

Original Article

Geographic information system based noise study in crowded areas of Isfahan city in 2010–2011

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ABSTRACT

Aims: The aim of this study was to evaluate noise pollution levels (NPLs) in Isfahan, compare with guideline values and providing a zoning map.

Materials and Methods: This study was a descriptive cross-sectional type. Totally, 19 stations were selected from most congested areas throughout the city. In determination of these stations, the Isfahan information maps of the city traffic (obtained from Isfahan traffic and transportation organization) were used. Noise parameters L_{10} , L_{50} , L_{90} , L_{95} , L_{99} , equivalent sound level (L_{eq}), sound exposure level, sound pressure level, L_{min} , L_{max} , and L_{peak} were measured using a CEL-440 sound level meter for 3 months of winter 2010–2011. The NPL and traffic noise index were calculated by a mathematical formula. All measurements were carried out twice a day (morning [a.m.] and afternoon [p.m.]) with the time interval of 0.5 h. To prepare the zoning map of the measured L_{eq} , ArcGIS software version 9.3 was used.

Results: The mean and standard deviation of the measured L_{eq} values in the a.m. and p.m. were 74.6 ± 2.78 and 72.6 ± 4.43 dB_(A), respectively. In comparison, there was a significant difference between the average L_{eq} values of a.m. and p.m. ($P < 0.001$) and both were higher than the noise guidelines suggested by Iranian environmental protection organization. The zoning maps show that the maximum L_{eq} in the a.m. (78.3 dB_(A)) was related to Ferdowsi bridge station and in the p.m. (79.6 dB_(A)) was dedicated to Jomhoori square station.

Conclusion: It can be concluded that as in the most cases the noise levels of Isfahan exceeded from the guideline values. This city is categorized in the noisy/crowded cities in Iran. Thus, noise pollution of Isfahan can be a serious problem and investigating its reasons is recommended.

Key words: Isfahan, noise pollution, sound pressure level

INTRODUCTION

Today, noise pollution is recognized as a serious health problem. Road traffic is the most significant source of the noise pollution in the cities. Generally, this type of pollution is considered as more intrusive than other types of noise pollutions such as industrial noise, airport, and community noise. Noise pollution is one of the undesirable impacts of the

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vehicular traffic and is especially important in urban areas.^[1] Noise is as the result of a part of human routine life activities. Sound as all the pollutants is reduced the quality of life and is made many sanitary risks.^[2] WHO introduces noise pollution in big cities as the third type of dangerous pollutions after air and water pollution.^[3] It was defined for a long time that long-term exposure to noise leads to deafness. Now, there is some evidence that defining noise-related stress caused many mental and physiological problems (from sensitivity to heart diseases). While, the number of people who are affected by the surrounding noise is increasing daily.^[4] Noise pollution has harmful effects on the people of the cities, including hearing loss, sleep problem, high blood pressure, fatigue, digestion problems, sensitivity and depression.^[5]

There were several studies carried out in various cities in Iran such as Qazvin,^[6] Tehran,^[7] Kerman,^[3] Yazd,^[8,9] Zanjan,^[10] Sari,^[11] Khorramabad,^[12] Yasuj,^[13] Isfahan,^[14] Hamadan,^[15] and some other countries as Kuala Lumpur.^[16]

In the study directed in 2007 in India, the noise pollution problem and its effects on the people of the city was investigated. It was defined that the noise level reached the warning level. About 85% of the studied people had a problem due to the traffic noise. About 90% of that people had some problems as headache, high blood pressure, dizziness, and fatigue.^[17] In another study conducted in Umman (Jordan), it was clear that about 81% of people working around the main streets were exposed to the traffic noise, and their daily activities were disturbed by the noise. Also, high education level and more income was directly associated with the knowledge of people about the sanitary effects of traffic noise and related problems.^[18] In a study was done in Italy, it was shown that >25% of the residents were suffering from road traffic noise.^[19] In another study performed in Canada, it was defined that about 8% of the samples were seriously injured by environmental noise, and the noise damages were insignificant on half of the studied people. According to this study, traffic noise was the paramount important source of nuisance in Canada.^[20] In a study conducted in Malaysia, the health effects of noise pollution in urban highways were investigated. The results revealed that noise pollution could cause sleep disorder and conversation, anxiety and sometimes hearing problems.^[21]

Isfahan is located in the center of Iran's plateau with different industrial, social and commercial activities. The population of >1 million people and diverse vehicles in this city and the lack of suitable capacity of the streets for the great number of vehicles is turned that to a crowded city. Due to the lack of correct zoning of unlike commercial, industrial and residential regions, this city is exposed to varying pollutions, including noise pollution (traffic noise pollution). So the most important noise pollutant sources in Isfahan are distinct kinds of transportation vehicles that affect the surrounding regions. As noise pollution in Isfahan city is less considered compared to the other pollutants, this study was carried out to zone the condition of noise pollution in crowded

locations of Isfahan by geographic information system and the comparison to the existing standard.

