

Noise Pollution Evaluation Method for Identification of the Critical Zones in Tehran

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ABSTRACT: The equivalent noise level in large cities has been growing due to the population growth, uncontrolled production of cars, and the existence of worn out cars. On the other hand, heavy traffic has increased the amount of noise problems for residents of medical and educational centers, research institutes and residential area (or sensitive centers to noise) built in highway bounds and it has also caused and added to their stress and discomfort. This paper presents the results of measurement of equivalent noise level (L_{eq}) on various roads in Tehran. The noise maps and color contours resulted from modeling of the noise emission sources, and the critical zones in these area have been identified through the noise pollution aspect and have been studied and the appropriate solutions have been suggested. It is possible to decrease the level of noise pollution in those zones effectively, through modeling and identifying the critical zones and also by presenting noise control solution.

Key words: Equivalent noise level, Critical zones, Noise maps, Noise modeling, Acoustic barriers

INTRODUCTION

Human beings can communicate to their environment better through their sense of hearing. For instance, human beings can detect danger by hearing warning sounds and can become calm by listening to rhythmic sounds. Vehicle noise comes from the engine and transmits to surroundings, exhaust noise, gear change, and use of heavy gear in patch surfaces roads, vehicle weak maintenance, which are the important agents in the road traffic noise production. Also in high speeds the noise increases, because of friction between vehicle and air and road surface. Aerodynamic shape of cars decreases this effect and then noise pollution (EPA, 1999). Road traffic noise level depends on many factors such as the kind of the tire, the kind and condition of the road asphalt. Also drivers cause a high traffic noise by using of vehicle horn, playing loud music, unnecessary gear change and braking. Road, highway and freeway construction and maintenance, generally require using of heavy machinery, so on at this condition the noise level will be increased (Tsunokawa and Hoban, 1997). By

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measuring of road noise level, modeling and reviewing the noise maps by calculation can evaluate the situation of noise pollution levels, and can assign critical noise pollution zones. By attention to critical noise pollution zones about city development planning and layout of remedial, educational, research and residential centers (or sensitive centers to noise), can make a calm city (Ahsan, *et al.*, 2009 ; Berglund, *et al.*, 1999). According to noise allowance criteria in Iran, threshold limit values and determination of critical noise pollution zones depend on the landuse and periods of time(day or night time) (Table 1).

As shabby cars are still used in Tehran streets, the quantity of the noise production made by automobile components such as motor, exhaust and motive power is in a very high level. If worn out cars are substituted with new ones, the automobile noise pollution will reduce considerably. By prevention heavy vehicle from traveling during day time, they can not enter to the main streets except for necessary affairs and tasks at night. We have observed this problem in

Tehran and this is the main extra noise at night. By attention to high load transportation because of high engine power, and addition contact surface with asphalt (number of tires), and type of brake system, in comparison of light vehicle, there is intensification of noise (Fig. 1) (Office of E., 1995). In a steady and continuous traffic stream (traffic management), the speed and also the noise level of road is reduced. Reducing speeds to half, decreases road noise level up to 6 decibels (Fig. 2).

Table 1. Outdoor or environmental noise allowance criteria in Iran

Landuse	Day(7-22)- dB(A)	Night(22-7)- dB(A)
Residential	55	45
Residential- Commercial	60	50
Commercial	65	55
Residential- Industrial	70	60
Industrial	75	65

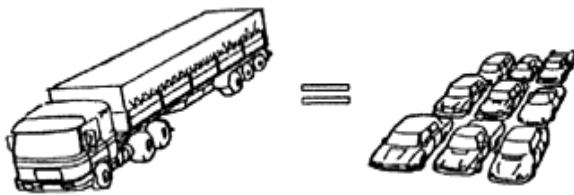


Fig. 1. Noise emission equivalence between heavy and light vehicles (Tsunokawa, et al., 1998)

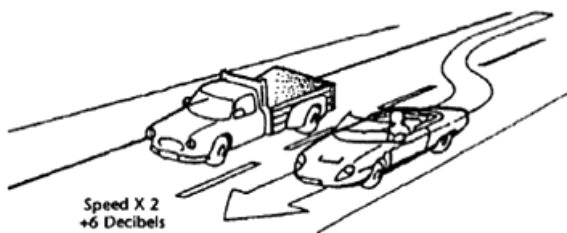


Fig. 2. Doubling the speed increases 6 dB (A) noise level (Tsunokawa, et al., 1998)

