JAIEP

Urban Noise Pollution: A Dataset for Spatiotemporal and Environmental Analysis

Marwa M. Eid[1] , Anis Ben Ghorbal[2*] , Ehab M. Almetwally[2], Ibrahim Elbatal[3]

[1] Faculty of Artificial Intelligence, Delta University for Science and Technology, Mansoura 11152, Egypt, mmm@ieee.org

[2] Department of Mathematics and Statistics, Faculty of Science, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh 11432, Saudi Arabia, assghorbal@imamu.edu.sa, emalmetwally@imamu.edu.sa , iielbatal@imamu.edu.sa

* Corresponding author: assghorbal@imamu.edu.sa

Abstract

To establish noise pollution levels in El Mansoura, Egypt during 2023, the current study utilizes all around acoustic data acquired from May to December. Concerning noise control in urban areas, the study focuses on change over time, environmental conditions, as well as legal requirements. The analysis of the 1465 measurements provided the following results: Mean equivalent sound pressure level of 81.73 dB That exceeded the recommended level by 10 dB; 95.9% of all the measurements exceeded regulatory levels. Crosstabulation tests further revealed the influences of noise pollution by vehicle count, types of road and time of day. Midday had the highest noise level at 96.62 and the least at night at 61.31. Density zones and areas with high traffic revealed the highest noise pollution. In proving its findings, the study shows that noise pollution is a serious issue in El Mansoura and offers practical suggestions for acoustic control, urban development guidelines, and improved legislation to enhance the quality of the acoustic environment and ultimately the health standards within the city.

Keywords: Urban noise pollution; Environmental dataset; Spatiotemporal analysis; Traffic density; Developing cities; Noise monitoring; Public health; Environmental acoustics
MSC: 62J05; 93B45

Doi : https://doi.org/10.21608/jaiep.2024.421438
Received: May 17, 2024, Revised:October 13, 2024, Accepted: December 11, 2024

1. Introduction

1.1. Background and Motivation

Urban noise pollution has now become one of the rising environmental and health concerns in the recent decades especially in the congested and fast developing cities. Acoustic noise originating from human activities and which interferes with the quality of ambient air is defined as noise pollution and is becoming a source of stress with adverse profound health effects [1]. As stated by WHO, chronic noise exposure causes several effects, such as cardiovascular diseases, cognitive dysfunction in children, sleep interference, and increased annoyance in residents [2]. As a result, the risk of chronic noise exposure remains high among most inhabitants of low- and middle-income cities due to rapid urbanization, increasing vehicle use, congestion, and poor or nonexistent zoning [3]. In such contexts, there are usually inadequate provisions for evaluating and controlling noise exposure implying that people in urban areas are at the receiving end of increasing environmental noise levels. It is, therefore, imperative to include spatial, temporal, and contextual data in the study of noise pollution in order to determine the hotspots, the driving forces behind noise pollution, and guide policy-making for improved quality of life in cities [4].

figure 1 illustrates the average value of the recorded noise level in El Mansoura at various hours within the year 2023. The noise level data have a clear diurnal pattern with peaks during the midmorning and after the midday up to early evening period. Such time frames refer to different hours of the day that have high levels of activities such as vehicle usage, business-related activities, and walking. Conversely, the levels were much lower and remained relatively steady at the lowest level between 00:00 to 06:00, a time when there are few people around or any operating machines. These variations imply temporal instability in urban noise and suggest the role of time-variant approaches to mitigate the population exposure level.

