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Key words: *noise pollution, vehicles, sustainability, regression, road traffic*
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MODELLING AND ANALYSIS OF AN URBAN ROAD TRAFFIC NOISE POLLUTION (CASE STUDY OF AN INTERRUPTED FLOW TRAFFIC NOISE AT A SIGNALIZED INTERSECTION)

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This research aimed at modeling interrupted flow traffic noise at a signalized intersection. In this study, a new approach has been used with SPSS and Arc GIS with urban road traffic noise. The measured parameters of noise include noise equivalent level, volume of light vehicles, heavy vehicles and time mean speed. The results showed that the Spearman correlation coefficient between the interface and the level of the noise at morning, evening and total time were 0.241, 0.35 and 0.45. The spearman correlation coefficient between the interface of the buildings and the intersection of all types of vehicles passing through the morning, evening and total time equal to 0.534, 0.328 and 0.409. The results showed that noise level can be predicted through the speed variables of the vehicles, the volume of vehicles passing heavy and the use of land use of buildings. According to the results and the noise maps for the modeling noise of the estimated coefficients from the equation, it can be found that in building highway in urban, closer look on internationally acting Green Building Labels and noise protection is seen as an important part of the social sustainability aspects of a building.

Key words: noise pollution, vehicles, sustainability, regression, road traffic

INTRODUCTION

As new products or technologies roll out, communities adopt them advocating their advantages while turning a blind eye to their shortcomings, unless they are truly crippling. The constantly growing number of cities and the consequent need for moving material and people between them has led to use of various vehicles. Today, the evaluation of traffic noise, the most important noise source in the cities, and anticipating solutions to decrease the pollution level in the city environment has gained ever increasing importance [1]. Studies have shown that road traffic causes noise pollution leading to health issues either related or unrelated to hearing [2]. American studies have shown that 48% of the people in this country are exposed to 55 dB and 9% are exposed to 67 dB of noise pollution on a daily basis [3]. Acknowledging the sound of road traffic as one of the main sources of environmental pollution has led to the development of noise level prediction models using fundamental variables [1].

Subramani et al. analyzed noise pollution at different crossroads. They first performed a time analysis on noise data in different time periods at different crossroads, thus generating the noise map via GIS [4]. In another work, Mendal et al. assessed and analyzed noise pollution in Kolkata, India at the time of a festival [5].

We need to build sustainably to:

1. Preserve our environment
2. Reduce the buildings' costs
3. Increase efficiency & durability
4. Provide healthy environments for people.

Sustainability of a building is influenced by:

– Building performance
– Environmental, economical & social impacts.

BIM (Building Information Modeling) advantages include:

– Ability to analyze
– Ability to evaluate green buildings
– Access to information to make sustainable decisions.

Construction effects on the surroundings and environment measuring:

– Energy use
– Noise pollution
– Any environmental effect [6].

It seems to pay more attention to the concept of noise pollution. Therefore, our goal in this study is to create noise pollution maps of the intersection between Hafte-Tir Boulevard and Emamzade-Hasan Boulevard in Karaj using GIS software and to model the traffic noise in this intersection using SPSS.

RESEARCH METHODOLOGY AND THEORY AND EXPERIMENTAL

First, various parameters and factors involved in noise pollu-

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Table 1: The summary of back ground research

Author	Year	Country	Title
Case report. Journal of Rafsanjan University of Medical Sciences[14]	2016	Iran	Level Distribution of noise pollution By using geographical information system(GIS) In area one District Six of Tehran
E. Chevallier, A. C., M. Nadji, L. Leclercq [15]	2009	France	Improving noise assessment at intersections by modeling traffic dynamics
Guarnaccia, C [16]	2010	WSEAS TRANSACTIONS on SYSTEMS	Analysis of Traffic Noise in a Road Intersection
Bilaşco, Ş., Govor, C., Roşca, S., Vescan, I., Filip, S., & Fodorean, I [17]	2014	Germany	GIS model for identifying urban areas vulnerable to noise pollution: case study
Ki-Hyunkim, D. X. H., Richard J.C. Brown , J.-M. OH , Chan Goo Park [18]	2012	China	Some insights into the relationship between urban air pollution and noise levels

tion were identified and their spatial data were generated as raster files to generate a pollution map, which are listed below.

- The volume of traffic
- Time Mean Speed
- Urban land use
- Road maps
- Noise measurement data

After collecting the data in accordance with the purpose of the research, an initial processing is performed on them to prepare them for spatial analysis. In the next step, the data are analyzed in the three sections and spatial and temporal analyzes are performed on them. For more detailed studies, the importance of each parameter and the extent of their impact on changes in noise level will be studied. The intersection was selected based on their traffic and urban importance. Measurements were performed during morning and evening time for one week.

As per the New South Wales Road Noise Policy the assessment process is shown in Figure 1 as follows [7]. In general, the equivalent levels evaluated with a statistical noise model are moderately reliable for standard traffic flow conditions such as constant speeds, no abrupt changes and an absence of any intersections, etc. The prediction of traffic noise impact for a standard situation can be successfully performed with many statistical noise models such as regression [8].

In this study, hypotheses are considered and shown in Table 2.

Table 2: The summary of hypothesis

Hypothesis	Description
First	Relationship between the speed parameter of different types of passing vehicles and noise level
Second	Relationship between the land use of buildings around the intersection and the volume of vehicles.
Third	Relationship between the use parameter of buildings around the intersection and the noise level
Fourth	Relationship between the time mean speed parameter of different types of passing vehicles and the volume of passing vehicles
Fifth	Relationship between the noise levels parameter and the volume parameter of passing vehicles
Six	Relationship between the use parameter of buildings around the intersection and the speed of various passing vehicles.

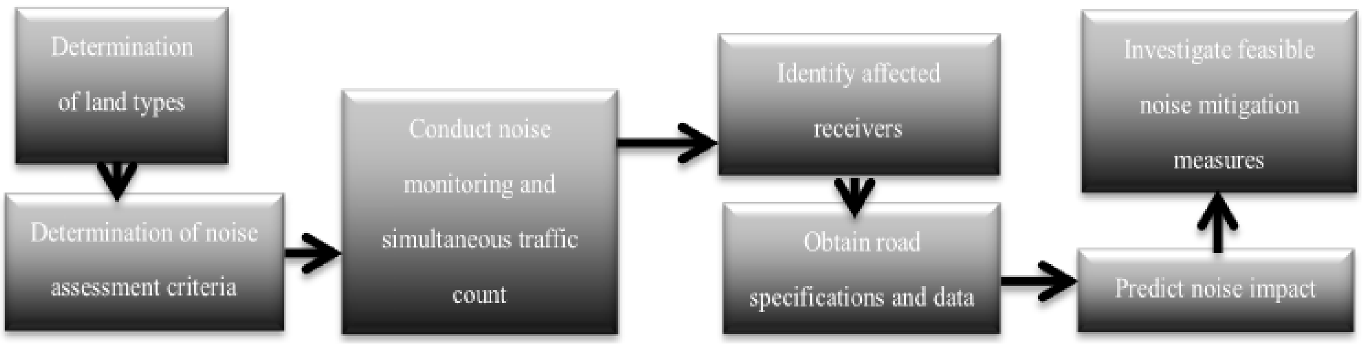

Figure 1: Traffic noise prediction process

INFLUENTIAL PARAMETERS IN THIS STUDY

Karaj city is the capital of Alborz province and the largest city of this province in the rank of three urban populations in the country after Tehran and Mashhad with a population of one million and nine hundred and forty thousand people. Karaj city is located in the east of Alborz province and borders Tehran province from the east and south, Savojbolagh and Taleghan cities from the west and Mazandaran province from the north. In figure 2 shows Alborz province and location of Karaj city.