If the line of sight between receiver and highways is blocked with barriers, the 5 dBA attenuation can be expected. Then, adding 1 meter to the barrier height provides the additional 1.5 dBA attenuation. Length of barriers should be long enough, to diffract only small portion of noise through the edge of the barriers. Bar-

riers should be so long that the distance between receiver and barrier end in at least four times of the perpendicular distance between receiver and barrier (Romick-Allen, et al., 1999; Fleming, et al., 2000). Vegetation with appropriate height, width and enough density can decrease the traffic noise. According to the Federal Highway Administration (FHWA) reports, vegetation is not adequate to provide instance reduction. It is necessary to use the combination of barrier and berm with vegetation to obtain a good aspect (Fig. 3). (Watts, et al., 1999).



Fig. 3. Vegetated barrier and obtaining a good aspect of cities

On high speed roads the predominant noise is that produced by vehicle tires as they roll over the road surface. There are three effective factors on noise production when the vehicles tires contact with road surface: shape of curves or treads on surface of tire, kind of tires of vehicles and age of asphalts. Generally, smooth, good maintenance, porous and perforated asphalt, without grooves and cracks keeps noise at a minimum (Watts, et al., 1999). Increasing distance between residential buildings (receivers) with road decreases the noise pollution effectively. Consequently, using of noise buffer zones between buildings and highways is one of the main attenuation methods for the noise pollution before implementation development plan (Fig. 4). (Thalheimer, 2000).

Vehicles in steep roads and sharp corners produce more noise pollution. Hence this factor should be considered when a road is designed (Tsunokawa and Hoban, 1997). Building insulation, such as double windows glazing and noise absorption material in walls, can prevent the traffic noise effects on buildings as a receptor. When the buildings are designed adjacent the highways, bedrooms, seating rooms and balconies should not face the highway in order to reduce the noise effects (Office of E., 1995).



Fig. 4. Using of noise buffer zone in combination with planting vegetation in order to reduce highway noise (Center for T., 2002)

MATERIALS & METHODS

According to high volume of vehicles in big towns like Tehran, road traffic noise pollution problem is inevitable. In order to determine the noise pollution in any point, the noise level in that point should be measured. Of course, the period of time that is measured should be extended enough, so that the quantities can represent the reality of noise pollution level. If the equivalent noise level is measured continuously within successive days and in a long period of time in one point, this data could be considered as the real representation of the noise pollution level in that point. In other words, this can reduce the deviation from the real noise level.

But the measured data just identifies the noise pollution situation in that specific point, and the measurement can not be extended to even a limited area around that point. According to nature of sound, when distance increases, air absorption and reflection effect, cause noise quantity change. Considering the large extent of measuring areas in Tehran, and heavy costs of field measurement, application of modeling software (calculation method) has been increased. Calculation (noise modeling software) can show the noise pollution situation of any district with noise map and colored contours in any points. In fact, using of these maps can aware from situation of noise pollution in any place, and sensitive points to noise like health and remedial centers, hospitals, educational, research and residential centers (Zabani, *et al.*, 2008). Also would be possible to determine the critical zones exactly and by presenting the appropriate controlling methods the noise level is reduced effectively. In this paper we don't explain calculation method (The NMPB calculation method that the europe union uses has been se-

lected), and we just use the result of model for Tehran and we adjust the model with measurement. In source oriented calculation, type, speed, and volume of cars as road noise traffic sources and objects like buildings, parks, berm and topography should be considered. The object effects on the noise propagation are absorption, reflection, diffraction and Transmission. Also for noise absorption in atmosphere, we need the meteorological data like humidity, air pressure, rain, temperature, speed and wind direction. In NMPB method, cars are classified in two categories: light and heavy vehicles.

After evaluation the whole district, we select a few points for confirmation and installation of noise monitoring terminal in order to measure noise level continuously. In the selection process of measuring points we must pay attention to two factors:

1. Total of measuring station that settled in research district must be divided in homogeneous form.
2. Measuring station must be settled and installed in adjacent of the main streets.

Noise monitoring process in any station must be in operation more than two weeks (for the average noise during weekdays), and any data and information should be collected continuously. It is obvious that if the number of measuring points increases, the adjusting model will be in a better state (Nasiri, *et al.*, 2008).