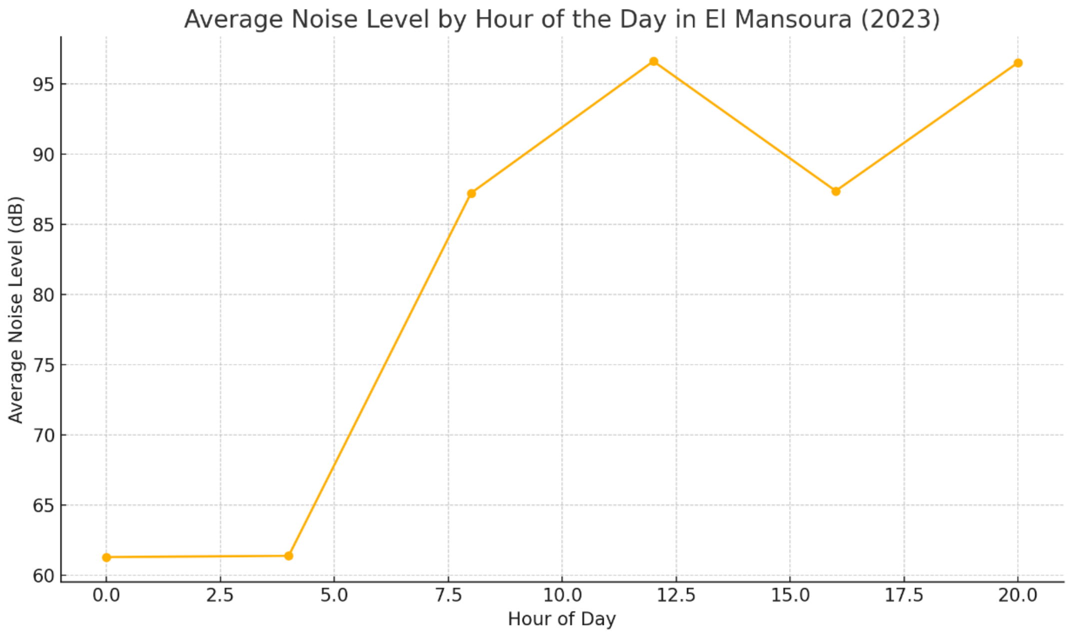

Figure 1: Average Noise Level by Hour of the Day in El Mansoura (2023)

1.2. Study Area Context

As one of the mid-sized cities in Egypt that is experiencing rapid urban change, El Mansoura is the capital of the Dakahlia Governorate. Geographically located in the Nile Delta region, this city is important in the medical, education and commerce in the northeastern part of Egypt. It has a population of more than one million and a high urban population density of 5,200 persons per square kilometer from the dataset [5]. Figure 2 shows the distribution of the noise level recorded in El Mansoura to show how often the noise occurred in each range of decibels. The distribution is positively skewed, with most of the measurements concentrated at between 60 and 90 dB and with a few data points in the upper end of the scale. The noisy line in the graph is dashed red and it shows the mean noise level, this is a primary level of reference. The results suggest that a sizeable segment of the urban population is constantly exposed to sound levels over the recommended safe exposure limit; information that can have serious implications for one’s health down the line. This distributional analysis also provides evidences for the effective noise control in high-exposure areas.

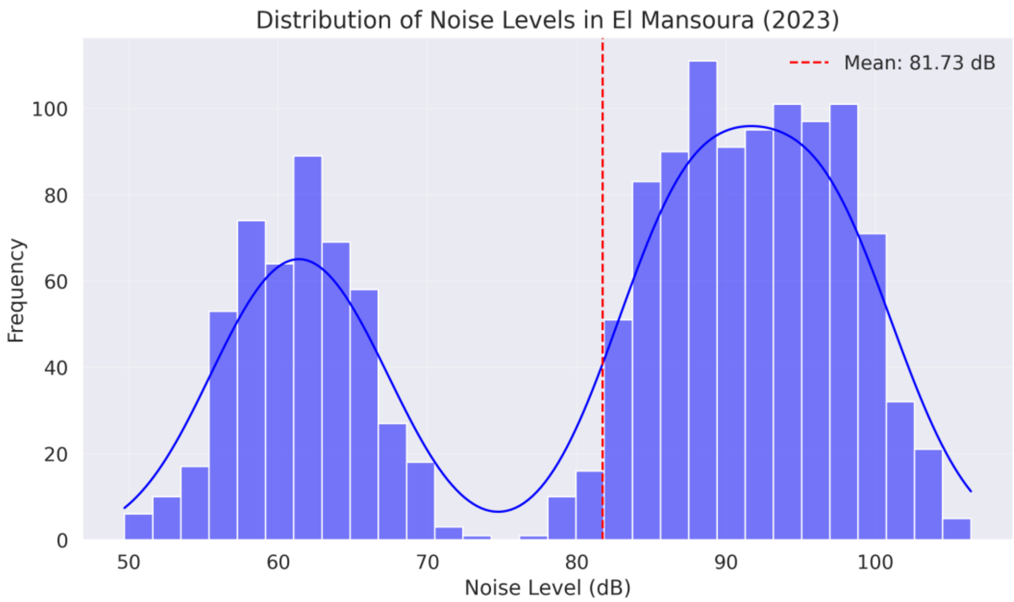

Figure 2: Distribution of noise levels in El Mansoura, showing the frequency of different noise measurements and the mean noise level (red dashed line).

The physical development of El Mansoura is also marked by high-rise buildings, network of roads, densely populated residential areas, commercial areas, and very few recreational areas. This high level of land usage alongside increased traffic flow and poor measures put in place to reduce noise makes it a rather difficult environment to deal with in terms of acoustics. Thus, El Mansoura's diverse urban structure lends itself perfectly to evaluating the effects of environmental and anthropogenic factors on distributions of noise in space and time in an emergent Egyptian city.

