from development policies adopted by governments and local authorities, including activities and urban functions distribution, land use policies, and transport policies. Such policies contribute significantly to shaping the features of the acoustic environment in urban areas, which vary depending on the urban context and its physical and functional characteristics.

1.4.1 Urban form and acoustic environment

Urban form relates to the physical and spatial structure of urban areas. It encompasses the arrangement and characteristics of buildings, streets, land uses, and transportation systems. It functions at various spatial levels, ranging from individual buildings and streets to neighborhoods and the city as a whole. Urban form is

commonly described through a set of interrelated elements, including density, land use, accessibility and transport infrastructure, urban layout, and housing and building characteristics [21]. The entirety of these elements contributes to shaping the way cities function and influence environmental, social, and economic conditions within urban areas. Urban form refers to the spatial configuration of fixed elements within a metropolitan region [22], also known as the spatial pattern of human activities at a certain point in time [23].

There are mainly two urban development patterns identified in the literature: compact and dispersed (sprawled) development. Compact development is often referred to as having less quality of life due to higher density and noise. However, this idea overlooks key factors such as mixed land use, public transport, and urban design. On the other hand, dispersed development increases car dependency and raises traffic noise, while well-planned compact areas can support better and more balanced soundscapes.

From an acoustic environment perspective, the proper urban form is mainly contingent on achieving less traffic movement, as traffic movement is the key element of urban noise, which represents about 60–80% of noise sources [12], particularly in big cities. Further, it relies on embracing sustainable mobility systems and land use patterns that support a balanced acoustic environment appropriate to the spatial and functional context of urban spaces.

1) Urban density

Urban density has a pivotal role to play in shaping the acoustic environment due to its influence on land use patterns and mobility systems. Studies indicate that dependence on private cars decreases with increasing density, while reliance

on public transport rises [24, 25]. Similarly, residential density is identified as a key determinant of travel behavior and associated traffic volumes [26]. Urban density refers to the intensity of the built environment, expressed as the amount of built floor area accommodated within a given land area. As an operational measure of building density, the study employs the Floor Area Ratio (FAR), which is defined as the ratio of the total gross floor area of all buildings to the total site area.

Compact development promotes high density, availability of convenience services, land use proximity that encourage sustainable transport modes such as walking, cycling, and public transit and it reduces private car ownership [27], thereby reducing traffic-related noise. In contrast, low-density urban pattern increases private vehicles dependency, leading to higher noise levels and a deterioration in acoustic quality. Consequently, balanced urban density represents an effective planning strategy for enhancing the sustainability and quality of the urban acoustic environment.

To facilitate the interpretation of FAR values, the study adopts the indicative residential density classifications established by the Egyptian New Urban Communities Authority (NUCA). The corresponding FAR ranges for the different residential density categories are presented in Table 3 and are used as reference thresholds for assessing development intensity within the study areas.

Table 3. Operational Floor Area Ratio (FAR) thresholds for urban density classification

Urban Density Category	FAR
Low density	1.00
Medium density	1.25–1.50
High density	1.75

Source: The Egyptian New Urban Communities Authority (NUCA).

Based on the reference thresholds presented in Table 3, FAR values exceeding 1.75 fall beyond the indicative range for high-density residential development. Therefore, within the context of the present study, urban areas with FAR values above this threshold are classified as over-compacted developments, representing an exceptionally high level of development intensity.

2) Land use

Due to its direct role in organizing the way activities and services are distributed, land use patterns serve as one of the most impactful factors in shaping the urban acoustic environment. Consequently, they have a significant effect on mobility patterns and sound sources. Adopting traditional planning approaches of functional segregation (zoning) for separating land uses results in increasing the distances between residential areas, workplaces, and services. Thus, high dependence on private cars develops, causing increased traffic movement and higher noise levels within urban environments. Conversely, mixed-use development enhances the use of a combination of multiple activities within close distances. This leads to a reduction in long-distance travel and promotes sustainable mobility modes such as walking, public transit modes and cycling [28, 29]. Additionally, it lowers the percentage of private car ownership [30, 31]. This spatial proximity leads to fewer daily trips, private vehicle dependency, and thus reduces noise related to traffic movement.

Moreover, multiple land uses relate to various sound sources from activities. It provides a more balanced and better soundscape. The inclusion of social and cultural activities

within the urban fabric enhances the positive perceptual dimension of the acoustic environment. It not only leads to a reduction of noise, but it also improves the overall soundscape quality through the inclusion of favorable sounds. Thus, mixed-use planning is considered an influential strategy for making the acoustic environment better by lowering traffic noise, enhancing accessibility, and creating a more sustainable and acoustically balanced environment.

3) Transport infrastructure

Addressing constant acoustic problems depends on reducing traffic dominance within urban streets, especially private cars. Traffic impacts can be significantly mitigated by adopting policies to lessen private car possession, in addition to the number, length, and duration of motorized trips. This entails limiting the use of private cars, minimizing car-oriented policies, enhancing effective public transport systems, and establishing a pedestrian-friendly urban environment. These measures help reduce traffic volumes and lessen noise levels created by urban mobility.

Similarly, the factors of the built environment, including density, transport policies, land use patterns, urban design, and infrastructure, have a significant effect on travel behavior and travel demand characteristics such as trip frequency, travel distance, travel time and mode selection [25, 32]. Therefore, the process of controlling travel behavior plays a pivotal role in attaining a better acoustic environment.

4) Urban layout

Urban layout refers to the spatial arrangement and configuration of urban elements, including streets, buildings, and blocks. The character of the urban environment is largely influenced by the size and arrangement of urban blocks. The structure and scale of urban blocks have a great influence on the traffic patterns and the spatial distribution of human activities [33], which in turn affects the patterns of the acoustic environment. Medium-sized blocks reduce façade exposure to noise and disperse traffic across multiple routes, which contributes to lowering traffic noise levels [33].

Similarly, street network studies conclude that strongly connected and permeable networks support walking and sustainable mobility, enabling the opportunity to access daily services and activities. On the other hand, poorly connected or closed networks result in increased dependence on private cars and their consequent environmental impacts [32-34].

Furthermore, the elements of landscape are not only responsible for reducing noise levels, but also contribute to enhancing the overall acoustic quality and shaping of the soundscape. Landscape helps improve the acoustic environment through vegetation, water features, and surface materials. Vegetation, in particular, plays a key role on both the physical and perceptual levels. On the physical level, it lowers sound levels through mechanisms such as sound absorption, scattering, and diffraction by plants' leaves and branches. Thus, it helps in lowering sound energy [35-37]. On the perceptual level, vegetation contributes to what is known as psychological noise reduction, where the presence of greenery lessens the perception of noise and annoyance, even when actual sound levels stay relatively unchanged [38-40].

Likewise, water features act as significant sustainable elements in improving the acoustic environment. They enable users to improve their perception of the soundscape, allow for better psychological comfort, and improve the overall sensory experience of place due to their inherently positive qualities [20, 41]. These features participate in hiding unwanted sounds which contributes to raising the acoustic quality.

5) Housing/building types

In residential environments, building design, construction materials, and façade treatment play a significant role in the absorption or reflection of sound, which largely affects the quality of the soundscape. Therefore, urban planning that considers building and housing characteristics can efficiently

reduce noise levels and enhance soundscape quality.

The following section (Figure 2) outlines key urban characteristics that can improve the acoustic environment. They are classified into five urban form components and their underlying mechanisms.

