Estimating Traffic Induced Noise in Urban Area: An Overview

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Abstract: *In recent years, urban noise pollution has risen to the top of the list of the most serious human health issues. Automobiles are the most common source of noise in urban areas. This study provides an overview of various approaches to traffic noise modelling methods. It examines the components that influence traffic-induced noise before critically evaluating various methods for estimating traffic-induced noise in metropolitan areas. Finally, suggestions are provided for future investigation.*

Keywords: Approach, Modeling, Noise, Review, Traffic

1. Introduction

The road system is important part of infrastructure which can affect economic development of any country. Rapid urbanization due to infrastructure expansion has negative consequences for the environment in the form of air, noise, water, and land pollution. Noise pollution is caused by a variety of factors, including traffic and vehicle transportation. Noise is defined as a level of sound that surpasses what is considered acceptable and causes aggravation. Noise is an undesirable or unpleasant sound that affects a person's psychological and physical well-being, causing irritation, headaches, ear impairment, nausea, vomiting, sleep disruption, hypertension, and cardiovascular difficulties. It also has a negative impact on task performance. The noise produced by automobiles is referred to as "community noise." Community noise is defined as noise emitted from all sources except noise at the industrial workplace. Road, rail, and air traffic, construction and public works, and the neighbourhood are all major sources of community noise.

The sound pressure level is defined as,

$L_p = 10 \log_{10} (P/P_r)^2$ ……………………… (1)

Where, L_p = Sound pressure Level in dB

P = root mean square sound pressure usually in $\mu N/m^2$

P_r = reference sound pressure

The reference sound pressure Pr has an internationally agreed value of 20 $\mu N/m^2$ (CPCB 2001).

L_{eq} (equivalent continuous sound level): Sound levels often fluctuate over a wide range with time. Equivalent sound level can be obtained from variable sound pressure level L, over a time period T, by using following equation,

$L_{eq} = 10 \log_{10} [1/T \int_0^t 10^{\frac{L}{10}}\, dt]$ ……………… (2)

Many countries have implemented noise regulations by enacting emission guidelines and regulating building acoustics. Few countries, on the other hand, have regulations on neighbourhood noise, but due to a lack of methods to define and measure it, as well as the difficulty of controlling it, the health effects of these exposures have arisen and resulted to interference with communication.

Sunday Olayinka Oyedepo (2012) conducted a study to review noise pollution levels and sources in Nigerian urban areas. The study found that noise pollution in Nigerian cities is relatively high when compared to recommended levels by the

World Health Organization (WHO), Housing and Urban Development (HUD). Table-1 shows the limiting value of noise level of various countries for the defined zone, industrial, commercial, residential, and silent zone respectively.

Table-1 Standard Noise Levels

Countries	Industrial (dB)		Commercial (dB)		Residential (dB)		Silent zones (dB)	
	Day	Night	Day	Night	Day	Night	Day	Night
India	75	70	65	55	55	45	50	40
Australia	55	55	55	45	45	35	45	35
Japan	60	50	60	50	50	40	45	35
US, EPA WHO	70	60	60	50	55	45	45	35

There is no legislative framework in Nigeria that can be used to reduce noise pollution. According to the report, Nigerian cities are plagued by noise, with road traffic, industrial machinery and generators being the main culprits [1]. Environmental influences are interconnected, and human comfort is a complicated state influenced by all of these aspects as perceived by the individual. Sepehari S. et al. (2019) showed that how noise affected human cognitive performance and thermal perception in varied air temperatures.[2]

2. Factors affecting traffic induced noise level

The major factors that affect the noise level in urban area are includes various conditions such as traffic condition, location condition and atmospheric condition. Figure 1 lists out some parameters which may be included by various researcher for traffic noise modelling.

