Traffic Noise Modeling of National Highways and Mid-Size Indian City Enviroscape Including High-Rise Residential Buildings

राष्ट्रीय राजमार्गों और मध्यम आकार के भारतीय शहर के परिवेश का यातायात शोर मॉडलिंग जिसमें ऊंची आवासीय इमारतें शामिल हैं

Thesis submitted in partial fulfillment for the
Award of Degree

Doctor of Philosophy

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Year 2025

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7.1 General

In recent years, urbanization of mid-sized Indian city has been a key factor contributing to the rise in traffic noise pollution. Each country, due to its distinct geographical location, experiences a unique combination of environmental factors and traffic patterns because, there are no universal solutions that can be applied to address environmental challenges in all situations. Major findings are discussed in this chapter.

7.2 Traffic Noise Modeling for Heterogeneous Traffic Flow in Mid-size Indian City

This study aimed to develop a computer-based software for predicting the traffic noise of heterogeneous traffic condition at MP, OP and EP hours. Traffic noise is modelled using machine learning algorithms like Principle component analysis and K – nearest neighbor. Important findings are given below :

1. The 2-w constituted the largest share of traffic, ranging from 47% to 77% of the total volume. Passenger cars made up 3% to 28%, followed by non-motorized vehicles at 1.90% to 26.22%, and 3-w at 0.5% to 24%. Light commercial vehicles represented up to 6.3%, buses up to 4.3%, trucks up to 2.2%, and e-rickshaws up to 8.97% of the traffic volume.

2. 13 Out of 16 locations, which have a 4-lane divided (2-way) carriageway and 6 Out of 7 locations, which have a 2-lane (2-way) carriageway exceeded the design service volume of IRC :106-1990.
3. The range of noise level were found to be 70-84 dB(A) for commercial zone, 70-82 dB(A) for Residential zone, 72- 80 dB(A) for industrial zone and 69-82 dB(A) for silence zone. The commercial zone experiences high traffic volumes, with noise levels exceeding the WHO limit of 70 dB(A) by over 0-13 dB(A). In residential and silence zones, the WHO limit of 50-55 dB(A) was surpassed by more than 19- 25 dB(A), creating an unhealthy environment and highlighting the need for noise mitigation.
4. The developed PCA based K-NN model was sufficient to explain 81%, 77.5% and 77.4% variability in the MP, OP and EP, respectively, in terms of L_{eq}, whereas, 85.8%, 80.4% and 84.3% in terms of L_{10} value. The MAE value for different peak were lies in the range of 0.6 – 1 dB(A) while RMSE value were in the range of 0.8 – 1.3 dB(A).
5. The proposed models were found to predict more than 94% observations within ±3% variations. The developed computer software would be useful for the transportation planner and design engineer in predicting the traffic noise for a particular region under heterogeneous traffic condition.

7.3 Vehicular Source Noise Emission Model and Modified Highway Noise Prediction Model

1. Emission curves were developed for different vehicle categories under free-flowing conditions, which can be used for building the future highway traffic noise models and mitigation planning. The emission curves seek to replace the FHWA curve while

developing a modified highway noise prediction model for mid-size Indian city with heterogeneous traffic.

2. The descriptive analysis shows that tractors produced the highest noise emissions among all vehicle categories, closely followed by trucks, with both reaching peak levels above 94 dB(A). In contrast, the peak noise emissions of all other vehicles were below 90 dB(A).

7.4 Measurement and Prediction of Road Traffic Noise at Different Floor Levels of Buildings in a Mid-size Indian City

In a mid-size Indian city, many high–rise buildings are situated at less than 10 meters from the road edge. Exposure to traffic noise can cause a variety of health problems to apartment dwellers. Realizing the importance of the noise variability at various floor level, forecasting model were developed for tall buildings. Important findings are summed up below:

1. Noise level changes with altitude in high-rise buildings. It was observed that noise level increases to a maximum at a certain height before dropping off again. The LA_{eq} level were ranged between 62.9-73.8 dB(A) for building 1 and 69.4 – 74.2 dB(A) for building 2. Floor level 3, 4, 5, 6 was the noisiest in the buildings studied. Therefore, from the perspective of noise, it may be suggested that the 1st floor or any floor above 10th may afford serene living conditions. Also, lower noise at the 1st floor may generally be attributed to the boundary wall along roadside for apartment complexes.
2. Building 2 positioned closer to the road, exhibits a notably higher TNI having range of 69.5 to 85.1dB(A) and NC range of 8.9 dB(A) to 12.8 dB(A) than building 1 having TNI range of 63.3 dB(A) to 71.3 dB(A) and NC range of 8.4 dB(A) to 10.1 dB(A).