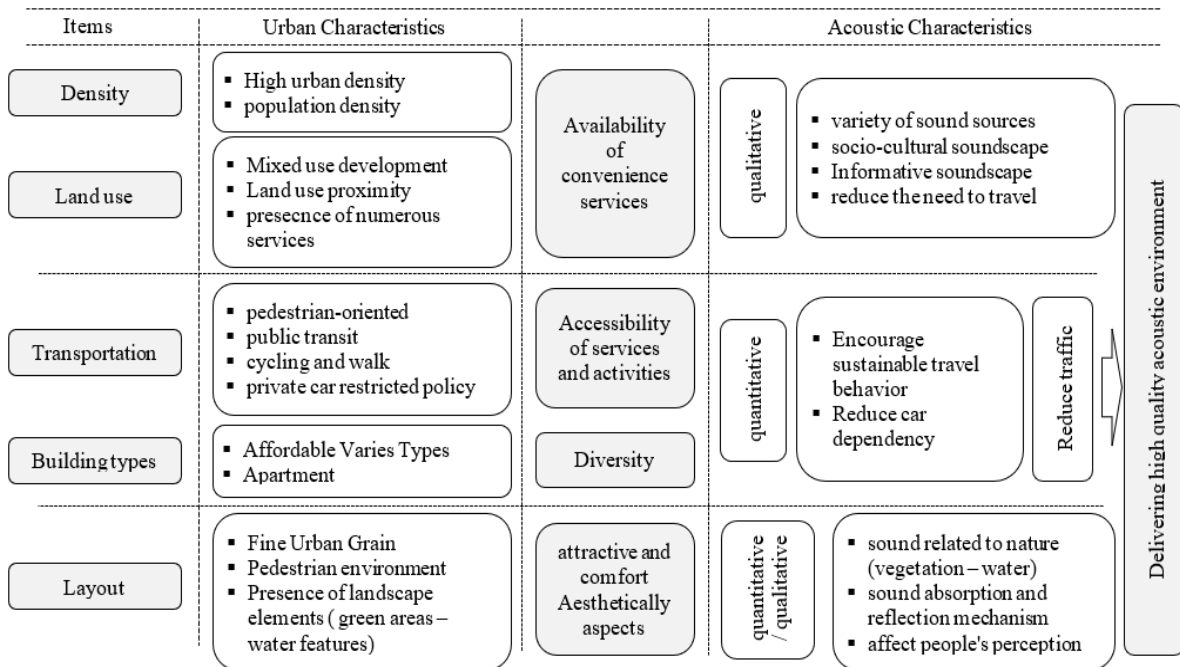


Figure 2. Factors contributing to traffic noise in Cairo

Source: The researcher based on previous studies [21, 23, 25, 28, 34, 36, 38].

2. RESEARCH METHOD

The field study adopted an integrated methodological framework to stand on the relationship between the urban form and the acoustic environment from both physical and perceptual perspectives. It was structured sequentially to ensure a logical link between data collection and analysis, enhancing the reliability and comparability of results across the case studies. As shown in Figure 3, the study is divided into five main parts, from case study selection and tool preparation to field data collection and analysis. It highlights the inclusion of both physical and social dimensions.

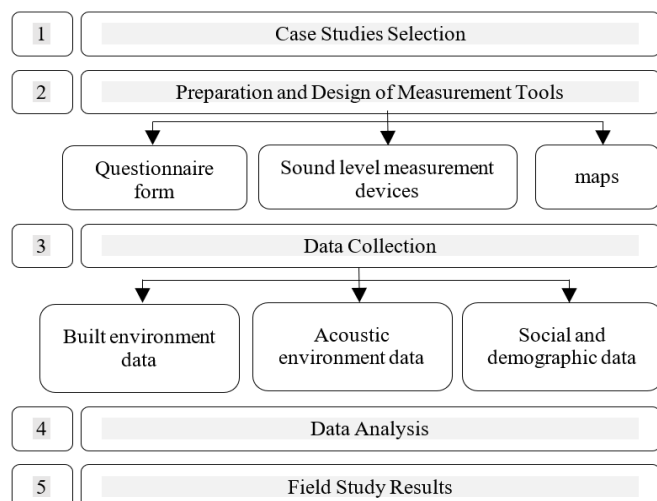


Figure 3. Study methodology

2.1 Case study selection

As shown in Figure 4, case studies were selected within the region of Greater Cairo for its strong acoustic challenges and the diversity of its urban form patterns. The selection emphasizes the diversity of urban density (very high, high, medium), land use (residential and mixed-use), and socio-demographic characteristics. Furthermore, other areas with remarkable morphological features are taken into consideration, including street network configuration, building heights, and open space distribution.

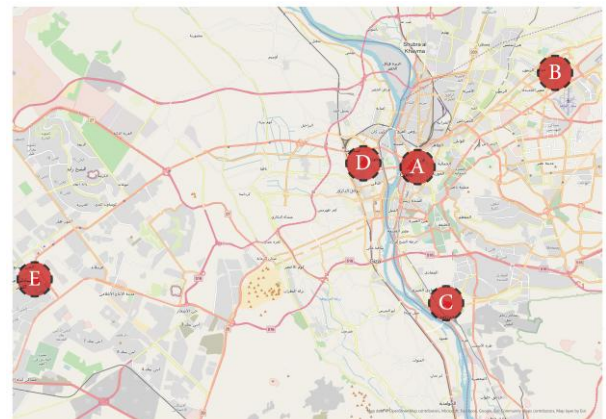


Figure 4. Case study locations – Greater Cairo region (A- Downtown, B-Masr Al-Gadeeda, C-Al-Maady, D-Al-Mohandseen, E-6th of October City)

Source: The researcher based on GIS database.



Figure 5. Urban layout of the case study areas

Source: The researcher based on GIS database.

Figure 5 shows five case study areas selected based on these criteria. It provides a comparative analysis linking built environment characteristics, users' preferences of the acoustic environment, and field-measured acoustic indicators to provide a better understanding of the relationship between urban form and soundscape quality.

2.2 Preparation and design of measurement tools

In this stage, both quantitative and qualitative measurement tools are prepared for the field study. Quantitatively, sound level meters (SLM) were calibrated and used to measure actual noise levels in each study area. On the qualitative level, a questionnaire was prepared to determine the types of sounds in each case study, identify different favorable sounds for users from different sources, and investigate how individual characteristics affect these preferences.

2.3 Data collection

In this stage, an urban survey is conducted to document built environment characteristics, along with field measurements of sound levels. Additionally, questionnaires were collected at the same time to ensure reliable conditions. Spatial analysis, field observation, and measurements are used in this stage for the purpose of collecting integrated data on the built environment, acoustic environment, and users' preferences.

First: Aerial images and base map preparation

For each study area, recent aerial images were utilized to prepare base maps. These images served as a spatial

framework for recording field data. Base maps supported the analysis of street networks, block structure, and land use patterns along with the documentation of open spaces. Moreover, they were employed to detect users' survey points during fieldwork.

Second: Field urban survey

A detailed field survey was carried out to analyze the properties of urban fabric, such as street patterns, building density, land use, and green and open spaces. This provides a basis for understanding the physical context of the acoustic environment.

Third: Sound level meter

In each study area, a TM-102 SLM was employed to measure real noise levels. To capture spatial variations in sound levels, measurements were classified into two types: along external road networks and main corridors, and within internal circulation networks and open spaces. The device was set to A-weighting (dBA) to reflect human auditory response, guaranteeing precise representation of the sound levels present in the urban environment.

Fourth: Questionnaire survey

A questionnaire was prepared to collect socio-demographic data (e.g., gender, age, education) and evaluate users' perception of the acoustic environment. It incorporated sections on preferences of users for common sound sources (natural, human, and mechanical), distinguishing the most remarkable sounds (top three), and a general assessment of acoustic environment quality by employing a rating scale from "very comfortable" to "very annoying."

Table 4. Data collection tools and expected outputs

Data Category		Method Type	Data Collection Tools	Expected Outputs
Built Environment Data		Descriptive–Analytical Method	Field urban survey, maps, aerial images, density analysis, street network analysis, land use analysis	Identification of urban form patterns, building density, degree of land use mix, street network characteristics, and green/open spaces
Acoustic Environment Data	Physical Data	Quantitative Measurement Method	Sound Level Meter (SLM), Leq (dBA), A-weighting	Identification of sound pressure levels (SPL), spatial variations in noise levels
	Perceptual Data	Qualitative–Analytical Method	Sound source inventory, field observation, sound classification (natural, human, mechanical)	Identify soundscape composition, sound source, and evaluation of acoustic environment quality
Users' Preference Data		Perceptual–Analytical Method (Socio-Acoustic Approach)	Questionnaire survey, rating scales, socio-demographic data (age, gender, education)	Measurement of satisfaction levels, preferred sounds, and analysis of socio-demographic influences on perception

Source: The researcher.