MATERIALS AND METHODS

This study was descriptive cross-sectional type that was conducted during the last month of 2010 and three 1st month of 2011 to investigate the noise pollution condition in Isfahan. The reason to select winter for this study was less number of the passengers and tourists in Isfahan compared to other months of the year and the more real results of the study. In this study, 19 measurement stations were selected in Isfahan, including the key and crowded locations of the city. In determining the stations, the traffic divisions of Isfahan prepared by urban transportation and traffic organization were used. To evaluate the level of sound, a CEL-440 sound level meter was used. The environmental noise parameters, including L_{10} , L_{50} , L_{90} , L_{95} , L_{99} , L_{eq} (30 min), sound exposure level (SEL), sound pressure level (SPL), L_{min} , L_{max} (is a SPL in a linear network) L_{peak} (indicates occurred suddenly sounds in environment),^[22] were measured. To compute traffic indices of noise pollution, noise pollution level (NPL) and traffic noise index (TNI), the math equations (1) and (2) were used.^[10] To ensure the accuracy of the results and calibration of noise level meter, an acoustic calibrator model CEL-282 was used. This calibrator creates the sound of 114 dB in one KHz frequency. The sampling's procedure was carried out according to the standard methods and to the sound level meter manufacturer recommendations. The measurement times were in the a.m. from 8 to 12 and p.m. from 16 to 20 with a time interval of 0.5 h. These were done in each station 1 m beside the curb side streets and in the city squares with the distance of 1.5 m from the ground level (ISO 1996-part 2:2007).^[23] The measurements were read in dB_(A) from the mentioned device and were registered in a specific form. The average indexes of L_{eq} were used for data analysis, and the data were compared statistically with the L_{eq} Iranian ambient guideline values of the air noise^[24] by *t*-test.

$$TNI = 4 (L_{10} - L_{90}) + L_{90} - 30 \quad (1)$$

$$NPL = L_{eq} + (L_{10} - L_{90}) \quad (2)$$

Geographic information system work

This study was cross-sectional type. For zoning map creation, the ArcGIS/ArcInfo software, version 9.3, ESRI Co., USA was used. The results of separated measurement's periods (a.m./p.m.) of equivalent level sound evaluation L_{eq} were loaded into the software. The rasters were made for each mentioned period by the spatial analyst and inverse distance weight interpolation model. The results of this operation are shown in Figures 1 and 2.

RESULTS

Figure 3 shows the location of measurement stations of noise pollution in Isfahan in the a.m. and p.m. Table 1 shows the

coordination of the sampling stations and the measurement results of noise pollution parameters in different locations of Isfahan in the a.m. and p.m. According to this table, five stations of 19 stations including of Hakim Nezami crossroad, Sheikh Saduq crossroad, Jomhoori square, Ferdowsi bridge crossroad, and Artech square, had the highest noise pollution parameters. Also, this table shows that the average of L_{min} , L_{90} , L_{95} , and L_{99} in the residential-commercial regions of Isfahan in the morning were 64.6, 69.2, 68.3 and 66.7 $dB_{(A)}$, respectively and in the afternoon were 62.4, 66.8, 66.1 and 64.3 $dB_{(A)}$.

However, the L_{10} and NPL had the highest values in Artech square station in the a.m. 81 $dB_{(A)}$ and 88.5 $dB_{(A)}$, respectively. The L_{50} and L_{90} also in the a.m. had the highest values in Hakim Nezami crossroad station 77 $dB_{(A)}$ and 73.5 $dB_{(A)}$, respectively. Also, Hakim Nezami crossroad and Artech square stations had the highest similar values of the SEL (107.6 $dB_{(A)}$) and SPL (63 $dB_{(A)}$) in the a.m., respectively.

The Persian ambient guidelines of the air noise pollution from 7 a.m. to 10 p.m. and from 10 p.m. to 7 a.m. are shown

in Table 2. According to this Table, noise pollution guideline in the a.m. and p.m. is 60 $dB_{(A)}$.

