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Chapter

A Mathematical Model of Noise Pollution in Streets of Tehran near IKIA Airport

Amir Esmael Forouhid

Abstract

This chapter attempts to investigate noise pollution in the street of Tehran near IKIA airport considering the population growth and large contribution of ground vehicles to noise pollution. The operation of airports results in environmental impact associated with high levels of different sources of noise. If there is to be growth in aviation, the environmental impacts of aviation must be mitigated. In this chapter, a model for the noise pollution near IKIA airport in Tehran has been calibrated with the use of a noise forecasting software. The study areas consisted of high traffic areas of Tajrish Street near the airport. In a field study, the noise level was measured via sound meter and the noise map was generated based on geo-statistical methods via GIS software. For this purpose, the factors influencing noise level (e.g. traffic, road width, slope, and residential or administrative-commercial land use) were surveyed and recorded for each point and their local and time dependencies were computed via SPSS. According to the results obtained from 324 survey points, the highest noise levels belonged to Tajrish area (69 dB). It is higher than standard noise level for residential and commercial and in conclusion, suggestions for reducing it are given.

Keywords: noise pollution, GIS, SPSS, regression, airport

1. Introduction

Public pressure led to the introduction of many different types of constraint at an increasing number of airports in an effort to keep both annoyance and complaints to a minimum. Noise pollution surrounding IKIA airport is a growing concern in Tehran.

The computer simulation of the noise exposure level that we use at IKIA airport and its surrounding areas is conducted using the noise exposure forcasting modeling, The Noise Exposure Forecasting modeling, as used in the current study, computes noise exposure levels. The noise metric computed by the model is the annual average Day–Night Sound Level. The widely-used DNL metric is known to be highly correlated with community annoyance and is associated with a variety of land use guidelines that suggest where incompatibilities are expected to exist between the noise environment and various human activities [1].

Noise is an adverse factor in the living environments of today's communities. This type of pollution has drawn attention to itself in the three recent decades, being a major problem in larger cities and seen as one of the significant environmental problems which is on the rise due to an array of factors including increased population density, motor vehicles, industrial activities in the proximity of urban areas and construction activities. Above-standard noise levels negatively affect all living beings and are therefore classified as environmental pollution. Research shows that both short- and long-term exposure to noise pollution weakens hearing, increases blood pressure leading to cardiovascular disorders, causes sleep and mood disorders, and changes behavior patterns [2]. Basner et al. studied the auditory and non-auditory influences of noise on cardiac diseases and neural disorders [3]. Therefore studying noise pollution and generating noise level maps for metropolises such as Tehran is of significant importance. Sound measuring in each certain area would take a considerable time and cost [4] because the level of noise emitted by vehicles in streets varies depending on traffic condition and such variation needs to be considered in measurements.

Another way used to measure noise pollution in a certain area is employing noise pollution models, which indeed is a mathematical technique. Mostly traffic-based parameters, which are very diverse, are used as the model's inputs. There are many factors that may affect sound emission in the space; hence, numerous models have been developed in this area so far. Most of them are physical factors which cover sound properties. As a result, measuring and examining such parameters is very difficult and complicated. However, other parameters including traffic-related ones such as velocity of vehicles and traffic flow are measured very easily [4].

Many studies have focused on noise pollution with different methods. Bilasco et al. proposed an information system model to identify areas exposed to noise pollution. Their model generated a noise map using sound measurements, building heights, land uses, digital land altitude model, and wind speed and direction in GIS software [5]. Subramani et al. analyzed noise pollution at different crossroads. They first performed a time analysis on sound data in different time periods at different crossroads, thus generating the noise map via GIS [6]. In another work, Mendal et al. assessed and analyzed noise pollution in Kolkata, India at the time of a festival [7]. Abbaspour et al. performed a hierarchical analysis of noise pollution in a region of Tehran [8]. Investigating the research performed on noise pollution analysis indicates that for noise pollution studies, GIS system is highly capable in generating noise maps and data analysis. The most important influential factors on the subject are traffic, width and type of roads, urban land use, green space, and slope. Traffic is important because increased traffic means increased vehicles, therefore increased noise. Road width also influences the capacity for holding vehicles. Road slope influences vehicle speeds, with higher speeds generating higher levels of noise. Land use influences generated noise by changing the population density and commenting levels.