An all-inclusive analytical framework is achieved through the combination of these methods. It involved a spatial analysis, physical measurements, and human perception of the acoustic environment. Consequently, the collected data can be classified into three main categories as shown in Table 4.

2.4 Data analysis

Data were statistically analyzed to examine the relationship between the built environment, sound levels, sound types, and users' perception across the five case studies.

2.5 Study results

A comparative analysis was carried out to determine key factors that affect the acoustic environment. Consequently, planning indicators were developed to achieve a better acoustic quality in urban areas.

3. RESULTS

As shown in Figure 4, five urban areas were selected to serve as case studies to indicate the spatial, urban, and social diversity within the region of Greater Cairo. Three areas are included in Cairo Governorate (Downtown, Al-Maady, and Masr Al-Gadeeda) and two in Giza Governorate (Al-Mohandseen and 6th of October City). This selection highlights the diversity in urban form, density, land use, and socio-demographic characteristics.

Figure 5 shows the urban layout of each case study area. It indicates building distribution, street network patterns, land use, and the distribution of green spaces. Recently, satellite images were used to obtain these data. Furthermore, detailed field urban surveys were employed to specify key built environment characteristics such as density, land use,

circulation networks, and green areas.

3.1 Urban form characteristics data

A field survey was carried out to examine the characteristics of the built environment of each area. Additionally, recent satellite and aerial images were utilized to analyze land use patterns, street networks, green space distribution, and urban density. This was presented as a set of urban indicators that were utilized to draw a comparative analysis across the case studies to assess sustainable built environment characteristics from an acoustic point of view. These indicators were compared with measured SPL and users' preferences and evaluations of the acoustic environment.

Table 5 presents urban indicators for each case study with key traits of the built environment. These indicators offer a basis for comparative analysis to better understand the relationship between the urban form and the acoustic environment.

3.2 Acoustic environment data

Acoustic environment data were collected at two levels: the physical level and the qualitative level. On the physical level, field measurements of SPL in both internal spaces and along external main roads surrounding each study area were conducted by using a SLM (TM-102). Several measurements were taken along internal and external roads to produce contour maps that show the spatial distribution of noise levels. On the other hand, the qualitative level aimed to determine the types of sounds in the acoustic environment and represent the activities present within each area. A structured questionnaire was employed to collect data. In the following section, the key findings of acoustic environment characteristics are introduced using a comparative analysis across the five case studies.

Table 5. Urban form indicators of the case study areas

Case Studies		Building Coverage Ratio (BCR) (%)	Building Height Average floor no.	Building Density	Non-Residential Land Use Concentration (Ground Floor) (%)	Green Space Ratio (%)	Tree Density (tree/acre)
1	Downtown	53%	10	5.3	100%	0.4%	5
2	Masr Al-Gadeeda	29%	8	2.3	23%	11.2%	20
3	Al-Maady	26%	6	1.6	21%	29.8%	30
4	Al-Mohandseen	33%	12	3.9	100%	3.4%	12
5	6th of October	29%	5	1.5	41%	6.9%	10

Source: The researcher based on site survey.

Acoustic quantitative data (sound pressure level)

In this section, to understand the SPL within each case study area, a series of field measurements were conducted using a SLM (TM-102) during the first half of February 2026. Table 6 presents the distribution of survey days across the study areas, along with the corresponding weather conditions during the measurement period. A total of 40 measurement points were selected for each case study, comprising 16 points along the external roads (area boundaries) and 24 points distributed across internal streets and public open spaces. All measurements were conducted following a consistent field measurement protocol. The duration of each measurement was not less than 10 minutes to ensure representative sound level recordings. Measurements were taken from pedestrian sidewalks, with the SLM positioned at the edge of the pedestrian sidewalk adjacent to the traffic lanes to minimize

the influence of sound reflections from surrounding buildings and mounted at a height of 1.5 m above ground level. This procedure was adopted to ensure consistency and comparability across all measurement locations.

Table 7 presents a comparative analysis of average SPL along external and internal roads. It shows a distinct variation associated with the urban form and traffic intensity. The highest average SPLs are observed in Downtown, where they amount approximately to 75 dB(A) along external roads and 68 dB(A) along internal roads.

In contrast, Al-Maady indicates the lowest Average SPL values, with approximately 63 dB(A) on external roads and 50 dB(A) on internal roads. The remaining case studies, including 6th of October, Al-Mohandseen, and Masr Al-Gadeeda, indicate intermediate noise levels.

Table 6. Average weather conditions across the case study areas during the survey period

Case Study Area	Survey Dates	Average Temperature (°C)	Average Wind Speed (km/h)	Average Humidity (%)
Masr Al-Gadeeda	1–3 February	22.6	23.8	28.0
Al-Maady	4–5 February	21.3	15.6	31.2
Downtown	8–10 February	25.9	23.8	23.3
6th of October	11–12 February	23.4	27.7	25.2
Al-Mohandseen	15–17 February	26.5	17.5	16.5

Source: Calculated by the researcher based on <https://www.timeanddate.com/>.

Table 7. Measured sound pressure levels (SPL) for case studies

Case Studies	Average SPL along External Roads		Average SPL along Internal Roads	
	dB(A)		dB(A)	
1 Downtown	75		68	
2 Masr Al-Gadeeda	70		57	
3 Al-Maady	63		50	
4 Al-Mohandseen	72		63	
5 6th of October	68		60	

Source: The researcher based on field-measured SPL.

Table 8. Socio-demographic characteristics of respondents across the study areas

Study Area	Sample Size (n)	Gender			Age		Education Level	
		Male	Female	Young	Middle-Aged	Older	Basic/No Formal Education	University Education
Masr Al-Gadeeda	45	27	18	14	18	13	13	32
Al-Maady	43	26	17	21	14	9	7	36
Downtown	45	31	14	22	14	9	18	27
6th of October	40	22	18	16	13	11	11	29
Al-Mohandseen	42	24	18	17	15	10	10	32

Source: The researcher based on field study.

Acoustic qualitative data (sound nature)

In parallel with the field measurements of SPL, the questionnaire survey was conducted during the same period, in the first half of February, to investigate the characteristics of the acoustic environment from the users' perspective. A structured questionnaire was specifically designed for this purpose, and respondents were selected using a random sampling approach. Between 40 and 45 questionnaires were completed in each case study area.

Table 8 presents the sample size for each study area and classifies the respondents into three main demographic categories: gender, age group, and educational level. Conducting the questionnaire survey concurrently with the field measurements ensured that the participants' subjective evaluations corresponded closely to the actual acoustic conditions prevailing in each case study area during the survey

period.

The questionnaire was designed to address three main sections:

The first section: It includes a set of common urban sound sources. To assess preferences, the evaluation is conducted by users on a 1–10 scale. As shown in Figure 6, the results reveal that natural sounds (birds, water, trees) and culturally accepted sounds are rated as highly comfortable, while traffic and mechanical sounds are the most annoying, especially in crowded areas. Human and café sounds are generally acceptable, indicating that positive soundscape perception is linked to natural and familiar sounds, whereas urban traffic noise lessens acoustic comfort.

The second section: Users are required to determine the first three sound sources they perceive within the urban environment. This serves as an indicator of acoustic

environment quality, as user preference is generally associated with the presence of natural sounds. However, dominance of mechanical sounds, particularly traffic noise, is linked to lower perceived quality. As shown in Figure 7, the results reveal a diversity in dominant sound sources across the case studies, largely produced by land use and urban traffic activities. In areas such as 6th of October and Al-Mohandseen, traffic and commercial sounds are the most prominent. They reflect higher activity levels and mixed-use characteristics. Conversely, Al-Maady and Masr Al-Gadeeda indicate a

relatively greater presence of natural sounds, such as birds and wind, alongside traffic noise, due to their greater residential character and higher green space availability. Likewise, Downtown Cairo is occupied by intense urban sounds, particularly traffic and human activities, reflecting its high density and activity dominance. Despite these differences, traffic and human-related sounds remain the most dominant across most cases. Nonetheless, natural sounds seem to be clearer in medium-density residential areas.