1.3. Research Objectives

This study seeks to provide a data-driven understanding of environmental noise patterns in El Mansoura using a comprehensive dataset collected during 2023. The main objectives are threefold:

1. **To analyze the spatial and temporal distribution of urban noise levels**, capturing variations across different times of day, days of the week, and seasons.
2. **To examine correlations between noise levels and environmental or anthropogenic variables**, including traffic density, building density, humidity, and road type.
3. **To assess the extent to which recorded noise levels exceed national or international thresholds**, with attention to day and night time limits.

Through this analysis, the study aims to contribute empirical evidence to support urban noise mitigation strategies and sustainable city planning in Egypt.

2. Related Work

Environmental noise pollution has continued to gain attention among researchers, urban planning experts, and health professionals worldwide [3]. With increasing city populations and the development of road infrastructures across the globe the level of environmental noise within these metropolises has been on the rise [5]. Various investigations have also been conducted on the sources, characteristics, and effects of noise pollution especially from traffic, industries and high populated areas [7]. Most previous work has aimed at establishing noise levels in the different urban environments using short-term measurements and long-term monitoring devices. Such investigations provide information that noise levels in large metropolitan areas are generally above the normative values, which negatively affect health by interfering with sleep, causing cardiovascular issues, and impeding cognitive abilities. It is also crucial as urban noise is becoming more and more a development issue in influencing the quality of life and well-being of people in urban centers [8].

Doi : https://doi.org/10.21608/jaiep.2024.421438
Received: May 17, 2024, Revised:October 13, 2024, Accepted: December 11, 2024

Several studies have investigated the problem of noise pollution in tourists' cities of Egypt especially Greater Cairo city and Alexandria. As the analysis of these studies has revealed, traffic congestion itself constituted one of the most crucial factors in the level of environmental noise, which in its turn exceeded national standards and policies [9], [10]. As for Egypt, recent studies have investigated the problems associated with environmental noise especially in the crowded areas such as Cairo [11]. Transportation has been cited as the main source of noise pollution in Cairo, with surveys revealing that the noise level at some sites is above those provided for by the Egyptian noise standards that aim at safeguarding the health of the people [10]. Various research techniques have been used in noise investigations, including simple SPL measurements using sound level meter to combined physical/infrastructure arrays or networks and geographic information system (GIS). Some of the existing research used temporal analysis in which researchers compare hourly, daily and seasonal variations and spatial analysis to determine areas of high and low noise levels [12].

Furthermore, environmental and anthropogenic factors such as the weather conditions of the place, traffic flow, types of roads, and land use have been studied to determine their impacts on the urban sound environment [13]. Nevertheless, there are certain shortcomings of the literature, predominantly focusing on the marginalized areas in the Global South that currently experience rapid urbanization. these aspects are usually considered as infrastructures for monitoring and data collection is commonly irregular or geographically inadequate. This calls for constant and detailed data acquisition to help in urban planning and policy making.

In addition, the expansion of research towards exploring the use of noise pollution as a component within a larger set of environmental and social indices for assessing urban sustainability is emerging [14]. The current study adds to this line of literature by providing a year's worth of noise level recordings of a middle-sized city. It expands on existing research methods and imposes further context and conditions specific to the environment, the concrete structures within this environment, and the overall climate. It offers a more thorough analysis of the noise phenomenon, which strengthens the theoretical and pragmatic groundwork for exploring cities' futures [15].

3. Materials and Methods

3.1. Data Collection

The data used in this study were collected in an organized environmental samples survey conducted in El Mansoura-Egypt during the calender year 2023. Sound data was collected from fixed stations mounted in designated locations throughout the city to determine the range of A-weighted sound levels in various environments that are residential, commercial, roads, and vicinity of park and recreation areas. The sampling was conducted at four-hour intervals to obtain a final number of 1465 observations thus encompassing all the hour of the day, days of the week and seasons. Sourcing the participants at this relatively high frequency meant that it was easy to undertake temporal analyses in the study such as daily and seasonal variations, or even differences between weekdays and weekends.

Specifically, the sound levels were captured by the use of sound level meters that conform to the IEC 61672 Class 1 standards which are widely used in environmental acoustic measurements. The prerequisite of these measurements was the calibration of the instruments using certified acoustic calibrators as per ISO 10052:2004. In each of the monitoring sessions, noise intensity was recorded in decibels (dB (A)) since this is an internationally acceptable units of measurement for noise, especially as they factor in the frequency at which human ears are sensitive to. To ensure sound control of data collector experience, type of the equipment used and quality index, each station had been managed by trained field personnel and the data collectors were asked to record information on the methodology used for every data collected as a measure of procedural accountability.

