

## Urban Design

# Soundscape quality assessment in Naghshe Jahan square

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### Abstract

Sound, as a non-visual component of landscape, has a significant impact on an individual's perception of space. Lack of attention to quality of the sounds emitted in the environment may lead to problems such as noise pollution, lack of concentration, noise annoyance, disturbance and lack of privacy when people have a conversation in the urban spaces. The aim of this study was to evaluate the quality of soundscape in Naghshe Jahan square. The lead question of the study was: 'How is the sonic quality at different areas according to the sound maps?' To answer this, soundwalk and in-situ sound assessment methods were adopted to determine people's perception about pleasantness of sounds and physical quality of soundscape. Indicators of  $L_{Aeq}$  and  $L_{den}$  were evaluated via St-8851 Sound Level Meter. Field sound metering was done. In order to cover all noise events and acoustic conditions, three temporal frames - day time (07-19), evening (19-22), night (22-07) - were selected. All field studies were done in winter of 2016. Collected data were entered into the GIS map, and noise maps were produced. Results from the questionnaires showed that the most unpleasant sounds were motorcycles, cars, and handcarts, and the most pleasant one was the water sound. Results showed that in some locations such as around the central fountain, entrance of Qeysariyyeh Bazaar, the loop between Sepah and Hafez St., and the horse carriage path, the mean overall  $L_{den}$  is higher than the standard levels of noise - 55 dB (A) - for urban spaces and they need to be controlled and reduced to standard levels.

**Keywords:** Soundscape, Sonic pleasure, Noise map,  $L_{den}$ , Naghshe Jahan square.

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## 1. INTRODUCTION

Urban open public spaces are important components of modern cities. The evaluation and design of an urban open public space is no longer visually dominant [1]. Past studies on environmental quality in urban spaces focused on spatial form and visual aesthetics, but these studies were flawed due to inadequate attention to sonic elements [2]. However, perception of environment is multi-sensory and visual and audio aspects are of the greatest importance [3]. There is a new trend of considering the soundscape as an integral part of landscape studies that highlights the importance of soundscape quality [4-6]. Environmental sounds, like the sound of road traffic, nature, or people, are meaningful and provide information. Some sounds have a positive impact, whereas others have a negative meaning or character, regardless of their sound levels [7]. In the case of poor acoustic quality, and noise pollution to be

exact, and weak management, planning, and designing, problems in physical and psychological health will ensue. The negative effects of noise pollution on health engenders hearing impairment, lessens speech communication, causes cardiovascular risk and sleep disturbance, has deteriorating effects on psychological state and performance, and enhances the feel of annoyance [8]. This is why the study of soundscape quality comes to be important. It should be noticed that, apart from noise reduction, soundscape and acoustic research concentrates on how people consciously perceive their environment, that is the interactions between people and sounds [1]. In this regard, assessing the soundscape quality of Naghshe-Jahan square as a historical and cultural heritage that hosts tourists from all over the world, is essential. Assessing and producing the noise map can represent acoustic quality of sonic ambience, and it can determine the unauthorized amount of noise. Drawing up the noise map can be a notable step in noise control strategies and policies. Qualitative assessments of people's perception of pleasant and unpleasant sounds can help us to know what sounds we are going to reduce or reinforce in a sonic ambient. In

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this regard, the study aims to evaluate the soundscape quality of Naghshe-Jahan square. The questions raised in this study are as follows: (1) What are the minimums and maximums of sound levels in various temporal frames? (2) How is the sonic quality at different areas according to the noise maps? (3) What were the pleasant and unpleasant sounds?

### 1.1. Urban soundscape

Although the concept of "Soundscape" is originally rooted in the music and acoustic ecology research areas, it has quickly expanded to other disciplines such as acoustics, architecture and environmental studies, etc [9]. Schafer in his first book *The Tuning of the World* first used the word "Soundscape" for the acoustic features of landscape. Schafer defined soundscape as the impacts of sonic ambience on the physical or behavioral responses of the living organisms [10]. After Schafer's contribution to the field, Southworth expanded the concept to the cities and constructed environments [11]. The chief notion in soundscape, is an individual's, or society's, perception and understanding of the acoustic environment [12-13]. As a part of landscape, various authors have defined the soundscape as the auditory equivalent of landscape [10, 14-19]. In this regard, Brown (2012) has defined the soundscape as "The acoustic environment of a place, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors [19]. As defined by Payne [20], "Soundscapes are the totality of all sounds within a location with an emphasis on the relationship between individual's or society's perception of, understanding of and interaction with the sonic environment"[20]. In spite of the key common aspects in various definitions of the soundscape, there was no common definition adopted before the definition of ISO: "The acoustic environment as perceived or expressed and/or understood by a person or people, in context" [21]. Still the definition does not include the objects heard or the sources of the sounds. In his recent work, Farina (2014) has given a classification of sounds according to their sources: Biophonies (emerging nonhuman sound produced by living organisms in a given biome [22]); Geophonies (represented by all the sounds produced by non-biological natural agents such as wind, volcanoes, sea waves, running water, rain, thunderstorms, lightning, avalanches, earthquakes, and floods, and represent the sonic background with which other sounds can overlap, mix, or mask); Anthrophonies (the anthrophonies are the results of the movements of artificial devices such as cars, trains, airplanes, industrial machinery, and bells) [8].

