# Evaluation of Traffic Noise Pollution Around The Shrine of Imam Reza Using GIS And Descriptive Statistics Analysis (A Case Study of Mashhad, Iran)

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# Abstract

The environmental consequences and the epidemiologic results of noise pollution have chronic effects and lead to widespread complications in the long run. Thus it might receive less attention by pollution monitoring and control systems when compared with other environmental pollutants. The city of Mashhad is Iran's second largest metropolitan city and it is one of the biggest world religious cities in the world. Each year it becomes one of the main destinations for travel for tourists and pilgrims in Iran and abroad in the holidays of the beginning of the year and the summer. In this research study the distribution of sound pollutants in the streets and sidewalks leading to the Holy shrine of Imam Reza is investigated. Field measurements were carried out by noise level meters and on longitudinal and transverse points of the sidewalk of the streets leading to the Holy Shrine. All of the measurements and recordings were done during the peak of morning crowd (AM 10-12) and evening crowd (PM 4-6) and on both of the sidewalks of each street. The study showed that the pollution in all of the studied streets in the evening time span (PM 4-6) has the maximum level of noise. Among all of the studied streets, Tabarsi street has the most amount of noise pollution with a mean of 78 dB(A) for the mean intensity for each point and Imam Reza street has the minimum amount of pollution with a mean of 72.75 dB(A). The investigations showed that, from the temporal perspective, the noise pollution peaks in the evening, when weather conditions are most favorable for visiting the area. From the spatial perspective, the most intensive noise pollution was observed in the areas with residential and accommodation land use, which have the highest number of arterial routes towards the shrine.

# Introduction

The increased growth in the population of cities on the one hand and the emergence of new needs for the citizens on the other hand have led to a variety of problems for those living in cities (Basu et al. 2021). We can point noise pollution as one of these environmental problems. This kind of pollution may lead to various long-term (chronic) and short-term (severe) effects on the health of the citizens (WHO 2012). Epidemiological and physiological evaluations show that noise pollution causes hearing impairment (Díaz et al. 2021; Münzel et al. 2021), excessive adrenalin hormone secretion, blood pressure, increase of heart rate (Ferrier-Pagès et al., 2021), muscle cramps, migraine headaches and digestive disorder (Korte and Grant 2001). Therefore, it is of utmost importance to study how this kind of pollution is distributed. The studies performed in Italy suggest that more than 25 percent of the residents of this country suffer from noise pollution due to their vicinity to road traffic (Piccolo et al. 2011). Also, the investigation of the dose – response relationship for road traffic noise in Egypt (Ali 2004) showed that 71.9% of the individuals in the study have suffered from a high level of noise pollution and 37.2 percent of the population are highly sensitive to noise pollution. The intensity of noise present in industrial and business places and city traffic should not exceed 70 dB(A) in a 24-hour time interval according to the standards of the World Health Organization (Berglund et al. 1999). It should be noted that Iran's standard limits the utmost intensity of noise for the residential areas during the day to 55 dB(A) and during the night to 45 dB(A), for the residential-business areas to 60 dB(A) and during the night to 50 dB(A) and in business places 65 dB(A) during the day and during the night to 55 dB(A) (Abbaspour et al. 2015). Margarits and Kang (2017) examined the effect of the green spaces inside the city on reducing noise pollutions. In this research which has been done in 25 regions of Europe, different distributions and patterns have been reported in between the city green spaces and noise pollution. It should be mentioned that the mentioned researchers used the geographical information system (GIS) for geographical and morphological modeling. The results of this study showed that greener parts of the city do not necessarily have a lower noise pollution and that urban greenery patterns do not match the noise pollution patterns.

Aparisio et al. (2016) examined the effects of air pollution and noise pollutions that are caused by road traffic on bike riders. In this study which was carried out in the central region of the city of Montreal, the region under study was modeled and layered by using GIS in addition to calculating the correlation of air pollutions with noise pollution. This research has shown that there is an inverse relationship between the level of noise pollution and the distance of bikeway from the road edge. Moreover, in another research study conducted by Carrier et al. (2016) the effects of air pollutions (especially $NO_2$) and noise pollution on the residents of the city of Montreal were evaluated. The results of this study showed that 460 blocks of the studied areas had poor conditions and the people aged 65 years and over were the group most significantly affected.

Gulliver et al. (2015) developed an open-source road traffic noise model for prediction of exposure assessment to noise pollution. These models were obtained as a result of mixing the GIS and Postgre SQL techniques of the R software and based upon the statistical data (2003–2010) related to the residents of the city of London. Also, it should be mentioned that the calculations of the innovative model were calibrated with the results of field measurements in order to validate the results of predictions made in this study. The analyses of this study showed that approximately one million London residents were exposed to noise pollution in morning and night periods.

In another research study, Morley et al. (2015) offered a model for predicting the epidemiological effects resulting from noise pollution of road traffic. The above mentioned study was done across Europe using a mixture of the models of GIS and statistical analyses. The result of this study indicated that the proposed prediction model can be used for accurate estimation of the epidemiological effects of noise pollution. Murphy et al. (2009) modeled and predicted the amount of noise pollution that people encounter in the downtown of the city of Dublin in Ireland that is generated due to traffic by combining the Harmonoise and GIS. They concluded that the effects and levels of noise pollution in downtown Dublin were much greater at night than at other times. In a research study, Pathak et al. (2008) evaluated the damage of noise pollutions caused by traffic in the city of Varanasi in India. They showed that 85% of people in the studied area were exposed to noise pollution and 90% of the observed headaches were caused by this pollution. Moreover, Lee et al. (2014) evaluated the correlation between the amount of traffic and noise pollution in the three cities of New York, Atlanta and Los Angeles. The results of this study showed that irrespective of the city type, noise pollution has a direct relationship with traffic and the size of the transportation network.

The main purpose of the present study was to analyze the distribution of noise pollution data over the area of interest, that is, the area around the Shrine of Imam Reza in Mashhad. This shrine is an important hub of religious tourism for Muslims and attracts a particularly large number of visitors around certain religious holy days. Naturally, this trend causes shock loads of noise pollution in the area. What distinguishes this study from similar works on noise pollution is the geography, customs, and culture of the area studied, as the city of Mashhad and particularly the area around the Shrine of Imam Reza attracts a large population of visitors within a two-month time period, which result in excessively exacerbated traffic and hence a unique diffusion model for noise pollution during this time. Thus, we intend in this research study to (*i*) evaluate noise pollution resulting from traffic in the streets ending to the Shrine of Imam Reza (Iran, Khorasan Razavi, Mashhad) during the holidays when religious ceremonies are conducted and (*ii*) evaluate the extent of distribution of noise pollution by using GIS.

## Materials And Methods

# 2.1. The studied area

The city of Mashhad is considered to be the center of the Khorasan Razavi Province and it is the second largest city in Iran after Tehran (Iran's Capital). With an area of 328 square kilometers, this city is located in between the Binalood mountain range and the Hezar Masjed Mountains in the Kashafrud River waterfall area. According to the latest nationwide census of population and housing (in 2016), the population of the city of Mashhad has been reported to be equal to 3001184 individuals. Each year a very large number of tourists and pilgrims enter the city of Mashhad during the holidays. According to the official statistics of the Organization of the Mashhad Municipality, the number of travelers who entered the city of Mashhad in 2016 from the passenger terminal, airport and railway station has been 12478071, 3976793 and 6371743 individuals, respectively. From amongst the most important peak times when a lot of people enter the city of Mashhad we can refer to the time span from August 7th until September 7th. The amount of noise pollution in the streets leading to the Holy Shrine of Imam Reza in the above mentioned time spans has been analyzed in this research study.