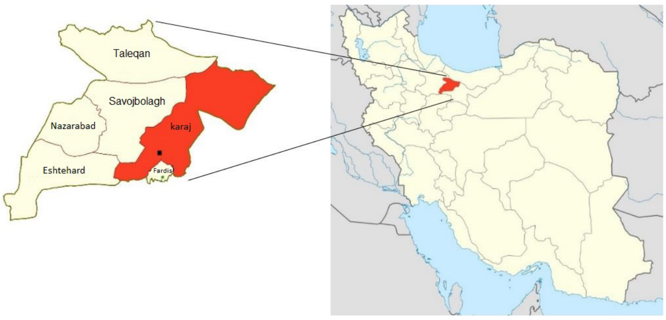

Figure 2: Alborz province and location of Karaj city

For this purpose, first the axis of the required route determined so the sort of use of all lands and buildings at a distance of 100 meters from either side of the axis of the route was examined. In the following figure 3 and figure 4, the location has shown. In the figure 5 and figure 6, map and station (points) of our study, which is located at the intersection of Haft Tir Boulevard and Imamzadeh Hassan Boulevard, have been selected.

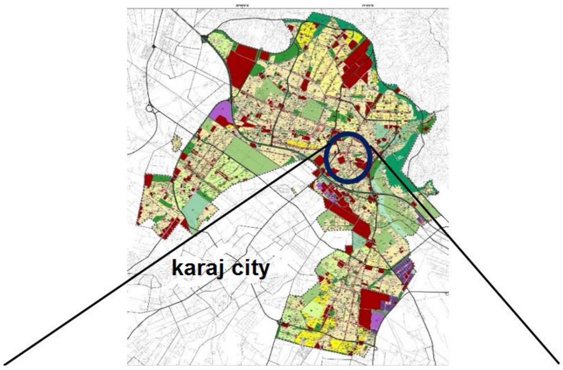

Figure 3: Location of intersection

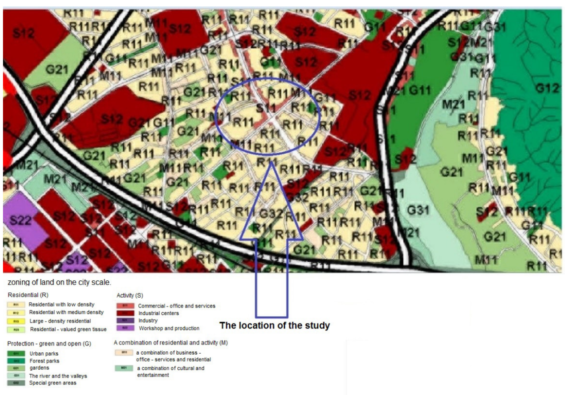

Figure 4: Map and station (points)

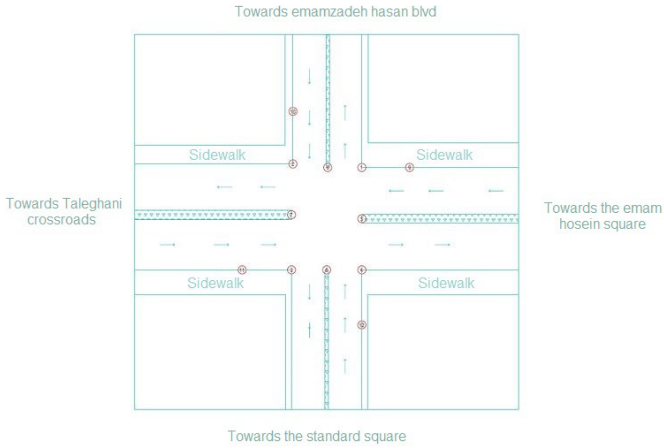

Figure 5: Location of selected points (stations) at the intersection

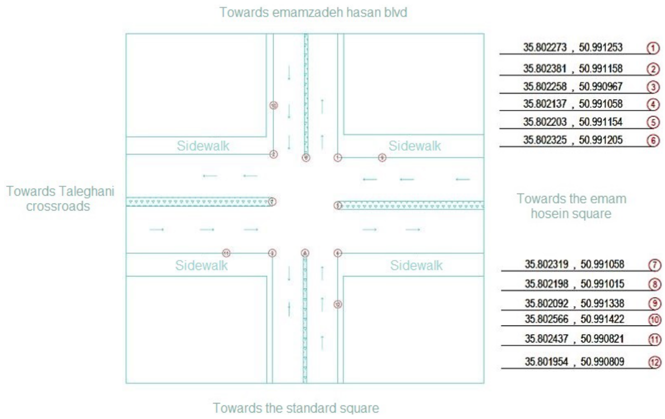

Figure 6: Selected points (stations) at the intersection with Coordinates

Noise Measuring

As a first step in this study, 30 stations were selected for sampling and evaluation. The stations were selected in a manner that most of the important roads and building types are included and traffic distribution in the area is represented sufficiently and comprehensively. GPS devices on smart phones were used to determine the exact location of the stations and a sound level meter to measure the sound level at each station. A CEL 450 with CEL 110/2 calibrator was used to measure noise at peak hours, in four areas: within 7-10 morning in west-to-east and north-to-south axes and within 17-19 evening in south-to-north and east-to-west axes in accordance with the standard environmental method [19]. As the sound was recorded at each station, the vehicles were video-taped simultaneously and were counted later. The Time Mean Speed (TMS) was evaluated based on location observation. Data analysis was conducted quantitatively using SPSS statistical analysis software and finally, the noise pollution map was formed using GIS. The map with the details of stations are shown in the figure 7 and table 3.

In this research, CEL 450 device with CEL 2.101 calibrator has been used. In the figure 8 the device for noise measuring is shown.