### 2.1. Soundscape Evaluation

Gozalo et al (2015) have mentioned 3 approaches to the study of acoustic environment: (1) Physical approach that aims at the objective evaluation of the acoustic environment and its comparison with certain reference values of sound levels ( $L_{eq}$ ,  $L_{Aeq}$ ). (2) Psychophysical approach is aimed at studying the relationship between

the sound environment and human sensations. For instance "Sound level" is enriched with a subjective contribution (in terms of annoyance, unpleasantness, disturbance, etc.). And (3) Perceptual approach that aims at identifying and describing the bases of the psychological processes that underlie people's appraisal of sound [23]. In line with these approaches, 4 methods of soundscape assessment can be considered: (1) Sound walks, (2) Laboratory experiments, (3) Narrative interviews, and (4) Behavioral observations [7].

Aletta et al (2016) after a far-reaching literature review, have classified soundscapes descriptors as: (1) Noise annoyance, (2) Pleasantness, (3) Quietness or Tranquility, (4) Music-likeness, (5) Perceived affective quality (can include number 4 above), (6) Restoriveness, (7) Soundscape quality, and they have added (8) Appropriateness.

Soundscape indicators are measures used to predict the value of a soundscape descriptor and can be qualitative or quantitative.

## 2. METHODOLOGICAL BACKGROUND

In the last decades, many studies have been conducted in the field of soundscape evaluation, and the relevant standards of sound level have been established. US Environmental Protection Agency has recommended a maximum outdoor noise level of 55 dB for intelligible communication [24]. Many European countries have introduced a legislation about permitted noise level in urban areas that is obviously less than the permitted noise level introduced by Britain (68 dB (A) for 18 h of exposer). Of these, Netherland and Denmark have adopted a standard level of 55 dB (A) eq/ 12 h [25]. Researches showed that noise levels more than 55 dB can cause annoyance [26]. Some studies have focused on these standards, and have made evaluations to clarify the difference between the actual and the standard values. While others have considered the pleasantness for people, as well. Lam et al (2005) have evaluated the soundscape quality of urban parks in Hong Kong. The methods used included laboratory experiments and soundwalk, and the index adopted for describing the quality of soundscape was  $L_{Aeq}$  [27]. In their study, Kang & Zhang (2010) have assessed the soundscape quality in urban open public spaces. Their study includes 3 main stages: pilot study, detailed soundscape evaluation, and comparative assessment. The main method was on-site study that included soundwalk and interviews, as well as laboratory experiments. Semantic differential scales and the indexes of  $L_{eq}$ ,  $L_{eq,90}$ ,  $L_{eq,50}$ , and  $L_{eq,10}$  were assessed through these methods [1]. Brambilla et al. (2013) have assessed the soundscape quality of urban parks in Milan, Italy, via different sonic measures including  $L_{Aeq}$  [28]. The other study that addressed the environmental noise was King et al. (2012) study that assessed SPL,  $L_{Aeq}$ , and  $L_{den}$  in two neighborhoods, first a residential land use area, and second a mixed-use area, each divided by a grid into six identical cells. A Centre 322 logging Sound Level Meter (SLM) and a Marantz PMD-660 Solid State Digital Recorder were

used in this research. Results showed significant variability in noise within the studied areas, and significantly higher levels of environmental noise in the mixed-use area [29]. In another study, different urban acoustic environments were evaluated based on 31 recordings obtained using binaural techniques of recording and reproduction. The relationships of the perception of pleasantness/unpleasantness of these urban environments with two psychoacoustic magnitudes (loudness and sharpness) and two traditional magnitudes (equivalent sound level in dB,  $L_{eq}$  and equivalent sound level in dBA,  $L_{Aeq}$ ) were analyzed [23].

Another study that stands for psychophysics approach, is Bahali & Tamer-Bayazit (2017) study. In this study, soundscape research was designed and applied in practice, regarding the Gezi Park-Tunel Square route, specially at key locations such as Gezi park, Taksim square, Galatasary square, and Tunel square. Soundwalks were applied in the fields being studied, with silent walk along the route, and, after the walk, questions about the soundscape characteristics of the route and its perceptual features were answered by participants. In order to find out the perceived soundscape characteristics of the four key locations, and factors that affect soundscape classification along the route, subjective parameters and psychoacoustic parameters obtained via binaural recordings and post-signal analysis were compared with regard to their effects on soundscapes

[30]. There are different measures to evaluate the sonic ambience of the environment, but according to the purpose of the study, researchers may choose one or more. Craig et al. (2016) introduced a new tool for sampling the sonic experiences. They have used an application that installs on the smart phone to assess the soundscape experience. The application allows the collection and assessment of soundscape using the provided set of response questions, and exploiting the native audio recording application on a GPS-enabled smart phone. Participants were asked to download the mobile application for their respective device from the relevant app store. As this study followed an event-contingent ESM protocol, participants were asked to submit a response whenever they encountered a sound which had affected them in some way whether that was a sound that was out of the ordinary or not part of their daily routine, and either positive or negative. This approach enabled the assessment of rare or specialized occurrences that would not normally be captured by fixed or random interval assessments. Participants were encouraged to submit any number of sound occurrences during the 14-day study period. At each sound event, they were asked to make a short recording of the experience (around 30 s) to accompany their responses, and complete the questionnaire about the situation and the sound event itself [31]. Table 1 shows some of the studies in the field of soundscape evaluation in brief.

