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Investigating of environmental traffic noise modelling by using FHWA TNM in Tehran township

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Abstract
There are several noise modeling software packages in order to predict noise level, each of them has different accuracy in different country. The present study was undertaken to analyze Traffic Noise Model software package (TNM) for two large highway in Tehran township. Firstly, field measurement for equivalent noise level (Leq) was carried out by sound level meter(SLM), then Leq prediction by the software was done. Finally, the results of the two previous steps were compared. the mean deviation of the results for sound levels below 80 dB was 0.33 dB, but for values further than 80 dB, the deviation was high. due to the obsolescence of a large number of the trucks inside Iran, new trucks instead of using software-defined trucks, were defined. With this change, the modeling and measurement results were more coordinated. The coefficient of determination (R^2) increased from 0.4915 to 0.7312.

Keywords
Leq, noise prediction, noise measurement

Introduction

Noise is one of the most important environmental problems in metropolitan areas associated with rapid urbanization, industrialization, and expansion of road networks. It will also continue to grow because of sustained growth in highway, rail, and air traffic, which remain major sources of environmental noise in urban areas (Abbaspour et al., 2006; Agarwal and Swami, 2010; Debnath and Singh, 2018; de Donato and Morri, 2001; Goines and Hagler, 2007).
The latest studies have shown that more than 20% of the world population lives under unacceptable noise levels (Rivas et al., 2003). During the last decades, different studies have been carried out in urban areas in order to evaluate the noise pollution and its management (Covaciu et al., 2015; Eduardo et al. 2015; Garg and Maji, 2014; Nega et al., 2013; Shu et al., 2007; Swinburn et al., 2015; Yücel and Çolakkadıog˘lu, 2017). studies have showed that the equivalent noise pollution level in most part of Tehran city has exceeded the permissible values (Abbaspour et al., 2015; Alesheikh and Omidvari, 2010; Mehravaran et al., 2011).
The potential health effects of noise pollution are medically and socially significant. Noise produces direct and cumulative adverse effects that impair health, like temporary or permanent hearing loss, occurrence of hypertension, cardiovascular disease

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and that degrade residential, social, working, and learning environments with corresponding real (economic) and intangible (well-being) losses. It interferes with sleep, concentration, communication, and recreation (Basner et al., 2014; Goines and Hagler, 2007; Yi and Paparaju, 2013).

To investigate noise pollution level at any point, we can use the direct measurements by using a monitoring device, or indirect measurements by using predictive noise pollution software. Traffic noise prediction models mainly are required as aids in design of roads and sometimes in assessment of existing, or envisaged changes in traffic noise conditions(Steele, 2001). Experiences have pointed out that the changes in traffic noise pressure levels in a time interval of 10 to 15 minutes could forecast the hourly changes (Abbaspour et al., 2006), Therefore, it takes approximately 10-15 minutes at each station to measure the equivalent noise pollution level using a sound level meter(SLM). By using noise predictive software, not only the time of environmental monitoring is reduced, the costs also significantly decrease but the uncertainty will increase because the uncertainty of the simulated results is the sum of the uncertainties of the applied standard, the computer program and the physical representation of the reality in a computer model(Berndt, 2004). The accuracy of a noise model is an important part of designing road noise reduction measures, as there are often specific noise purposes that must be met). SoundPlan and Cadna/A are two of the most widely used software programs in the prediction of environmental noise (Arana et al., 2008). Another readily-available software package is called TNM (Traffic Noise Model), which has been released by FHWA (Federal Highway Administration). The official FHWA TNM software package is relatively inexpensive. The algorithm includes up-to-date noise emission factors, consistent with North American traffic types. However, Cadna/A and SoundPLAN offer better user interfaces and additional analysis features.

Traffic noise in countries is potentially different from each other because of different types of vehicles, different levels of vehicular maintenance and possibly different ways of driving behavior (Alsaif and Foda, 2015), So in that countries which don't have integrated simulation program, finding a trustworthy program whose simulations results has the least deviation from measurements is necessary, as there are often very strict noise goals.