Table 3: Latitude and longitude of points

Station	Latitude	Longitude	Latitude	Longitude	Station	Latitude	Longitude	Latitude	Longitude
1	35.802007	50.990520	35°48′ 07.23″	50°59′ 25.87″	16	35.798656	50.994599	35°47′ 55.16″	50°59′ 40.55″
2	35.802260	50.990900	35°48′ 08.13″	50°59′ 27.24″	17	35.798410	50.995767	35°47′ 54.27″	50°59′ 44.76″
3	35.802609	50.990600	35°48′ 09.39″	50°59′ 26.16″	18	35.798252	50.997268	35°48′ 09″	50°59′ 50.16″
4	35.802830	50.990800	35°48′ 10″	50°59′ 26.8″	19	35.798176	50.997944	35°47′ 53.43″	50°59′ 52.59″
5	35.802419	50.991160	35°48′ 08″	50°59′ 28″	20	35.798076	50.998890	35°47′ 53.07″	50°59′ 56.00″
6	35.802829	50.991725	35°48′ 10″	50°59′ 30″	21	35.797963	51.000134	35°47′ 52.66″	51°00′ 0.48″
7	35.802716	50.991920	35°48′ 09.77″	50°59′ 30.91″	22	35.798214	51.000232	35°47′ 53.57″	51°00′ 0.83″
8	35.802270	50.991290	35°48′ 08.17″	50°59′ 28.64″	23	35.798344	50.998952	35°47′ 54.03″	50°59′ 56.22″
9	35.801893	50.991637	35°48′ 06.81″	50°59′ 29.89″	24	35.798437	50.997833	35°47′ 54.37″	50°59′ 52.19″
10	35.801669	50.991468	35°48′ 06″	50°59′ 29.28″	25	35.798533	50.997355	35°47′ 54.71″	50°59′ 50.47″
11	35.802101	50.991061	35°48′ 07.56″	50°59′ 27.81″	26	35.798682	50.995806	35°47′ 55.25″	50°59′ 44.90″
12	35.801887	50.990781	35°48′ 06.79″	50°59′ 26.18″	27	35.798861	50.994767	35°47′ 55.89″	50°59′ 41.16″
13	35.801048	50.991959	35°48′ 03.77″	50°59′ 31.05″	28	35.799669	50.993483	35°47′ 58.80″	50°59′ 36.53″
14	35.800502	50.992400	35°48′ 01.80″	50°59′ 32.64″	29	35.800607	50.992687	35°48′ 02.18″	50°59′ 33.67″
15	35.799519	50.993265	35°48′ 58.26″	50°59′ 35.75″	30	35.801185	50.992151	35°48′ 04.26″	50°59′ 31.74″

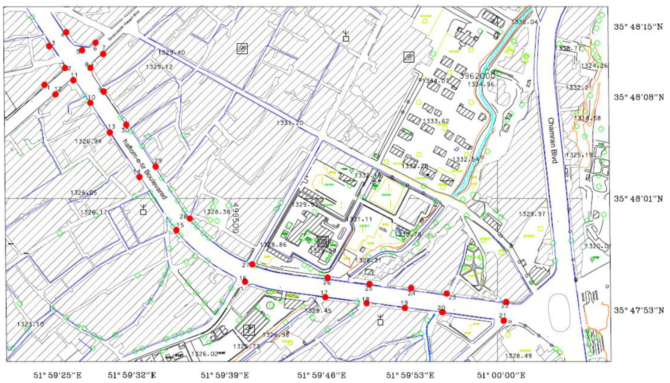

Figure 7: Points for noise pollution map

Figure 8: CEL 450 device with CEL 2.101 calibrator

Traffic volume

The vehicle data, converted to their equivalent according to saloon vehicles, were calculated using Eq. (1) [9].

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

– Where V_a is traffic volume in a complete period (vehicle/hour)

– V the calculated traffic during the measurement time in a period (vehicle/hour)

– C_f the correction factor of the measurement. (minute/minute)

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 (minute)

– Ts the short stoppage time (minute).

The vehicle volume for six days of study are presented in Table 4. The results show that the total volume of vehicles in the morning of the first day is 207, of which 203 are light vehicles and 4 are heavy vehicles. Also, the total volume of vehicles in the evening of the first day is 195, of which 194 are light vehicles and one is a heavy vehicle.

Table 4: Vehicle Volume for six days

Total volume (veh/h)	HV2	LV1	Bus	Truck	Motorcycle	Pick up	Car (veh/h)	Time(minute)	Station	
207	4	203	3	1	0	1	202	5	First day	Morning
210	4	206	3	1	1	2	203	5	Second day	
213	4	209	3	1	1	2	204	5	Third day	
216	4	212	3	1	3	4	204	5	Fourth day	
214	4	210	3	1	2	3	205	5	Fifth day	
218	4	214	3	1	3	4	207	5	Sixth day	
195	1	194	1	0	4	3	187	5	First day	Evening
199	2	197	2	0	5	4	188	5	Second day	
202	2	200	2	0	6	5	189	5	Third day	
235	2	233	2	0	11	10	212	5	Forth day	
203	2	201	2	0	6	5	190	5	Fifth day	
218	4	214	3	1	3	4	207	5	Sixth day	

Time Mean Speed Measuring

Measurement of the speed of an individual vehicle requires observation over both time and space. The instantaneous speed of an individual vehicle is defined as equation 3 [20].

$$u_i = \frac{dx}{dt} \text{-} limit(t_2 - t_1) \rightarrow 0 \frac{x_2 - x_1}{t_2 - x_1} \tag{3}$$

Radar would appear to be able to provide speed measurements conforming most closely to this definition, but even these rely on the motion of the vehicle, which means they take place over a finite distance and time, however small those may be. Vehicle speeds are also measured over short sections, such as the distance between two closely-spaced (6 m) inductive loops, in which case one no longer has the instantaneous speed of the vehicle, but a close approximation to it (except during rapid acceleration or deceleration).

The average vehicle speed at 30 stations is presented in Figure 9. The results show that in almost all stations, vehicles are faster in the evening than in the morning.

The noise levels of vehicles for 30 stations is presented in Figure 10. The results show that in almost all stations the noise levels is higher in the morning than in the evening.

The average volume of vehicles for 30 stations is presented in Figure 11. The results show that in some stations the volume of vehicles is more in the morning than in the evening and in some others the volume of vehicles is more in the evening than in the morning.