**Table 1** Studies conducted in different locations

	Study area	method	measures	Similarities with present study
Lam et al (2005) [27]	Urban parks in Hong Kong	Laboratory experiment	$L_{Aeq}$	Using the $L_{Aeq}$ index
Nilsson (2007) [32]	Sweden urban parks	Laboratory experiment, soundwalk	$L_{Aeq}$ in 15 min time frames	Using the $L_{Aeq}$ index Using 5scale questionnaires after Soundwalks
Jakovljevic (2009) [33]	Belgrade	Laboratory experiment, soundwalk	$L_{Aeq}$ , $L_{max}$ , $L_{day}$ , $L_{evening}$ , $L_{night}$ , $L_{max}$ , $L_{den}$	Using the $L_{Aeq}$ , $L_{den}$ index Using scaled questionnaires after Soundwalks
Weber & Luzzi (2010) [34]	Florence and Rotterdam	Laboratory experiment, narrative interview	$L_{Aeq}$ , noise map, Auditory records	Interviews Using the $L_{Aeq}$ index
Kang & Zhang (2010) [1]	Urban open public spaces	Laboratory experiment, soundwalk, narrative interview	$Leq$ , $Leq90$ , $Leq50$ , $Leq10$	Questionnaire and interviews Using the $L_{Aeq}$ index Using 5scale questionnaires after Soundwalks
Blanco et al (2012) [35]	Plaza Neuva in Bilbao	Laboratory experiment, narrative interview	$L_{Aeq}$ , $L_{A90}$ , $L_{A50}$ , $L_{A10}$ , $L_{min}$ , $L_{max}$	Questionnaire about perceived quality of soundscape Using the $L_{Aeq}$ index Using questionnaires after Soundwalks
Brambilla et al (2013) [28]	5 urban parks in Milan	Laboratory experiment, narrative interview	$L_{Aeq}$ , 1/3 octave spectrum, $L_{A95}$ , $L_{A90}$ , $L_{A50}$ , $L_{A10}$	Questionnaire about perceived quality of soundscape with a 5degree scale Using the $L_{Aeq}$ index Using 5scale questionnaires after Soundwalks
Asdrubali et al (2013) [36]	Urban parks in Rome	Laboratory experiment, soundwalk	$L_{Aeq}$ , $L_{A90}$ , $L_{A95}$ , $L_{A50}$ , $L_{A10}$ , $L_{min}$ , $L_{max}$ , 1/3 octave spectrum	Interviews, soundscape pleasantness. Questionnaire with a 10 degree scale Using the $L_{Aeq}$ index Using scaled questionnaires after Soundwalks

Filipan (2014) [37]	Antwerp parks	Laboratory experiment	$L_{Aeq}$ , $L_{A90}$ , $L_{A50}$ , $L_{A10}$ , $L_{Ceq}$ in 15 min records	-	Using the LAeq index
Gozalo (2015) [23]	Urban acoustic environment	Laboratory experiment, soundwalk	$L_{eq}$ , $L_{Aeq}$	Loudness, sharpness	Using the LAeq index
Bahali & Tamer- Bayazit (2017) [30]	Gezi Park-Tunel Square route	soundwalk		Pleasantness	Using scaled questionnaires after soundwalks
Summary	After a review of the literature, based on the purpose of the study, methods of laboratory experiments and soundwalk, as well as measures of $L_{Aeq}$ and $L_{den}$ were selected to be used in this study.				

### 3. METHODS AND MATERIALS

The purpose of this study is to assess the quality of soundscape in Naghshe-Jahan square, in Isfahan, Iran. Research includes two main steps: (1) Subjective assessment, and (2) Objective assessment. The psychophysical approach and methods of soundwalk and laboratory experiment were adopted for the research.

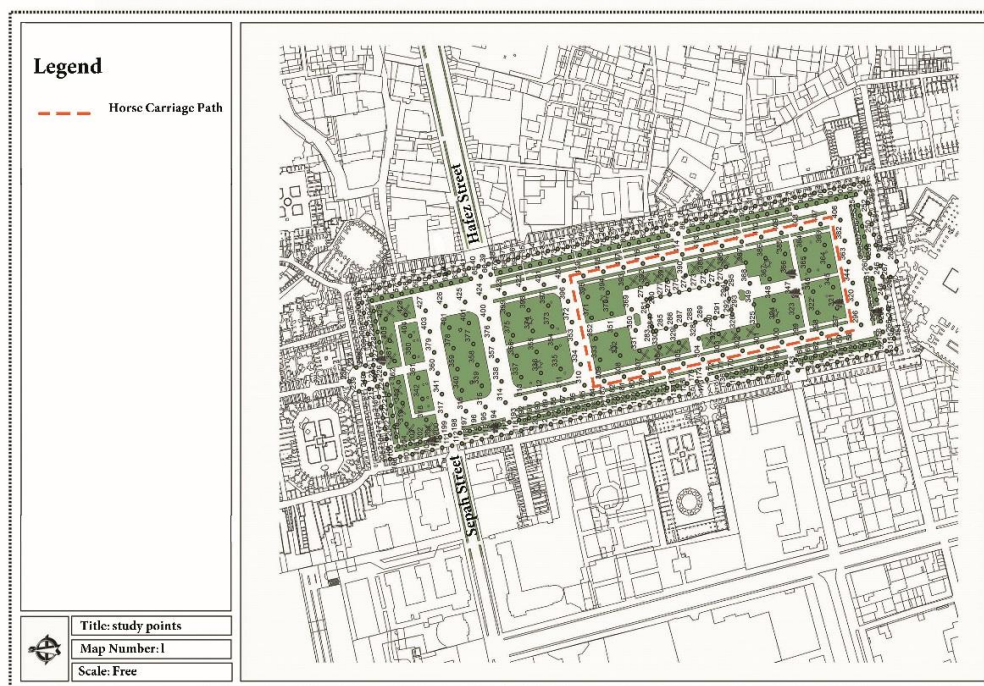
#### 3.1. Subjective assessment

In this phase, researchers conducted different soundwalks to identify all the potential sound sources from 3 categories of anthrophony, biophony, and geophony during autumn and winter. Different records were provided from different areas of the square during the soundwalks. The identified sources are shown in Table 2.