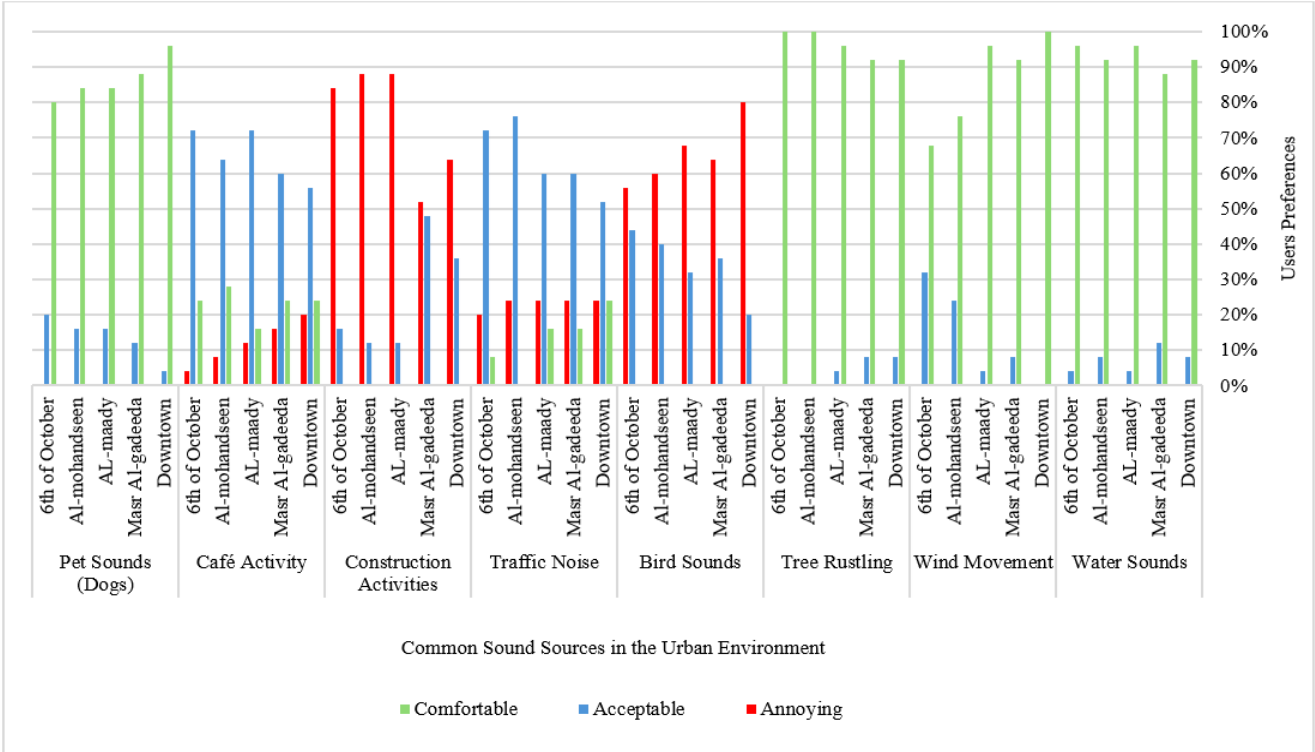


Figure 6. Users' evaluation of common sound sources in urban areas
Source: The researcher based on field study.

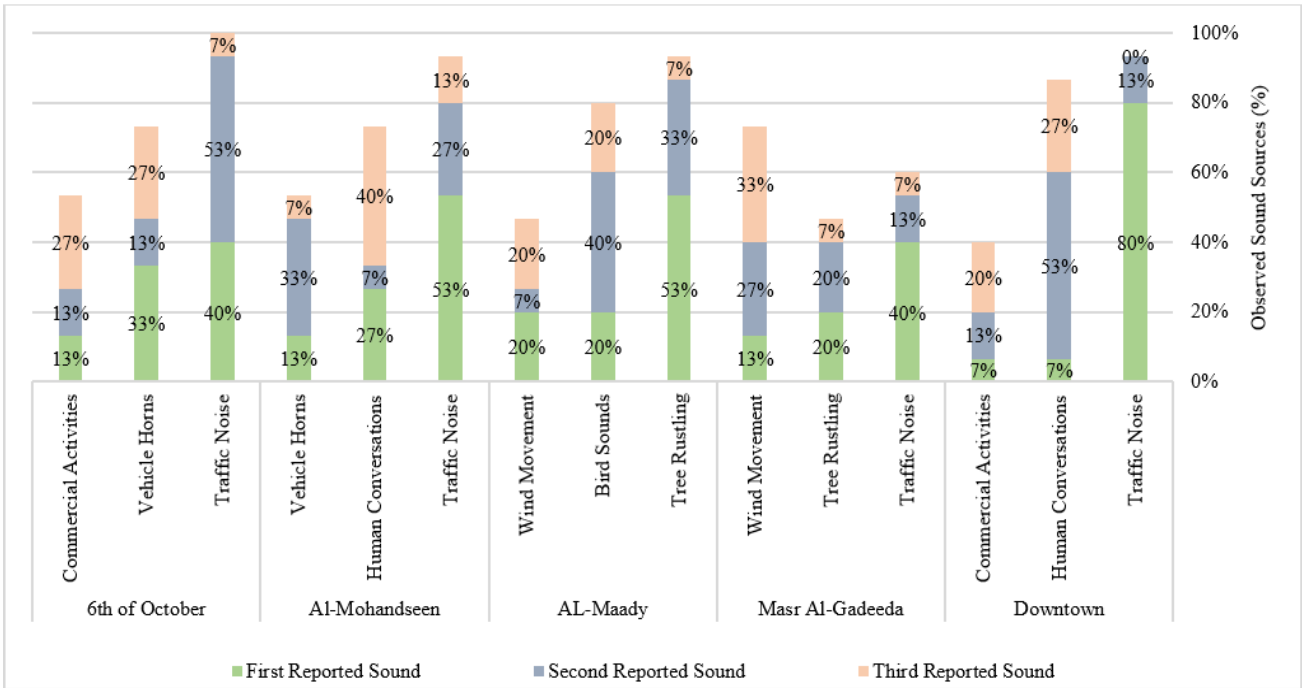


Figure 7. Observed sound sources in spaces along internal roads
Source: The researcher based on field study.

The third section: Users were required to assess the acoustic environment through the use of a five-point scale: very comfortable, comfortable, acceptable, annoying, very annoying. This section is intended to assess general user perception of acoustic environment quality across the different case studies.

As shown in Figure 8, the results reveal a clear contrast between soundscape perception along external and internal roads. External roads are dominated by high “annoying” responses, reaching up to 80% in Downtown and around 70% in 6th of October and Al-Mohandseen, with very low “comfortable” ratings, often near 0–20%, indicating poor acoustic conditions due to heavy traffic. On the other hand, Al-Maady recorded a “comfortable” rating of about 40%, indicating higher acoustic comfort than other areas. This can be linked to moderate traffic flow, lower driving speeds, limited horn use, and dense street vegetation, all of which improve acoustic conditions both physically and perceptually.

In contrast, internal roads indicate significantly enhanced perception, where Al-Maady ranks first, recording the highest percentage of comfort at 80%, followed by Masr Al-Gadeeda at 60%. Al-Mohandseen takes a moderate position with a comfort level of 33%, while 6th of October records 20%. Downtown ranks last, with the lowest comfort level at 13%, exhibiting comparatively less favorable acoustic conditions.

This diversity can be linked to differences in urban traits, including building density, concentration of non-residential activities, traffic intensity, and the presence of through-traffic corridors. Areas with higher acoustic comfort generally show moderate densities, balanced non-residential activities, and

higher proportions of green spaces, supporting diverse and pleasant sound sources. These areas are often dominated by natural sounds (e.g., birds and wind through trees) and cultural or human activity sounds, which improve the perceived acoustic quality.

Conversely, areas with lower acoustic quality indicate very high densities, intense commercial activity, heavy traffic flows, and limited greenery. In these areas, the soundscape is largely dominated by traffic noise, which significantly reduces acoustic comfort.

Individual differences, including age groups, gender, and educational level, were found to have a significant impact on their ability to perceive the acoustic environment. According to the findings, age acts as a key element, where older users exhibit a higher tendency toward natural sounds and quieter environments, younger users show more acceptance of socially active sounds, and middle-aged groups have more balanced preferences.