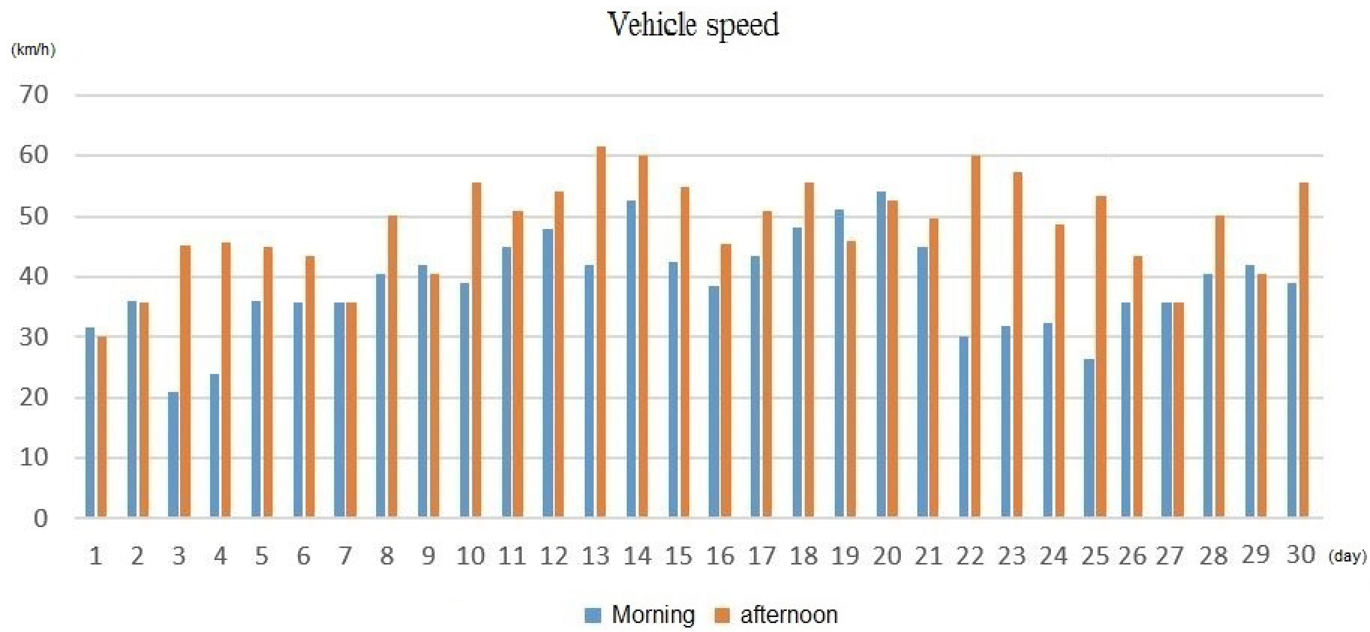

Figure 9: Average Vehicle Speed at 30 Study Stations

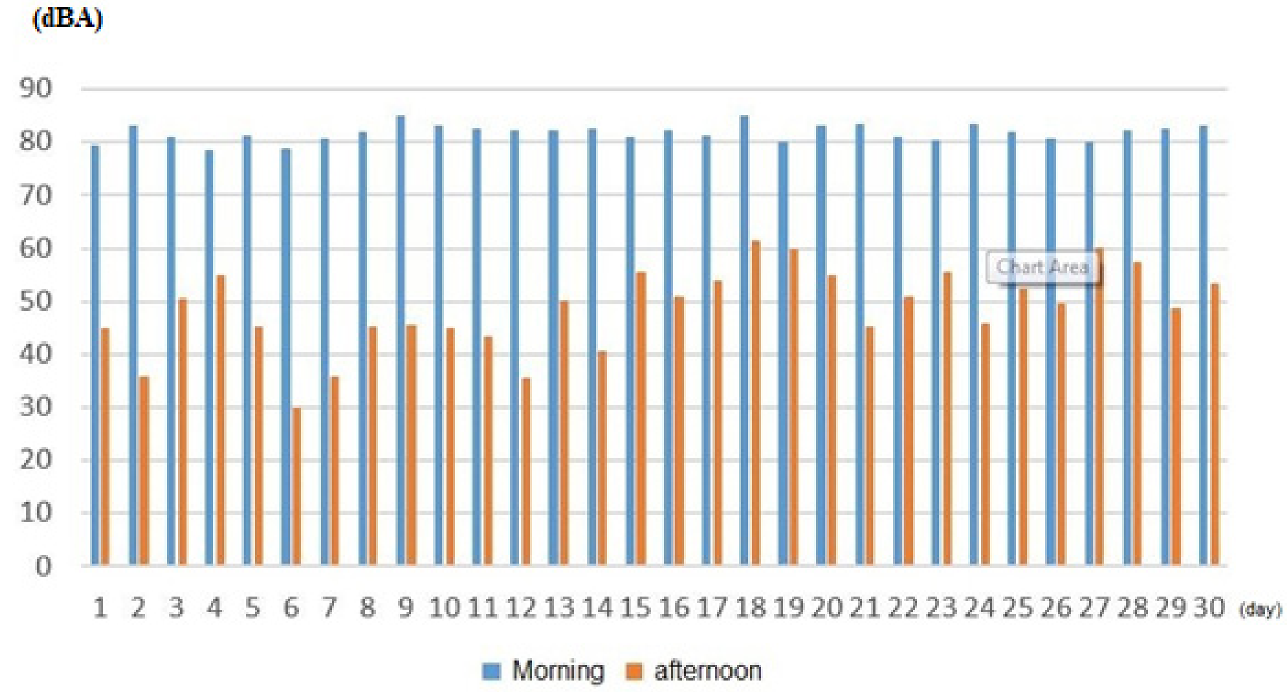

Figure 10: Noise levels for 30 stations

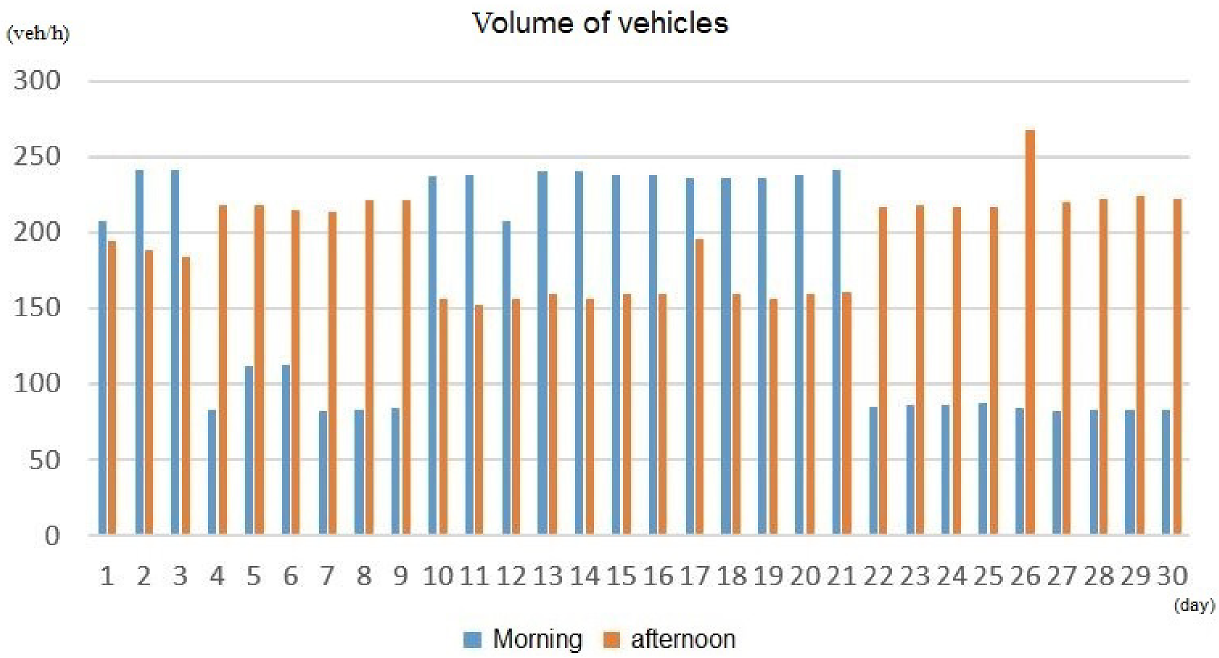

Figure 11: Volume of Vehicles for 30 Study Stations

RESULTS AND ANALYSIS

The significance of the test for the variables of volume intensity in the morning, afternoon and total time (morning and evening) and the variable of speed of all passing vehicles in the morning is greater than 0.05, so it can be said that these variables are normal in table 5. Also, the significance level of the test for the variables of sound speed in the afternoon and total time, volume of light and heavy passing vehicles in the morning, afternoon and total time and use of buildings around the intersection is less than 0.05. To examine the correlation of variables, if the data distribution of both variables is normal, Pearson correlation coefficient is used and if even the data distribution of one of the variables is abnormal, Spearman correlation coefficient is used.