# 2.2. The method of measuring noise pollution

Considering the absence of any online measurement system to monitor noise pollution, we needed a logically justifiable approach for collecting the required data. Five streets leading to the Holy Shrine namely Imam Reza, Khosravi, Shirazi, Navab Safavi and Tabarsi were used for this study as shown Fig. 1. In this study, the Holy Shrine has been defined as the central point (with the coordinates of 0.00) and the measurements have been done at the longitudinal distance of 700 meters, with the longitude of 50 meters station from the central point and along all five streets. In other words, 15 stations on each sidewalk and a total of 30 longitudinal stations were considered in each street of the streets leading to the Holy Shrine. The measurement points (noise recording stations) were selected such that transversely they were at least 1 meter away from the street edge and 1 meter away from the nearest wall. Since sidewalks of the study area are 2 meters or more wide, for sidewalks with a width of 2 meters, one transverse point, and for sidewalks wider than 2 meters two transverse points were selected. The complete explanation of all of the longitudinal and latitudinal stations have been summarized in Table 1. The intensity of noise was estimated for every station in 2 time spans of the morning peak of traffic (10–12 AM) and evening peak of traffic (4–6 PM) and in each measurement instance the four values of minimum, average, maximum and absolute maximum of noise pollution were recorded. Also it should be mentioned that the noise level meter was fixed for 30 seconds in the sampling place for recording the absolute maximum noise pollution, so as to record the maximum intensity of noise in this time span.

**Table 1.** Specifications of the longitudinal and the latitudinal stations of the streets leading to the Holy Shrine

| **Street Name** | ***Sidewalks on both sides* of *streets*** | **The number of longitudinal stations** | **The number of latitudinal stations** |
|---|---|---|---|
| Khosravi | A | 15 | 16 |
| | B | 15 | 15 |
| Imam Reza | C | 15 | 30 |
| | D | 15 | 30 |
| Shirazi | E | 15 | 25 |
| | F | 15 | 24 |
| Navab Safavi | G | 15 | 23 |
| | H | 15 | 16 |
| Tabarsi | I | 15 | 15 |
| | J | 15 | 15 |

In this research all of the noise levels and coordinates of measurement stations were reported by using sound level meters BE804 manufactured by BESTONE and Garmin GPS model “In reach Explore”, respectively. Also, it should be mentioned that all of the related measurements were done based on the [S1.4-1983 & S1.4-1971(R1976)] ANSI standards. One of the most important measures for determining the level of annoyance is the DNL model proposed by the U.S. Air Force (Ouis, 2001). In this mode, the average day and night noise level (DNL) is computed from Eq. 1 as follows:

$$DNL = 10 Log \frac{15 \times 10^{L_d/10} + 9 \times 10^{(Ln+10)/10}}{24} \quad (1)$$

where $L_d$ and $L_n$ show the average noise pollution intensity in a 15 hour daytime period and the average noise pollution intensity in a 9 hour night period. In this study, we have used some simplification and used $L_d$ and $L_n$ for the average noise pollution intensity in the mornings and the afternoons. Then, Eq. 2 was used to compute the level of annoyance (HA) (Ouis, 2001).

$$HA(\%) = \frac{100}{1+\exp(11.13-0.14DNL)} \quad (2)$$

## 2.3. GIS modeling

This study aimed to consider not only spatial variations but also temporal variations over a given period (around the peak of tourism activity). Thus, the method had to be able to deal with the lack of specific data and spatial-temporal analyses. For this purpose, the data collected by the GIS was overlaid on the map. Given the spatial and temporal distribution of pollution data in different arterial routes over different time periods, there had to be a descriptive and conceptual comparison between the obtained data. In this part of the study, the goal was to analyze the level and distribution of noise pollution on different parts of the streets leading to the shrine. The Arc map 10.2 software was used in this study for modeling and mapping of the amount of noise pollutions in the streets leading to the Holy Shrine. In the first step of modeling, the information related to the amount of noise pollutions was input to GIS based on their real coordinates. In the next step, the patterns related to the deterministic methods, i.e. Local Polynomial Interpolation, Radial Basis Function, Global Polynomial Interpolation and Inverse Distance Weighting) Geo statistical Method (Kriging, Areal Interpolation, Empirical Bayesian Kriging (Interpolation With Barrier(, Kernel Smoothing and Diffusion Kernel were evaluated and examined (Kluijver and Stoter 2003; Yilmaz and Hocanli 2006; Farcaş and Sivertunb 2010; Ditmer et al., 2021) for the interpolation of the amount of noise pollution of the midpoints between the stations.

The judgments were done based upon the maximum amounts of R-square and the minimum amounts of SE and RSME in order to determine the best system and the interpolation pattern (Li et al. 2002). Also in the last step by deriving the raster and vector outputs, the mapping curves and the alignment lines of noise pollution were obtained for analyzing the distribution of pollution (Reed et al. 2012; Ko et al. 2011; Kurakula 2007; Monazzam et al., 2021).

## 2.4. Statistical analyses

In this part of the study the mean of the data of noise pollution of every street was analyzed in the time spans of morning and afternoon by means of descriptive statistics (Brainard et al. 2004). It should be mentioned that all of the calculations and analysis of data after calculating the mean of the minimum and the maximum amounts of noise pollution were done by using the Minitab 17 software.

# Results And Discussion

The results of the interpolations and calculations at the midpoints showed that the method of Inverse Distance Weighting that is one of the branches of the Deterministic Method creates the minimum RSME value (Table 2). For this reason, the data that was obtained from this calculation method (Inverse Distance Weighting) was used as the basis for modeling and mapping. This is the case even though

Alesheikh and Omidvari (2010) used the Co-kriging method for interpolation and smoothing the alignment curves of noise pollution in their research study. Also, in the study reported by Gholami et al. (2012) the Spline method was used in the environment of Arc-GIS for the interpolation and smoothing the alignment curves of noise pollution. In addition, Taghizadeh et al. (2013) compared and examined different kinds of interpolation for drawing the curves of alignment of noise pollution and they finally chose the Kriging system. The mapping of the distribution of noise pollutants has been shown for the average, minimum, maximum and absolute maximum amounts of morning and evening in Figs. 2 to 5.

**Table 2.** The average of the RSME amounts of interpolation with the method of Inverse Distance Weighting for the data obtained

| RSME | A- max | ave | min | max |
|---|---|---|---|---|
| Morning data | 5.21 | 4.04 | 4.11 | 6.96 |
| Evening data | 5.42 | 3.67 | 2.47 | 2.57 |

The amount of noise pollution in Khosravi street increases a lot from the morning until the evening as seen in Figs. 2–5. The above mentioned street is a business zone where the businesses there engage in commercial activities from 8 AM until 2 PM and there is little movement towards the Holy Shrine. This is the case while this street is known to be one of the main routes of traffic for the tourists and pilgrims from 4 PM to 8 PM. Considering Figs. 2B, 3B, 4B and 5B it is clear that the most amount of pollution exists at the beginning and end of Khosravi street. The beginning of this street is the crossing of four crowded streets and field measurements show that the main factor that contributes to noise pollution in this range is due to the disturbing noise of motor cycles and the sound of the worn away brake pads of personal cars and public transport vehicles when they stop behind the stop light.

Moreover, Khosravi street ends at the Holy Shrine where all of the public transport vehicles as well as other vehicles and motorcycles stop which cause a great deal of noise pollution due to worn out brake pads of the transport vehicles. Also, we must mention the fact that sometimes the amount of noise pollution increases because of the beeping sound of objection of the drivers who get stuck behind public transport vehicles. Of course, the results of the field data collection showed that the beeping sound of vehicles ranks second after the sound of the worn away pads of automobiles and the sound of the starting of the movement of motorcycles. In addition, Alesheikh and Omidvari (2010) also in their research introduced personal vehicles as the main factor in the distribution of noise pollution. In this research study that was done with the aim of modeling noise pollution in the city of Tehran each bus in the bus transportation system was considered to be equal to 25 personal vehicles in terms of passenger carrying capacity. Therefore, it can be noted that the expansion of the public transport system can considerably help reduce the amount of noise pollution.

The Tabarsi street is one of the oldest major streets for the pilgrims to go back and forth when they want to visit the Holy Shrine. The section of this street that is located near the Holy Shrine is used for business and the rest of it that is farther away from the Holy Shrine is used for Hotels and Hotel apartments. A look at the above Figures shows that the number of extreme points of noise pollution in the evening is more than that of the morning. The fact that there are more pollution extreme points in the evenings is due to the dominant presence of residential and hotel apartments in this part of town and the increased movement of travelers back and forth at this time. Moreover, a comparison of Figs. 2A with 2B, 3A with 3B and 4A with 4B shows that the peaks of pollution move from the various points on Tabarsi street in the morning to near the Holy Shrine in the evening. The reason for the peaks of noise pollution being at the end of Tabarsi street is that it is mainly the point where various types of automobiles stop and cause noise since they constantly stop and go. Navab Safavi street is also one of the streets ending at the Shrine similar to Tabarsi street, it is used for business near the Holy Shrine and there are hotels and hotel apartments on it at a distance from the Holy Shrine. The interpretation of maps indicates that the intensity of noise in the evenings is more than that of the mornings. Moreover, there is maximum amount of pollution in the beginning of the street due to the stop light and at its end because of approaching the Holy Shrine compared to other areas.