According to gender, males tend to be more patient with social sounds such as conversations and café noise. On the other hand, females are more sensitive to these sounds despite their preference for them. However, it was noted that natural sounds are usually preferred by both genders with little distinction between them.

On the educational level, individuals who received higher education are more likely to be sensitive to traffic noise. Moreover, they consider traffic noise more infuriating. Rather, individuals with lower education exhibit greater tolerance, likely due to differences in awareness and work-related concentration demands.

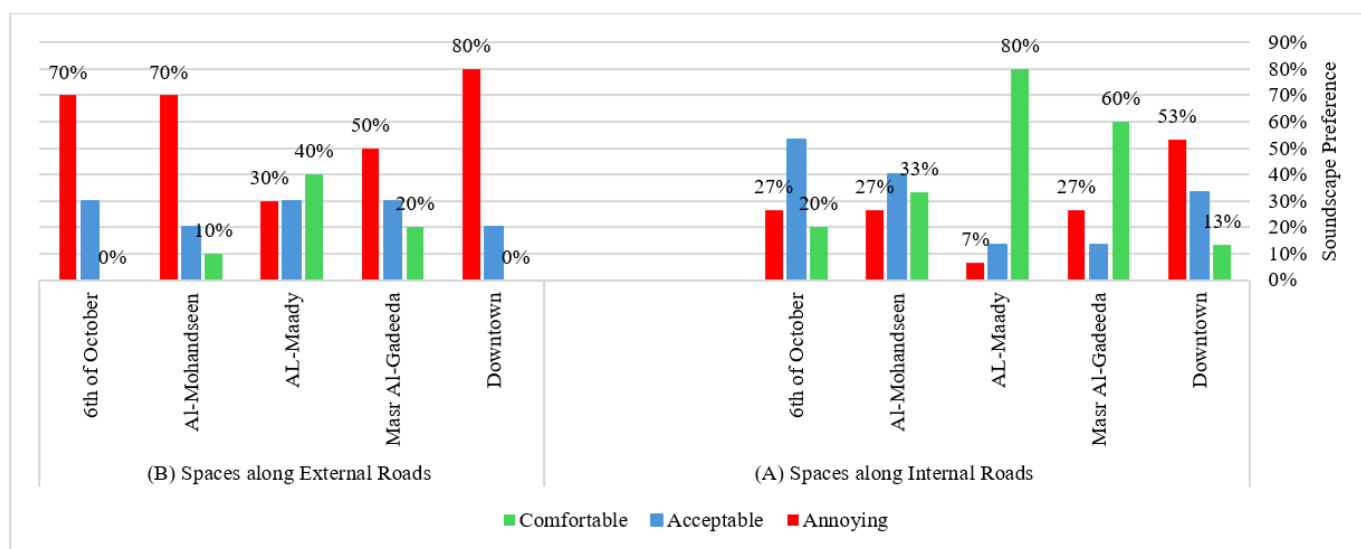


Figure 8. Users' evaluation of the acoustic environment quality across the case studies

Source: The researcher based on field study.

3.3 Investigating the relationship between urban form indicators and acoustic environment

As shown in Figure 9, by studying the relationship between urban form characteristics and average SPL, a clear relationship between building density and average SPL was detected across the case studies. Areas with higher building density tend to record higher SPL values, indicating a general positive correlation between them. For instance, in Downtown, the highest building density (5.3) and the highest SPL (68 dB) can be detected. This reveals intense urban activity and traffic congestion. Likewise, in Al-Mohandseen,

a relatively high density (3.3) with increasing SPL levels (63 dB) is detected. Conversely, lower SPL values (50 dB and 60 dB, respectively) are detected in lower-density areas such as Al-Maady (1.6) and 6th of October (1.5). This shows quieter acoustic conditions associated with less dense urban structures. An intermediate pattern is detected in Masr Al-Gadeeda (2.7), where moderate density corresponds to moderate SPL levels (57 dB).

A comparable relationship is detected between building coverage ratio (BCR) and SPL. In areas with higher BCR, such as Downtown (53%, 68 dB) and Al-Mohandseen (33%, 63 dB), higher noise levels are detected due to a dense built

environment and increased activities. Conversely, in areas with lower BCR, such as Al-Maady (26%, 50 dB), lower noise levels are detected due to the presence of open spaces that allow sound dispersion.

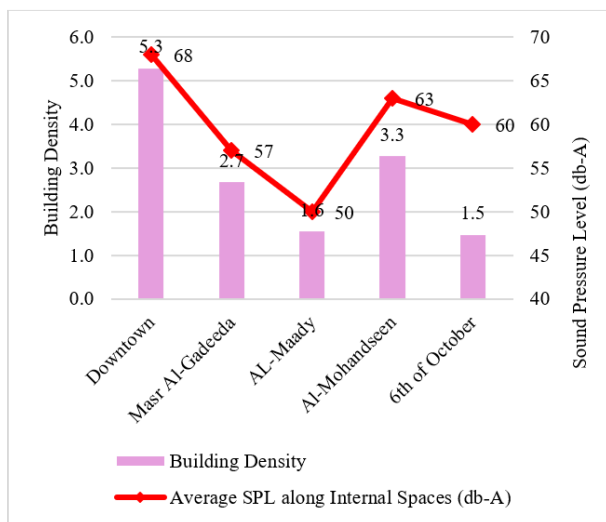


Figure 9. Relationship between building density (Floor Area Ratio (FAR)) and average sound pressure levels (SPL) along internal roads

Source: The researcher based on field study.

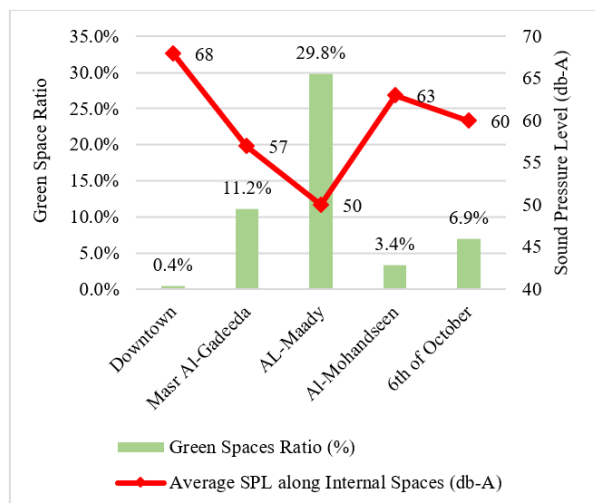


Figure 10. Effect of green spaces on average sound pressure levels (SPL) along internal roads

Source: The researcher based on field study.

As shown in Figure 10, the findings based on examining the relationship of green spaces indicated a distinct inverse relationship between green space ratio and average SPL across the case studies. Higher noise levels are detected in areas with little greenery, such as Downtown (0.4%, 68 dB) and Al-Mohandseen (3.4%, 63 dB). Conversely, lower SPL values are detected in areas with higher green space ratios, such as Al-Maady (29.8%, 50 dB) and Masr Al-Gadeeda (11.2%, 57 dB). A moderate condition is detected in 6th of October (6.9%, 60 dB).

A similar relationship is observed between tree density and average SPL. Lower noise levels are detected in areas with higher tree density, such as Al-Maady (30 trees/acre, 50 dB). A higher SPL is detected in areas with low tree density, such as Downtown (5 trees/acre, 68 dB).

Based on the findings, increasing green space ratio and tree density play a key role in lowering SPL and enhancing the acoustic environment. This stresses the necessity of incorporating green infrastructure within urban design strategies.

Vegetation plays a pivotal role in lowering noise levels. Additionally, it has a significant psychological impact on how the sound environment is perceived by different individuals. The findings, as shown in Figure 11, indicate that areas with higher green space ratios generally have better soundscape evaluations.