Research Hypotheses Testing

The first hypothesis: there is a positive and significant correlation between the type of the buildings around the intersection and the sound level, in order to determine the noise pollution due to traffic noise. BIM helps to track the collision of calculated noise levels with residential

Table 5: Test The Normality of Research Variables

Significance level	Value	Time	Variable
0.20	0.045	Morning	Noise level
0.20	0.053	Evening	
0.20	0.033	Total	
0.20	0.048	Morning	Time Mean Speed
0.00	0.122	Evening	
0.00	0.098	Total	
0.00	0.282	Morning	Volume of light Vehicles
0.00	0.263	Evening	
0.00	0.203	Total	
0.00	0.259	Morning	Volume of Heavy Vehicles
0.00	0.151	Evening	
0.00	0.173	Total	
0.00	0.320		Use of buildings around the intersection

buildings, protected premises and workplaces. It lays a basis for the sound proof allocation of workplaces and development of protection measures. BIM also serves as a support tool for the design process of sound protection barriers, since it helps to avoid interconnection of noise barriers basement with engineering networks or paste a barrier in the proper place to provide its efficiency. As the type of the buildings around the intersection is not a variable with normal distribution, Spearman's correlation can be used to test the first hypothesis. Table 6 shows the results obtained from the Spearman correlation test.

Table 6: The Spearman Correlation Test Results

Sound intensity				Variable
Total	Afternoon	Morning		
0.451	0.351	0.241	Coefficient of correlation	Use of buildings around the station
0.000	0.000	0.000	A significant level	

Based on table, the Spearman correlation coefficient between the type of the buildings around the intersection and the sound level in the morning, evening and in total equals 0.241, 0.351 and 0.451, respectively. And the significance level is 0.000. As the significance level of the test is less than 0.05, it can be concluded that the correlation between these two parameters is significant. Therefore the null hypothesis (H0) in the Spearman correlation test is rejected. In other words, the correlation between the type of the buildings around the intersection and the sound level parameter is significant, and the first hypothesis is confirmed.

The second hypothesis: there is a positive and significant correlation between the speed and the number of the passing vehicles, in order to determine the noise pollution due to traffic noise. As the number of the passing vehicles is not a variable with normal distribution, Spearman's correlation can be applied to test the second hypothesis. The results obtained from the Spearman correlation test are shown in table 7.

In addition, the Spearman correlation coefficient between the speed of the heavy vehicles and the number of different vehicles passing by in the morning, evening and in total is equal to 0.168, 0.153 and 0.170, respectively. And the significance level of the test is smaller than 0.05. As the significance level is less than 0.05, it can be concluded that the correlation between the two variables is significant. Therefore, the null hypothesis (H_0) in the Spearman correlation test is rejected. In other words, the correlation between the speed and the number of the passing vehicles is significant and the second hypothesis is confirmed.

The third hypothesis: there is a positive and significant correlation between the sound level parameter and the number of the passing vehicles, in order to determine the noise pollution due to traffic noise. As the number of the passing vehicles is not a variable with normal distribution, Spearman's correlation can be applied to test the third hypothesis. The results obtained from the Spearman correlation test are shown in table 8.

Based on the results in table 8, the Spearman correlation coefficient between the sound level and the number of the light vehicles passing by in the morning, evening and

Table 7: The Spearman Correlation Test Results

Volume of heavy transit vehicles			Volume of light transit vehicles				Variable
Total	Afternoon	Morning	Total	Afternoon	Morning		
0.170	0.153	0.168	0.302	0.308	0.546	Coefficient of correlation	Vehicle speed
0.000	0.031	0.016	0.000	0.000	0.000	A significant level	

Table 8: The Spearman Correlation Test Results

Volume of heavy transit vehicles			Volume of light transit vehicles				Variable
Total	Afternoon	Morning	Total	Afternoon	Morning		
0.248	0.224	0.216	0.159	0.076	0.142	Coefficient of correlation	Noise levels
0.000	0.002	0.000	0.002	0.310	0.057	A significant level	

in total is equal to 0.142, 0.076 and 0.159 and the significance level of the test is 0.057, 0.310 and 0.002, respectively. As the significance level is more than 0.05 for the morning and evening hours, it is concluded that the correlation between the two variables is not significant. In addition, the Spearman correlation coefficient between the sound level variable and the number of heavy vehicles passing by in the morning, evening and in total is equal to 0.216, 0.224 and 0.248 and the significance level of the test is less than 0.05. Given that the significance level is smaller than 0.05, it can be concluded that the correlation between the two variables is significant.

The fourth hypothesis: there is a positive and significant correlation between the type of the buildings around the intersection and the speed of the passing vehicles, in order to determine the noise pollution due to traffic noise. As the type of the buildings around the intersection is not a variable with normal distribution, Spearman's correlation can be applied to test the fourth hypothesis. The results obtained from the Spearman correlation test are shown in table 9.

Table 9: Results of Spearman Correlation Test Hypothesis 4

Vehicle Speed				Variable
Total	Afternoon	Morning		
0.409	0.328	0.534	Coefficient of correlation	Use of buildings around the station
0.000	0.000	0.000	A significant level	

Based on table 9, the Spearman correlation between the type of the buildings around the intersection and the speed of the passing vehicles in the morning, evening and in total equals 0.534, 0.328 and 0.409, respectively. And the significance level is 0.000. As the significance level of the test is less than 0.05, it can be concluded that the correlation between these two parameters is significant. Therefore the null hypothesis (H_0) in the Spearman correlation test is rejected. In other words, the correlation between the type of the buildings around the intersection and the speed of the passing vehicles is significant, and the fourth hypothesis is confirmed. In table 10 the result of hypothesis has shown.

Multivariate Linear Regression Analysis

The process of performing a regression allows you to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other. In order to understand regression analysis fully, it's essential to comprehend the following terms [10]:

Dependent Variable: This is the main factor that you're trying to understand or predict. Independent Variables: These are the factors that you hypothesize have an impact on your dependent variable.

In this research the dependent variable (noise level) was a constant variable and due to the correlation of independent variables of the study, linear regression was used. The assumptions of linear regression and linearity or nonlinearity of the relationship were tested. A model of the relationship is hypothesized, and estimates of the parameter values are used to develop an estimated regression equation.

The correlation coefficient is a measure of linear association between two variables. Values of the correlation coefficient are always between -1 and +1. A correlation coefficient of +1 indicates that two variables are perfectly related in a positive linear sense, a correlation coefficient of -1 indicates that two variables are perfectly related in a negative linear sense, and a correlation coefficient of 0 indicates that there is no linear relationship between the two variables [11].