2. Research method

The paper studied Tehran, Iran. The study areas consisted of Tajrish Sq. (region 1) street of Tehran. The study areas were selected based on their traffic and urban importance. Measurements were performed during 7–8 am on August 5–8, 2018. The survey measured sound levels, road slope, road width, traffic, and land use (residential, commercial, administrative, and green space) that are presented in the following sections.

The computer simulation of the noise exposure level that use at IKIA airport and its surrounding areas is conducted using the noise exposure forecasting modeling, The noise exposure forecasting modeling, as used in the current study, computes noise exposure levels. The noise metric computed by the model is the annual average Day–Night Sound Level. The widely-used DNL metric is known to be highly correlated with community annoyance and is associated with a variety of land use guidelines that suggest where incompatibilities are expected to exist between the noise environments and various human activities. Data input to the NEF includes runway coordinates, flight tracks, flight operations and types of aircraft. NEF computes the overall noise exposure at points on the ground around the airport. Data was modeled for a period of one year. The use of NEF in computer-based noise modeling not only gives the noise exposure levels based on the current flight operations, but also allows for the prediction of future noise levels due to a projected increase in flight operations. This is especially useful for a rapidly growing city like Tehran and IKIA airport.

The data and assumptions used for leading such a study are presented and detailed below.

Data summary:

- Distance to city center: 40 km
- Airport site area: 13,500 Ha
- Airport reference point coordinates:
  - Latitude: 35°24′58″N;
  - Longitude: 051°09′08″E;
  - Elevation: 1007 m.

Specifications for all planned runways are summed up below:

- Length of scheduled runways is 4200 m;
- Width of runways is 60 m with 15 m shoulders;
- Distance between parallel runways will be 400 m;

According to IKIA existing Airport Information Publication (AIP), the procedures for outbound aircraft are mainly concentrated on seven radials originating from IMAM KHOMAINI VOR/DME or destination to KAHRIZAK NDB. These exit radials were used to model the flight tracks followed by the various aircraft that will be accommodated at IKIA airport. Straight-in approaches were assumed on each runway.

This paper uses the noise exposure forcasting because its availability. The NEF consists of a map of the noise contours plotted over the airport layout at each time period. Noise contours for NEF 30, 35, 40 and 45 noise levels are shown on the map.

In this software, NEF+35 = DECIBEL and for discussion, should change the numbers of NEF to decibels. In the chart below, define the steps for modeling the noise of the airport .

It does this first by making the runways shown in **Figure 1** and then with the data from the runway, start the software.