Noise pollution zoning maps in terms of equivalent sound level (L_{eq}) in Isfahan in the a.m. and p.m. are shown in Figures 1 and 2, respectively. As can be seen, the L_{eq} in the a.m. was the highest value in Ferdowsi bridge crossroad station (78.3 $dB_{(A)}$) [Figure 1]. While the L_{eq} , SEL, SPL, NPL, L_{10} , L_{50} , and L_{90} had the highest values in the p.m. in Jomhoori square station as 79.6, 109.1, 64.6, 87.6, 82, 78.5, and 74 $dB_{(A)}$, respectively. Also, TNI in the p.m. had the highest value in Sheikh Saduq crossroad station (77.5 $dB_{(A)}$) [Figure 2].

The average of traffic indexes NPL and TNI in Isfahan city residential-commercial regions were 82.2 and 69.6 $dB_{(A)}$, separately in the morning and 80.7 and 69.1 $dB_{(A)}$, correspondingly in the afternoon [Table 1].

The equivalent sound level (L_{eq}) values of a.m. and p.m. sampling times were compared with the persian guideline of the environment protection organization 60 $dB_{(A)}$ [Figure 4].

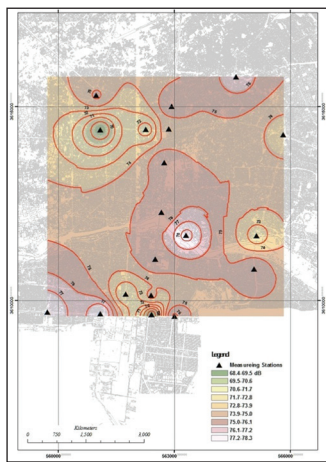


Figure 1: Noise pollution zoning map in terms of equivalent sound level index (L_{eq}) $dB_{(A)}$ in Isfahan in the a.m

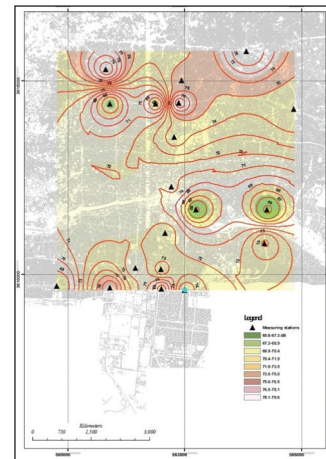


Figure 2: Noise pollution zoning map in terms of equivalent sound level index (L_{eq}) $dB_{(A)}$ in Isfahan in the p.m

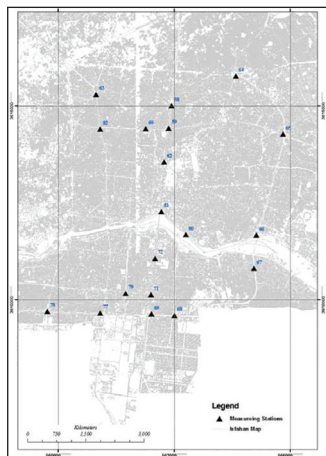


Figure 3: The location of measurement stations of noise pollution in Isfahan in the a.m. and p.m

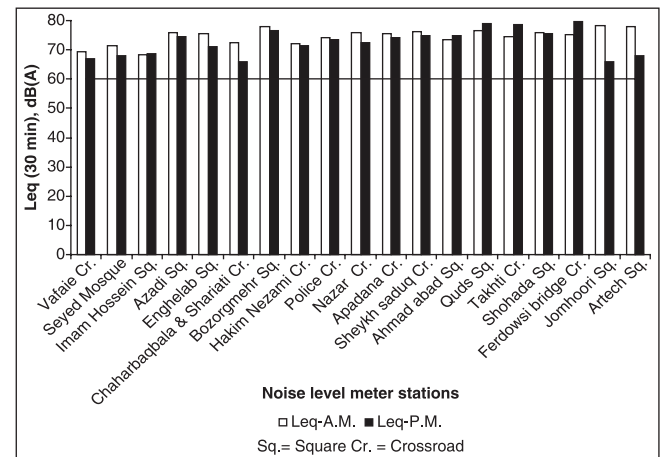


Figure 4: The comparison of the equivalent sound level (L_{eq}) $dB_{(A)}$ with Iranian environment protection organization guideline in the a.m. and p.m

Table 1: The coordination of the sampling stations and the measurement results of noise pollution parameters (in dB_(A)) in different locations of Isfahan in the a.m. and p.m