In this research TNM 2.5 software package was investigated in Tehran.

Materials and Methods

Study area

The present study has been covered a part of Tehran township, from 51°28'8"E longitude to 51°30'1"E longitude and from 35°39'23"N latitude to 35°40'9"N latitude with an average elevation of 1100 m. The total area had been around 1,6 km^2. The average relative humidity in Tehran is 40%, the dominant wind is western (270°) and its average speed is 5.5 m/s.

Noise measurement

A TES-1353H Sound Level Meter(SLM) used to measure sound levels. It has the measurement range of 30–130 dB (A), dB (A) means decibels in A-weighted scale. The Leq dB(A) is the time weighted average of the sound pressure level in decibels on scale A which is related to human hearing. At all stations, according to ISO 2001 acoustics standard, the sound level meter was set to Fast mood and the Leq value was recorded. Measurements were made at 9 main stations located near the most important uses and streets. At each station, mean LAeq was determined. Besides noise monitoring, traffic density count was taken simultaneously. The latitude and longitude of each points which is shown in Figure1 were also collected by a Garmin Montana 680 GPS. In addition to the 9 main stations, for increasing the accuracy of the noise pollution map, 20 auxiliary stations, shown with yellow triangles in the figure, were selected by dividing the area into squares. Figure1 depicts the road map with monitoring locations.

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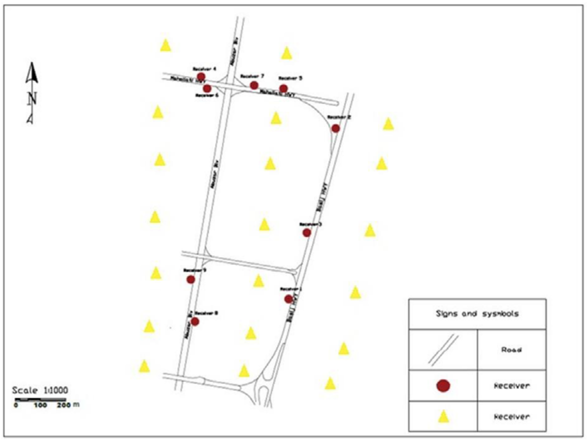

Figure 1. *Location of the monitoring stations.*

Figure 2. *Complete map modeled in software.*

Noise pollution modeling

The FHWA TNM software only uses the TNM standard for modeling. This model considers barriers, trees, pavement, slope and other parameters in noise emission caused by traffic. To begin, the study area map was imported in DXF format. While TNM may be able to handle complex geometries and a large number of roadway segments, practically, the model bogs down quickly with increasing complexities in the runs. In the next step, it was not possible to model trees in the software, because there were individual trees or only a few rows of trees, TNM allows the user to model tree zones which consist long, wide regions of heavy, non- deciduous woods and undergrowth, not just individual trees or several rows of trees. Then the streets' information was entered into the software. Finally, the location of the noise measurement points was entered. The full map is shown in Figure 2.

Validation

The values for Leq which were obtained by using TNM software at the receivers' location were compared with the measurements' results. the deviation in some points were too high. In the next step, an attempt was made to decrease errors. At first, the number of vehicles was changed to check for possible errors in counting, but the software output line did not change much from the measured value. Next, instead of using software-defined trucks, new trucks were defined. With this change, the modeling and measurement results were more coordinated.

Results and Discussion

Noise measurement and modeling

The number of different category of vehicles at the location of each station is presented in table 1.

The results of the equivalent sound pressure level obtained from the measurement and modeling are shown in table 2 and figure 3.

As it is showed the deviation between two results of stations 1 and 2 was high. The maximum deviation from the measurement results was 13.69. Modeling and measurement results for sound levels below 80 dB differed by an average of 0.33 dB. Figures 4 and 5 demonstrate the modeling and measurement results that have been interpolated using Surfer software.