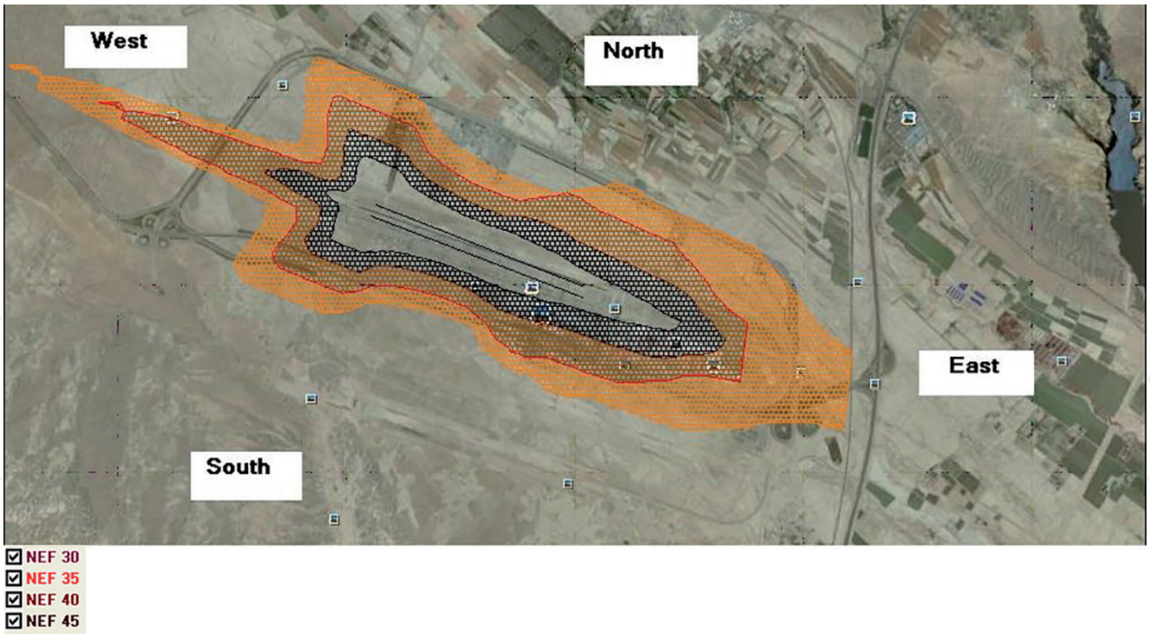

Figure 1.
Contours of the noise around the airport. Invert the output of software to decibels: Black contour: 80 dB; Brown contour: 75 dB; red contour: 70 dB; and at last contour 65 dB.

Night (10 pm–7 am) Unit in dB	Day (7 am–10 pm) Unit in dB	Type of region
45	55	Residential region
50	60	Residential-commercial region
55	65	Commercial region
60	70	Residential-industry region
65	75	Industry region

Table 1.
Standard for noise values [9].

Standard suggestion of the environmental organization of Iran for noise is shown in **Table 1**. From the results of contour map and this table, divide four the regions and in **Figure 1** the result is shown.

With comparison the noise map from the noise exposure forecast modeling with the ICAO land use recommendations in **Table 1**, and knowing that in the airport, we also have noise pollution from numerous vehicles and factories that may develop in the near future, should have a master plan for decreasing the noise of the airport, should do it first at the origin of it and then by barriers with a suitable plan for building near IKIA. The next section suggests some recommendations that may be used for the airport.

2.1 Influential parameters

2.1.1 Slope

Road slope greatly influences commuting, traffic arrangement, speed, and driving patterns. Noise pollution varies between roads with different slopes. The mean slope of the study areas was 0–3%.

2.1.2 Land use

The National Cartographic Center's 1:2000 maps, field studies, and Google Maps™ were used to calculate land use (residential, commercial, administrative, and natural ground).

2.1.3 Traffic

Considering the direct influence of urban traffic on the noise level, the authors measured raw data for the number of vehicles, survey time, and other data at each point in order to calculate the traffic of survey points via extra processing. The correlation between traffic level and noise level made this data essential. A reasonable high-traffic hour at the peak mounting traffic (7–8 am) was selected to measure peak traffic. The vehicle data, converted to their equivalent according to saloon vehicles, were calculated using Eq. (1) [10].

$$V_a = V \times C_f \tag{1}$$

where V_a is traffic volume in a complete period, V is the calculated traffic during the measurement time in a period, C_f is the correction factor of the measurement.

C_f is calculated via Eq. (2)

$$C_f = \frac{T_c}{T_c - T_s} \tag{2}$$

where T_c is the complete measurement period (min), T_s is the short stoppage time (min).

2.1.4 Road width

Due to high traffic and impossibility of direct measurements, road widths were estimated base on the number of lanes (every 3–3.65 m) and matching them with Google Earth maps and the mean value for multiple sections of each road.