Location code	Location	UTM		Lmax		Lmin		Leq		Lpeak	
		X	Y	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M
58	Shohada Cr*	562933	3615017	94.1	104.3	62.6	64.6	76	75.5	107	112.2
59	Takhti Cr	562865	3614437	88.6	100.2	66.2	68.9	74.5	78.7	110.7	117.7
60	Seyed Mosque	562267	3614420	92.8	85.9	60.7	59.2	71.5	67.9	106.1	107.8
62	Imam Hossein Sq**	562745	3613563	99.2	88.2	65.6	64.4	76	74.4	108	107.6
63	Jomhoori Sq	560989	3615307	90.8	91.5	67.2	63.6	75.1	79.6	106.2	104.8
64	Quds Sq	564601	3615776	95.5	102.8	67.9	68.6	76.5	79	111.3	116.8
65	Ahmadabad Sq	565815	3614283	95.5	88.7	66.1	69.6	73.6	74.8	107.7	106.8
66	Bozorgmehr Sq	565128	3611678	89.4	84.8	65.5	58.3	72.6	65.8	103.1	101.1
67	Apadana Cr	565067	3610818	99.4	90.7	64.4	64.2	75.6	74.1	110.7	111.8
68	Sheykh Saduq Cr	563005	3609606	100.3	94.2	62	63.6	76.1	74.8	114.6	110.1
69	Azadi Sq	562411	3609640	88.4	92.9	62.9	57.4	68.4	68.5	103.3	102.7
71	Chaharbaq bala Shariati Cr	562406	3610142	93	91.3	64.1	61.1	74.2	73.6	111	108.5
72	Nazar Cr	562507	3611078	91.8	90.4	63.9	59.9	72.5	72.5	107.5	106.1
77	Hakim Nezami Cr	561086	3609667	90.3	95.3	69	65.5	78	76.7	107.9	108.8
78	Artech Sq	559727	3609710	97.6	90.6	63	58.6	78	68.1	111.7	102.6
79	Police Cr	561747	3610178	86.1	90.7	63.3	61.8	72	71.4	112.3	105.9
80	Ferdowsi Bridge Cr	563308	3611685	90.2	84.3	65.3	57	78.3	65.9	108.9	109.3
81	Enghelab Sq	562673	3612279	94.7	86.8	65.5	61.3	75.4	71.1	109	114.7
82	Vafaei Cr	561089	3614412	84.8	82	61.5	58.6	69.2	67	101.6	99.9
Mean				92.8	91.3	64.6	62.4	74.6	72.6	108.3	108.2
STDEV				4.5	6	2.2	3.9	2.8	4.4	3.4	5

SEL	SPL		L10		L50		L90		L95		L99		NPL		TNI		
	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	
105.5	105.5	60.9	60.5	79.5	76.5	73	71	69	67.5	68	67	65.5	66	86.5	84.5	81	73.5
104.1	108.3	59.5	63.7	77.5	80.5	72	75.5	69.5	72	69	71	67.5	70	82.5	87.2	71.5	76
104.2	97.3	59.6	52.7	74	70.5	69	66	65.5	62.5	65	62	63.5	60.5	80	75.9	69.5	64.5
103.8	103.9	59.2	59.3	77	77	72.5	72.5	70	69.5	69.5	68.5	67.5	67	83	81.9	68	69.5
104.7	109.1	60.1	64.6	77.5	82	74	78.5	71	74	70.5	72	69	63.5	81.6	87.6	67	76
106.1	108.6	61.5	64	78.5	80	75	75.5	72.5	73	71.5	72	70	71	82.5	86	66.5	71
103.1	104.3	58.5	59.7	75	76.5	72.5	74	70	72	69	72	68	71	78.6	79.3	60	60
102.1	95.4	57.6	50.8	74.5	68.5	71.5	64.5	68.5	61.5	68	61	66.5	60	78.6	72.8	62.5	59.5
105.1	102.6	60.5	59.1	77.5	77	72.5	72	68.5	68	67.5	67	66	65.5	84.6	83.1	74.5	74
105.6	104.4	61	59.8	77.5	77.5	72	71.5	68	67.5	67	66.5	64.5	65	85.6	84.8	76	77.5
99.9	98.3	55.3	53.7	70.5	70.5	67.5	65.5	65	62	64.5	61.5	64	60	73.9	77	57	66
103.7	103.2	59.2	58.6	77	76	72	71	68.5	67	68	66.5	66.5	64.5	82.7	82.6	72.5	73
105.6	102.1	61	57.5	79	75.5	73.5	69	70	65	68.5	64	66.5	62.5	85	83	76	77
107.6	106.2	63	61.6	80.5	79.5	77	75	73.5	71.5	72.5	70.5	71	68	85	84.7	71.5	73.5
107.6	97.7	63	53.1	81	70.5	75	66	70.5	62.5	69	62	65.5	60.5	88.5	76.1	82.5	64.5
101.6	100.9	57	56.3	74.5	73.5	70.5	69.5	67.5	66.5	66.5	66	65	64.5	79	78.4	65.5	64.5
105.4	95.5	60.8	50.9	78.5	68.5	74.5	63	71	60	70	59.5	68	58	85.8	74.4	71	64
105	100.8	60.4	56.2	77	73.5	75.5	69	70.5	66.5	70	65.5	69.5	64.5	81.9	78.1	66.5	64.5
98.9	96.5	54.3	51.9	72	69.5	67.5	65	65	61.5	64.5	61	63	60	76.2	75	63	63.5
104.2	102.1	59.6	57.6	76.8	74.9	72.5	70.2	69.2	66.8	68.3	66.1	66.7	64.3	82.2	80.7	69.6	69.1
2.3	4.4	2.3	4.4	2.7	4.2	2.6	4.4	2.3	4.4	2.2	4.2	2.2	3.9	3.7	4.6	6.7	5.9