A multivariate regression analysis is used here to study the simultaneous effect of the speed of the passing vehicles, the number of light vehicles passing by, the number of heavy vehicles passing by and the type of buildings around the station on sound level and also to predict the sound level using the aforementioned variables. In this model, sound level is the dependent variable while the speed of the passing vehicles, the number of light vehicles,

Table 10: Results of Test Hypothesis

Sub-hypothesis	Description	Result
First	There is a positive relationship between the speed parameter of different types of passing vehicles and noise intensity There is meaning.	Confirmed
Second	There is a positive and significant relationship between the use parameter of buildings around the intersection and the volume parameter of passing vehicles.	Confirmed
Third	There a positive and significant relationship between the use parameter of buildings around the intersection and the noise intensity parameter.	Confirmed
Fourth	There a positive and significant relationship between the speed parameter of different types of passing vehicles and the volume of passing vehicles.	Confirmed
Fifth	There a positive and significant relationship between the noise intensity parameter and the volume parameter of passing vehicles.	Confirmed
Six	There is a positive and significant relationship between the use parameter of buildings around the intersection and the speed of various passing vehicles.	Confirmed

the number of heavy vehicles and the type of the buildings around the station are the independent variables. The linear regression model used here is as follows:

Noise level=β_0+β_1(Vehicle speed)+β_2(volume of Light transit vehicles)+β_3(Volume of heavy transit vehicles)+β_4 (Use of buildings around the station)+ε (4)

The β_i (i=0,1,2,3,4) in the model are the estimated regression coefficients.

The regression model for morning:

Based on the results, sound level can be predicted using the speed of different passing vehicles, the number of heavy vehicles and the type of the buildings around the station. As a result, the following regression model describes the relationship between the aforementioned variables in the morning:

Noise level=48.593+0.123(Vehicle Speed)+
+0.145(volume of Light transit vehicles)+
+0.241(Volume of heavy transit vehicles)+
+0.098(Use of buildings around the station) (5)

The regression model for evening:

And the following describes the relationship between the aforementioned variables in the evening:

Noise level=46.524+0.131 (Vehicle Speed)+
+0.125(volume of Light transit vehicles)+
+0.236(Volume of heavy transit vehicles)+
+0.216 (Use of buildings around the station) (6)

Total time regression model (morning and evening):

Finally, the following regression model describes the relationship between the variables in morning and evening:

Noise level=51.222+0.134(Vehicle Speed)+
+0.157(volume of Light transit vehicles)+
+0.137(Volume of heavy transit vehicles)+
+0.109(Use of buildings around the station) (7)

Noise Mapping

ArcGIS Desktop is a state-of-the art GIS software package developed by ESRI. The software can be used in a wide area of general as well as specific GIS applications and can be extended easily via its Application Interface (API). The API gives fine grain access to data stored as well in general data base formats as topologically indexed vector data in the industry standard "shape" format as well as different GRID and geo-referenced raster formats [12]. The noise prediction method was implemented as one of several extensions of ArcGIS Desktop. The implementation has been coded in Visual Basic and uses the ArcGIS Desktop API for data query and manipulation. The buildings usually are not very high which means that they are not a very effective barrier against traffic noise. Because the streets are mostly narrow in the city center, noise barriers are hard to apply. The noise pollution contour maps for models for evening, morning and total hours are shown, respectively, on figure 12, 13 and 14. Figure 15 shows the sound level and the actual observations on the morning of the sixth day.

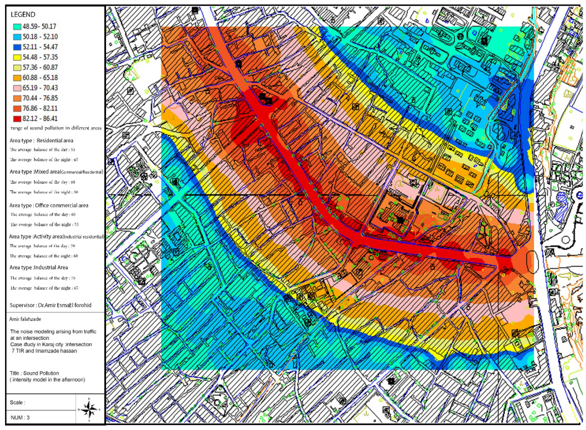

Figure 12: Noise pollution model in the afternoon

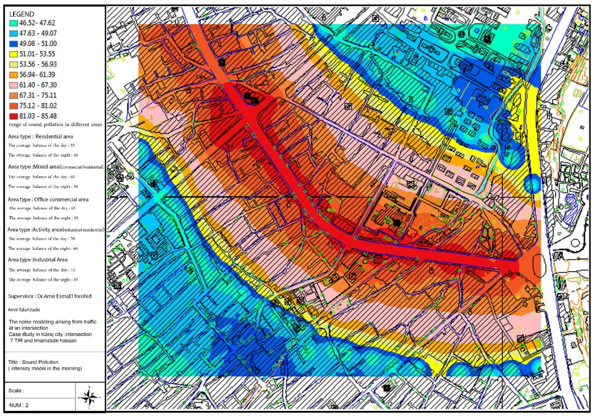

Figure 13: Noise pollution model in the morning

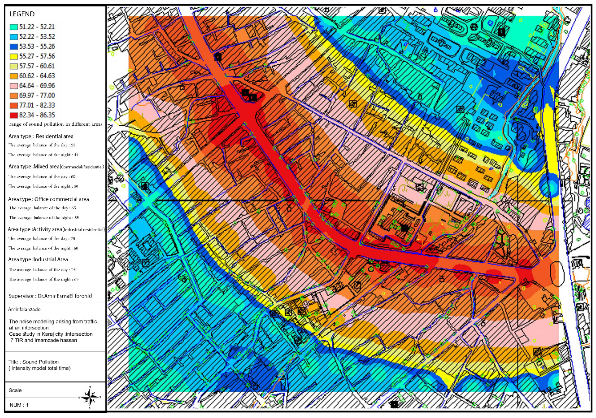

Figure 14: Noise pollution model for morning and evening

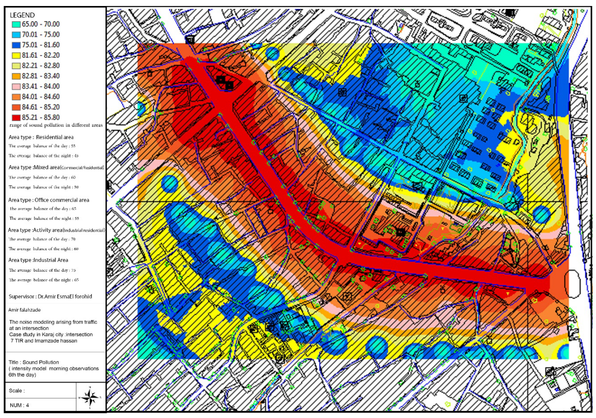

Figure 15: Noise pollution for the measuring points in the morning

Table 8: Noise level of observations related to the morning of the sixth day and its estimation under regression models predicting noise at different times