There are some procedures for site selection, for instance, the microphone must be settled far away from any reflecting objects (about 3m) and it must see the road surface because we want to measure and model the road traffic noise. This information is analyzed, and all of noise levels for daily, nightly, 24 hours, weekly and monthly are obtained (Fig. 5).



Fig. 5. Noise monitoring terminal in Social security of district 2 in Tehran

RESULTS & DISCUSSION

Results of each station which measured continuously should be analyzed. The data (SPL) is collected in each half second and this analyzer calculates the L_{eq} for hourly, daily, nightly, 24 hour, weekly and monthly reports (you can do these with some easy and specific formulas). We separate the weekdays from Saturday to Friday in three parts (day time, night time and 24 hour) for comparison of noise fluctuation in weekdays.

The allowable noise in Iran is divided to two periods which is from 7:00 to 22:00 for day period and the rest is night period (Table 1). We use these levels to compare the noise with allowable limits. Also, model obtains the noise levels in these periods of time, from vehicle data that have been categorized in these periods of time. Below you can see the results of 4 measuring stations (as a sample) which have settled in different parts of Tehran city (Noise M., 1999-2008).

Maximum daily and nightly noise level in Shariati hospital is 69.9 dB (A) and 63.5 dB (A) (Fig. 6). According to table 1, maximum noise level of the residential area during the day and night time period is 55 and 45 decibel (A). Azadi street station has a commercial landuse and maximum daily and nightly noise level in this station is 72.1, and 70.3 dB (A) (Fig. 7). According to table 1 in commercial area during the day and night time is 65 and 55 dB (A). Of course, noise level of Azadi street station in day and night time, by turns, 4.9 until 7.1 and 13.1 until 15.3dB which are higher than threshold limit value. Kalej crossroads station has a residential-commercial usage. According to Fig.8. maximum daily and nightly noise level respectively, is 74.6 and 69.4 dB. Iran noise pollution standard in residential - commercial area in day time and night time by turns are 60 and 50 dB (A). Of course noise level of Kalej crossroads in day and night time by turns are 11.6 until 14.6 dB, and 18.4 until 19.4 dB which are higher than threshold limit value. Almost all measurements data have this deviation from threshold limits.