3.2. Dataset Description

It includes 40 variables such as features related to Acoustics, Time, Environment and Urban, and Metadata regarding data acquisition. The core acoustic variables include average noise level (Noise_Level_dB), maximum and minimum values (Peak_Noise_dB, Min_Noise_dB), and derived indicators such as fluctuation (Noise_Fluctuation_dB), standard deviation (Std_Dev_Noise_dB), and inter-hour variability (Hourly_Noise_Variation_dB). In addition, daily (Day_Noise) and nightly (Night_Noise) sound levels were recorded where available, and a rolling 24-hour average (24h_Moving_Avg) was computed to assess longer-term exposure patterns.

To enable time-based analyses, temporal factors all-encompassing hour of the day, day of the week, calendar month, and season were included in the analysis. Variables such as Time_of_Day and Arabic_Month were also incorporated to contextualize the dataset within local cultural and linguistic frameworks. A binary indicator (Is_Weekend) distinguishes weekend from weekday data points to facilitate behavioral comparisons.

Environmental and meteorological data were collected concurrently, including Humidity_% and general weather conditions (Weather). Urban and infrastructural factors included the classification of the adjacent roadway (Road_Type), traffic conditions (Traffic_Influence), and vehicular density (Vehicle_Count_per_hour). Other spatial features such as the proximity and area of nearby parks (Nearby_Parks_Area_sq_km), building density (Building_Density_per_km2), and population density (City_Population_Density_per_km2) were used to examine the role of urban form in shaping the acoustic environment. The dataset also recorded the likely source of noise (Noise_Source), a categorical estimate of overall noise intensity (Noise_Period), and land-use typology (Station_Location_Type).

To evaluate compliance with environmental regulations, the dataset includes permissible daytime and nighttime thresholds (Limit_Day_dB, Limit_Night_dB), an exceedance flag (Limit_Exceeded), and the magnitude of exceedance (Exceedance_Amount_dB). Finally, several metadata fields were included to document the measurement process, such as the identity and experience of the data collector (Data_Collector, Collector_Experience_Years), the type of equipment used (Equipment_Type), and an overall data quality score (Data_Quality_Index).

In conclusion, this work is designed to illustrate a high-resolution and comprehensive picture of the ordinary noise pollution condition in the context of El Mansoura for both exploratory and hypothesis testing. Its design enables systematic analysis of noise exposure throughout a specific period and along with the environmental and man-made factors and can be useful for urban studies, environmental and health science, and policy development.

4. Results

4.1. Noise Variation by Road Type

Figure 3 presents the average noise level readings taken at different roads in El Mansoura. From the data, the highly noisy areas are by the highway because they are the areas close to highways, then followed by arterial and commercial zones. Non-arterial local and domestic roads had much smaller averages although several of those were close or above the national daytime mean. This supports previous findings which correlate road hierarchy with acoustic exposure or simply, the more that is carried on the roads, the louder these spaces are.

Doi : https://doi.org/10.21608/jaiep.2024.421438
Received: May 17, 2024, Revised:October 13, 2024, Accepted: December 11, 2024

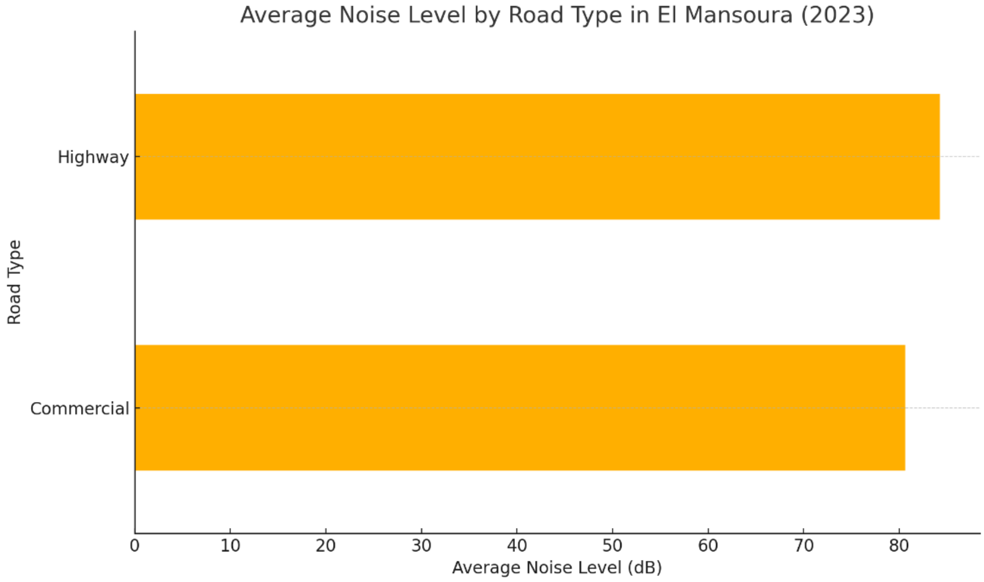

Figure 3: Average noise levels by road type, showing higher levels in highway areas compared to commercial areas.