Station	The amount of real observations, The morning of the sixth day (dBA)	Morning noise level(dBA)	Afternoon noise level(dBA)	The noise level of the modeling of the sixth day(dBA)
1	82.4	83.22	83.55	83.71
2	82.9	82.85	81.93	82.97
3	82.3	82.75	82.54	83.37
4	85.1	83.44	84.85	84.47
5	81.4	82.15	82.75	83.73
6	82.2	83.68	82.81	83.30
7	82.1	83.64	83.49	81.97
8	83.4	81.75	81.92	82.87
9	82.2	81.87	81.52	82.67
10	84.9	83.39	83.34	83.83
11	81.9	82.82	83.15	83.60
12	83	82.75	83.46	83.74
13	85	83.25	85.42	84.88
14	84.8	83.52	84.34	84.55
15	85.4	84.42	85.22	85.27
16	85.3	84.63	85.42	85.67
17	85.8	84.50	84.61	85.49
18	83.4	83.28	84.21	84.57
19	85.8	85.49	86.42	85.44
20	84	84.37	84.26	84.86
21	82.9	83.62	84.59	84.45
22	83.7	83.79	84.24	84.56
23	81.1	81.52	81.57	81.79
24	84.4	84.12	84.32	81.42
25	85.7	85.27	86.17	86.38
26	83.5	84.75	85.28	85.67
27	83.1	83.29	83.96	83.37
28	82.5	82.63	83.37	83.97
29	82.2	82.49	82.93	82.27
30	82.9	82.79	83.89	83.75

DISCUSSION

The purpose of this study was to present a model of the traffic noise in an intersection (case study: the intersection between 7Tir Boulevard and Emamzade-Hasan Boulevard in Karaj) during the morning and evening rush hours for a period of one month, considering the fact that there is a lot of traffic in this area. The evaluation of the maps, tables and the data from this project shows that the area under study faces high sound levels in the evening and the main reason is the presence of commercial, administrative and educational centers in the surrounding neighborhood. And this pollution is mainly due to high car traffic.

In this section, the collected data were analyzed and the research hypotheses were tested. For this purpose, this chapter consists of two parts. In the first part, the sample was described using descriptive statistics. In the second part, hypotheses were tested using inferential statistics. At first, the normality and abnormality of the data were checked. Then, Pearson and Spearman correlation tests were performed to test the hypotheses and then multivariate linear regression was used to predict the volume intensity model in the morning, afternoon and total time. Table 8 presents the volume intensity of the observations related to the morning of the sixth day and its estimation under the regression models of predicting the volume

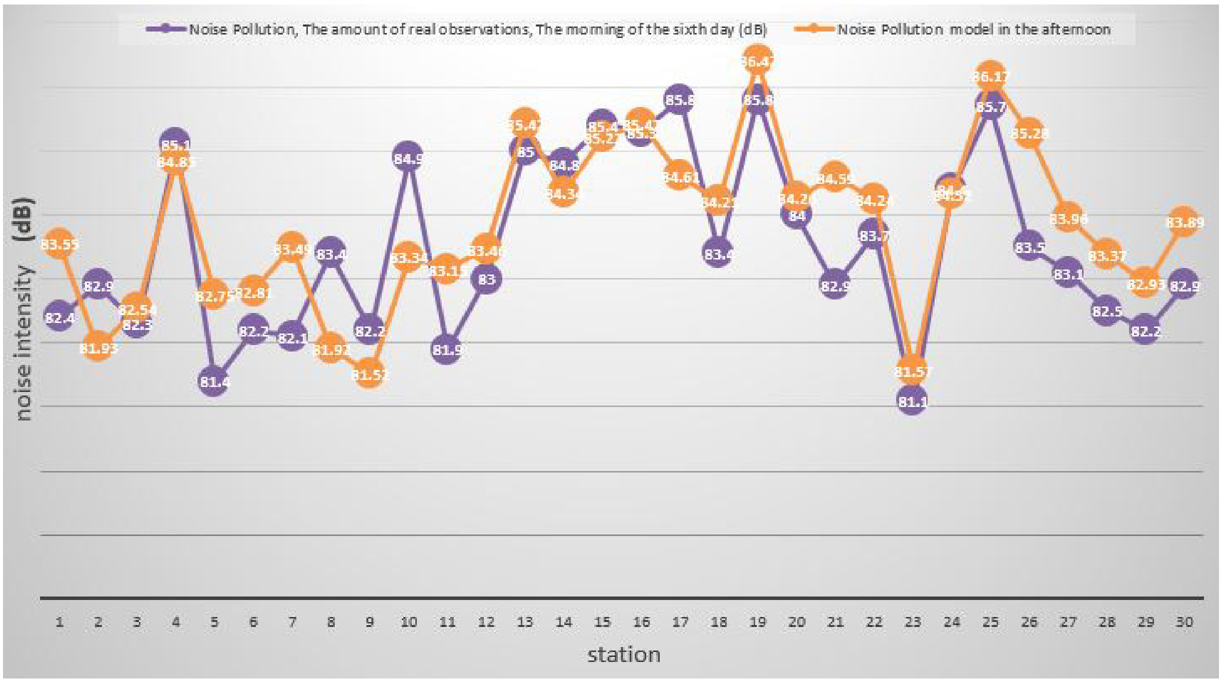

Figure 16: Comparison of noise intensity in the actual observations of the sixth day and the noise intensity model in the afternoon

intensity model in the morning, afternoon and general time. Figure 16 shows comparison of noise intensity in the actual observations of the sixth day and the noise intensity model in the afternoon.

CONCLUSION

According to the Department of Environment, the permissible limit of noise pollution for daytime (7 a.m. to 10 p.m.) in Iran is 55 dB for residential areas and 60 dB for commercial-residential areas. These limits are 10 dB lower for night time (10 p.m. to 7 a.m.). The World Health Organization (WHO) guidelines suggest standard sound levels based on zone type and hour, e.g. in industrial and commercial areas exposed to urban traffic, the suggested sound level is 70 dB, and the maximum equivalent sound level is 110 dB over a 24 hour's period. For other purposes, significantly lower sound levels are suggested based on the evaluation and comparison of results. The measured sound levels in this study are remarkably higher than the guidelines suggested by WHO for these purposes (30 and 35 dB, respectively). The comparison of these rules with the results obtained in this study shows that in most cases, the existing sound levels are higher than the permissible limits suggested by the National Building Regulations. The evaluation of the plots indicates that the minimum and maximum sound levels exceed the standard value suggested by the Iranian Department of Environment on all days, both in the morning and evening. As a result, it can be concluded that noise pollution is present in most of the main areas of the studied region on all days, both in the morning and evening hours, and the amount of pollution in evening is higher than morning hours to some extent.

For comparing the results with the noise standard for different land uses in table 9 shows the environment standard of Iran which is released by Department of Environment. County regions of Iran are divided into 5 categories based on land use. Law on determining the permissible limits of sound in the open air of Iran. Pursuant to Article 2 of the Executive Regulations on the Prevention of Noise Pollution, approved at the meeting dated 2002 of the Council of Ministers, the permissible limits of noise in the open air of Iran are determined as follows and agreed to be implemented in the country from the date of approval. [13].