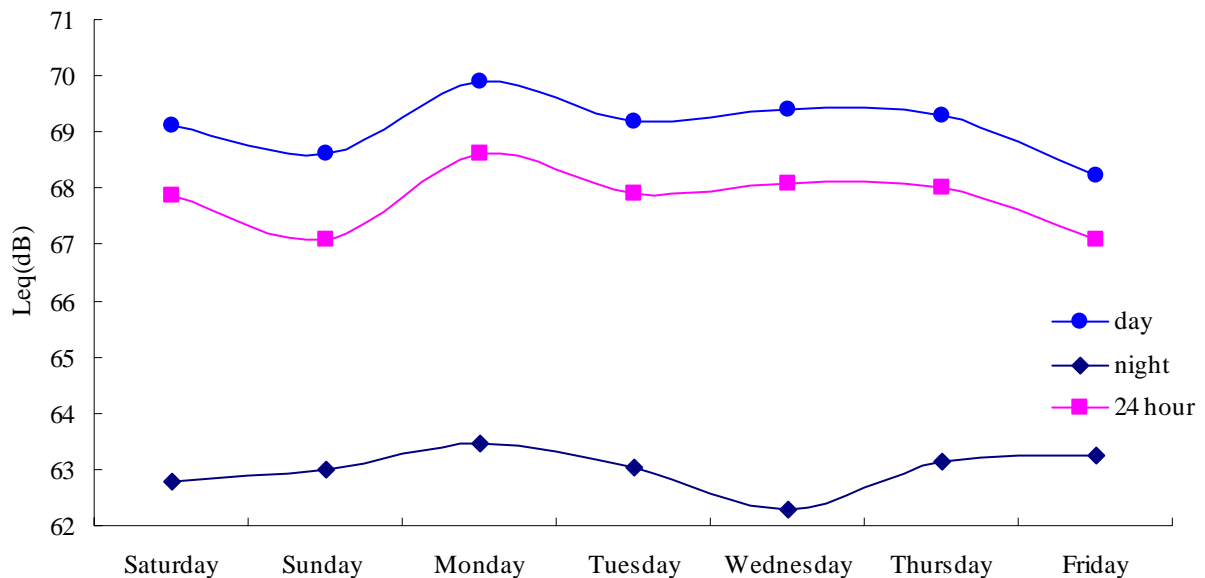


Fig. 6. Equivalent noise level (Leq) in Shariati hospital station

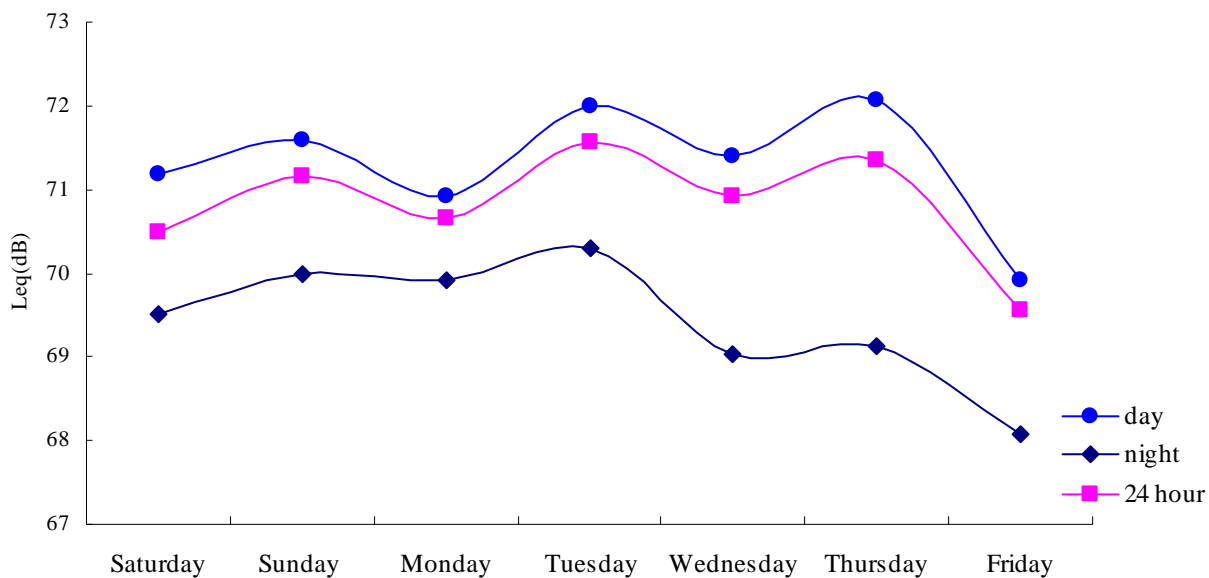


Fig . 7. Equivalent noise level (Leq) in Azadi street station

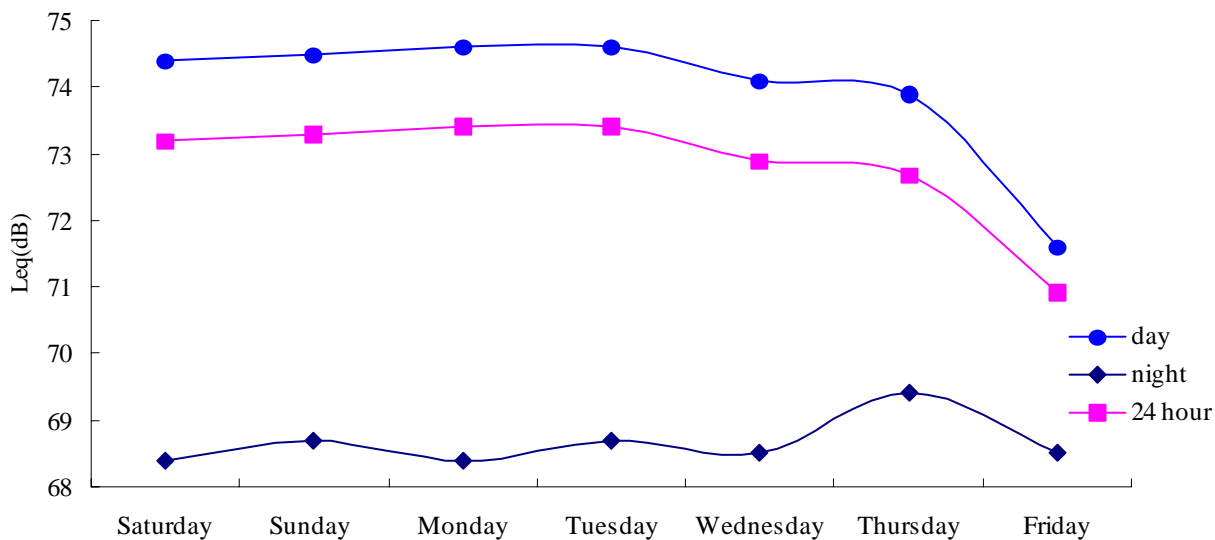


Fig. 8. Equivalent noise level (Leq) in subway station (Kalej crossroads)