The Imam Reza street may be considered to be the main street leading to the Holy Shrine. This street also is used for hotel apartments and business applications such that on the whole it can be considered to be mainly a business center. Figures 2 to 5 show this street has a high intensity of noise in the evening time span like Khosravi street. Moreover, the general trend of noise pollution is toward the Holy Shrine and it reaches its maximum near the Shrine. An overall consideration of all passages and paths leading to the Holy Shrine explains the important fact that there is a lower intensity of noise in Imam Reza street compared with other streets. As stated before it was pointed out that many of the public or private vehicles get a chance to pick up some speed and then they come to a quick stop at the red light or when they approach the Holy Shrine they are forced to push on the brake. This causes serious noise pollution since many of these cars have worn out brake pads. This is the case while Imam Reza street has a severe traffic and the cars in the middle of that street cannot pick up speed suddenly come to a stop. For this reason, the severity of noise pollution decreases in this street.

Considering traffic and city planning issues, Shirazi street has especial and unique conditions. This street connects the central square of the city (Shohada square) to the Holy Shrine. This sample passage does not have a red light at the beginning of the path and there is no stoppage of vehicles due to traffic jam on it although there is a red light in the middle and one large cross section with red light just before it reaches the Holy Shrine. The amount of noise pollution reaches its utmost value in the middle of this route as shown in Figs. 2 to 5. It is also noteworthy that the intensity of noise on this street on the evenings is much more than in the mornings.

The results of analysis of descriptive statistics related to the average of noise pollution data of Khosravi street in the morning and evening time spans have been shown in Table 3 and Fig. 6. Table 3 shows that the Median and Mode of the intensity of noise in the morning time span are equal to 71 and 72 dB(A), respectively. This is the case while the Median and the Mode of the intensity of noise of Khosravi street in the evening time span has an increase of 75 dB(A) relative to the mornings. Also, examining Fig. 6 shows that the maximum frequency of noise pollution data in morning and evening time spans are approximately 73.5 and 75.68 dB(A), respectively. All of these statistical results tell the increase in the level of the noise pollutions' level recorded in the evening time span in comparison with morning time span.

**Table 3.** The results of analysis of descriptive statistics of the average of the noise pollution data of Khosravi street

| Statistical Parameters | Ave - Morning | Ave – Afternoon |
|---|---|---|
| Mean | 73.7069 | 75.3603448 |
| Standard Error | 1.066022 | 0.40189958 |
| Median | 72 | 75 |
| Mode | 71 | 75 |
| Standard Deviation | 5.740702 | 2.16429547 |
| Sample Variance | 32.95567 | 4.68417488 |
| Kurtosis | 10.0522 | -0.41777334 |
| Skewness | 2.636582 | -0.22334144 |
| Range | 30 | 8.3 |
| Minimum | 67.5 | 70.7 |
| Maximum | 97.5 | 79 |
| Count | 29 | 29 |
| Confidence Level (95.0%) | 2.183646 | 0.82325397 |

Table 4 and Figure.7 show that the mean intensity of noise of Tabarsi street in the evening time span is around 81.1 dB(A) and in the morning time span it is around 73.25 dB(A). Moreover, a comparison of the minimum and the maximum amounts of noise pollution in the morning and evening time spans shows that there is a higher intensity of noise in the evenings compared with the mornings. We must mention that the amount of positive skewness of the evening data is more than that of the morning data and it tends more to the right with a higher slope.

**Table 4.** The results of analysis of descriptive statistics of the mean of the noise pollution data of Tabarsi street

| Statistical Parameters | Ave - Morning | Ave – Afternoon |
|---|---|---|
| Mean | 73.80667 | 77.775 |
| Standard Error | 0.570469 | 0.49398 |
| Median | 73.775 | 78 |
| Mode | 72.5 | 78 |
| Standard Deviation | 3.124589 | 2.705637 |
| Sample Variance | 9.763057 | 7.320474 |
| Kurtosis | -0.10119 | 5.7639 |
| Skewness | 0.054088 | 1.037124 |
| Range | 13.75 | 16 |
| Minimum | 67.75 | 71.5 |
| Maximum | 81.5 | 87.5 |
| Count | 30 | 30 |
| Confidence Level (95.0%) | 1.166741 | 1.010302 |

The analyses of descriptive statistics related to Navab Safavi street are shown in Table 5 and Fig. 8. The mean and the mode of the average noise pollution data have been estimated to be equal to 74.5 and 74 dB(A), respectively in the evening time span and equal to 73 and 71.5 dB(A) in the morning time span. A comparison of the above values certifies the assumption of increased level of noise pollution in the evening samples. Moreover, analysis of the average noise pollution data of Navab Safavi street shows that both the evening and morning data have positive skewness and they tend to the right. However, the slope of tendency to the right is more severe in the case of the evening data.

**Table 5.** The results of analysis of descriptive statistics of the average of noise pollution data of Navab Safavi street

| Statistical Parameters | Ave - Morning | Ave – Afternoon |
|---|---|---|
| Mean | 73.55946 | 74.66216 |
| Standard Error | 0.363778 | 0.424058 |
| Median | 73 | 74.5 |
| Mode | 71.5 | 74 |
| Standard Deviation | 2.212773 | 2.579443 |
| Sample Variance | 4.896366 | 6.653529 |
| Kurtosis | -0.39428 | 4.830493 |
| Skewness | 0.647483 | 1.389026 |
| Range | 8.5 | 15 |
| Minimum | 70 | 69.5 |
| Maximum | 78.5 | 84.5 |
| Count | 37 | 37 |
| Confidence Level (95.0%) | 0.737775 | 0.860029 |

From the scrutiny of the results shown in Table 6 and Fig. 9 it becomes clear that the intensity of noise in Imam Reza street in the evening time span is more than the intensity of pollution in the mornings. A comparisons shows that in the morning time span it is near 70.7 dB(A) and in the evening time span it is nearly 72 and 74.5 dB(A) as the maximum intensity of noise. Considering Table 7 it becomes clear that the mean and the mode of the average of the intensity of noise in Shirazi street in the evening time spans are 76.75 and 74 dB(A), respectively and in the morning time span they are 72 and 71 dB(A). Also, we can see that the intensity of noise is higher in the evening time span as shown in Fig. 10.

**Table 6.** The results of analysis of descriptive statistics of the average of noise pollution data of Imam Reza street

| Statistical Parameters | Ave - Morning | Ave – Afternoon |
|---|---|---|
| Mean | 71.26333 | 73.2775 |
| Standard Error | 0.279307 | 0.414609 |
| Median | 70.5 | 72.75 |
| Mode | 70 | 69.5 |
| Standard Deviation | 2.163504 | 3.211545 |
| Sample Variance | 4.680751 | 10.31402 |
| Kurtosis | -0.62141 | -1.09373 |
| Skewness | 0.345888 | 0.211911 |
| Range | 8 | 12.5 |
| Minimum | 67.5 | 67 |
| Maximum | 75.5 | 79.5 |
| Count | 60 | 60 |
| Confidence Level (95.0%) | 0.558892 | 0.82963 |

**Table 7.** The results of analysis of descriptive statistics of the average of noise pollution data for Shirazi street

| Statistical Parameters | Ave - Morning | Ave – Afternoon |
|---|---|---|
| Mean | 72.5625 | 76.80417 |
| Standard Error | 0.362414 | 0.45423 |
| Median | 72 | 76.75 |
| Mode | 71 | 74 |
| Standard Deviation | 2.510881 | 3.146998 |
| Sample Variance | 6.304521 | 9.903599 |
| Kurtosis | 3.875721 | 1.127408 |
| Skewness | -0.23046 | 0.022996 |
| Range | 17 | 17.5 |
| Minimum | 63.5 | 68 |
| Maximum | 80.5 | 85.5 |
| Count | 48 | 48 |
| Confidence Level (95.0%) | 0.729084 | 0.913793 |