Validation

Next, instead of using software-defined trucks, new trucks were defined. The reference noise level for medium truck was 77 dB and for heavy truck was 79 dB, with this change, the modeling and measurement results were more coordinated. The coefficient of determination (R^2) increased from 0.4915 to 0.7312. Figures 6 and 7 showed the result of regression analysis of the noise level.

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Table 1. *Hourly traffic data on highways.*

Receivers	Number of hourly vehicles in near lines					Number of hourly vehicles in opposite lines				
	Heavy truck	Medium truck	Bus	Auto mobile	Motor cycle	Heavy truck	Medium truck	Bus	Auto mobile	Motor cycle
1	120	330	42	5160	396	102	336	42	4416	324
2	66	138	30	4788	302	54	90	48	5400	264
3	27	157	103	4698	382	102	336	42	4416	324
4	0	0	8	1275	30	12	12	12	1830	464
5	0	20	11	2260	510	0	10	9	1376	319
6	12	12	12	1830	464	0	0	8	1275	30
7	0	20	11	2260	510	0	0	9	1376	319
8	0	5	9	667	142	0	7	13	824	177
9	0	7	13	824	177	0	5	9	667	142

Table 2. *Comparing the results of the equivalent sound pressure level.*

Receivers	Measurements (Leq()dBA)	TNM) dBA)
1	89/04	75/35
2	85/86	77/6
3	77/68	77
4	74/36	72/6
5	73/31	70/85
6	70/52	73/7
7	70/34	70/6
8	69/43	67/6
9	67/87	67/3

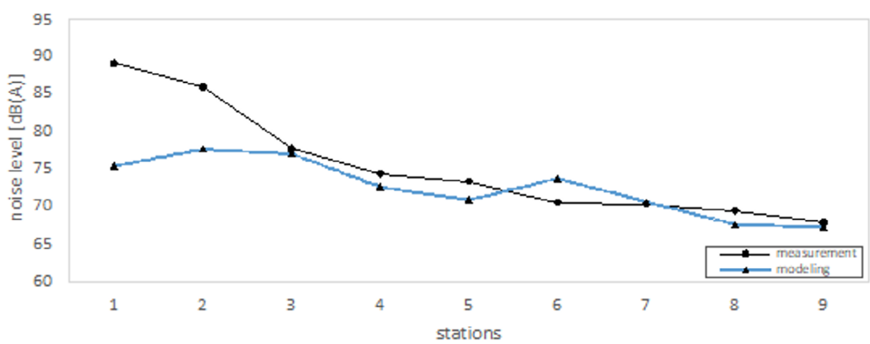

Figure 3. *Highway noise level by measuring and modeling.*

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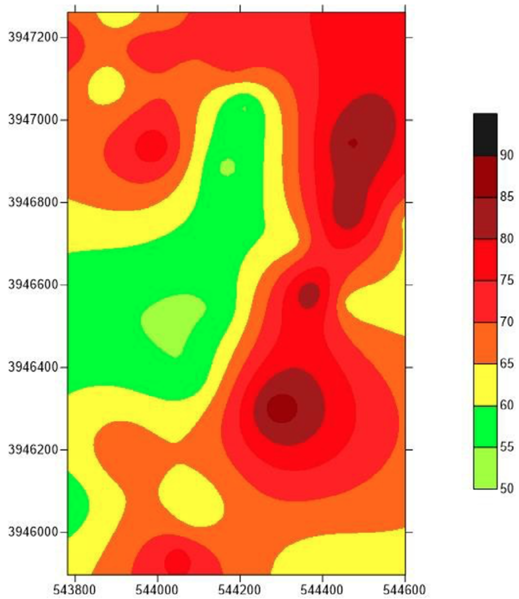