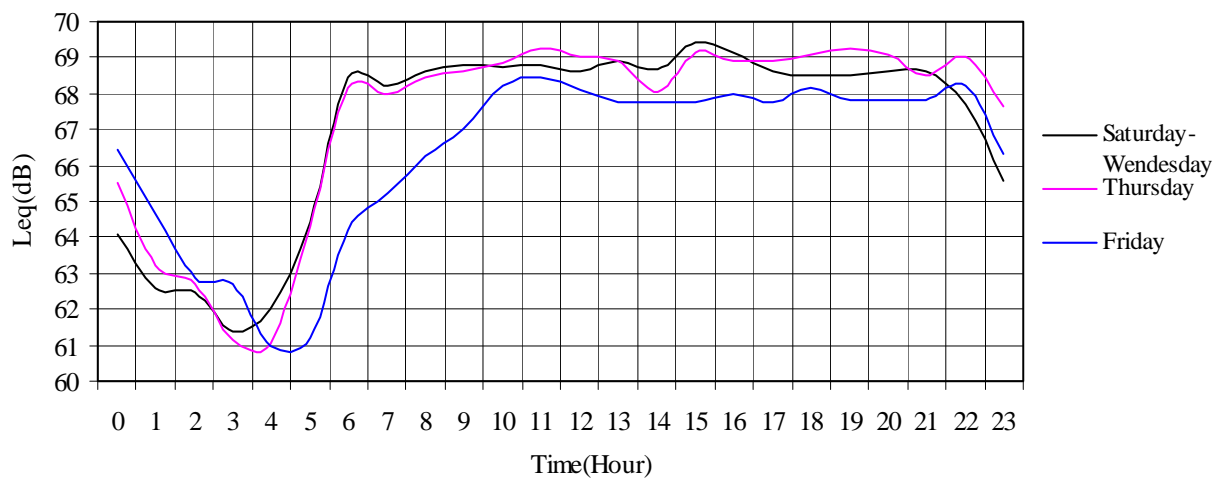


Fig. 9. Equivalent noise level (Leq) in Ajodanie St. (Bank Meli)

We use the GPS for determining the coordinates of station that we must use to adjust the model. The trend of variation during weekdays is related to the place of station. For instance, on Friday all the results decrease and the difference between daily and nightly noise level decreases in entrance of the Tehran, like Azadi station. These changes show the high deviation from environmental noise allowance criteria in night time. The important conclusion that we find from this matter is it occurs because of starting day period from 7 o'clock in Iran, while all of noise measurement station (90 stations) show the high slope to maximum that begins at 6 o'clock, which means the day period starts from 6 not 7 (Fig. 9).

Also the trend of changing of 24 hour reports and daily reports are the same. This is because of less effect of nightly reports in comparison to the 24 hour reports. There is only 9 hours for night time in comparison to 15 hours for day time and the main reason refer to logarithmic calculation to obtain 24 hour report from daily and nightly reports.

For Modeling noise level and comparing with measurement we enter the data for Geographical Information System (GIS), like buildings, roads, parks, height of the ground and buildings and information about the climate situation such as relative humidity, atmosphere pressure, and temperature, in to the modeling software (Wahadj, et al., 2007). We also assign the volume and speed of light and heavy vehicles to roads like a line

source and assign height of building to them for obtaining a 3D map. For topography, we use height of ground to calculate digital ground model (DGM) on which we put all items on it. After that we have a real model with the object effect to calculate the noise pollution level. The distribution situation of the noise pollution in the related area is obtained from noise maps with color contours. Studying on noise maps, informs us about the distribution of noise pollution and identifies the critical zones with noise accumulation. In noise maps you can find any building as background with noise pollution distribution on it, and when we study on these maps we can determine the critical zones. The validity of the model is checked and if there is a big difference (upper than 3 dB), the model must be adjusted by measurement (Mehravarani, et al., 2004).