Finally, we must point to the fact that the latitudinal comparison of sampling shows that the Tabarsi street has the maximum amount of noise pollution (with a mean of 78 dB(A)) and the Imam Reza street has the minimum amount of pollution (with a mean of 72.75 dB(A)) when there are religious ceremonies held in the city of Mashhad. This is the case while the Khosravi, Navab Safavi and Shirazi streets have nearly the same amounts of intensity of pollution. Moreover, Omidvari and Alesheikh (2010) have recorded the maximum intensity of noise in the city of Tehran to be (averaged equivalent value of) 78.9 dB(A) in their simulations for noise pollution distribution in Tehran. In the study conducted by Gholami et al. (2012) the maximum amount of noise pollution in the streets of Tehran were found to be 77.7 dB(A) during the time span of (7–9 AM) in a business zone and 57.8 dB(A) as the minimum amount of pollution during the time span of (5–7 PM) in an academic zone of the city. On the other hand, investigations have showed that the streets that terminate at the Holy Shrine of Imam Reza have a higher intensity of pollution in the evenings when compared with the mornings and the intensity of pollution in these streets reaches around its maximum amount around the (4–6 PM) time interval. The noise pollution measurement and recording are also done during the various time intervals in the morning to noon, evening and night. From amongst these studies we can point to the inputs of the SoundPlan software model in the research carried out by Nikolova et al. (2012). However, in the present research study we identified the intervals of peak traffic in the streets that end up in the Holy Shrine before sampling, and we recorded the data in the morning (AM 10–12) and the evening (PM 4–6) time spans.

The most important reasons behind analysis of noise pollution are the negative effects and the epidemiologic interactions of this kind of pollutant on human health. The side effects of unwanted noise on humans include nervous sensitivity, dizziness and headache, physical and spiritual fatigue, stress and agitation, disruption of digestive system and body metabolism, increased blood pressure, difficulty in breathing, violence and lack of concentration, reduced work efficiency, etc (Korte and Grant 2001).

Various research studies have been done to measure the degree of effects of noise pollution on human health. In these studies, several nonlinear statistical relations have been presented for road traffic noise level and annoyance level (HA) in terms of dose-interaction. Among these studies, we can cite Ali's research (2004) in Egypt, Schultz study (1982) in London, Paris, the United States and Switzerland and Arana and Garcia's study (1998) in Pamplona – Spain. It should be noted that annoyance level refers to the percentage of the people in a given region who are exposed to severe noise pollution and suffer from loss of peace and calm (Morel et al. 2016). Additionally, the amount of noise pollution due to traffic is highly related to the cultural conditions in a given society (Zannin et al. 2002). Since Iran is much closer to Egypt in terms of culture and development, from Ali's research study (2004) where DNL noise pollution intensity data were processed and curves have been reported has been used for comparison in addition to the model presented by the U.S. Air Force. Thus, the noise pollution data for five streets terminating at the Holy Shrine of Imam Reza were analyzed and the level of annoyance based on average intensity of noise in these streets were reported in Table 8.

**Table 8.** The level of annoyance based on average intensity of noise

| Street | Level of Annoyance (%) | |
|---|---|---|
| | Based on U.S. Air Force | Based on Ali's Study |
| Khosravi | 57.19 | 59.14 |
| Tabarsi | 64.58 | 65.22 |
| Navab Safavi | 54.98 | 55.25 |
| Imam Reza | 49.80 | 51.35 |
| Shirazi | 61.36 | 63.45 |

These results indicate that based on the relations given by the U.S. Air Force, the minimum and maximum levels of annoyance are 49.8% and 64.58% for Imam Reza and Tabarsi streets, respectively. A comparison of results shows that the level of annoyance computed based on Ali's model in Egypt is in most cases similar to or slightly higher than those obtained by the U.S. Air Force relations. The results also indicate that a higher percentage of the people in Tabarsi street are exposed to the severe epidemiologic effects of noise pollution. As the analysis results show, the highest level of noise pollution is related to evening periods. Therefore to address this issue, it is recommended to develop and enforce traffic control plans and vehicle access restrictions to the streets leading to the areas with the highest number of visitors. In particular, a high priority should be given to implementing traffic restrictions for

Tabarsi Street. Also, intuitive examinations showed that the highest noise intensity originates from worn out brake pads of motorcycles. Therefore, it is imperative to stop the access of these vehicles to the area around the Shrine of Imam Reza during the times of peak tourism activity. If properly enforced, such traffic restrictions can lead to significantly reduced noise pollution in the studied area.

# Conclusion

The city of Mashhad that is Iran's second metropolitan city that has a religious position hosts a huge number of visitors that visit the Holy Shrine of Imam Reza. The number of travelers and automobiles entering the city of Mashhad becomes critically high on some of the days during the year. In this research study, the distribution of noise pollutions resulting from the movement of automobiles travelling in the streets and terminating at the Holy Shrine of Imam Reza were investigated. In this study, the distribution of noise pollution in five streets namely Imam Reza street, Khosravi street, Navab Safavi street, Tabarsi street and Shirazi street was examined and evaluated in the peak period of travelers entering Mashhad (*i.e.* peak of summer religious ceremonies).

The results of the present study showed that the pollution wave has a direct relationship with the number of crossroads and the number of traffic lights and the main factor that intensifies this pollution is the wearing out of the brake pads of personal and public vehicles. Moreover, GIS analysis of the data explains the fact that the wave of the distribution of pollution reaches its maximum in a time slice in the cross sections of the streets. Also, by comparing the statistical data of the severity of pollution in morning and evening time spans it became clear that the highest intensity of noise occurs at the (4–6 PM) timespans due to the peak intensity of travelling of pilgrims to the Shrine. A comparison of the average of the data of severity of pollution in different streets showed that Tabarsi street with a mean of 78 dB(A) noise pollution and Imam Reza street with a mean of 72.75 dB(A) noise pollution have the highest and the least amounts of noise pollution.

# Declarations

### Ethical Approval

Not applicable

### Consent to Participate

Not applicable

### Consent to Publish

Not applicable

### Authors Contributions

**MK** and **AMF** devised the project, the main conceptual ideas and proof outline. **MG** and **PL** collected field data and carried out statistical analysis. **MK** supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.


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### Competing Interests

The authors declare that they have no competing interests

### Availability of data and materials

All data generated or analysed during this study are included in this published article

# References


1. Abbaspour M, Karimi E, Nassiri P, Monazzam MR, Taghavi L (2015) Hierarchal assessment of noise pollution in urban areas – A case study. Transport Res D-TR E 34:95–103
2. Alesheikh AA, Omidvari M (2010) Application of GIS in urban traffic noise pollution. Int J Occup Hyg 2(2):79–84
3. Ali SA (2004) Investigation of the dose – response relationship for road traffic noise in Assiut, Egypt. Appl Acoust 65(11):1113–1120
4. Annual statistical report (2016) Department of Planning and Development, Mashhad's municipally
5. ANSI S1.4 (1983) Specifications for Sound Level Meters. American National Standards Institute
6. Apparicio P, Carrier M, Gelb J, Séguin AM, Kingham S (2016) Cyclists' exposure to air pollution and road traffic noise in central city neighbourhoods of Montreal. J Transp Geogr 57:63–69
7. Arana M, Garcia A (1998) A social survey on the effect of environment noise on the residents of Pamplona, Spain. Appl Acoust 53(4):245–253
8. Basu B, Murphy E, Molter A, Basu AS, Sannigrahi S, Belmonte M, Pilla F (2021) Investigating changes in noise pollution due to the COVID-19 lockdown: The case of Dublin, Ireland. Sustain Cities Soc 65:102597
9. Berglund B, Lindvall T, Schwela DH (1999) Guidelines for Community Noise. World Health Organization, Occupational and Environmental Health Team
10. Brainard JS, Jones AP, Bateman IJ, Lovett AA (2004) Exposure to environmental urban noise pollution in Birmingham, UK. Urban Stud 41(13):2581–2600
11. Carrier M, Apparicio P, Séguin AM, Crouse D (2016) The cumulative effect of nuisances from road transportation in residential sectors on the Island of Montreal – Identification of the most exposed groups and areas. Transport Res D-TR E 46:11–25