Figure 4. *Highway traffic noise map by modeling*

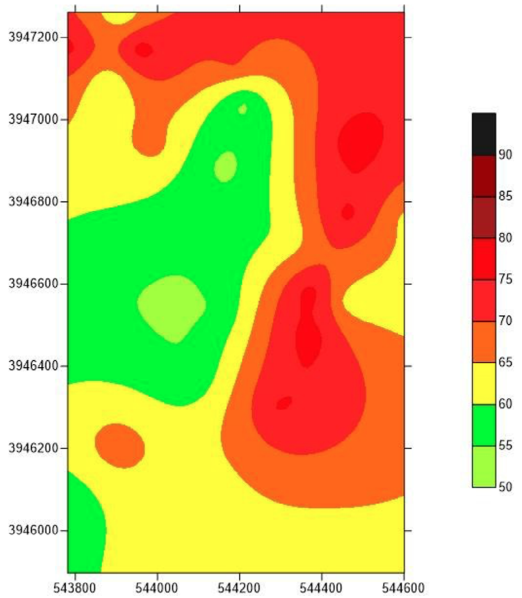

Figure 5. *Highway traffic noise map by measuring*

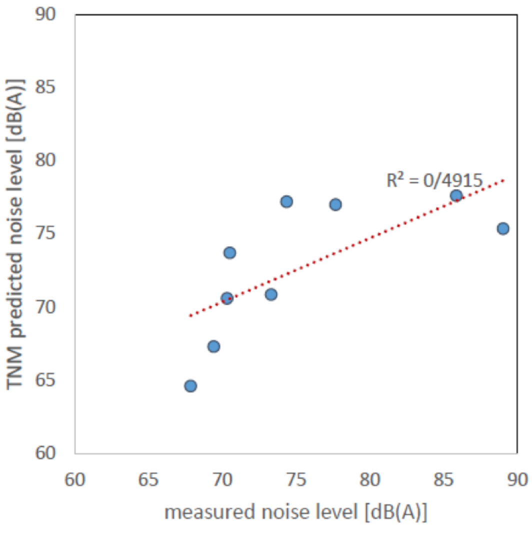

Figure 6. *Measured noise level [dB(A)] against the TNM predicted noise level [dB(A)].*

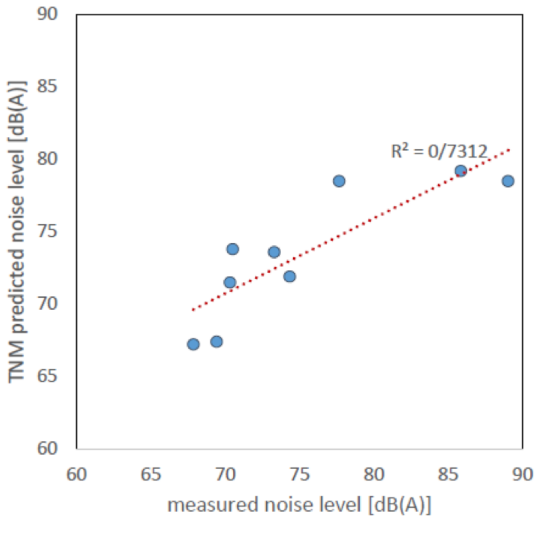

Figure 7. *Measured noise level [dB(A)] against the TNM predicted noise level [dB(A)] after definition of domestic trucks.*

For validation, several stations across the highway were selected and their Leq was measured, 4 stations which their Leq value were greater than 80 dB were choosed for re-examination and the software was run again. As we can see in table 3 and 4, the average deviation from measured results decreased from 6.325 to 2.6. the results have been showed in table 3 and table 4.

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Table 3. *Comparing the results of the equivalent sound pressure level in new stations.*

Station	Measurement	TNM	Difference
10	86/9	77/0	9/9
11	80/4	75/1	5/3
12	80/4	74/1	6/3
13	80/0	76/2	3/8

Table 4. *Comparing the results of the equivalent sound pressure level in new stations in new modeling.*

Station	Measurement	TNM new	Difference
10	86/9	82/1	4/8
11	80/4	81/2	0/8
12	80/4	76/5	3/9
13	80/0	80/9	0/9

Conclusion

The overall findings of this study showed that due to the fact that most of the trucks in Tehran are worn out, in places where the number of trucks is high, the software cannot predict the equivalent sound pressure level well. but for other regions it predicts the equivalent sound level with good accuracy (averaging 0.33 dB).

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