In Table 2 there is the comparison of calculation by measuring in district 6 in Tehran in which the average of deviation is 2.1 dB(A). Noise level maps for district 1, 2, 3, 6, 7, 9, 10, 11, 12 Tehran's Municipality have been determined in good average deviation. In Fig. 9 the 3D cross section road traffic noise map of Navab highway during day time has been specified with noise receiver in each window's floor and noise level in ground. In Figs. 10 & 11 the road traffic noise map at part of district 10 in Tehran has been specified during day time, near the Azadi hospital. In model you can find noise level in each side and floor of building and specify the critical and calm zones very explicit.

Table 2. Comparison of measurement and calculation

Measuring station	Measurement(dB)	Calculate (dB)	Deviation (dB)
Transportation and traffic organization (Gomnam highway)	72.5	73.6	1.1
Mirzai-e- Shirazi street	69.0	71.7	2.7
Imam Khomeini hospital (Bagher Khan street)	73.3	75.6	2.3
Carpet museum (Fatemi street)	67.7	70.5	2.8
Kalej crossroads (Hafez-Enghe lab street)	74.3	74.7	0.4
Darvazehdolat subway (Enghelab street)	73.0	75.9	2.9
Haft-e- Tir square	69.5	71.7	2.2
Shariati hospital (Jalale Ale Ahmad highway)	69.3	71.8	2.5
Khadamat motori shahrdari (Taleghani street)	72.8	73.3	0.5
Fatemi – Valiasr crossroads	70.4	73.8	3.4
Mojtame Ghazae e Beheshti (Somaie street)	71.2	73.3	2.1
Average of deviation			2.1