12. Ditmer MA, Francis CD, Barber JR, Stoner DC, Seymoure BM, Fristrup KM, Carter NH (2021) Assessing the Vulnerabilities of Vertebrate Species to Light and Noise Pollution: Expert Surveys Illuminate the Impacts on Specialist Species. *Integr Comp Biol*, In press
13. Farcaş F, Sivertunb Å (2010) Road traffic noise: GIS tools for noise mapping and a case study for Skåne region. Sweden. ISPRS Archives 34:1–10
14. Gholami A, Nasiri P, Monazzam M, Gharagozlou A, Monavvari SM, Afrous A (2012) Evaluation of traffic noise pollution in a central area of Tehran through noise mapping in GIS. Adv Environ Biol 6(8):2365–2374
15. Gulliver J, Morley D, Vienneau D, Fabbri F, Bell M, Goodman P, Beevers S, Dajnak D, Kelly FJ, Fecht D (2015) Development of an open-source road traffic noise model for exposure assessment. Environ Modell Softw 74:183–193
16. Díaz J, Antonio-López-Bueno J, Culqui D, Asensio C, Sánchez-Martínez G, Linares C (2021) Does exposure to noise pollution influence the incidence and severity of COVID-19? Environ Res 195:110766
17. Kluijver H, Stoter J (2003) Noise mapping and GIS: optimising quality and efficiency of noise effect studies. Comput Environ Urban 27(1):85–102
18. Ko JH, Chang SI, Lee BC (2011) Noise impact assessment by utilizing noise map and GIS: A case study in the city of Chungju, Republic of Korea. Appl Acoust 72(8):544–550
19. Korte C, Grant R (2001) Traffic noise, environmental awareness, and pedestran behaviour. Environ Behav 12(3):408–420
20. Kurakula V (2007) A GIS based approach for 3D noise modelling using 3D city models. *ITC Publisher*
21. Lee EY, Jerrett M, Ross Z, Coogan PF, Seto EY (2014) Assessment of traffic-related noise in three cities in the United States. Environ Res 132:182–189
22. Li B, Tao S, Dawson RW, Cao J, Lam K (2002) A GIS based road traffic noise prediction model. Appl Acoust 63(6):679–691
23. Margaritis E, Kang J (2017) Relationship between green space-related morphology and noise pollution. Ecol Indic 72:921–933
24. Monazzam MR, Karimi E, Shahbazi H, Shahidzadeh H (2021) Effect of cycling development as a non-motorized transport on reducing air and noise pollution-case study: Central districts of Tehran. Urban Clim 38:100887
25. Münzel T, Sørensen M, Daiber A (2021) Transportation noise pollution and cardiovascular disease. *Nat Rev Cardiol*, 1–18
26. Morel J, Marquis-Favre C, Gille LA (2016) Noise annoyance assessment of various urban road vehicle pass-by noise in isolation and combined with industrialnoise: A laboratory study. Appl Acoust 101:47–57
27. Morley D, Hoogh K, Fecht D, Fabbri F, Bell M, Goodman P, Elliott P, Hodgson S, Hansell AL, Gulliver J (2015) International scale implementation of the CNOSSOS-EU road traffic noise prediction model for

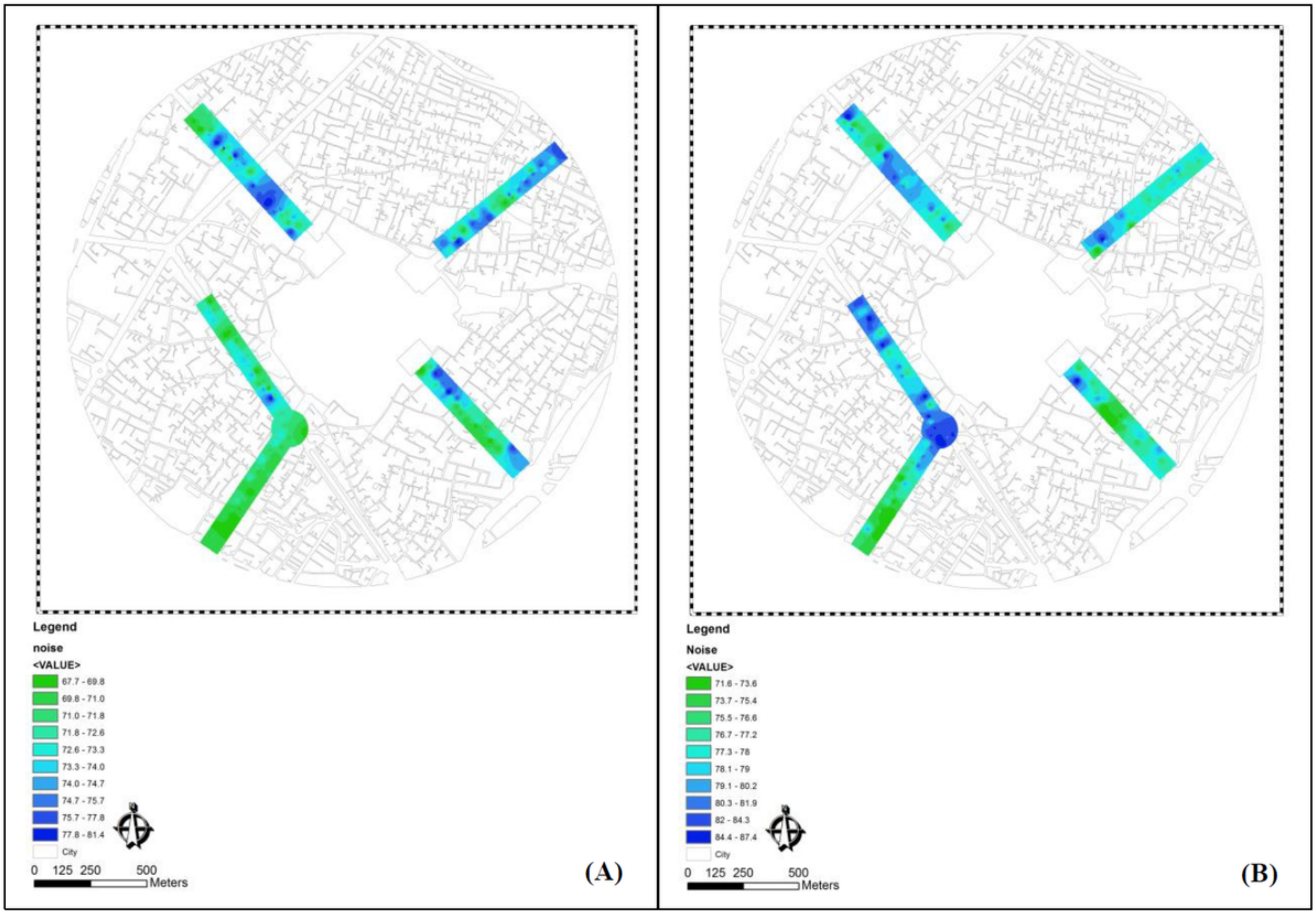
epidemiological studies. Environ Pollut 206:332–341

28. Murphy E, King EA, Rice HJ (2009) Estimating human exposure to transport noise in central Dublin, Ireland. Environ Int 35(2):298–302
29. Nikolova M, Mirakovski D, Ristova E, Stefanovska Ceravolo L (2012) Modeling and Mapping of Urban Noise Pollution with SoundPLAN Software. International Journal for Science Technics Innovations for the Industry *MTM (Machines Tecnologies Materials)* 6(5):38–42
30. Ouis D (2001) Annoyance from road traffic noise: a review. J Environ Psychol 21(1):101–120
31. Pathak V, Tripathi BD, Kumar Mishra V (2008) Evaluation of traffic noise pollution and attitudes of exposed individuals in working place. Atmos Environ 42(16):3892–3898
32. Piccolo A, Plutino D, Cannistraro G (2011) Evaluation and analysis of the environmental noise of Messina, Italy. Appl Acoust 66(4):447–465
33. Reed SE, Boggs JL, Mann JP (2012) A GIS tool for modeling anthropogenic noise propagation in natural ecosystems. Environ Modell Softw 37:1–5
34. Schultz TJ (1982) Community Noise Rating. Elsevier Applied Science
35. Seyedi Farkhod SM (2003) A Look at Historical Geography of Mashhad. Research Center of Islamic Council Publication, Mashhad
36. Ferrier-Pagès C, Leal MC, Calado R, Schmid DW, Bertucci F, Lecchini D, Allemand D (2021) Noise pollution on coral reefs?—A yet underestimated threat to coral reef communities. Mar Pollut Bull 165:112129
37. Taghizadeh R, Zare M, Zare S (2013) Mapping of noise pollution by different interpolation methods in recovery section of Ghandi telecommunication Cables Company. J Occup Health Epidemiol 2(1):1–11
38. World Health Organization (2012) Environmental health, inequalities in Europe. *WHO Regional Office for Europe*, Denmark
39. Yilmaz G, Hocanli Y (2006) Mapping of noise by using GIS in Şanliurfa. Environ Monit Assess 121(1):103–108
40. Zannin PHT, Diniz FB, Barbosa WA (2002) Environmental noise pollution in the city of Curitiba, Brazil. Appl Acoust 63(4):351–358

