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Statistical models for traffic noise at signalized intersections

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Abstract

A total of 14,235 noise levels measurements were utilized in developing statistical models that have the capability to predict different noise levels including: equivalent, maximum, or minimum noise level in terms of parameters affecting each level. Different parameters expected to have an effect on noise levels were collected. These parameters included traffic volume, composition of traffic, traffic speed, horn using effect, number of lanes, width of lanes, approach width, road slope, and pavement surface texture. The parameters affecting each noise level were selected based on simple correlation matrices, scatter plots, and statistical *t*-test. Different forms of models were evaluated for each noise level. The best model describing the relationship between each noise level and parameters affecting it are presented in this paper. The reliability of the nonlinear developed models were judged based on coefficient of multiple determination (R^2), the significance of each variable at α-level of 0.05, and the standard error of the estimates. While the reliability of linear developed models were judged based on the general linear regression tests represented by F-value and t-value in addition to the coefficient of multiple determination (R^2), the significance of each variable at α-level of 0.05, and the standard error of the estimates.

Based on the analysis of the collected data, three groups of models were developed. The first group of models predicts the equivalent noise level in terms of traffic volume, traffic speed, distance, heavy vehicles and British Pendulum Number (BPN). The second group presents models that describe the relationships between maximum noise levels, heavy vehicles and use of horn. While, the third group presents minimum noise level prediction models in terms of BPN and lane width. A verification of the developed models was performed by comparing the predictive noise levels with those measured at different sites. Results of this verification indicated that the developed models were found to have good prediction capability.

Keywords: Traffic; Noise; Modeling; Pollution; Intersection

1. Introduction

Noise is a major issue that should be considered during the design and construction of new transportation systems, as well as in improvements of the existing systems. Current technologies make it impossible to design a transportation system that does not produce noise. Also, in an era of reduced government funding, the cost of constructing mitigation measures for environmental impacts is being strictly evaluated. In light of these considerations, issues in the forefront of transportation noise research over the next few years include: improvements in methodologies used to predict noise levels from transportation sources; and analyzing noise mitigation measures with emphasis on more aesthetically pleasing methods and alternatives to traditional noise barriers [1].

In developing new noise prediction models need to consider the analysis of: constant-flow and interrupted traffic flow, effects of parallel noise barriers, results of multiple diffraction, and noise contours need to be considered. The introduction of these models is expected to improve the accuracy as well as the ease of highway noise prediction [1].

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As part of a study to evaluate environmental impacts of constructing or upgrading roads in Jordan, Abu Qdais and Abo-Qudais [2] used a model to predict traffic noise. The finding of this study indicated that traffic noise has a significant negative psychological impact on the residents of the buildings adjacent to the roads.

Dravitzki and Wood [3] introduced noise models that have the capability to predict equivalent noise level (L_{eq}). An evaluation of models was performed by comparing the predicted levels at 20 sites to the measured noise levels. These sites included free traffic flow, highways, urban arterials and urban streets sections. Results of the comparison indicated that the L_{eq} models could give strongly indicative predictions of traffic noise. Also, road surface has significant effects on noise levels for accurate prediction.

Pamanikabud [4] investigated two existing and widely used traffic noise prediction models which were developed in two different countries. One of the two models was developed by the Federal Highway Administration (FHWA), while the other one was developed by the UK's Department of Environment (DOE). The two models were tested in order to evaluate their effectiveness when applied to the highway traffic and roadway conditions in Singapore. The results indicated the need to develop a new highway traffic noise model that will be sensitive to traffic, vehicle, and roadway characteristics in Asian countries.

A traffic noise prediction formula was proposed by Shuoxian [5]. The formula is based on an exponentially distributed vehicles model consisting of a single line flow of vehicles with the same acoustic power. It can be used for predicting the sound pressure level that exceeds x% of the measurement time (L_x) and L_{eq} levels generated by a free traffic flow on a multilane road. Comparison of predicted data with measurements have shown that the errors fall within 4 dB.

The normalized sound pressure level is used to express traffic noise in a study performed by Makarewicz and Sato [6]. A model that relates sound pressure level to the traffic speed and the percentage of heavy vehicles was developed. This study indicated that, for the same traffic volume, existence of heavy vehicles or higher traffic speed will cause an increase in sound pressure level. However, the presence of heavy vehicles destroys the dependence of the sound pressure level upon the traffic speed.

Field investigations showed that the correlation between the extent of annoyance due to road traffic noise and the noise dose expressed in L_{eq} is not preferable. A higher correlation was found when the expression of the noise dose was based upon the maximum noise level (L_{max}) from the single noisiest event [7].

Previous studies to establish evaluation measures for noise under non-free flowing traffic conditions in urban areas have not been entirely successful, due to the complexity of related influences. Jraiw [8] described the development of reliable prediction models for noise exposure and annoyance emanating from urban traffic where the flow is typically non-free flowing. The models are based on a wide ranging program of subjective and objective surveys. The level of traffic noise under various conditions, such as priority junctions, traffic lights and roundabouts control, is appraised in an integrated way by considering the role of land use, building, road and traffic variables, as well as human responses. Three groups of models are presented. The first group predicts L_{10} and L_{eq} noise levels in terms of three classes of vehicles, building facades, and various junctions and road configurations where the speed is below 50 km/h for traditional highly populated urban centers. The second group of models considers noise in terms of traffic flow, percentage of medium and heavy vehicles and other variables for a speed up to 80 km/h under traditional outer urban conditions. The third group of models evaluates people's attitudes to their surrounding environment in terms of various components. The use of these models is impractical, since in practice there is no seperated class of vehicles in the traffic stream.

Ogle and Wayson [9] conducted a study to investigate how the noise levels generated by motor vehicles are influenced by vehicle speed in urban areas. Based on this study, a mathematical relationship that predicts the shift in the frequency spectra and the subsequent change in the dominant frequency was developed.

Ishiyama et al. [10] described various factors affecting urban traffic noise propagation, including the distance from the road, the existence of a direct path of noise propagation, the density and height of buildings, and the procedure for predicting the attenuation of noise levels from roads. The analysis incorporates a large amount of survey data concerning urban traffic noise propagation. The survey of the traffic noise propagation around main roads was carried out in several residential areas in Tokyo. Multiple regression analysis performed on 691 measurements demonstrated that the distance from the road makes the most significant contribution to the explanation of the attenuation of the noise level.

A method for the prediction of traffic noise around relatively simple signalized intersections has been developed by Samuels [11]. Performance evaluation of the developed method involved comparison of measured and predicted traffic noise levels at selected intersections in two countries. The method was found to perform well and to be consistent with other previous free-flow traffic noise prediction models.

2. Objectives

Predicting traffic noise is not a simple procedure. It involves a fair amount of assumptions and, to a degree,