3. Most of the energy on floor of building 1 and building 2 was caused by low frequency noise. The dominant frequency for building 1 (33.3 metre from the road edge) were found to be in low frequency range of 63 Hz, while the dominant frequency for building 2 (18.4 metre from the road edge) were found to be in high frequency of 3.15 KHz. Frequency analysis show that, when building is closer to the roadway the honking noise dominates over the usual traffic noise. However, when the building is located at a distance of about 30m away, the traffic noise dominates, and the impact of honking noise is comparatively lower.

7.5 Practical and Policy Implication

1. In mid-sized cities, the scarcity of public transportation options often compels residents to rely on private vehicles. This leads to higher traffic volumes and increased honking, which in turn exacerbates noise pollution. Expanding the availability and coverage of public transportation can reduce the reliance on private vehicles, alleviate traffic congestion, and subsequently lower noise pollution levels. Investing in efficient and accessible public transit systems can help address these issues, improve overall urban mobility, and enhance residents' quality of life.
2. 2-w account for 47-77% of total traffic, 3-w contribute up to 24%, and passenger cars make up to 26%. Among these, 2-w are the largest contributors to traffic noise, responsible for 14.07% of the noise impact. 3-w follow as the second-largest contributors, accounting for 11.99%. To mitigate traffic noise pollution, increasing the use of public transportation and transitioning to electric versions of these vehicles can be highly effective. Public transit reduces the number of individual vehicles on the

road, while electric vehicles produce less noise compared to their conventional counterparts.

3. Honking plays a major role in increasing traffic noise levels. To address this issue, it is essential to implement comprehensive strategies such as public awareness campaigns to educate drivers about the impact of excessive honking, enforce bans on unnecessary horn use, and impose fines for non-compliance. These measures can help reduce noise pollution and improve the overall acoustic environment in urban areas.
4. In mid-sized cities, the lack of designated parking and stopping points for auto-rickshaws and e-rickshaws contributes to traffic congestion. This congestion often leads to increased honking, which exacerbates noise pollution. To address this issue, it is crucial to establish clear and well-defined parking and stopping areas for these vehicles. Additionally, implementing a system of fines for unnecessary stopping outside designated areas—while allowing temporary stops for passenger pick-up and drop-off—can help manage congestion more effectively and reduce noise pollution. By improving infrastructure and enforcing regulations, cities can enhance traffic flow and minimize environmental impact.
5. Built environment factors indirectly influence traffic noise levels. Policymakers should consider elements such as population density, land use patterns, and vehicular ownership when developing strategies to manage traffic noise. For example, high population density and mixed land use can increase traffic volumes and noise, while residential areas with high vehicular ownership may experience more significant noise impacts. By integrating considerations of these factors into urban planning and policy decisions, such as promoting sustainable land use, encouraging public transportation,

and managing vehicle ownership, policymakers can more effectively control and reduce traffic noise levels in urban areas.

6. Low-noise pavement , advancements in vehicle tire technology, the promotion of electric vehicle adoption , enhancing road infrastructure ,urban planning initiatives such as road network optimization, traffic flow management, traffic signal coordination ,speed restriction enforcement and reduction of heavy traffic congestion.
7. Use of noise barriers, natural greenery, structures, and various urban obstacles that notably contribute to reducing sound levels.
8. The government should implement comprehensive policies addressing the architectural design of buildings with a focus on mitigating noise pollution. These policies should encourage the use of soundproofing materials, strategic building orientation and advanced construction techniques to reduce the impact of external noise from traffic, industrial activities, and urban congestion. Additionally, guidelines should promote the incorporation of green spaces, noise barriers, double-glazed and plenum windows to enhance indoor acoustic comfort. Such policies would not only improve the quality of life for residents in densely populated areas but also contribute to healthier, more sustainable urban environments.
9. In this research, it was observed that Building 1, with a receiver located at a horizontal distance of 38.3 meters from the road edge, recorded a minimum traffic noise level of 62.9 dB(A). In contrast, building 2, with a receiver at a horizontal distance of 25.03 meters from the road edge, experienced a higher noise level of 69.4 dB(A). These findings demonstrate that traffic noise levels decrease with increased distance from the road. To address this, the government should introduce policies mandating a minimum setback distance for commercial and residential developments from road

edges. These regulations should align with WHO noise guidelines to ensure compliance with acceptable noise levels for different zones, thereby improving the quality of life in urban areas and protecting public health from the adverse effects of excessive noise exposure.