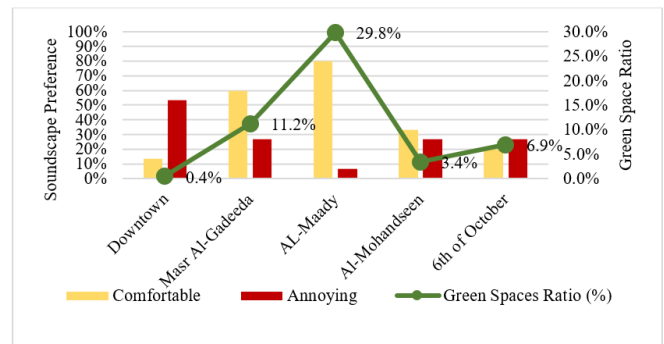


Figure 11. Effect of green spaces on users' soundscape preference along internal roads

Source: The researcher based on field study.

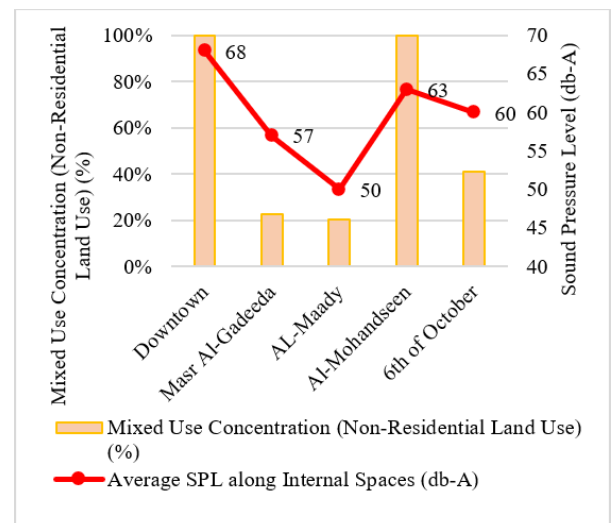


Figure 12. Relationship between mixed-use concentration and average sound pressure levels (SPL) along internal roads

Source: The researcher based on field study.

The highest level of comfort is detected in Al-Maady, with the highest green ratio (29.8%). Nonetheless, it exhibits the lowest level of annoyance. On the other hand, the highest annoyance levels and lowest level of comfort are detected in Downtown, where there is the lowest green ratio (0.4%). This is mainly attributed to high traffic intensity, a highly dense urban environment, and fewer green areas. The other areas, such as Masr Al-Gadeeda, Al-Mohandseen, and 6th of October, fall in between, where moderate green ratios correspond to moderate levels of comfort. Thus, a distinct relationship is observed between green space availability and user satisfaction with the acoustic environment.

The findings indicated that there is a clear positive relationship between mixed-use concentration on ground

floors and internal average SPL. As shown in Figure 12, higher noise levels are detected in areas with high non-residential concentration, such as Downtown (100%, ~68 dB) and Al-Mohandseen (100%, ~63 dB). This is attributed to heavy activities and traffic congestion. In contrast, lower SPL values are detected in areas with lower mixed-use concentration, such as Al-Maady (~20%, ~50 dB). Moderate cases like Masr Al-Gadeeda (~23%, ~57 dB) and 6th of October (~41%, ~60 dB) fall in between.

The findings reveal that greater mixed-use is associated with higher noise levels due to the increased activities and

corresponding traffic problems.

To further investigate the relationship between urban form parameters and the acoustic environment, Pearson correlation and linear regression analyses were performed to evaluate the strength of the relationships and quantify the influence of each urban form parameter on average SPL. The results are presented in Table 9.

To further illustrate these relationships, scatter plots with fitted regression lines were developed for each urban form parameter against the average SPL, as presented in Figure 13.

Table 9. Pearson correlation and linear regression results for urban form parameters and average sound pressure levels (SPL)

Urban Form Indicator	Pearson's r	Relationship Direction	Regression Equation	Regression Coefficient β (Slope)	Coefficient of Determination R^2
Building coverage ratio (BCR)	0.83	Positive	$SPL = 42.044 + 51.728(BCR)$	51.728	0.696
Building density	0.84	Positive	$SPL = 49.655 + 3.420(density)$	3.420	0.707
Green spaces ratio (%)	-0.95	Negative	$SPL = 65.322 - 55.307(green\ ratio)$	-55.307	0.907
Mixed-use concentration (%)	0.87	Positive	$SPL = 51.314 + 14.567(mixed\ use)$	14.567	0.756

Source: The researcher based on field study.

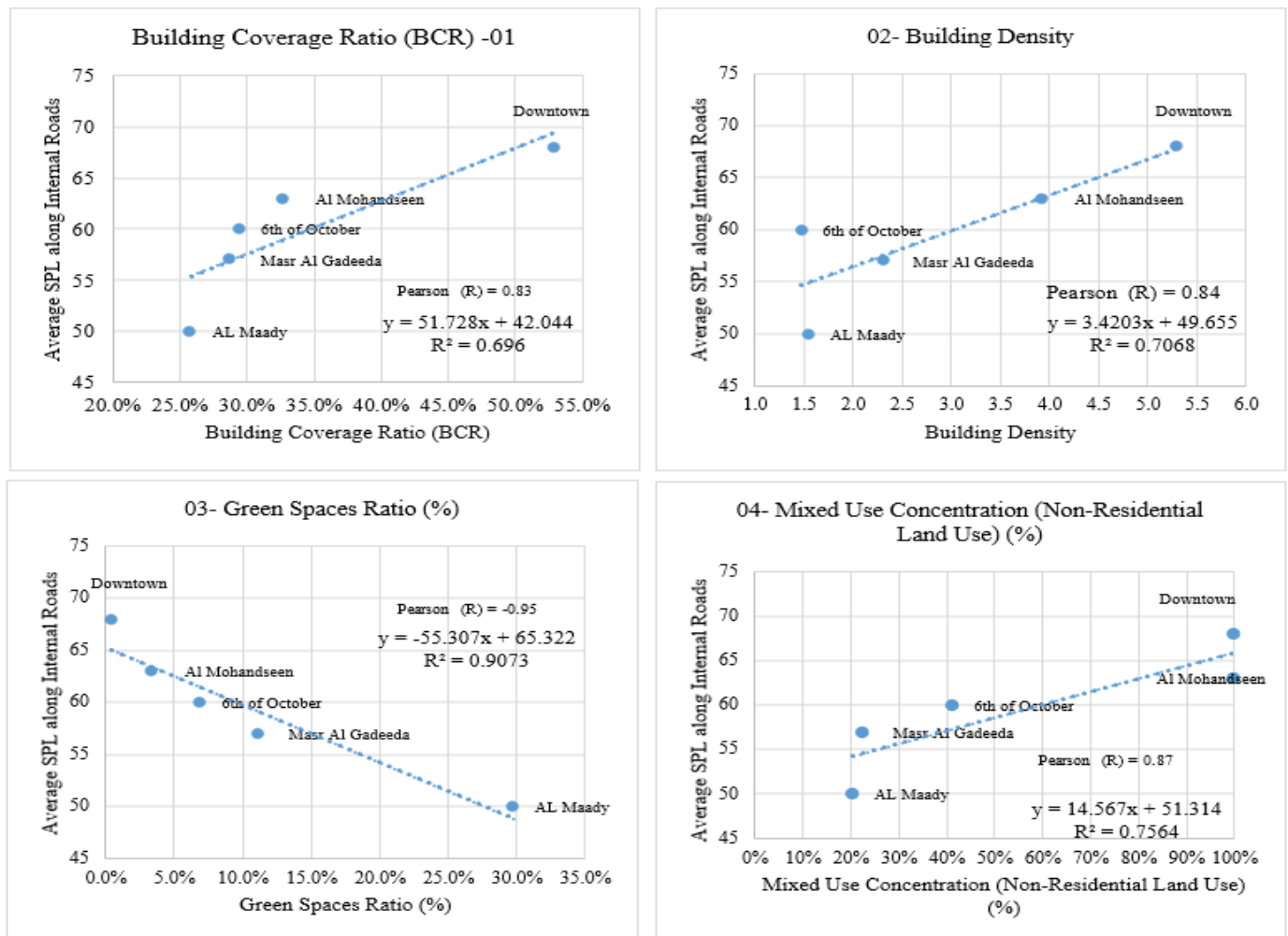


Figure 13. Relationship between urban form indicator and average sound pressure levels (SPL) along internal roads showing Pearson correlation coefficient and linear regression model across the five study areas

Source: The researcher based on field study.