Vishal Konbattulwar (2014) developed a noise prediction model that takes into account a variety of characteristics and can be used to measure the degree of noise experienced by commuters in India's Mumbai Metropolitan Region. They looked at a variety of vehicles, including air-conditioned (A/C) cars, non-A/C cars, buses, and three-wheeler autos. Noise levels were often greater in the area of intersections and signalized junctions, according to the researcher [3]. In urban areas, there is more traffic on the road during peak hours than during off peak hours, and so the noise level changes according to the amount of traffic on the road. Weijun Yang (2020) conducted the research in Foshan, China's Chancheng District. The city's level of noise is also higher at off periods than during peak period, which is likely due to faster speeds and larger traffic volume. [4] When the number of parameters affecting the traffic noise model are more, the accuracy of model increases subsequently, N. Genaro et al. (2010) considered 25 different parameters to create an artificial neural network based model, namely, traffic flow type, time of day, number of vehicles with siren, average vehicle speed, average building height, state of the pavement, type of pavement, road width, distance from noise source, commercial or leisure environment, construction work in the area, stabilization time, ascendant light vehicle flow, descendant light vehicle flow, ascendant motorcycle flow, descendant motorcycle flow, ascendant heavy vehicle flow, descendant heavy vehicle flow, abnormal events related to traffic, abnormal events unrelated to traffic, road slope, number of ascending lanes, number of descending lanes, street type, street width.[5] The overall noise level in the area is also influenced by land use and the surrounding neighbourhood. There is heterogeneous traffic in developing countries like India, which leads to an increase in noise levels due to mixed traffic, congestion, honking, and a lack of awareness. Ritesh Vijay (2015) studied the impact of honking on noise caused by a variety of traffic circumstances. He gathered information such as traffic volume, noise levels, honking, road shape, and vehicle speed, among other things. Due to various characteristics later discovered as honking, road layout, and vehicle speed, the initial study revealed a lack of association between traffic volume and comparable noise. Furthermore, a frequency analysis of traffic noise revealed that honking added 2 to 5 dB (A) of additional noise, which is rather considerable.[6]