# Figures

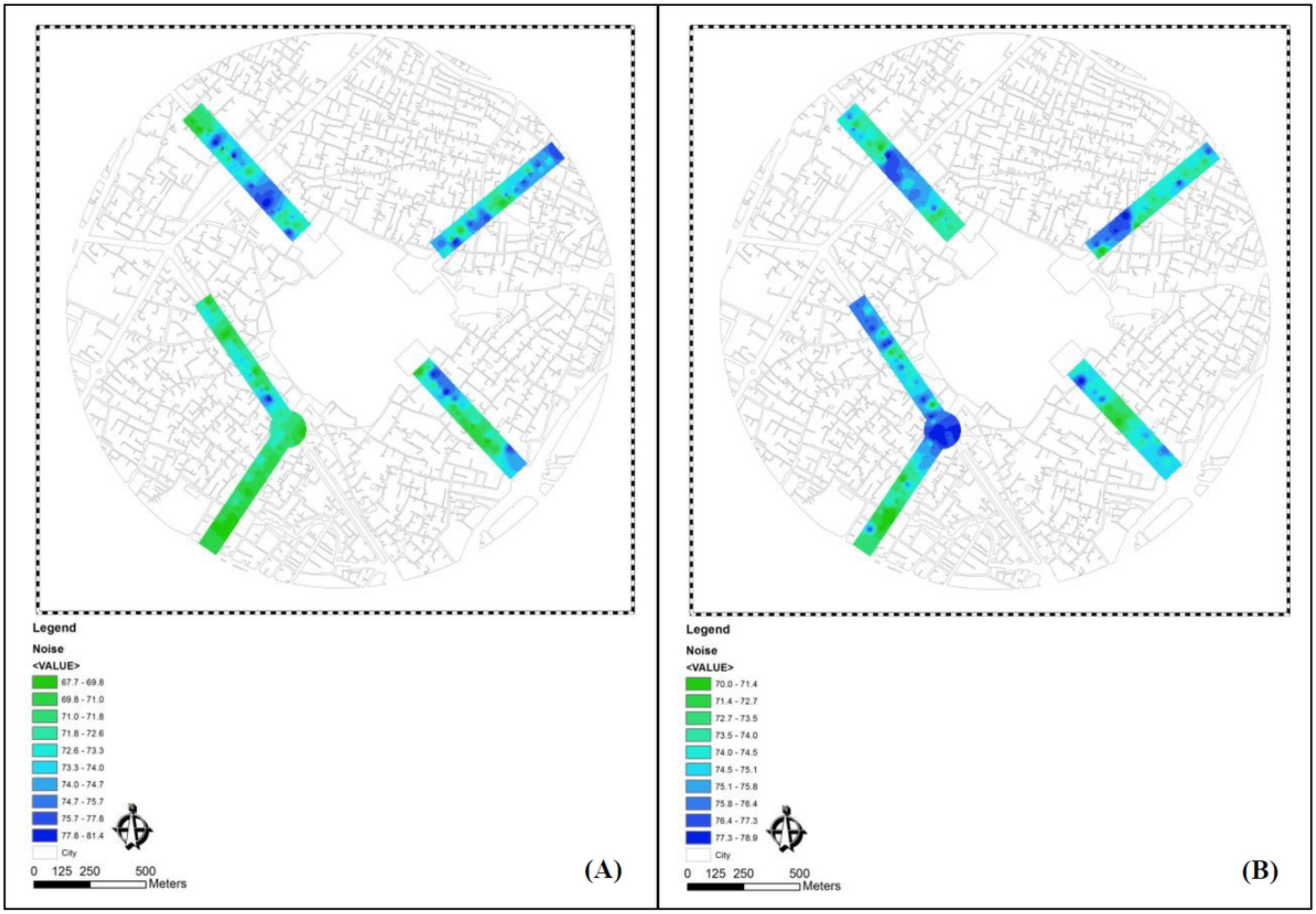

## Figure 1

The place of the latitudinal and longitudinal stations of the streets leading to the Holy Shrine of Imam Reza.



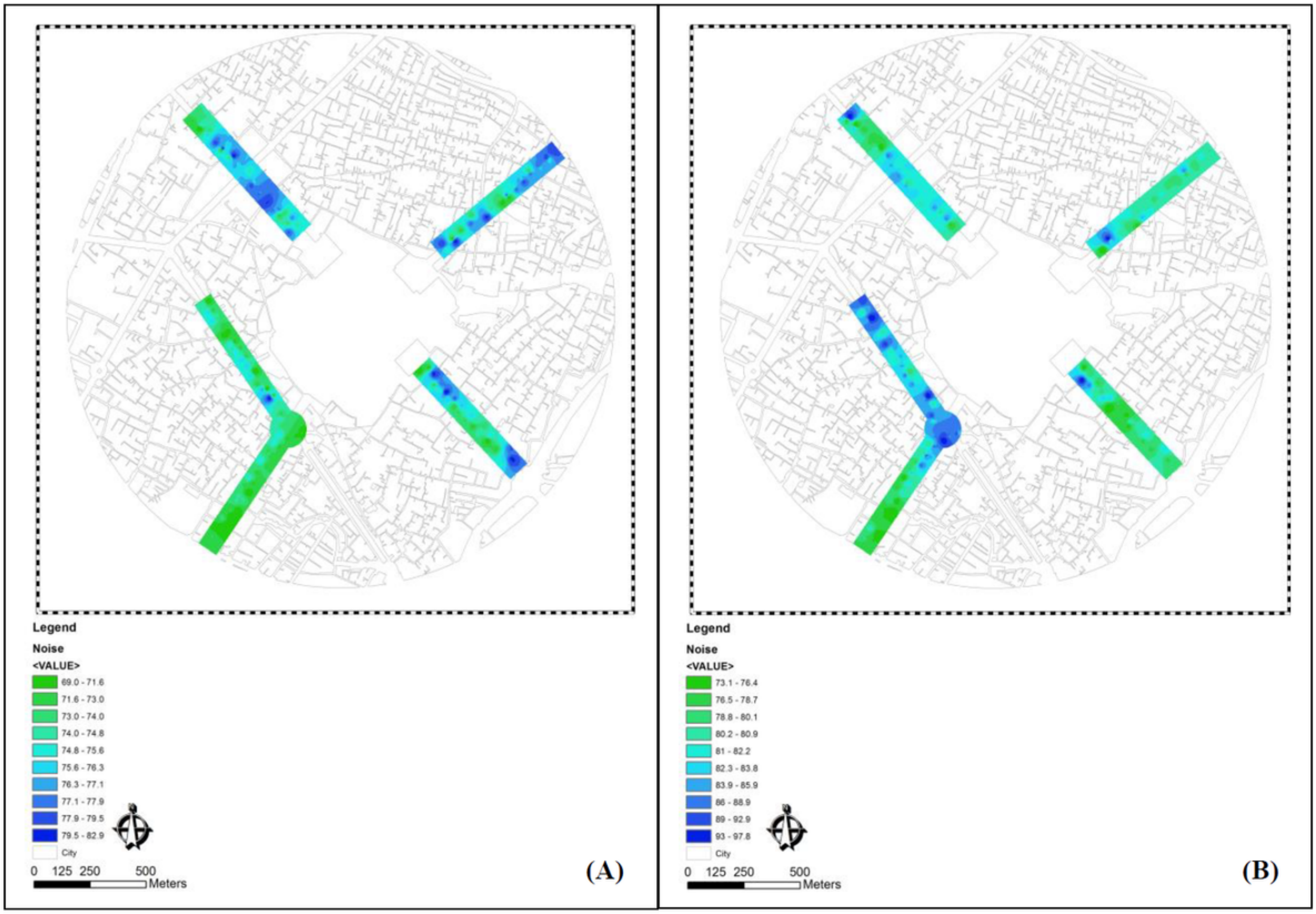

## Figure 2

Mapping of the distribution of noise pollution in the streets leading to the Holy Shrine (A) the mean of the recorded data in morning samples (B) The mean of the recorded data in evening samples.