2.2 Generating the noise level map

The sound data were collected using the device TES Sound Level Meter 1353H (calibrated by a qualified company) measurements were performed in the mornings at 15–20 m intervals. The longitude and latitude of each measurement point were recorded via a Garmin GPS device.

If during measurements, a vehicle with very high noise levels (bus, heavy truck, etc.) passed nearby the measuring device at low speeds or stopped, the authors attempted to remove its effect from measurements as it would introduce abnormal variations in measurements leading to statistical errors.

Data analysis was performed via ArcGIS 10.4.1. Raster polygon layers of sound data for the four studied areas are presented in **Figure 2**.

The data model:

After testing the relationship between noise level variable and different combinations of independent variables, the best model was selected using Eq. (3).

$$L_{eq\ (m)} = 70.554 + 0.002 \times Traffic - 0.078 \times Residential \tag{3}$$

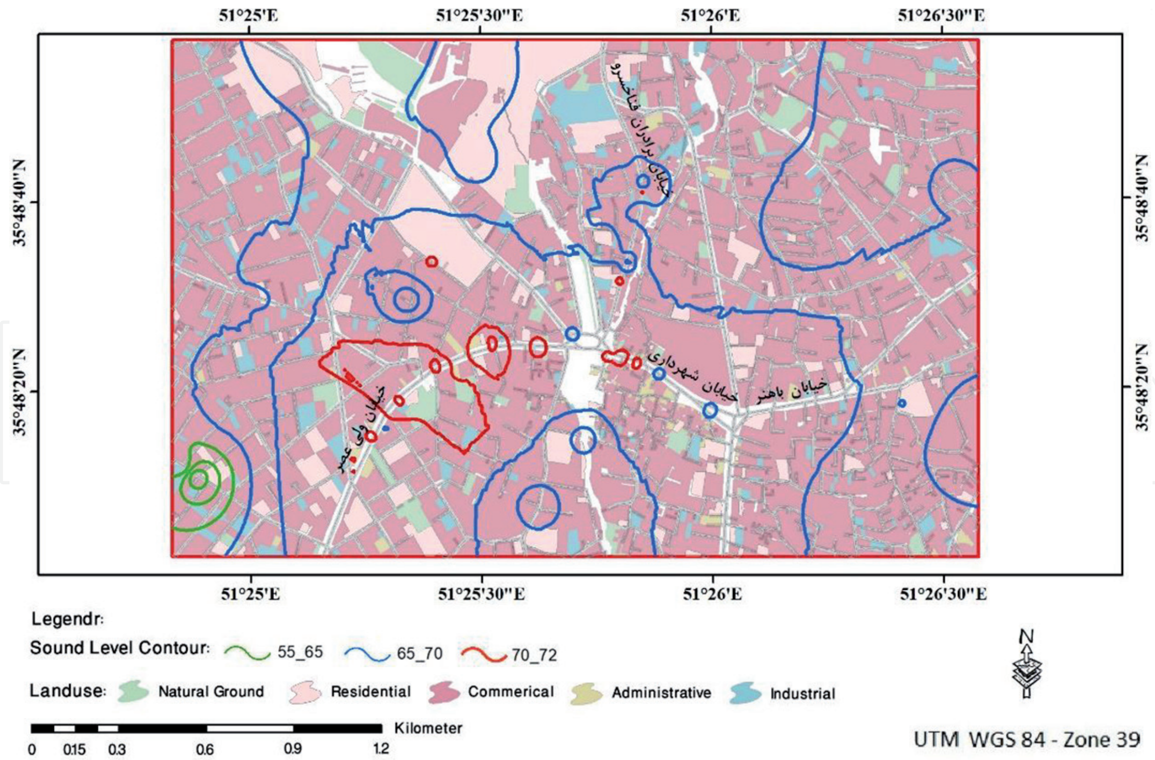

Figure 2.
Noise level map of Tajrish.

where $Leq_{(m)}$ is the noise level (dB), $Traffic_m$ is the vehicle traffic, and *Residential* denotes the percentage of residential land use.