The questionnaire for subjective evaluation was built upon these identified sources. The study population included all of the people who were visiting the square or were present for different reasons (shop keepers, tourists, and city people) from which 385 people were chosen randomly, in accordance with the sampling formula for undefined numbers of study population [38], as the study samples to do the soundwalks and to answer the questionnaires at the end of soundwalks. The passes of soundwalks were undefined to make the individuals free to step in wherever they want. People (age range of 15-65) were asked to evaluate the pleasantness of the sound sources on a 5-score scale (very unpleasant: -2, unpleasant: -1, non: 0, pleasant: 1, very pleasant: 2). To evaluate the validity of questionnaires the Alpha Cronbach test was done and it showed a relatively good validity of 0/805.

**Table 2** Sounds heard in Naghshe-Jahan square

Anthrophonies	Biophonies	Geophonies
children playing, footsteps, conversation, Azaan (a religious sound emitted from mosques three times a day), sellers, activities such as chisel works, horse carriages, handcart, bicycle, motorcycle and other vehicles, airplanes, camera flash, video and audio devices, outdoor equipment (air conditioner, fan,...), cellphone ringtones, music played via mp3 player or smart phones, hawkers, and people singing.	Birds, horses, cats, insects	Wind, rain, thunder, fountains



**Fig. 1** Study area

### 3.2. Objective assessment

Most of soundscape studies have utilized  $L_{Aeq}$  measure. In this study, in order to evaluate the dynamic nature of soundscape, the measure of  $L_{den}$  was used. Evaluation was conducted in 3 temporal frameworks: day time (07-19), evening (19-22), night (22-07). Sonic field study was conducted in winter, 2016. A St-8851 sound level meter was used, after calibration, to gather data. In various studies that have been conducted in urban open spaces, usually spots close to sound sources are selected by researchers. In this study, a network of points, 10-meter intervals in 2 depths near the walls and around the fountains, and 20-meter intervals in the inner space were evaluated. 429 points were selected. The spots are shown in Fig. 1. The time period of each sound evaluation at each point was 5 minutes. Capture speed was 0/5 S, it means every 0/5 second the value of sonic environment was captured. The average amount of values for

each point was calculated from which the interpolation sonic maps were produced.

### 4. FINDING

Findings will be analyzed in two parts, and then the integrated result of the psychophysical study of the soundscape of Naghshe-Jahan square will be presented.

*Qualitative assessment:* To understand people's perception of sound source pleasantness, the average scores of questionnaire responses were calculated. Results from the questionnaires determined the pleasant and unpleasant sounds. As seen in Table 3, the most pleasant sounds were Fountains (1/34) and Birds (0/85). And the most unpleasant sounds were motorcycles and cars (-1/28), and outdoor equipment (-0/79). On average, the observation was that natural sounds were pleasant, and anthroponies produced by technical devices were unpleasant.

**Table 3** Perceived quality of sounds

Sound	Scale					Average Score
	Very unpleasant	Unpleasant	Neutral	Pleasant	Very pleasant	
Birds				█		0/85
Horses				█		0/79
Cat and other animals		█				-0/04
Insects		█				-0/06
Wind				█		0/19
Rain					█	1/11
Thunder				█		0/44
Fountains					█	1/34
Playing children				█		0/48
Footsteps				█		0/37
Conversation				█		0/1
Azaan				█		0/66
Sellers		█				-0/23
Activities such as artistic metalworking				█		0/67
Horse carriages				█		0/84
Handcart		█				-0/34
Bicycle				█		0/21
Motorcycles and cars	█					-1/28
Airplanes		█				-0/62
Camera flash				█		0/17
Music played via mp3 player or smart phones, cellphone ringtones		█				-0/31
Video and audio devices						-0/3
Outdoor equipment (air conditioner, fan...)		█				-0/79
Hawkers and singing people				█		0/77

*Quantitative assessment:* In order to analyze the collected sonic data, average amounts of  $L_{Aeq}$  and SPL were entered into the GIS software via exact coordinates of points, and sonic maps were produced and then compared with permissible amounts of noise in urban spaces.

Day Time: According to Fig. 2, the lowest and highest  $L_{Aeq}$  are 42 and 64 dB (A), respectively. The color range

from red to pink indicates high levels of environmental noise. And the color range from yellow to green shows the low levels of  $L_{Aeq}$ . According to Fig. 2, specific sonic zones can be recognized during the day time:

- ❖ The area around the central fountain:  $L_{Aeq}$  in this area is more than 55 dB (A) and less than 64 dB (A). As this amount is caused by the fountain, it is not regarded as



annoying by people. Water can make a continuous background noise that can mask other unwanted sounds.

- ❖ The entrance of Qeysariyyeh Bazaar: Due to the presence of a fountain in this area, and the high mobility of people (e.g. shop keepers and visitors), the noise level is high. The masking characteristic of the sound of the fountain partly masks the background noise, but the background noise level that is more than 55 dB (A) may cause annoyance. The unwanted sounds, like handcart' noise, should be controlled in this area.
- ❖ The path of horse carriages: Because of the sounds of horse bells, carriages, and hooves hitting on the pavement, noise of motorcycles and passing cars, such as police cars, in this area,  $L_{aeq}$  is high. But the sound of horse carriages and related sounds were not annoying for the people. Just the noise events such as motorcycles, cars and handcarts were annoying for the people. These sonic events should be mitigated and controlled.