The L_{eq} in residential-commercial regions of Isfahan in the morning and in the afternoon were 74.6 dB_(A) and 72.6 dB_(A) that respectively were 14.6 dB_(A) and 12.6 dB_(A) higher than the air noise guidelines 60 dB_(A). Table 3 shows the results comparison of the present study with other studies.

DISCUSSION

As the earlier mentioned, the average of L_{min} , L_{90} , L_{95} , and L_{99} in the residential-commercial regions of Isfahan in both the morning and afternoon were higher than the Iranian ambient noise pollution guideline. However, one-way ANOVA showed a significant difference between the measured values of the morning and afternoon in the mentioned parameters ($P = 0.046, 0.048, 0.043$ and 0.028 , respectively). It means that there was a difference between the average measured values of the morning and afternoon. In addition, the background sound in the morning was more than afternoon. There was no significant difference in other measured parameters ($P > 0.05$) [Table 1].

The reason for the highest measured value of L_{eq} in the a.m. in Ferdowsi bridge crossroad station was because of high-traffic load of vehicles and the proximity to Zayandehrood river [Figure 1]. The SEL and SPL had the highest similar values in the a.m in Hakim Nezami crossroad and Artech square stations. These high measured values for Hakim Nezami crossroad station was due to the existence of an underpass and high speed of vehicles and for Artech square station was due to the presence of an army barrack and the traffic of military cars and the market presence at the end of the street leading into the Artech square.

Figure 2 shows the L_{eq} , SEL, SPL, NPL, L_{10} , L_{50} , and L_{90} had the highest values in the p.m. in Jomhoori square station that is probably due to that this sampling station is one of the most important squares and the exit location of the city as the crossroad of the streets leading into the Isfahan surrounding townships and created high-traffic load and also the final bus station of that route was located in this square. The highest value of TNI in Sheikh Saduq crossroad station in the p.m. was due to the centralization of this crossroad and high traffic of vehicle and also as it leads into the crowded Azadi square [Table 1].

In a study conducted in Isfahan, the mean of equivalent SPL determined as 71 dB_(A) in a total period of sampling, which was much more than the ambient noise guidelines.^[14] These results were in line with the current study. In a similar study conducted in Zanjan, the mean equivalent sound level (L_{eq}) in this city during the day was 62.17 dB_(A) and 58.58 dB_(A) during the night.^[10]

Another study conducted in Karachi, Pakistan, showed that traffic noise level was related to the road traffic load. The regions with high-traffic load such as city older areas in the

Table 2: Noise pollution guideline in Iranian ambient air from 7 a.m. to 10 p.m. and from 10 p.m. to 7 a.m

Region	Day: 7 a.m. to 10 p.m.	Night: 10 p.m. to 7 a.m.
	L_{eq} (30), dB _(A)	L_{eq} (30), dB _(A)
Residential region	55	45
Residential-commercial region	60	50
Commercial region	65	55
Residential-industrial region	70	60
Industrial region	75	65