As shown, noise level is related to the traffic volume and residential land use independent variables. There is a positive linear relationship between noise level and vehicle volume, indicating that higher vehicle volumes resulted in increased noise. The relationship predicts that one vehicle per hour increase in vehicle traffic volume will increase noise level by 0.002 dB. There is a negative, linear relationship between noise level and percentage of residential land use, indicating that 1% increase in residential land use will increase noise level by 0.078 dB. T**ables 2** and **3** show the data for observation times, goodness of fit indices (R^2, R^2_{Adj}), mean square error (MSE), results of t and F tests, and their respective significance, the estimated parameters (coefficients of independent variables) and their confidence interval, and the variance analysis table and F statistical value. The following section provides an analysis for each table.

2.2.1 Normality of the residuals

Figure 3 shows residuals according to their frequencies, representing a relatively normal distribution.

2.2.2 Linearly or nonlinearity of the relationships between dependent and independent variables

The linearity analysis was performed using a graph separating dependent and independent variables. According to **Figures 4** and **5**, the maximum value of goodness of fit index for the traffic and noise level relationship was 0.64, followed by 0.489 for the percentage of residential land use. Road width ranked third however it could simultaneously be used in the regression model due to very high correlation with the traffic variable.

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	Traffic	sound Level	Slope	Residential	Commercial	Administrative	Natural Ground	Road Width
Traffic	1							
Sound Level	0.6931	1						
Slope	−0.5235	−0.4349	1					
Residential	−0.6140	−0.6486	0.6459	1				
Commercial	0.1575	−0.1258	−0.1251	0.0715	1			
Administrative	−0.6536	−0.3095	0.0749	0.0175	0.0557	1		
Natural Ground	0.5788	0.5876	−0.2807	−0.7782	−0.5012	−0.3898	1	
Road Width	0.8285	0.6242	−0.5469	−0.5731	−0.0680	−0.6015	0.7075	1

Table 2.
Variable correlations.

Model	R	R^2	Adjusted R^2	Std. error of the estimate	Change statistics					Durbin-Watson
					R^2 change	F change	df1	df2	Sig. F Change	
1	0.800	0.640	0.638	2.8233	0.641	497.107	1	280	0.000	
2	0.826	0.682	0.680	2.6577	0.042	36.980	1	279	0.000	1.936

Table 3.
Model summary.

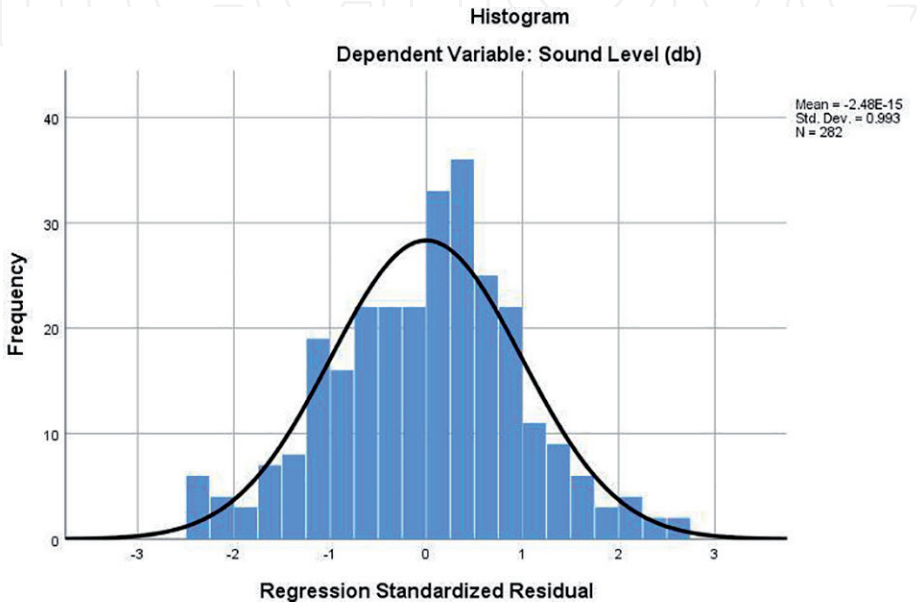

Figure 3.
The frequency of the regression model residuals.