- ❖ The paved loop between Hafez and Sepah streets: the transfer loop between Hafez Street and Sepah Street showed a high amount of  $L_{aeq}$  at some points. This is due to the noise events from passing motorcycles, vehicles and handcarts.
- ❖ The north-south axial pass of square is of high  $L_{aeq}$ , and this is a result of much pedestrian movement in this area.
- ❖ Frontage areas of shops on the sides: Despite the presence of shops, this area is quieter than the other areas and noise level is lower. One reason for this is the existence of pine trees and shrubs between the pavement near the walls and the horse carriage path, which propagates the sounds and acts as a noise barrier. Moreover, many of shops are closed in the morning (8:00-10:00).
- ❖ The other areas of square, such as the frontage of Emam mosque, are of low noise levels, and this indicates that people's movement in these parts is less.

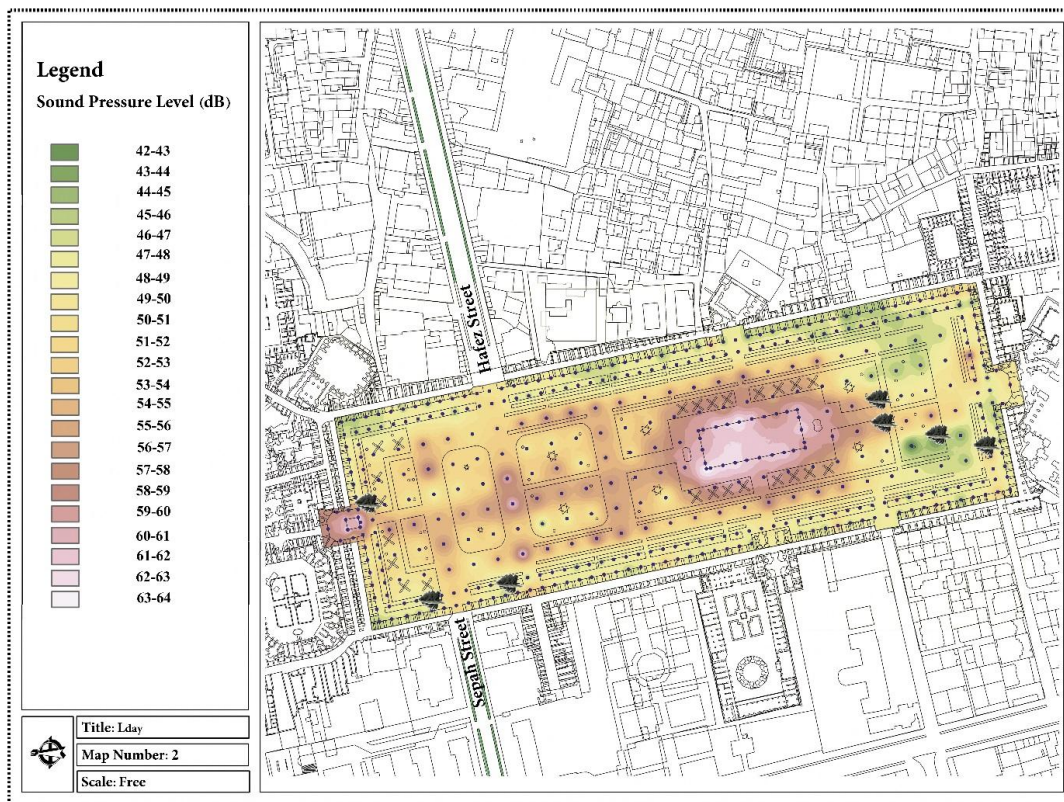


Fig. 2 Noise map of day time (07:00-19:00)

**Evening Time:** According to Fig. 3, it is clear that  $L_{aeq}$  in the evening time is between 46 and 68 dB (A). Pink and red color ranges indicate high, and green and yellow color ranges show low levels of environmental noise. With regard to evening time noise map, sonic zones can be identified as follows:

- ❖ The area around central fountain:  $L_{aeq}$  in this area is more than the permissible 55 dB (A), and is around 66 dB (A). This amount results from different sound sources such as people's conversations, footsteps, fountain, playing children. The fountain sound masks other sounds. Hence the masking characteristic of the

fountain is an advantage. Although this amount of masking noise from the jet does not cause annoyance, it may disturb speech intelligibility.

- ❖ Entrance of Qeysariyyeh Bazaar: this area has a high level of  $L_{aeq}$  caused by more movement of people (including visitors, city residents buying goods, and shopkeepers), and the active jet. Conversation privacy and speech intelligibility is weak in this part, and despite the masking characteristic of the fountain, still the high amounts of noise may cause annoyance.
- ❖ Southern and eastern parts of the square: according to the map, eastern and southern parts are of high  $L_{aeq}$ ,

and this is because of the volume of people passing by in these areas. People visiting the mosque are the other reason of crowdedness at the frontage of the mosque during the evening.

- ❖ Northern and western pedestrian areas in the square: The western and the northern part of the square, except for the entrance of Qeysariyeh Bazar, are quieter than

other parts adjacent to the walls. In the middle part and near Sepah Street, Laeq is about 57 dB (A).

- ❖ Central parts of the square: The central part, including the horse carriage path and the paved loop between Sepah and Hafez streets, has an Laeq of 55-57 dB (A). During the evening, the distribution of sound sources is almost monotonous and this leads to approximately monotonous noise levels.