Table 3: Results comparison of present study with other studies

City	Year	Measurement value (L_{eq} 30 min) dB _(A)	Present study dB _(A)	Agreement/not agreement
Zanjan, Iran ^[10]	2008	62.17	73.6	Yes*
Girona, Spain ^[25]	2011	63.3	73.6	Yes
Karachi, Pakistan ^[26]	2011	66	73.6	Yes
Isfahan-Iran ^[14]	2005	71	73.6	Yes
Qazvin-Iran ^[6]	2010	71.35	73.6	Yes
Kashan-Iran ^[5]	2002	79.6	73.6	Yes
Erzurum-Turkey ^[11]	2012	80	73.6	Yes
Hamadan ^[15]	2009	69.04	73.6	Yes
Kuala Lumpur ^[16]	2005	75.6	73.6	Yes
Malaysia ^[21]	2005	72	73.6	Yes
Kerman ^[3]	2009	66-79.5	73.6	Yes
French ^[27]	1986	65	73.6	Yes
Tokyo ^[28]	1986	78	73.6	Yes
Rom ^[29]	1991	80	73.6	Yes

*Higher than guidelines

times were encountered with a high level of sound. It was concluded that based on the measurements, the average traffic noise during morning, afternoon and evening exceeded 66 dB_(A).^[26] The results of this study are in agreement with the current study. Another study was carried out in Girona, Spain, showed that the average statistical level (L_{24h}) was 63.3 dB_(A) and statistical level at night (L_{night}) was 55.7 dB_(A).^[25] Another study was carried out in Hamadan, was concluded that the average of L_{eq} at all stations was 69.04 ± 4.25 dB_(A) and higher than Iranian guidelines.^[15] The results of this study are in agreement with the current study.

Table 1 also shows a considerable difference between L_{max} and L_{peak} . However, L_{peak} values are high and similar together. As a rule, L_{max} is the highest root mean square (RMS) SPL level within the measuring period. While L_{peak} is the crest of the SPL within the measuring period (this is not an RMS level).^[22] Thus, it is concluded that a background noise always was existed in the study area.

Pearson's correlation test showed there was a clear relationship between NPL and TNI values in the morning and afternoon (Pearson correlation coefficient = 0.877) and ($P < 0.001$). On the other hand, by increasing the commuter vehicles, NPL and TNI values were increased. In addition, there was a straight relationship between NPL and TNI values in the afternoon (Pearson's correlation coefficient = 0.884) and ($P < 0.001$) [Table 1].

According to Figure 4, it was defined that L_{eq} in both morning and afternoon periods in all of the sound meter stations was higher than the noise guidelines of residential-commercial areas of Iranian environmental protection agency [Table 2]. Other studies results are compared with the findings of the present study [Table 3].

Based on the results, it was clear that noise pollution problem of Isfahan is mostly due to the urbanization factors and its traffic problems. Urbanization factors are included the adverse condition of the streets and street bumps and the problem of the cars' namely heavy vehicles in these bumps that create much noise and the lack of street's suitable capacity for more vehicles.

CONCLUSIONS

Generally, considering the achieved results, it was defined that Isfahan had high noise pollution and in most cases was higher than Iranian guidelines of the environment protection organization in the study period (winter of 2010-2011). Thus, noise pollution in this city can be a serious problem and investigating its reasons is recommended. According to the results of this study, the maximum noise pollution was related to Jomhoori square station, Artech square, and Hakim Nezami crossroad.

It is recommended that with the collaboration of bus organization, the last bus station in Jomhoori square should be moved to another suitable location. Furthermore, the existing market in the end of the street leading into Artech square should be transferred to another appropriate place, or it should work for 3 days a week and for quiet vehicle's traffic times in Hakim Nezami, a new route is considered to take a trip to Shahr-e-Kord other than the current route. Considering the mentioned items, to reduce the noise pollution in Isfahan, it is recommended that the investigation of the noise produce by vehicles should be included in the annual test of automobile safety. The obligatory yearly test of motorcycle's safety, the modification of traffic issue's management and making some streets one-way, prevention of the traffic passing of old vehicles in full routes and quality control of the vehicle namely the buses, formulating new rules of driving, for example, for inappropriate use of horn during driving, putting noise barriers and grassy space and construction of green embankment around the streets as noise absorbent, creating the highways and construction of a detour in the ring road to prevent the passing of lorries' trucks and trailers into the city and centralization of the commercial areas outside of the residential area and transferring crowded noisy jobs to the city's margin to reduce noise pollution in various parts of the city are necessary.

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