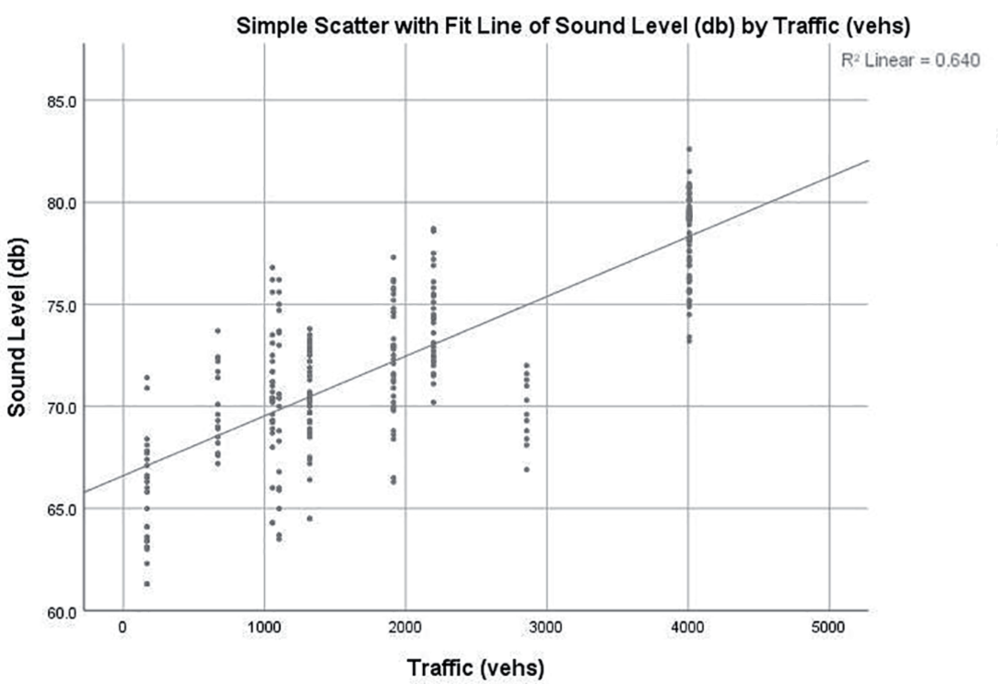

Figure 4.
Noise level and vehicle volume relationship.