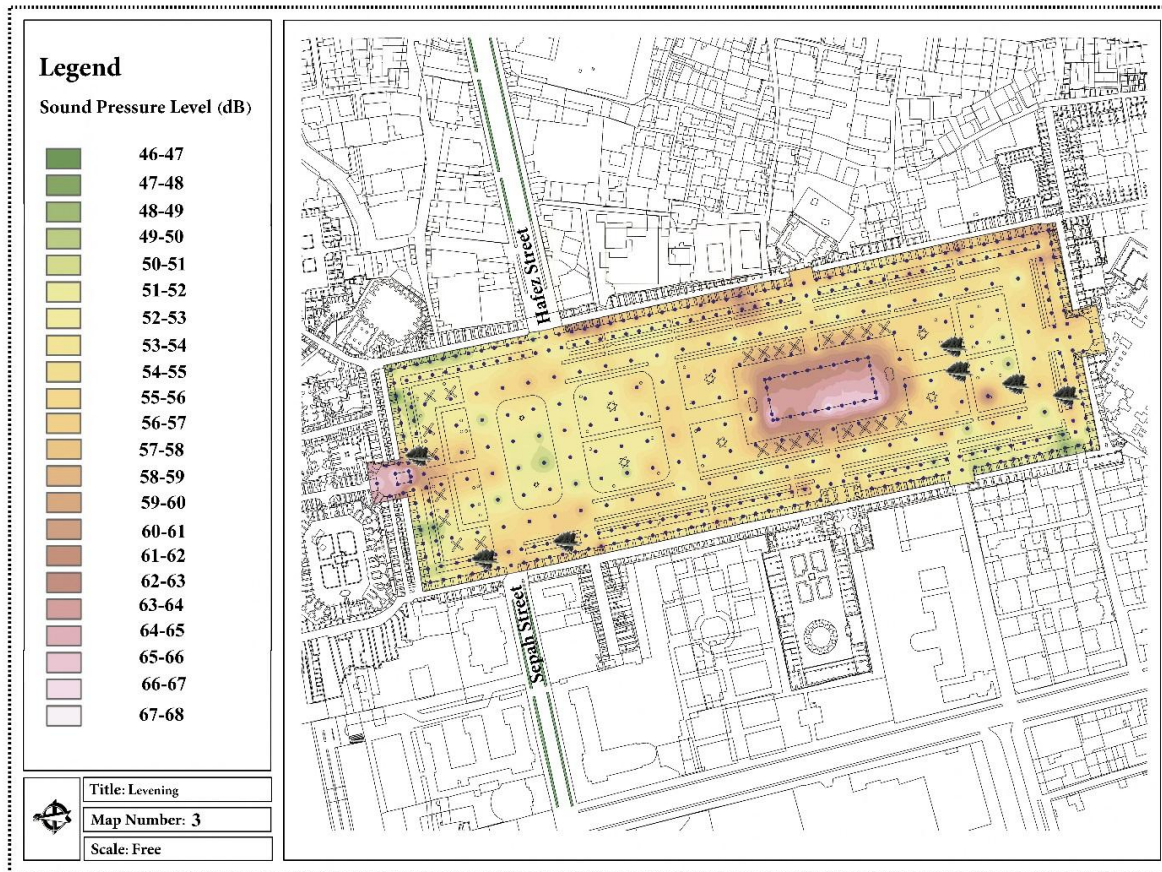


Fig. 3 Noise map of evening time (19:00-22:00)

**Night Time:** According to Fig. 4, it is clear that  $L_{aeq}$  is between 39 and 61 dB (A). Pink and red color ranges indicate high, and green and yellow color ranges indicate low levels of  $L_{aeq}$ . According to Fig. 4, sonic zones during night time (22:00-07:00) can be identified as follows:

- ❖ Northern area: As a result of the passing of some vehicles, including garbage trucks, motorcycles, and people passing through the loop between Sepah and Hafez streets, Laeq is higher than the southern area. Laeq is 50-61 dB (A).
- ❖ Western area of square: This area is quieter than other areas, and Laeq is 39-44 dB (A).
- ❖ Eastern area of square: Laeq in this area is 50-57 dB (A), and, compared with the western area, it is of higher levels of noise.
- ❖ Central part of square: This area includes the area around the central pool, and spaces on the map indicated in green shades. Spaces identifies with green shades of color that mainly include grassed areas, have a low Laeq of 39-43 dB (A). The inactivity of

fountains has caused the square to have a lower Laeq than other temporal frames. However, people mostly walk around the pool and the central parts of the square.

**$L_{den}$ :** It includes the  $L_{eq}$  of three temporal frames—daytime, evening and night time. According to Fig. 5, the minimum and the maximum value of  $L_{den}$  are 49 and 66 dB (A), respectively. Pink and red color ranges indicate high, and green and yellow color ranges indicate low levels of  $L_{den}$ .

According to Fig. 5, sonic zones can be recognized as follows:

- ❖ The area around the central pool: Despite the inactivity of the fountains during the night time, this area has a high Laeq about 62-65 dB (A). The evaluated amount is higher than 55 dB (A) in this area that may disturb conversation privacy and speech intelligibility. But, because it is mostly caused by the water sound, it may not be annoying.



- ❖ Entrance of Qeysariyyeh Bazaar: Laeq in this area was 62-67 dB (A). The high level of Laeq in this part is caused by the pedestrians, and also the existence of pool and fountain. Although the sound of fountain masks the other sounds, it may cause some annoyance for people.
- ❖ Transfer loop between Hafez and Sepah streets: Being the pass for the police cars, municipality vehicles, and

garbage trucs, this area has an Laeq of 60-64 dB (A). Noise events, including rushing motorcycles, handcart, bell-rings of bicycles, and cars, occur more frequently in this area than the other areas.