4.2. Noise and Traffic Intensity

Figure 4 shows averaged A-weighted equivalent sound pressure level and further analysis of the sound map with traffic influence categories The observations in the figure illustrate how traffic noise influences the acoustic environment. Those sites under heavy traffic influence recorded the highest mean noise levels more than 85 dB. However, the areas with little or moderate traffic rate reflected relatively low infections. Such results emphasize the importance of traffic density as an influence regarding the noise climate in cities and stress that the specific measures of traffic regulation could serve as a practical approach for the reduction of noise pollution in streets with high traffic intensity.

4.3. Diurnal Noise Patterns

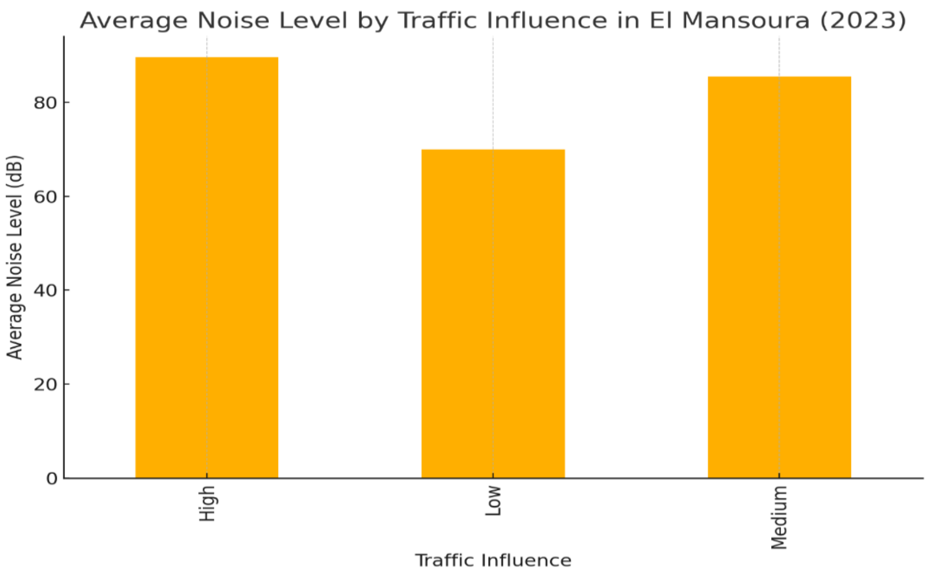

Figure 4: Average noise levels by traffic influence category, demonstrating the strong relationship between traffic intensity and noise pollution**.**

Figure 5 represents the average noise figure at different hours of the day. It becomes clear that sound intensity is highest between midmorning and early evening, as this time entails higher concentrations of people and cars. On the contrary, noise levels were significantly low during the night and early morning hours which showed that there are reduced vehicular movements and reduced commercial activities. This temporal variation gives valuable information in policy formulation and shows the possibilities that exist in the use of time factors in noise control especially during the periods of high noise exposure.

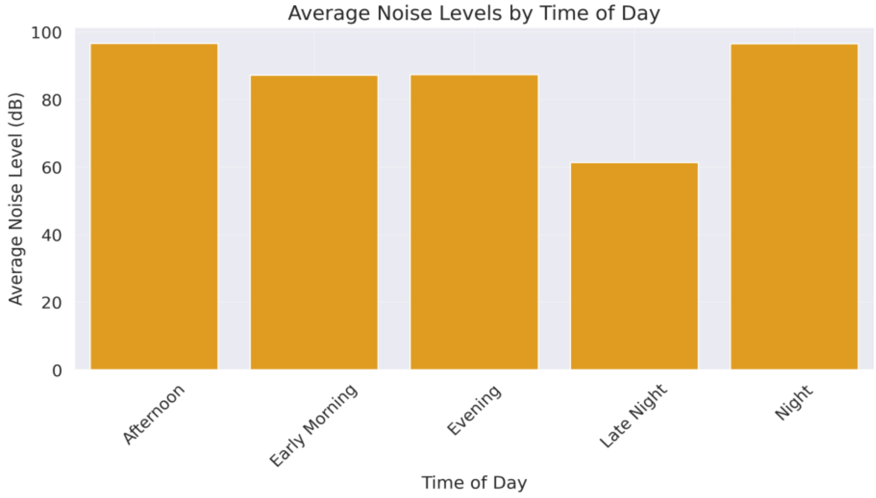

Figure 5: Average noise levels by time of day**,** showing variations across different periods of the day.