Table 9: Outdoor permitted amount of noise in Iran [13]

Type of area	Average Day Equivalent Sound Pressure Level, (LeqA) (dBA) (7 AM to 10 PM)	Average Night Equivalent Sound Pressure Level, (LeqA) (dBA) (10 PM to 7 AM)
Residential Area	55 dB	45 dB
Complex Area (Commercial-Residential)	60 dB	50 dB
Commercial – Administrative Area	65 dB	55 dB
Area of Activity (Residential-Industrial)	70 dB	60 dB
Industrial Zone	75 dB	65 dB

Studying the factors involved in the noise pollution shows that the increasing population, traffic and residential density have successively caused the rise of sound levels in the studied region. In contrast, the increase of greenery reduces the noise pollution. The results obtained from the studies conducted on this subject indicate the high sound levels in most areas. A great number of studies suggest that vehicle traffic is the main cause of noise pollution in this city, and the results of the present study are in accordance with them.

In this study, sound levels have been recorded on certain hours and consequently, the effect of noise pollution in other hours is overlooked. As expected, due to the closure of offices and educational centers, the lowest equivalent sound level happens on weekends. Compared to morning hours, the equivalent sound levels are higher in the evenings, mainly due to people going out for shopping or other purposes. Other studies have also shown that sound levels are lower on weekends and holidays. Due to existing limitations, the present study has been conducted in a period of one month on constant peak traffic hours. For better understanding of the current situation, it is suggested that future studies perform 24-hour measurements for a long term period. Moreover, factors such as weather condition, sunset hours and zone type, possibly modifying the rush hours in different seasons, are not considered in this study.

According to previous studies, it is suggested that the annual level monitoring plan be implemented with the aim of identifying hazardous areas in the metropolis of Karaj and by identifying places and uses that are exposed to high noise levels, control and preventive measures should be taken. Increasing the level of vegetation effective in reducing noise pollution around crowded areas, establishing institutions and buildings with sensitive use while maintaining a proper distance from streets and busy intersections, raising public awareness in social behaviors, expanding the use of non-motorized vehicles and preventing the traffic of worn-out cars and motorcycles in sensitive areas, optimizing the surface coverage of streets such as porous asphalt can be suggested as some effective and inexpensive solutions in reducing the level of sound levels in the study area. In addition, many shortcomings and problems from a legal point of view have caused noise pollution to be less considered as an urban problem affecting the health of citizens. Comparing to the laws of other countries, there are many shortcomings in various fields that need attention, review and reform in this area. The results showed that the uses and type of activity have a significant effect on the level of noise pollution in an area and this issue should be considered in the urban development model. Installation of noise-sensitive land uses (such as medical, educational and residential land uses) should be segregated from busy roads and driveways. The type of uses in terms of time can also affect the noise levels in the area. What can be deduced from this study and similar studies is that the high level of noise pollution reminds us of the need for control measures in this field. Failure to control noise pollution in the long run will cause irreparable damage to people's health. In addition, the reduction of concentration and efficiency of short-term injuries, caused by this type of pollution.

REFERENCES

1. Golmohamadi, Rostam. Abbaspoor, Majid. Nasiri, Parvin. Mahjoob, Hossein. 2006, Modeling Sound Pollution Traffic Main cities (Case study: Hamedan Town) PhD thesis Islamic Azad University Unit of Sciences and Researches.
2. Banerjee, D., Chakraborty, S.K., Bhattacharyya, S., and Gangopadhyay, A. 2008. Modeling of road traffic. https://doi.org/10.1016/j.trd.2008.09.008
3. Jeong, C.S., Tae, H.P., Joon, H.K., Seo, I.C., Minho, K., James, B.H. and Mohammed, R.M. 2011. Modeling of road traffic noise and estimated human exposure in Fulton County, Georgia, USA. Journal of Environment International, 37: 1336-1341. DOI: 10.1016/j.envint.2011.05.019
4. Subramani, T., & Sounder, S. A Case Study And Analysis Of Noise Pollution For Chennai Using GIS. International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), (2016), 5(3), 125-134. https://www.ijettcs.org/Volume5Issue3/IJETTCS-2016-05-24-40.
5. Mandal P.K., Bandyopadhyay A., Case study from West Bengal, India: Management of noise levels during festival time in Kolkata and Howrah Mu- nicipal Corporation Areas from 2002 to 2011, Environmental Quality Management, (2014), 23, 13–32. DOI: 10.1002/tqem.21366
6. BIM & Sustainability Sara Kamel (2018), LEED GA Dubai Municipality.
7. Department of Environment, Climate Change and Water, NSW Road Noise Policy. March 2011. United States.
8. Coensel B.D, Botteldooren D, Vanhove F, Logghe S. Microsimulation Based Corrections on the Road Traffic Noise Emission Near Intersections. ACTA Acustica United with Acustica 2006, Vol. 93. p. 241-252.11. http://hdl.handle.net/1854/LU-394261
9. Zoghi, H., Haj Ali, M., Jafari Haghighat Pour, P., Traffic Engineering (Analytical-Applied), Kian Publication, Tehran, (2015). (In Persian).
10. Mahdavi Damghani, Babak (2012). "The Misleading Value of Measured Correlation". Wilmott 2012 (1): 64–73. doi:10.1002/wilm.10167.
11. Aldrich, John (1995). "Correlations Genuine and Spurious in Pearson and Yule". Statistical Science 10 (4): 364–376. doi:10.1214/ss/1177009870. JSTOR 2246135.
12. ArcDesktop GIS package, www.esri.com

13. Determining the permissible limit of noise pollution in domestically produced vehicles, (2002), approved by the Supreme Environmental Council. THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION.
14. Surface assessment Level alignment. Level Distribution of noise pollution by using geographical information system (GIS) In area one District Six of Tehran In the year 1395-96: Case report. Journal of Rafsanjan University of Medical Sciences. February 2019 , Volume 17 , Number 11 ; Page(s) 1077 To 1092.
15. E. Chevallier, A. C., M. Nadji, L. Leclercq. 2009. " Improving noise assessment at intersections by modeling traffic dynamics". Universite de Lyon. DOI: 10.1016/j.trd.2008.09.014
16. Guarnaccia, C. (2010) "Analysis of Traffic Noise in a Road Intersection Configuration",WSEAS TRANSACTIONS on SYSTEMS, Volume 9, 865-874. https://www.academia.edu/2856334/Analysis_of_traffic_noise_in_a_road_intersection_configuration.
17. Bilaşco, Ş., Govor, C., Roşca, S., Vescan, I., Filip, S., & Fodorean, I. GIS model for identifying urban areas vulnerable to noise pollution: case study. Frontiers of Earth Science, (2017), 11(2), 214-228. https://link.springer.com/article/10.1007/s11707-017-0615-6.
18. Ki-Hyunkim, D. X. H., Richard J.C. Brown, J.-M. OH, Chan Goo Park, In Cheolryu (2012)" Some insights into the relationship between urban air pollution and noise levels", Science of the Total Environment, 424, 271-279. https://doi.org/10.1016/j.scitotenv.2012.02.066.
19. Acoustic- Description and measurement of environmental noise part 7: basic quantities and procedures. (ISO 1996/1:1987).
20. https://www.fhwa.dot.gov/ohim/handbook/chap1.pdf.

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