- ❖ Walls: The wall areas are quiet zones. Laeq is 49-60 dB (A). Just at the entrances of the square, Laeq is higher than 55 dB (A). However, walls are of acoustic comfort, and interference does not occur in conversations.

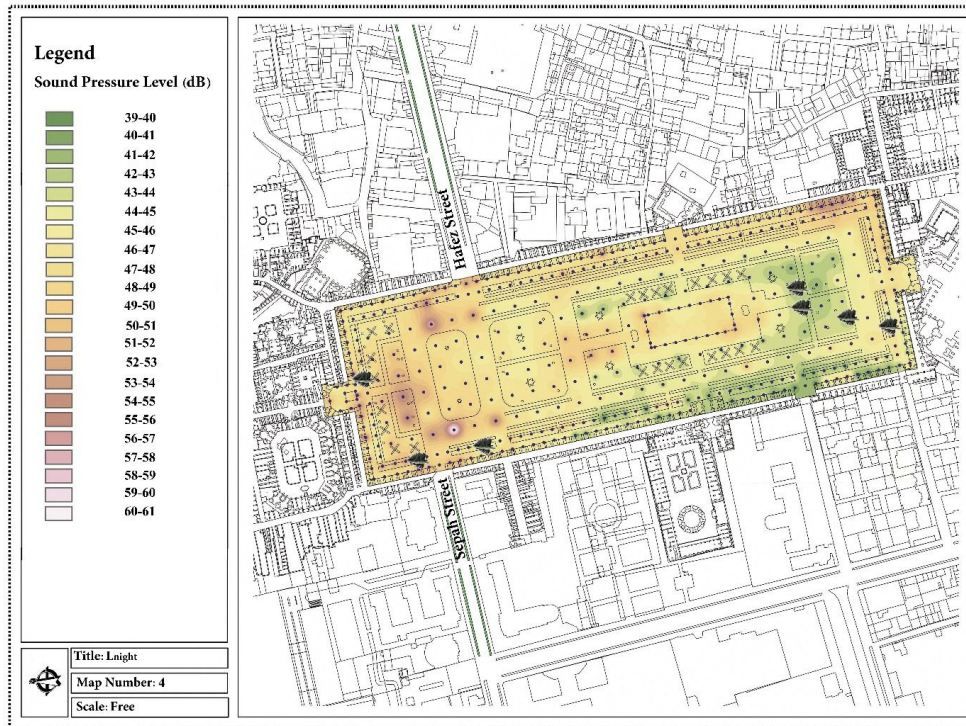


Fig. 4 Noise map of night time (22:00-07:00)