The statistical analysis revealed varying degrees of association between urban form indicators and SPL levels. The

Pearson correlation analysis revealed strong relationships between urban form indicators and average SPL across the five

study areas. Building density ($r = 0.84$), BCR ($r = 0.83$), and mixed-use concentration ($r = 0.87$) showed strong positive correlations with SPL, indicating that areas characterized by higher densities, greater building coverage, and more intensive non-residential activities tend to experience higher noise levels. In contrast, green space ratio exhibited a very strong negative correlation with SPL ($r = -0.95$), suggesting that the presence of green areas contributes significantly to reducing noise levels and improving the acoustic environment.

Regression analysis provides further insight into the magnitude of the observed relationships. The results indicate that each one-unit increase in building density is associated with an increase of approximately 3.42 dB(A) in SPL. Similarly, a 10% increase in BCR corresponds to an increase of about 5.17 dB(A), while a 10% increase in mixed-use concentration is associated with an increase of 1.46 dB(A). In contrast, green space ratio exhibited a negative effect, with a 10% increase in green space associated with a reduction of approximately 5.53 dB(A). These findings highlight the critical role of urban form characteristics in shaping the acoustic environment of urban areas.

4. DISCUSSION

Compact development is generally believed to be linked to lower quality of life. This is attributed to higher density and increased noise compared to dispersed (sprawled) development. Nonetheless, these beliefs are often based on a reductionist perspective that considers density solely or adopts excessively high densities (over-compacting development). A broader understanding of compact development entails considering its integrated components, including mixed land use, well-organized public transport systems, walkability, cycling infrastructure, and the provision of green spaces, which significantly impact the acoustic and urban environment as a whole.

In contemporary cities, urban noise is commonly distinguished by a mono-functional soundscape, dominated by traffic noise, with limited presence of natural sounds or those reflecting functional, cultural, and aesthetic dimensions. On the other hand, compact development provides distinct opportunities to lower traffic dominance by encouraging sustainable mobility such as public transport, walking, and cycling, supported by mixed land use patterns. Further, it supports a diverse soundscape with a variety of sound sources that reflect the identity and function of different urban areas, enhancing the overall acoustic quality.

The findings support adopting moderate density levels, as observed in Al-Maady (FAR 1.6, green spaces 29.8%, mixed-use ~21%) and Masr Al-Gadeeda (FAR 2.3, green spaces 11.2%, mixed-use ~23%), which is broadly consistent with previous studies emphasizing the benefits of moderate urban densities [27, 42], greater provision of green spaces [35, 36, 40], and well-planned mixed land-use patterns [28, 29, 31] in supporting walkability and reducing dependence on private cars. This, in turn, helps attain a balanced acoustic environment that integrates natural and human sounds without the dominance of traffic noise, fostering a more distinctive and high-quality soundscape [7].

On the other hand, over-compacted development changes the positive qualities of urban environments, converting them into pressures that adversely affect the acoustic environment. This is clearly marked in areas such as Downtown (FAR 5.3,

green spaces 0.4%, mixed-use 100%) and Al-Mohandseen (FAR 3.9, green spaces 3.4%, mixed-use 100%). In these areas with very high densities, minimal green spaces, and fully concentrated non-residential activities, increased traffic demand and higher noise levels can be witnessed, which is consistent with previous studies reporting similar relationships [43, 44]. Therefore, the acoustic environment is degraded with an increase in traffic noise within the urban soundscape.

Compact development involves moderate to high density, mixed land use, public transport, and walkability, resulting in a noticeable reduction in dependence on private vehicles as the primary source of urban noise.

Therefore, the impact of compact development on the acoustic environment should be evaluated through a comprehensive perspective of urban form, rather than depending on density alone.

From an economic efficiency standpoint, compact development enables better planning, distribution, and maintenance of landscape elements, including green spaces, street trees, and public open areas. To ensure higher quality and better spatial inclusion of these elements within the urban fabric, resources assigned for landscaping can be employed more efficiently. This can be achieved through the application of development within a more compact urban footprint. This efficiency not only lowers the expenses of both installation and maintenance, but it also improves the functional performance of landscape elements. Consequently, well-structured landscape elements have a significant effect on enhancing the acoustic environment. For instance, vegetation plays a dual role by physically lowering noise through absorption and diffusion mechanisms. Further, it enhances users' perceptual experience by introducing natural sounds and lessening the perceived impact of urban noise. Therefore, through the proper planning of compact development, economic efficiency, higher quality, and a more balanced acoustic environment can be achieved.

Therefore, for a better acoustic environment, the principles of compact urban form need to be adopted as an integrated system. This approach enables the development of a distinguished place identity, enhances the diversity of sound sources, and lessens traffic noise. Eventually, this offers a more attractive and well-balanced acoustic environment.

5. CONCLUSION

The present study emphasizes the idea that traditional noise reduction strategies cannot be adopted in isolation to improve the quality of the acoustic environment. Rather, the spatial configuration of the built environment, land use distribution, mobility patterns, and user perception are considered as strongly significant elements.

The findings indicated that the main source of urban noise is traffic, alongside the critical role played by transport policies in shaping the acoustic conditions. Meanwhile, urban form elements such as density, land use, accessibility and transport infrastructure, urban layout, and housing and building features have a significant impact on both sound levels and the soundscape experience as a whole.

Notably, the research identifies moderate-density urban forms as the finest condition for creating a balanced acoustic environment. Such configurations provide reduced noise levels while maintaining sound diversity, as a key element for improving user perception and environmental quality.

The study stresses the importance of incorporating green infrastructure and landscape elements, not only as physical noise reduction tools but also as key elements in the perceived acoustic improvement. This confirms the concept that sound should be treated as a resource rather than a mere pollutant.

This research represents a paradigm shift from noise control to soundscape-oriented urban planning. Planners and designers can create quieter, richer, more livable, and more acoustically sustainable urban environments by adopting a more all-inclusive and human-centered approach.

To conclude, it is essential to differentiate between compact development and over-compacting development. Compact development, with its moderate densities and availability of green and open spaces, can offer a high-quality acoustic environment. Rather, over-compacting development is associated with excessive densities, high traffic volumes, and an intense concentration of activities and population, which results in higher noise levels and a degradation of the overall acoustic environment.

DECLARATIONS

Ethics approval and consent to participate

The authors declare that all volunteer participants confirmed their willingness by informed consent to participate in this study before completing the survey. In addition, the authors demonstrate that the Faculty of Urban and Regional Planning, Cairo University, does not have an ethics committee. Informed consent was obtained from all participants on-site prior to completing the questionnaire during the field survey.

Study limitation

Due to the limited number of case studies ($n = 5$), the Pearson correlation results should be considered exploratory rather than statistically definitive. The analysis is intended to identify potential relationships and general trends between urban form indicators and sound levels across the selected study areas.