4.4. Relationship Between Vehicle Count and Noise Levels

Figure 6 shows that there exists a positive and linear correlation between the number of vehicles passing by per hour and the noise level recorded. The division of points by traffic influence category on the scatter plot shows that increase in the traffic volume is linked with the added noise level. There is some variation which is possibly attributable to the kind of vehicle that was used in the study, the type of road surface, as well as environmental factors, but the overall conclusion is in harmony with the fact that vehicular traffic flow is directly linked to high levels of noise. The color coding also underlines the fact that sites with high traffic influences are always located at the top region of noise range, as pointed out earlier.

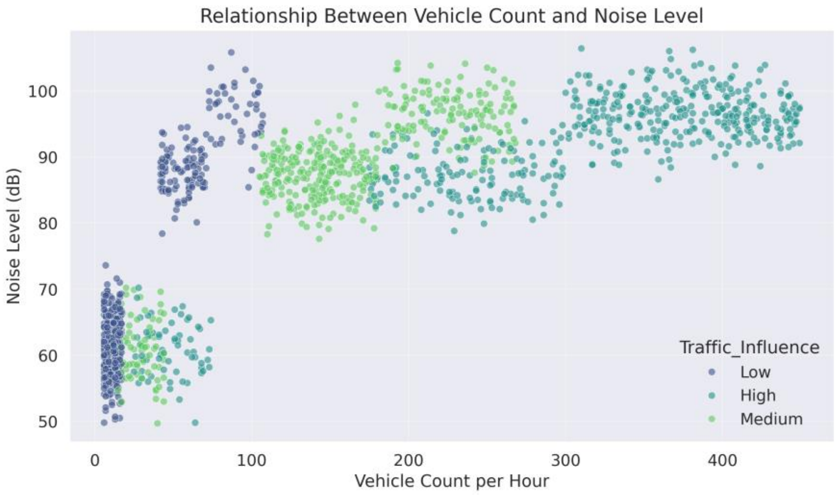

Figure 6: Scatter plot showing the relationship between vehicle count per hour and noise levels, colored by traffic influence category.

4.5. Noise Limit Exceedance Analysis

Figure 8 illustrates the distribution of noise exceedance compared to regulated noise levels during the day and night. A detailed analysis of the data shows that there is a significant number of recordings with a ratio above the acceptable limit, and in some instances, it goes up to 5–15 dB. The higher

Doi : https://doi.org/10.21608/jaiep.2024.421438
Received: May 17, 2024, Revised:October 13, 2024, Accepted: December 11, 2024

violation probability values taper gradually and stretch further towards the higher violation magnitudes which pose a great threat to public health. These findings show not only the problem of general non-compliance, but also offer data-based guidance for prioritizing noise reducing measures to areas most in need.

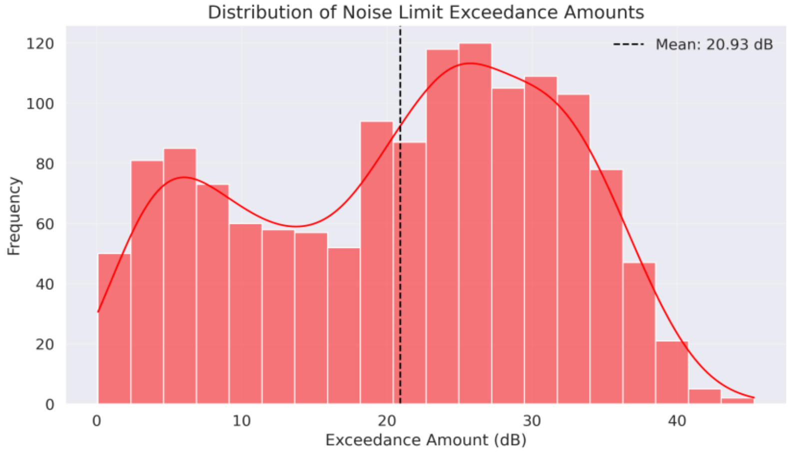

Figure 8: Distribution of noise limit exceedance amounts, showing the frequency and magnitude of regulatory violations.

4.6. Correlation Among Key Variables

Figure 7 highlights correlation between several key variables relating to noise pollution by indicating the form, intensity and direction of the correlation. These patterns are consistent with theoretical predictions that states areas with high densities, high traffic, and little vegetation are more prone to acoustic disturbance. The matrix makes the selection of variables plausible, and it adds a statistical premise to further multivariate analyses.