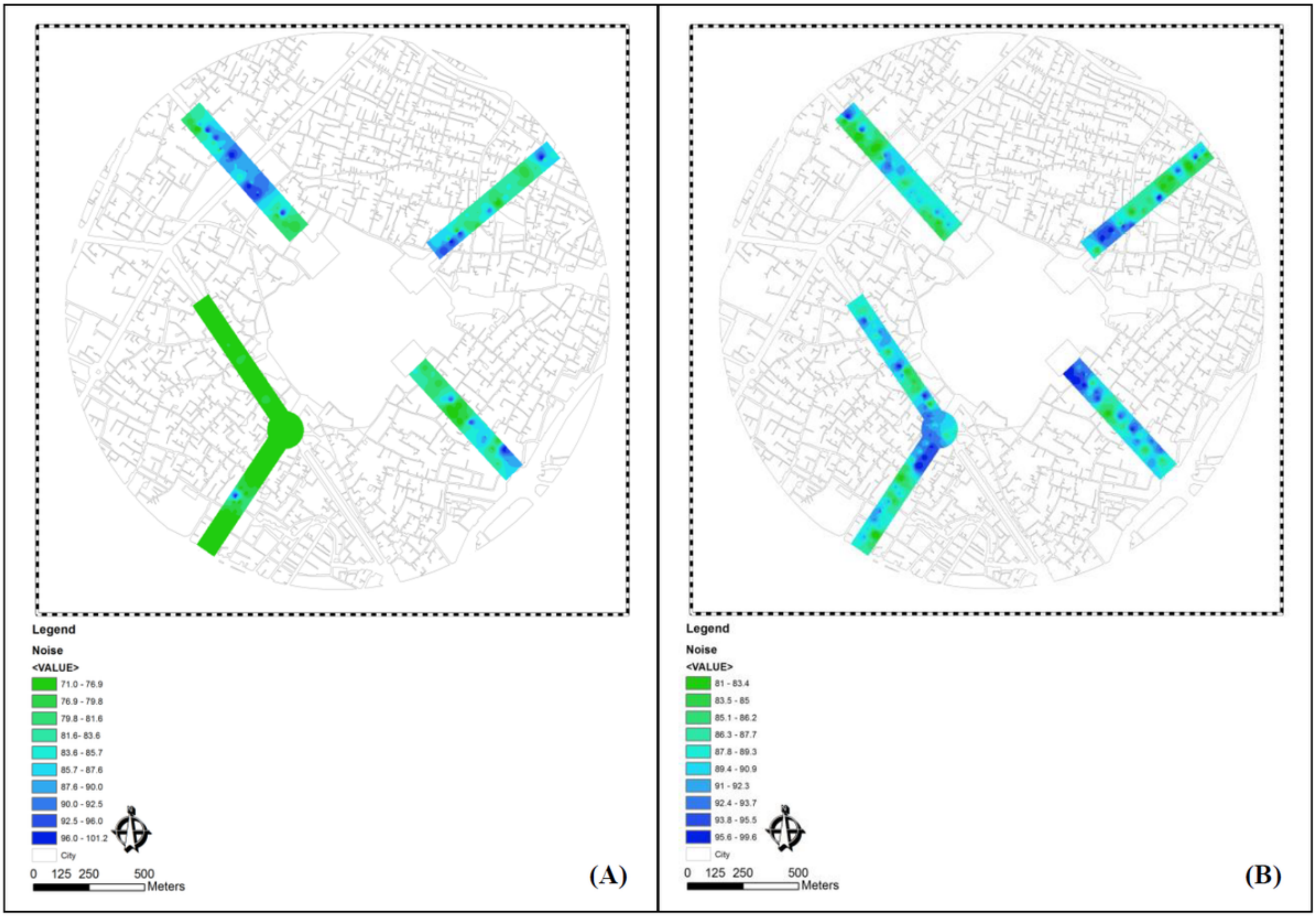

## Figure 3

Mapping of the distribution of noise pollution in the streets leading to the Holy Shrine (A) the minimum of the recorded data in morning samples (B) The mean of the recorded data in evening samples.



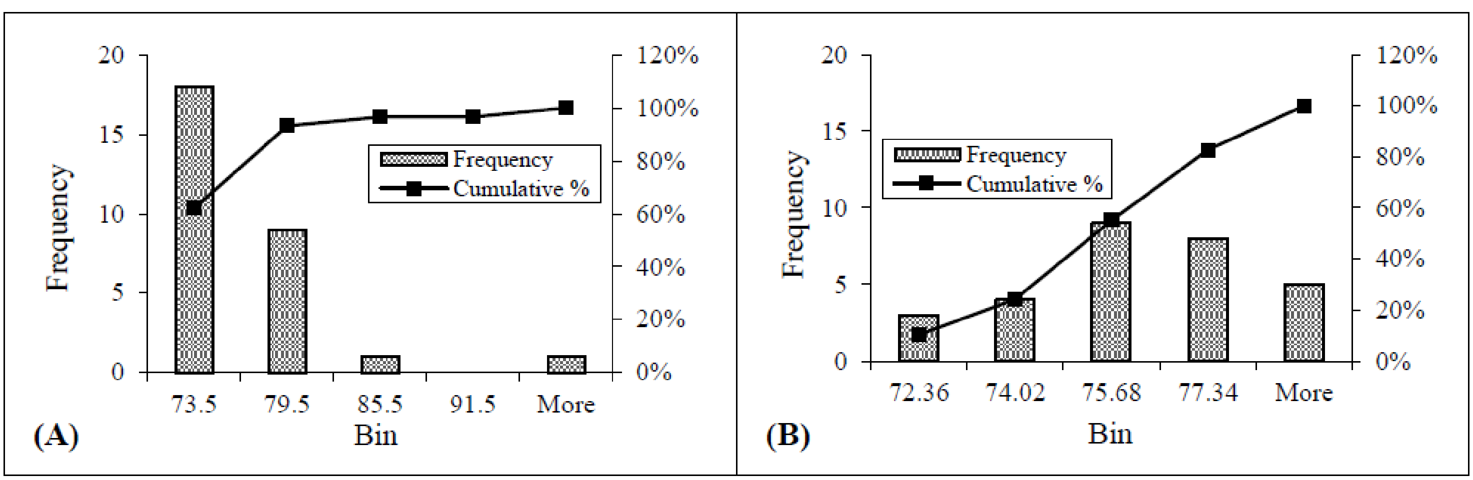

## Figure 4

Mapping of the distribution of noise pollution in the streets leading to the Holy Shrine (A) the maximum of the recorded data in morning samples (B) The mean of the recorded data in evening samples.




## Figure 5

Mapping of the distribution of noise pollution in the streets leading to the Holy Shrine (A) the absolute minimum of the recorded data in morning samples (B) The mean of the recorded data in evening samples.




## Figure 6

The histogram of the mean of noise pollution data of Khosravi street (A) in the morning time span and (B) in the evening time span.