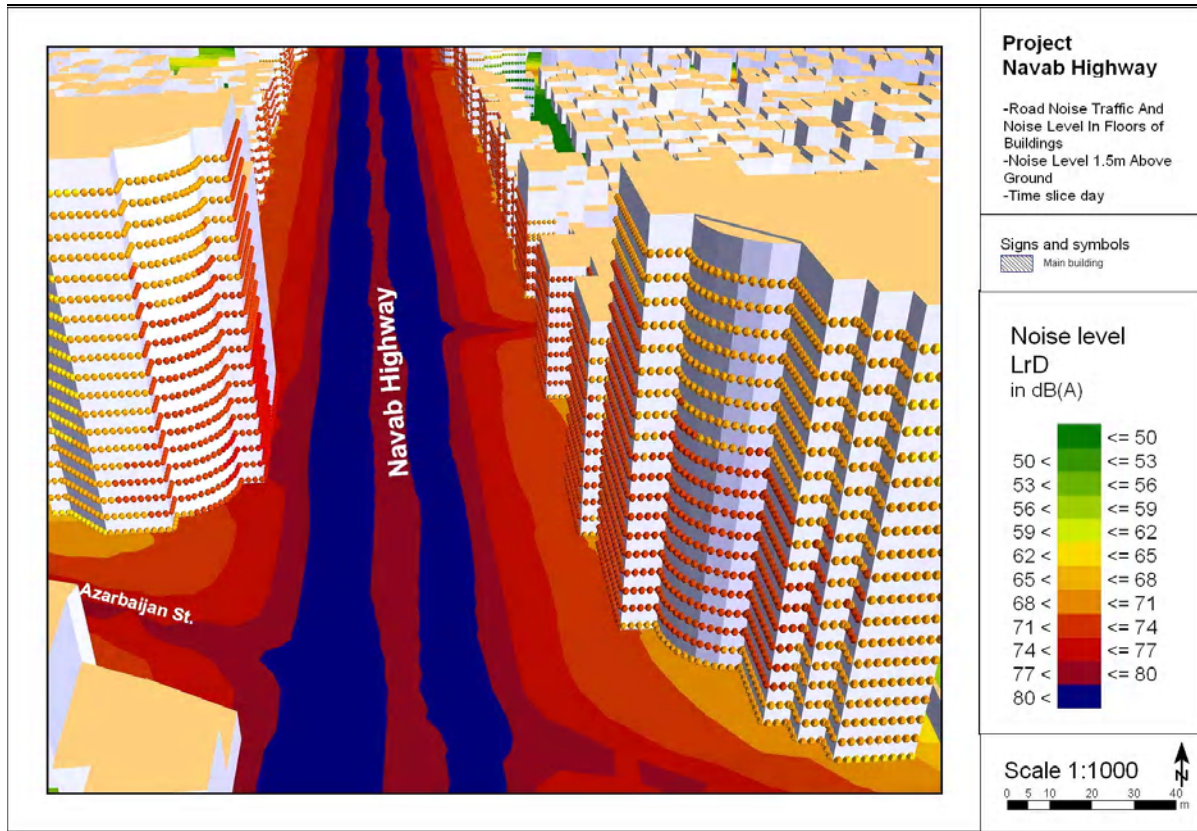


Fig. 10. 3D road traffic noise map of Navab highway (day time), Cross section with noise level on every window's floor. Noise level in ground is 1.5m above

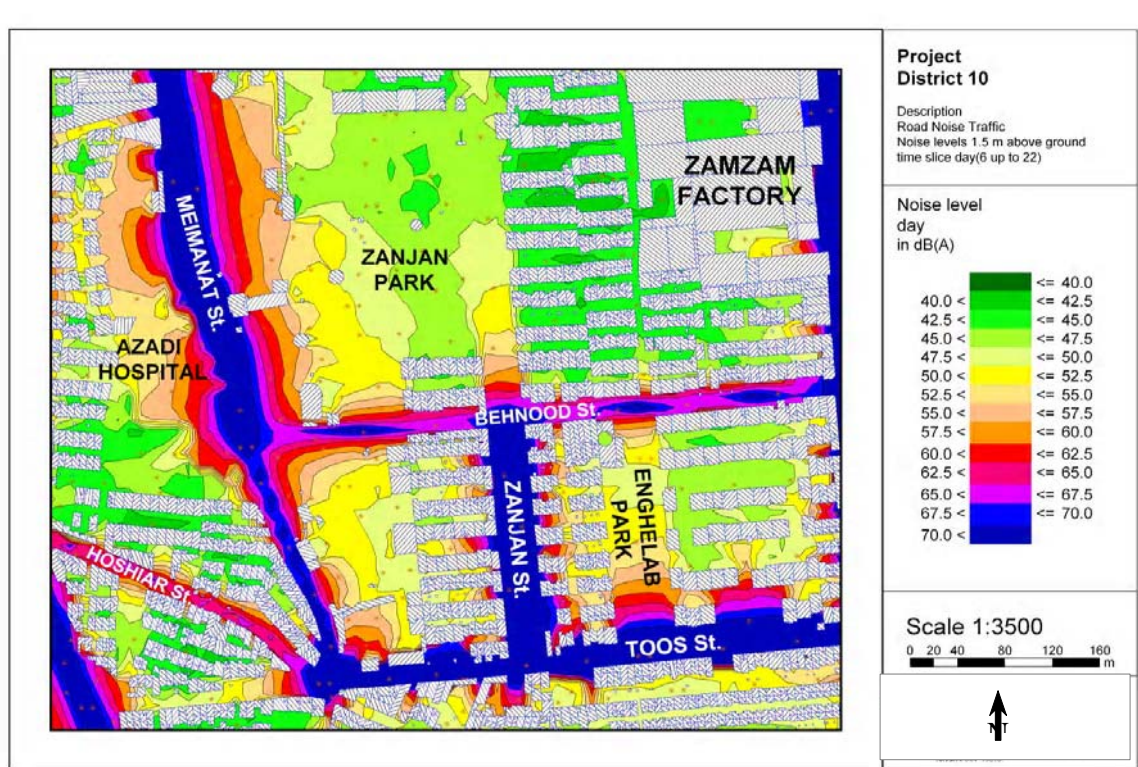


Fig. 11. Road traffic noise map at district 10 in Tehran (day time) With scale and name of streets, parks and hospital

CONCLUSION

The benefits of calculation instead of measurement for evaluation noise pollution distribution in big areas like cities especially Tehran is:

- Reduction of high expense of measurement.
- Reduction of accomplishment time of environmental monitoring project.
- Assigning of critical zones by reviewing noise maps.
- Evaluation of highway noise propagation into the adjacent districts, especially remedial, educational, research and residential centers.
- Evaluation green belt and dense vegetation role in reduction of highway noise level.
- Selection of quiet zones for placing hospital, schools, university construction and so on.
- Planning noise controls such as noise barriers before and after construction and evaluation the costs and the effects of noise control.

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