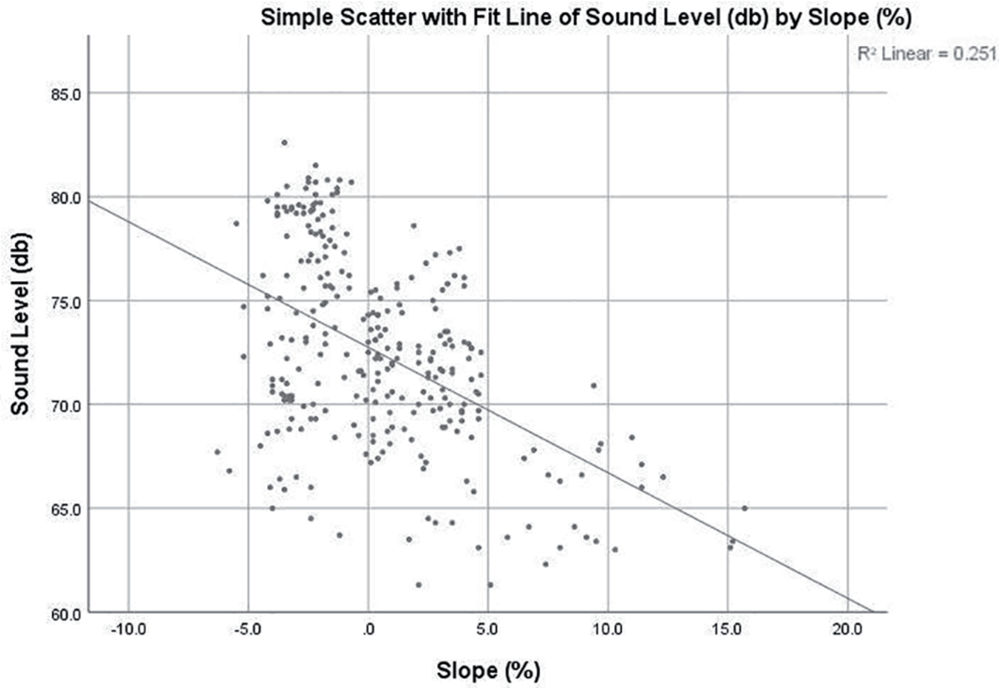

Figure 5.
Noise level and road slope relationship.

3. Conclusion

The negative impact of aircraft noise, in particular around airports, is increasing. More and more people suffer not only from annoyance, but recent studies indicate that intermediate and high noise levels also contribute to physiological and psychological effects that in extreme cases can cause severe health problems. The aircraft industry has launched an ambitious plan for the next 15 years to reduce the noise emission levels from aircraft by as much as 20 dB. Even if this goal can be reached, reduced noise emission levels for new aircraft will have little or no influence on the total noise situation around airports in future. This is due to a slow renewal rate for aircraft combined with an increase in passenger volume.

In order to stay competitive and to cope with an increasing number of neighborhood complaints and noise-impact related constraints, airport owners will have to look for novel solutions to reduce noise emission levels.

The International Civil Aviation Organization (ICAO) has defined a four-point "balanced approach" that includes:

Reduction of noise at source;

For improving this method airports authorities should develop and buy new aircrafts that have less noise such as boeing 757 instead of boeing 727 and etc.

Land-use planning;

The results indicate the critical significance of urban traffic in noise pollution, as by a large difference it had the highest contribution to noise level, followed by green space, administrative, and commercial land use; road width, and road slope.

Commercial and business land uses generated the highest noise pollutions. With their high commuting levels and passenger traffic, malls and commercial centers produce high noise levels, especially at certain hours in the morning, resulting in higher noise and environmental pollutions compared to natural ground or residential areas. Sound levels above 70 dB irritate humans.

For reduced noise pollution in Tehran and generally all urban areas, it is recommended to promote good driving behaviors and vehicle technical control for their sound level as well as implementing sound barriers for preventing the sound leaking into residential areas. Further, it is recommended that for future roads or revamping the existing ones, more lanes be implemented to produce wider roads, prevent the construction of tall buildings on the sided of main roads, and maintaining a standard distance between buildings and main roads, freeways, and other motorways.

The negative impact of aircraft noise, in particular around airports, is increasing. More and more people suffer not only from annoyance, but recent studies indicate that intermediate and high noise levels also contribute to physiological and psychological effects that in extreme cases can cause severe health problems. The aircraft industry has launched an ambitious plan for the coming 15 years to reduce the noise emission levels from aircraft by as much as 20 dB [1].

Other strategies for reducing noise pollution in urban areas include designating suitable locations for land uses in comprehensive and development plans, use of standard, low-noise vetches, imposing limitations on the passage of automobiles and motorcycles, imposing speed limits, improving traffic behaviors and extending public transport. Sound barriers around motorways and the use of sound-absorbent materials in commercial and residential buildings or natural ground near residential areas or roads will greatly reduce noise pollution levels. In addition, proper city-wide planning requires establishing sufficient noise-pollution measurement stations and sound level maps for different urban regions and land uses.

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