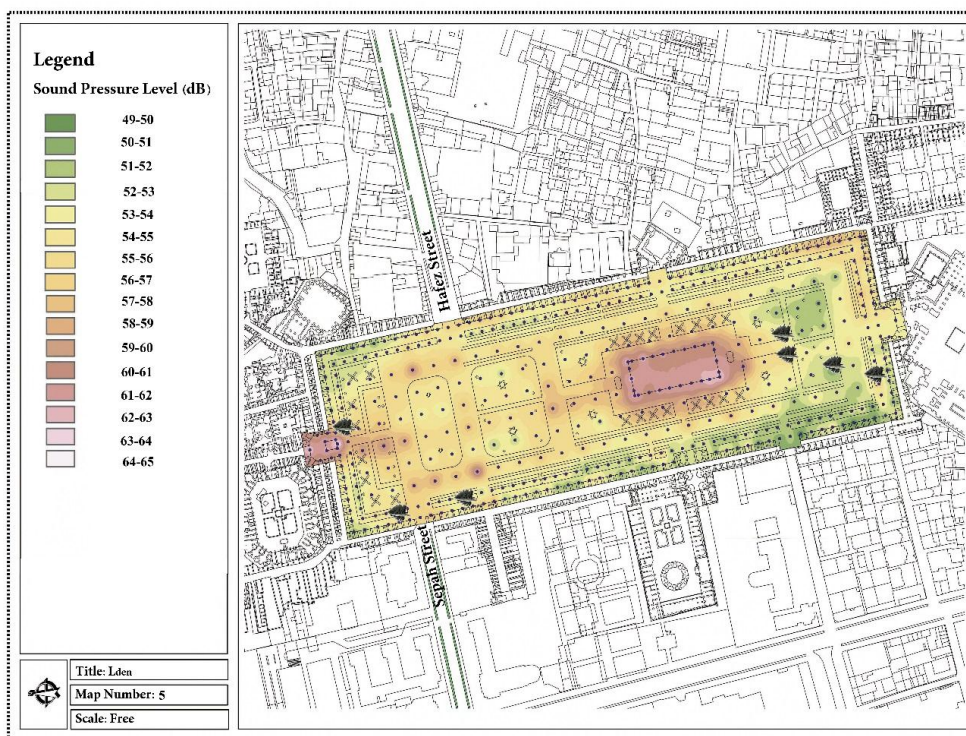


Fig. 5 Lden map



## 5. DISCUSSION

While the soundscape of a place is a perceived entity, soundscape management, soundscape planning, or soundscape design aims at management or manipulation of the acoustic environment of a place to change the way that its acoustic environment is perceived by humans [20]. This study aimed to assess the soundscape quality of Naghshe-Jahan square in Isfahan, Iran. In soundscape studies, different methods are used, such as soundwalks, laboratory experiments, simulations, interviews etc. In most of studies, methods for both understanding people's perception of sonic environment, like soundwalk and interviews, and for assessing the physical quality of sonic ambience, such as in-situ sound metering or simulation, and analysis of the field records, have been adopted to achieve a comprehensive assessment. One of these studies is Gozalo et al. (2015) research on urban acoustic environments. They have adopted laboratory experiments and soundwalk methods, and measures of  $L_{eq}$ ,  $L_{Aeq}$ , sharpness and loudness. These multi-method studies seem to give better evaluations of what we encounter with. Meanwhile, other studies relying on the purpose of the research may focus on a specific method, from among these the study by Bahali and Bayazit (2017) can be noted. They have used the soundwalk method and have assessed pleasantness of a route, including four sub-spaces, with regard to people's perception. It is clear that a mere people's perception assessment or in-situ evaluation cannot characterize the acoustic environment of a space. Only a study including both perception evaluation and assessment of physical situation of soundscape can demonstrate the perceptive/physical quality of a soundscape. This research is similar to the previous ones in terms of the adopted methods of soundwalk and laboratory experiment that characterize the soundscape quality of Naghshe-Jahan square. The difference, on the other hand, is how the physical quality of soundscape measure of  $L_{den}$  were analyzed based on values of  $L_{eq}$  that seem to better characterize the dynamic nature of an urban space soundscape, like an urban square. The other aspect of difference is the method of sampling the assessment points in a point-to-point way. In this study, due to the shorter intervals of the points (10 and 20 meters), accuracy of evaluation and monitoring has been boosted, and the sonic zones are displayed in Fig. 5. In previous studies, sampling was conducted randomly, while in this study a set of specific points with defined coordinates were chosen as study samples. In this way, the chance to capture most of sound events in a space increased and a more realistic evaluation was done. This point-to-point method can be useful in managing and redesigning the urban space, since it gives a clearer picture of sonic quality of the environment. To do this, in the present study the GIS software were used to visualize the sonic environment of the square so that captured values in 3 temporal frames turned into maps that can then get analyzed. Compared with other researches, such as the study conducted by Philipian et al (2014), in which points for SPL evaluation were erratic [27], in this study we have represented a

complete sound map, with definite sonic zones in relation with paths, activities and fixed and mobile sound potentials. In this regard, this study is more accurate. On the other hand, monitoring and assessment in 3 temporal frameworks have led to a relatively complete capturing of sound event changes during the study period. We chose the winter time for doing the evaluation because the maximum amount of site visiting by tourists takes place in this season and before Nowruz (the Iranian New Year). Also, this is the season when we could capture all of the sonic potentials like rain and thunder that may just happen at this time of the year. However, the sonic ambience of urban spaces needs to be monitored and evaluated on a long term basis. Although the study revealed the sound maps of the study area for a definite period of time, the question of how conversations or other sound sources, such as vehicles, can collectively and individually affect SPL and soundscape quality is a question for future studies to answer.

## 6. CONCLUSION

Soundscape, as an integral part of landscape, requires evaluation and management. Planning and designing of landscape in urban spaces is successful when the soundscape is considered in the context. Urban squares are of urban public open spaces that act as urban yards and a high-quality soundscape helps with a pleasant space. In this study we tried to analyze the soundscape quality of Naghshe-Jahan square. This study aimed to render a qualitative-quantitative assessment of sound in Naghshe Jahan square, and to produce place-based sound maps. 429 points were assessed in 3 temporal frames to make the  $L_{den}$  map. Assessing the  $L_{den}$  map revealed that the minimum value of  $L_{Aeq}$  was about 49 dB (A), and the maximum  $L_{Aeq}$  was 66 dB (A). Results of the qualitative assessment revealed people's perception of sound potentials, and pleasant and unpleasant sounds from which the sound of fountains, birds and horses were evaluated as pleasant and the sound of motorcycles, cars, and outdoor devices were evaluated as annoying by participants. This shows that people prefer to hear natural and biological sounds instead of technical and transportation-based sounds. Assessments of  $L_{eq}$  measure in 3 temporal frames demonstrated that the average equivalent values of sound pressure, in day time, from 7 am to 19 pm were higher than the other two frames. This is because of the intensity of activities and mobility caused by the activity of shops in the square in day time. Shops are closed at night time and fountains are off and this causes a lower sound pressure level in night time. Besides, a comparison of the 3 temporal frames, with different sonic zones in each frame, can be done in order to reach an aggregation of the sounds with high pressure levels. This makes the planning and management of sound sources possible. In 3 temporal frames, the path of horse carriages and motor vehicles are of high pressure levels, compared with other areas. In two frames of day time and evening time, the pressure level around the central fountain is higher than other areas, and this is

caused by the water sound. But in night time, these fountains are off and this makes a monotonous sonic environment.  $L_{den}$  map gives a 24 hour sonic pallet of space that can be used in redesigning and planning of Naghshe-Jahan square space. In view of the fact that this square is a historical site where physical changes are restricted, any radical change in the physical space is impossible. But some suggestions can be made for redesigning the non-historic elements. These suggestions are as follows:

- Management and control of motor vehicle movements, for instance, a restriction on motorcycle and car transportation.
- Insulation of annoying sounds in the source level, for example changing the material of wheels on handcarts into something, like resin, that makes less noise.
- Using materials with high values of absorption like using porous asphalt on the loop between Hafez and Sepah streets.
- Increasing the propagating surfaces. For instance, using shop signs made of bricks, wood, or Plexiglas, or broadleaf shrubs.

For urban spaces of great importance, like historic squares, it is greatly recommended to use sound maps with precise grids of points associated with people's perception. We propose to authorities who are involved with the management and planning of Naghshe jahan square to use the results of this paper when designing action plans in order to improve the soundscape quality of the square.

## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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