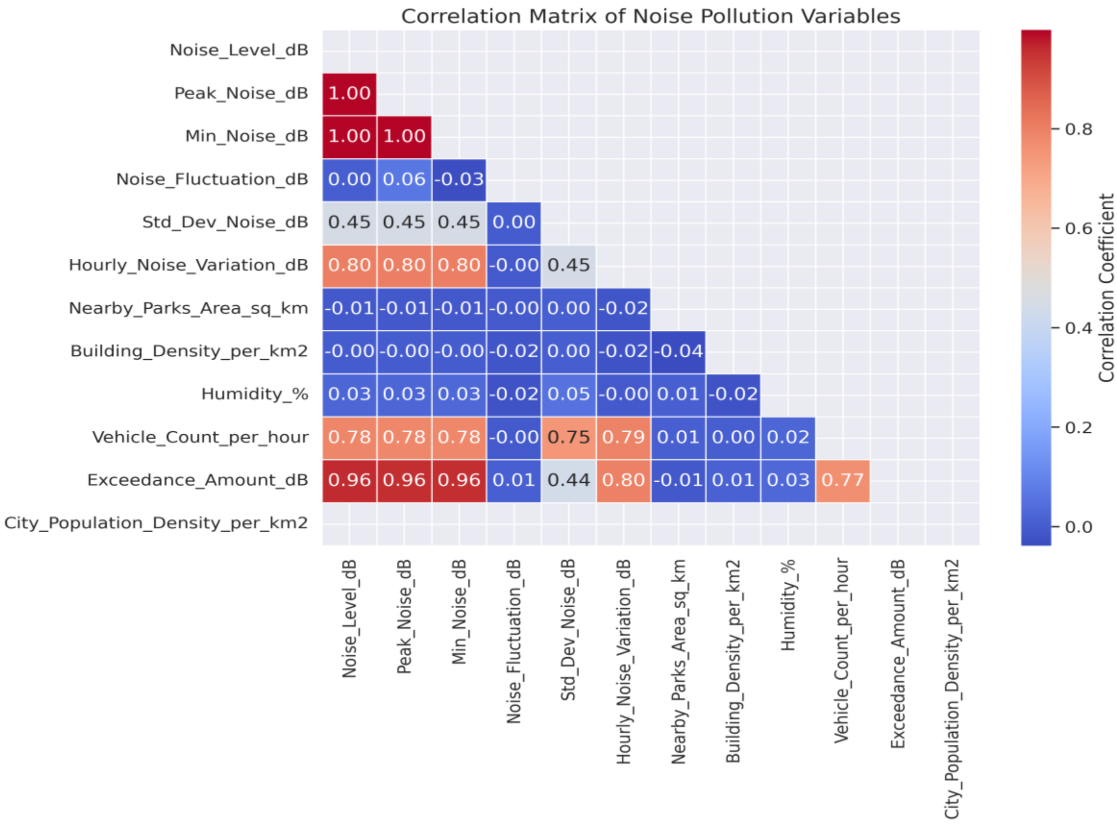

Figure 7: Correlation matrix of key variables related to noise pollution, showing the strength and direction of relationships.

5. Conclusion

This paper developed a detailed spatial and temporal study of noise pollution in El Mansoura, Egypt with the help of a multi-attribute database gathered during the year 2023. This study looked into variation in the environmental noise level on the basis of sample frequency, time of the day, day of the week, season, and urban environment by using 1465 measurements from monitoring stations. These environmental, infrastructural, and meteorological factors allowed for a comprehensive analysis of factors contributing to urban noise exposure. From the data presented here it can be concluded that noise levels in most locations of El Mansoura exceed national and international standards, especially within the busy traffic areas and/or during the daytime. Highway, Commercial areas were prominently characterized for highest ACP whereas internal road and green area exposed comparatively low ACP. Also, to the temporal studies, I established a clear diurnal pattern characteristic with noise pursuing the actions of the urban community. Positive correlation between noise level and number of vehicles, traffic impact and building population density supports the theory that anthropogenic factors play a crucial role in determining the acoustics of the city. Notably, this study adds to the scarce literature on noise pollution in Egyptian cities, other than Cairo. Thus the strengths of the study include the availability of the year-round, high frequency data, which may serve as a useful source of information for policymakers, urban planners, as well as environmental health experts. The study indicates that there is a growing demand for proper noise management with respect to traffic control, improving green spaces, and the implementation of the noise control laws. Therefore, the observed exceedances underscore the need to enhance the regulatory authorities and raise awareness programmes to reduce the constant exposition of residents to detrimental soundscapes.

Funding: This project was funded by the National Plan for Science, Technology and Innovation (MAARIFAH)—King Abdulaziz City for Science and Technology—the Kingdom of Saudi Arabia—award number (13-MAT377-08). The authors thank the Science and Technology Unit, King Abdulaziz University.

Conflicts of Interest: “The authors declare no conflict of interest.”