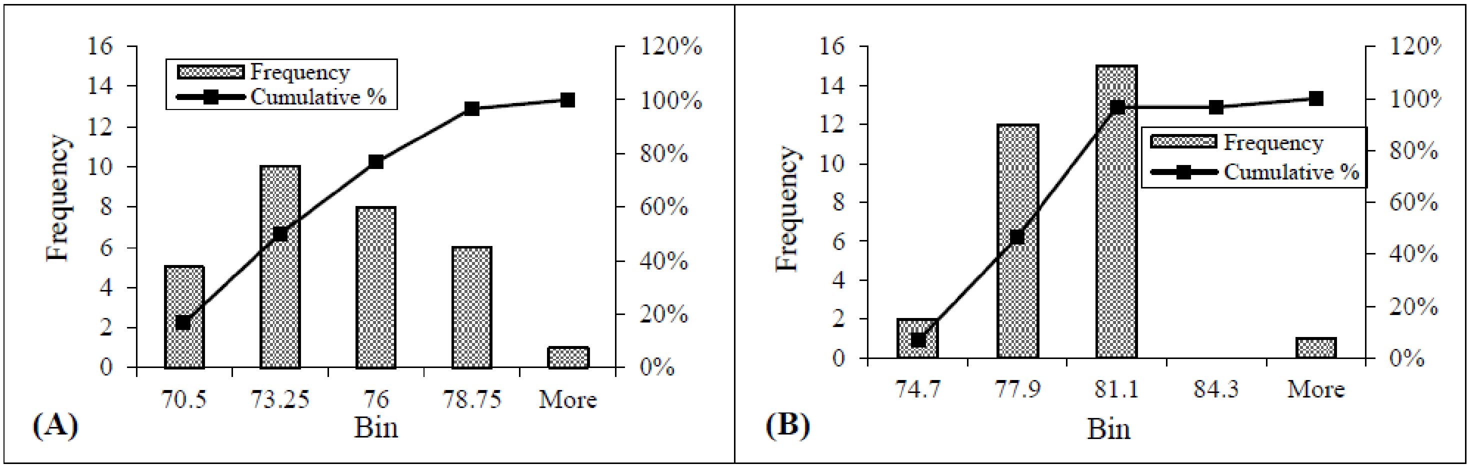



**Figure 7**

The histogram of the frequency of noise pollution data in Tabarsi street (A) in the morning time span and (B) in the evening time span.

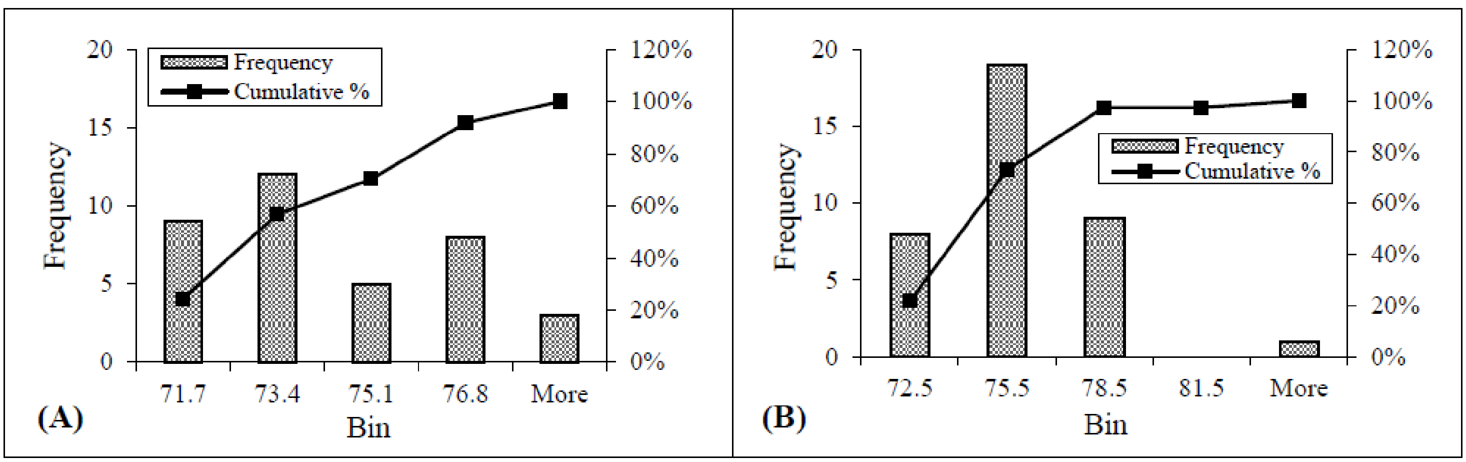
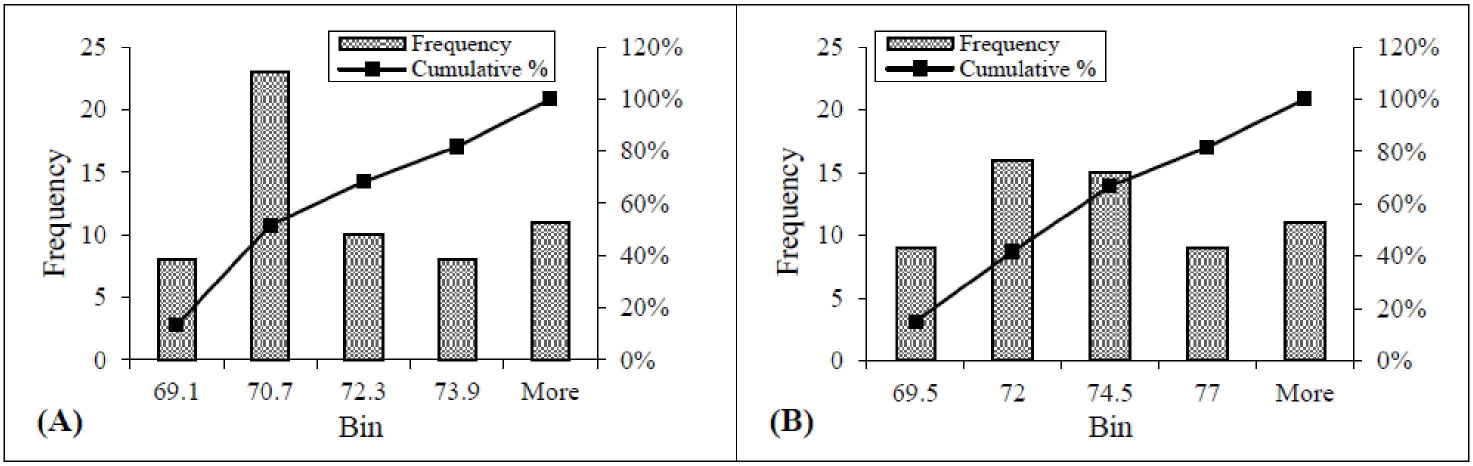


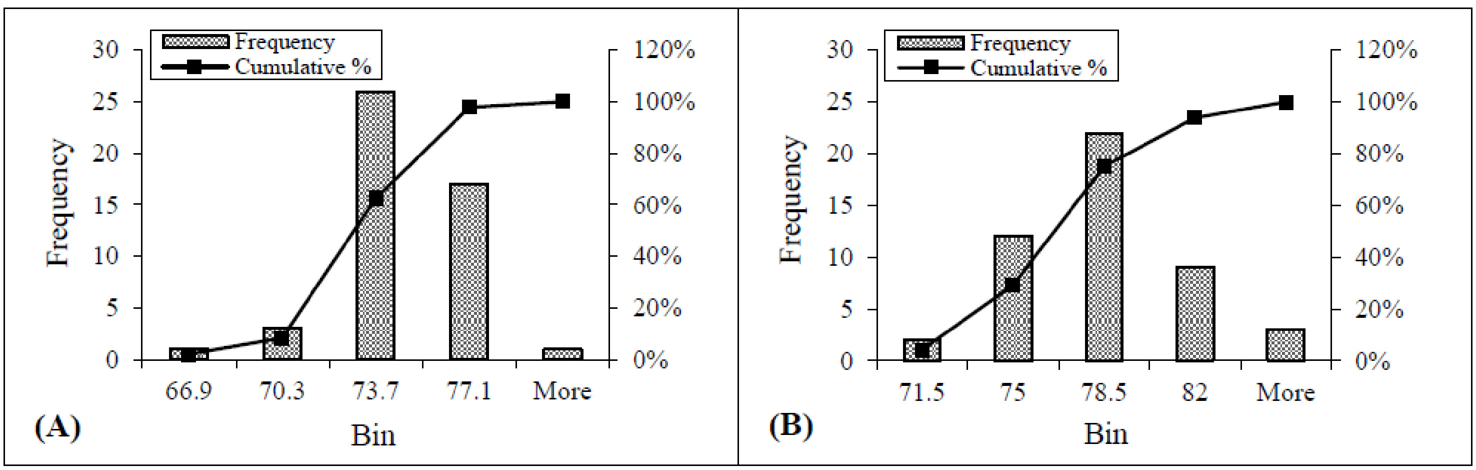

**Figure 8**

The distribution of the histogram of the frequency of the average of noise pollution data of Navab Safavi street (A) in morning time span and (B) in evening time span.




## Figure 9

The distribution of the histogram of the frequency of the average of noise pollution data of Imam Reza street (A) in morning time span and (B) in evening time span.




## Figure 10

The histogram of the frequency of the average of noise pollution data of Shirazi street (A) in morning time span and (B) in evening time span.