REFERENCES

- [1] Giunta, M.B., Suriano, M.T., Souza, L.C.L., Viviani, E. (2015). The role of traffic flow and the floor space index (FSI) in predicting environmental noise. CUPUM, 143: 1-19. https://web.mit.edu/cron/lockers/cupum2015/proceedings/Content/analytics/143_giunta_h.pdf.
- [2] Berglund, B., Lindvall, T., Schwela, D.H. (1999). Guidelines for community noise. World Health Organization. <https://www.who.int/publications/i/item/a68672>.
- [3] World Health Organization. (2011). Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. WHO Regional Office for Europe. <https://iris.who.int/server/api/core/bitstreams/4c6945b7-497a-4043-9e6f-98d6774b3b61/content>.
- [4] World Health Organization. (2018). Environmental noise guidelines for the European Region. WHO Regional Office for Europe. <https://www.who.int/europe/publications/i/item/9789289053563>.
- [5] El Samra, G. (2016). Community noise in Greater Cairo. Egyptian Journal of Occupational Medicine, 40(2): 267-285. <https://doi.org/10.21608/ejom.2016.845>
- [6] Marmolejo Duarte, C., González Tamez, C. (2009). Does noise have a stationary impact on residential values? Journal of European Real Estate Research, 2(3): 259-279. <https://doi.org/10.1108/17539260910999992>
- [7] Kang, J. (2006). Urban Sound Environment. CRC Press. <https://doi.org/10.1201/9781482265613>
- [8] Garrioch, D. (2003). Sounds of the city: The soundscape of early modern European towns. Urban History, 30(1): 5-25. <https://doi.org/10.1017/S0963926803001019>
- [9] Schafer, R.M. (1977). The Tuning of the World. New York: Alfred A. Knopf.
- [10] Central Agency for Public Mobilization and Statistics. (2025). Egypt in figures 2025. <https://www.capmas.gov.eg/publications/167>.
- [11] Ali, S.A., Tamura, A. (2001). Diagnostic study for traffic noise problems in Greater Cairo, Egypt. In INTER-NOISE and NOISE-CON Congress and Conference Proceedings, pp. 1177-1181. <https://trid.trb.org/View/721013>.
- [12] Ali, S.A., Tamura, A. (2002). Road traffic noise mitigation strategies in Greater Cairo, Egypt. Applied Acoustics, 63(12): 1257-1265. [https://doi.org/10.1016/S0003-682X\(02\)00046-4](https://doi.org/10.1016/S0003-682X(02)00046-4)
- [13] Truax, B. (1998). Models and strategies for acoustic design. In WFAE Conference Stockholm, Hey Listen!. https://www.sfu.ca/sonic-studio-webdav/WSP_Doc/Articles/Truax_Models&Strategies.pdf.
- [14] Southworth, M. (1969). The sonic environment of cities. Environment and Behavior, 1(1): 49-70. <https://doi.org/10.1177/001391656900100104>
- [15] Porteous, J.D., Mastin, J.F. (1985). Soundscape. Journal of Architectural and Planning Research, 2: 169-186. <https://www.jstor.org/stable/43028767>.
- [16] Truax, B. (2001). Acoustic communication. https://www.academia.edu/1355526/Acoustic_Communication_2001.
- [17] International Organization for Standardization (ISO). (2014). Acoustics — Soundscape — Part 1: Definition and conceptual framework. <https://www.iso.org/standard/52161.html>.
- [18] Ge, J., Guo, M., Hu, J., Yue, M. (2012). Three elements structure and sound expectation concept in soundscape—A case study of the new Lakeside Park, Hang Zhou. Lowland Technology International, 14(1): 31-44. https://cot.unhas.ac.id/journals/index.php/ialt_lti/article/view/433.
- [19] Brown, A.L., Muhar, A. (2004). An approach to the acoustic design of outdoor space. Journal of Environmental Planning and Management, 47(6): 827-842. <https://doi.org/10.1080/0964056042000284857>
- [20] Brown, A.L. (2011). Advancing the concepts of soundscapes and soundscape planning. In Acoustics 2011: Annual Conference of the Australian Acoustical Society. <http://hdl.handle.net/10072/43573>.
- [21] Dempsey, N., Brown, C., Raman, S., et al. (2009). Elements of urban form. In Dimensions of the Sustainable City, pp. 21-51. https://doi.org/10.1007/978-1-4020-8647-2_2
- [22] Anderson, W.P., Kanaroglou, P.S., Miller, E.J. (1996). Urban form, energy and the environment: A review of issues, evidence and policy. Urban Studies, 33(1): 7-35. <https://doi.org/10.1080/00420989650012095>

- [23] Silva, L.T., Oliveira, M., Silva, J.F. (2014). Urban form indicators as proxy on the noise exposure of buildings. *Applied Acoustics*, 76: 366-376. <https://doi.org/10.1016/j.apacoust.2013.07.027>
- [24] Kenworthy, J.R., Laube, F.B. (1999). Patterns of automobile dependence in cities: An international overview of key physical and economic dimensions with some implications for urban policy. *Transportation Research Part A: Policy and Practice*, 33(7-8): 691-723. [https://doi.org/10.1016/S0965-8564\(99\)00006-3](https://doi.org/10.1016/S0965-8564(99)00006-3)
- [25] Cervero, R., Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, 2(3): 199-219. [https://doi.org/10.1016/S1361-9209\(97\)00009-6](https://doi.org/10.1016/S1361-9209(97)00009-6)
- [26] Badoe, D.A., Miller, E.J. (2000). Transportation-land-use interaction: Empirical findings in North America, and their implications for modelling. *Transportation Research Part D: Transport and Environment*, 5(4): 235-263. [https://doi.org/10.1016/S1361-9209\(99\)00036-X](https://doi.org/10.1016/S1361-9209(99)00036-X)
- [27] Bhat, C.R., Guo, J.Y. (2007). A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research Part B: Methodological*, 41(5): 506-526. <https://doi.org/10.1016/j.trb.2005.12.005>
- [28] Alberti, M. (2013). Urban form and ecosystem dynamics: Empirical evidence and practical implications. In *Achieving Sustainable Urban Form*, pp. 84-96. <https://doi.org/10.4324/9780203827925-10>
- [29] Van, U.P., Senior, M. (2013). The contribution of mixed land uses to sustainable travel in cities. In *Achieving Sustainable Urban Form*, pp. 139-148.
- [30] Chu, Y.L. (2002). Automobile ownership analysis using ordered probit models. *Transportation Research Record*, 1805(1): 60-67. <https://doi.org/10.3141/1805-08>
- [31] Hess, D.B., Ong, P.M. (2002). Traditional neighborhoods and automobile ownership. *Transportation Research Record*, 1805(1): 35-44. <https://doi.org/10.3141/1805-05>
- [32] Ewing, R., Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American Planning Association*, 76(3): 265-294. <https://doi.org/10.1080/01944361003766766>
- [33] Carmona, M. (2021). *Public Places Urban Spaces: The Dimensions of Urban Design*. Routledge. <https://doi.org/10.4324/9781315158457>
- [34] Hillier, B., Hanson, J. (1984). *The Social Logic of Space*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511597237>
- [35] Aylor, D. (1972). Noise reduction by vegetation and ground. *The Journal of the Acoustical Society of America*, 51(1B): 197-205. <https://doi.org/10.1121/1.1912830>
- [36] Fang, C.F., Ling, D.L. (2003). Investigation of the noise reduction provided by tree belts. *Landscape and Urban Planning*, 63(4): 187-195. [https://doi.org/10.1016/S0169-2046\(02\)00190-1](https://doi.org/10.1016/S0169-2046(02)00190-1)
- [37] van Renterghem, T., Botteldooren, D. (2009). Reducing the acoustical façade load from road traffic with green roofs. *Building and Environment*, 44(5): 1081-1087. <https://doi.org/10.1016/j.buildenv.2008.07.013>
- [38] Yang, W., Kang, J. (2005). Soundscape and sound preferences in urban squares: A case study in Sheffield. *Journal of Urban Design*, 10(1): 61-80. <https://doi.org/10.1080/13574800500062395>
- [39] Jeon, J.Y., Lee, P.J., You, J., Kang, J. (2010). Perceptual assessment of quality of urban soundscapes with combined noise sources and water sounds. *The Journal of the Acoustical Society of America*, 127(3): 1357-1366. <https://doi.org/10.1121/1.3298437>
- [40] Rey-Gozalo, G., Barrigón Morillas, J.M., Montes González, D., Vilchez-Gómez, R. (2023). Influence of green areas on the urban sound environment. *Current Pollution Reports*, 9(4): 746-759. <https://doi.org/10.1007/s40726-023-00284-5>
- [41] Calarco, F.M.A., Galbrun, L. (2014). Semantic assessment of water features used over road traffic noise. In *Forum Acusticum 2014*, Kraków, Poland.
- [42] Rydin, Y. (1992). Environmental dimensions of residential development and the implications for local planning practice. *Journal of Environmental Planning and Management*, 35(1): 43-61. <https://doi.org/10.1080/09640569208711907>
- [43] Burton, E., Jenks, M., Williams, K. (1996). Achieving the compact city through intensification: An acceptable option? In *The Compact City: A Sustainable Urban Form?* pp. 83-96. <https://doi.org/10.4324/9780203362372>
- [44] Churchman, A. (1999). Disentangling the concept of density. *Journal of Planning Literature*, 13(4): 389-411. <https://doi.org/10.1177/08854129922092478>