6. References

[1] O. Hahad et al., “Noise and mental health: evidence, mechanisms, and consequences,” Journal of Exposure Science & Environmental Epidemiology. Springer Nature, Jan. 26, 2024. doi: 10.1038/s41370-024-00642-5.

[2] A. Tortorella et al., “New determinants of mental health: the role of noise pollution. A narrative review,” International Review of Psychiatry, vol. 34. Taylor & Francis, p. 783, Jul. 15, 2022. doi: 10.1080/09540261.2022.2095200.

[3] X. Zhang and S. Zhou, “Building a City with Low Noise Pollution: Exploring the Mental Health Effect Thresholds of Spatiotemporal Environmental Noise Exposure and Urban Planning Solution,” International Journal of Environmental Research and Public Health, vol. 20, no. 5, p. 4222, Feb. 2023, doi: 10.3390/ijerph20054222.

[4] M. Stuhlmacher, J. Woods, L. Yang, and S. Sarigai, “How Does the Composition and Configuration of Green Space Influence Urban Noise?: A Systematic Literature Review,” Current Landscape Ecology Reports, vol. 9, no. 4, p. 73, Aug. 2024, doi: 10.1007/s40823-024-00099-0.

[5] G. Gamal, T. M. Hassan, A. Gaber, and M. Abdelfattah, “Groundwater quality assessment along the West of New Damietta Coastal City of Egypt using an integrated geophysical and hydrochemical approaches,” Environmental Earth Sciences, vol. 82, no. 4, Feb. 2023, doi: 10.1007/s12665-023-10762-0.

[6] K. Frenis et al., “Redox Switches in Noise-Induced Cardiovascular and Neuronal Dysregulation,” Frontiers in Molecular Biosciences, vol. 8. Frontiers Media, Nov. 18, 2021. doi: 10.3389/fmolb.2021.784910.

Doi : https://doi.org/10.21608/jaiep.2024.421438
Received: May 17, 2024, Revised:October 13, 2024, Accepted: December 11, 2024

[7] G. H. King, M. Roland-Mieszkowski, T. Jason, and D. Rainham, “Noise Levels Associated with Urban Land Use,” Journal of Urban Health, vol. 89, no. 6, p. 1017, Jun. 2012, doi: 10.1007/s11524-012-9721-7.

[8] A. Y. Semeykin, “Risk Assessment for Public Health from Transportation Noise (on the example of the city of Belgorod),” in IOP Conference Series Earth and Environmental Science, IOP Publishing, Jan. 2018, p. 12019. doi: 10.1088/1755-1315/115/1/012019.

[9] S. A. Ali, “Investigation of the dose–response relationship for road traffic noise in Assiut, Egypt,” Applied Acoustics, vol. 65, no. 11, p. 1113, Aug. 2004, doi: 10.1016/j.apacoust.2004.06.007.

[10] S. A. Ali and A. Tamura, “Road traffic noise mitigation strategies in Greater Cairo, Egypt,” Applied Acoustics, vol. 63, no. 11, p. 1257, Oct. 2002, doi: 10.1016/s0003-682x(02)00046-4.

[11] A. Sakr, F. El-Dars, and M. Hewehey, “MONITORING NOISE LEVELS ALONG THE GREATER CAIRO URBAN REGION RING ROAD IN EGYPT,” Journal of Environmental Science, vol. 49, no. 2, p. 1, Feb. 2020, doi: 10.21608/jes.2020.158105.

[12] J. A. Casey, R. Morello-Frosch, D. J. Mennitt, K. M. Fristrup, E. L. Ogburn, and P. James, “Race/Ethnicity, Socioeconomic Status, Residential Segregation, and Spatial Variation in Noise Exposure in the Contiguous United States,” Environmental Health Perspectives, vol. 125, no. 7, Jul. 2017, doi: 10.1289/ehp898.

[13] A. Can et al., “The future of urban sound environments: Impacting mobility trends and insights for noise assessment and mitigation,” Applied Acoustics, vol. 170, p. 107518, Jul. 2020, doi: 10.1016/j.apacoust.2020.107518.

[14] P. Liu, C. Wu, M. Chen, X. Ye, Y. Peng, and L. Sheng, “A Spatiotemporal Analysis of the Effects of Urbanization’s Socio-Economic Factors on Landscape Patterns Considering Operational Scales,” Sustainability, vol. 12, no. 6, p. 2543, Mar. 2020, doi: 10.3390/su12062543.

[15] A. Can and B. Gauvreau, “Describing and classifying urban sound environments with a relevant set of physical indicators,” The Journal of the Acoustical Society of America, vol. 137, no. 1, p. 208, Jan. 2015, doi: 10.1121/1.4904555.