7.6 Limitations

The scope of the present study is limited to study of noise at mid-blocks only. The developed software for “Heterogeneous road traffic noise modeling at mid-block sections of mid-sized city in India” is applicable to all areas with uninterrupted mixed traffic flow in plain areas. The noise transmission should be free-field and with no barrier between the source and the receiver. The software is calibrated to weather conditions existing in the Indian tropical plains with wind speed not exceeding 4 m/s. The condition of the topography being plain area with mixed traffic, free-field transmission of noise signals, and no barriers between the source and receiver are its limitations. Subject to the above limitations, the software is replicable in all areas of mixed traffic flow with similar geographic, environmental and traffic conditions.

The replacement of standard FHWA (Federal Highway Administration) noise emission curves with customized emission curves specific to Indian traffic scenarios is essential due to stark differences in traffic composition, driver behaviour, road conditions, and ambient noise characteristics between the U.S. and Indian contexts. The FHWA model, while robust for homogeneous and disciplined traffic, does not account for the heterogeneity and high honking rates typical of Indian roads.

In our study, noise emission data were collected from two Indian cities—Gorakhpur and Varanasi—at a total of five distinct locations (as detailed in Section 3.3.1). Each site was carefully selected to minimize the influence of non-traffic noise sources to ensure the accuracy of the measured data, particularly when isolating emissions from single categories of vehicles. However, such locations are extremely limited, especially in urban Indian settings where ambient noise sources are pervasive. While the dataset may appear geographically limited, it still represents two diverse urban environments, contributing to the robustness of the emission curve development. Furthermore, due to resource and funding constraints, it was only feasible to collect data in the specified cities. The current REMEL (Reference Mean Emission Level) curves derived from this dataset thus serve as a regional alternative to FHWA curves, more suited to Indian traffic environments, even if not yet nationally representative. Going forward, the approach developed here lays the groundwork for broader data collection efforts in future. With expanded funding, similar methodologies can be applied to other cities across India to create a generalized Indian traffic noise prediction model.

The developed model for prediction of road traffic noise at different floor levels of buildings in a mid-sized Indian city are efficient in predicting the Leq and L10 at a different floor at the high-rise residential building for heterogeneous traffic flow conditions in a country like India. However, the developed model is likely to be applicable to similar geo-environmental conditions and heterogeneous traffic in the plain areas. It may however be ensured that there are no obstacles between the source and the receiver, and conditions for reverberant field exists. The wind speeds should be lower than 4 m/s and the weather should be fair. The SLM should be calibrated before use.

7.7 Future Scope

1. The traffic dynamics, geometric road design, and land use patterns in urban and metropolitan cities differ markedly from those in mid-sized cities. In urban and metro areas, in addition to a higher volume of private vehicles, there is a substantial presence of public transportation options such as buses, trams, and taxis, contributing to more complex traffic flow. Moreover, the proportion of non-motorized vehicles like bicycles, rickshaws, and pedestrians varies significantly, often being much higher in urban centres. This diverse mix of motorized and non-motorized traffic, coupled with higher population density and different land-use zoning, creates unique challenges in traffic management. Consequently, traditional traffic noise studies conducted in mid-sized cities may not accurately reflect the noise levels in urban and metro settings, indicating the need for specialized studies tailored to the specific conditions of these areas.
2. In mid-sized cities, a separate study focusing on honking patterns should be conducted to accurately assess the frequency of horn usage and its contribution to elevated noise levels. This analysis would provide valuable data on the impact of honking on overall traffic noise. By integrating these findings, a honking correction factor could be developed and incorporated into traffic noise modeling, ensuring a more precise and realistic representation of noise pollution in urban environments. This would allow for better noise management and mitigation strategies, tailored to the unique soundscape of mid-sized cities.
3. This study emphasized how urban canyon geometry significantly affects noise distribution, which varies across different cities. It focuses on vertical noise variation

in high-rise buildings within a mid-sized Indian city, where urban canyons generally feature streets bordered by moderately tall buildings, unlike the skyscrapers of larger cities or the shorter structures of smaller towns. However, urban and metropolitan areas present different urban canyon configurations, suggesting that further research could explore noise variation in these larger urban environments.

4. Future studies should evaluate the applicability of various conventional models—such as FHWA, CNOSSOS, and ASJ-RTN—as well as machine learning models like Linear Regression, Support Vector Regression (SVR), Random Forest, Gradient Boosting, and Artificial Neural Networks (ANN) for predicting noise generated by heterogeneous traffic flow.