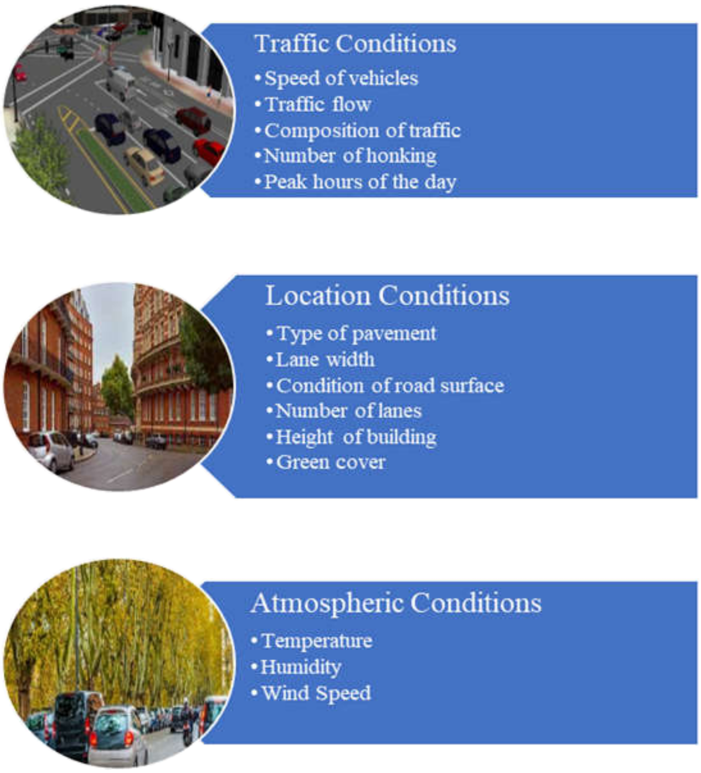

Figure-1 Factors affecting traffic induced noise level

Maya M.S. et al. (2015) also considered honking as one of the major causes of traffic noise pollution. They created a model in Thiruvananthapuram city using various parameters like, number of heavy vehicles, number of light vehicles, number of honking and speed of vehicles. [7] Noise propagation or absorption is also influenced by the land use and surroundings. Noise levels rise in areas with heavy traffic because of chaotic development, as opposed to sparse and well-planned development. Traffic noise surveying and analysis were conducted by Bengang Li et al. (2002) along three major routes in the Beijing urban region. The data demonstrate that during the day, traffic flow on these main thoroughfares is congested, and the levels of noise emitted by automobile traffic on them exceed important environmental regulations. The spatial pattern of vehicular traffic was also investigated, with the findings suggesting that the spatial variances are mostly due to the unequal expansion of Beijing's metropolitan districts. [8] The noise level fluctuations have been noticed at numerous spots along the road; as we walk away from the intersection, the noise level decreases. The noise level at roundabout and signalised intersections approaches the top limit, according to Feng Li et al (2017)

[9]. The traffic noise system is composed of the road traffic subsystem, the human subsystem, the environment subsystem, the traffic network subsystem. (Gilani et.al. 2021)[10]

3. Methods and technique for estimating traffic induced noise

Many academics throughout the world have utilized various approaches and strategies to anticipate noise levels, such as the parametric approach, the non-parametric approach, and simulation. When regulatory road traffic noise data is partial, incorrect, or missing, it is required to classify and qualify the data by prioritizing certain sources of information and criteria above others. Using the Morris screening method, Pierre Aumond et al. (2021) performed an overall sensitivity analysis of the CNOSSOS-EU model.[11] Mutasem El-Fadel (2002) demonstrated a pioneering use of the recently released Traffic Noise Model (TNM) by the US Federal Highway Administration (FHWA), which is presently being implemented in to replacing the outdated STAMINA package by the FHWA. In the context of an expanding metropolis with lax construction regulations and insufficient buffer widths between highways and building boundaries, TNM is used to assess the noise impact of multiple motorways running parallel and above one other. Table 2 shows some of the Traffic Noise Prediction Models among various countries. The features of traffic flow, such as volume, vehicle classification, and travel speeds, were determined for this purpose along existing and proposed highways [12]. Bhaskar A et. al. (2004) integrated the Dynamic areawide Road traffic noise simulator-DRONE by combining a road traffic noise prediction model (ASJ MODEL-1998) with a road traffic simulator (AVENUE). This combined traffic-noise-GIS-based toot has been updated to anticipate noise levels in densely populated areas. Traffic simulation combined with a noise model allows for dynamic access to traffic flow data and, as a result, automated and detailed traffic noise predictions. The prediction is made on a temporal as well as a spatial scale. The GIS connection creates dynamic areawide traffic noise contour maps, which provide a visual picture of noise pollution. [13] Traffic noise prediction is a significant issue in urban traffic environment planning. Because of the varied traffic conditions at crossings, forecasting traffic noise is difficult. To evaluate traffic noise around roundabouts and signalised intersections, Feng Li et al. (2017) suggested a microscopic traffic simulation-based dynamic traffic noise estimation approach. An experimental method is used to develop a vehicle noise emission model that takes into account the influence of acceleration. The model's accuracy is checked by comparing it to measured data. The effects of differing traffic volumes Simulated and contrasted traffic noise around roundabouts and signalised junctions. The mechanisms behind certain key correlations amongst vehicular noise and volume are studied. The data show that when traffic is congested, traffic noise reaches an upper limit, with the exit lane contributing much more noise energy than the entrance lane. [9]. Hunjae Ryu et al. (2017) proposed a statistical model for predicting noise levels. They used a noise map of a city in South Korea to examine spatial dependency on geographically surrounding locations. After that, using the spatial autoregressive model (SAR), the spatial error model (SEM), and an ordinary least squares (OLS) model, the population-weighted mean of the noise level was regressed on the average urban form [14]. Due to its predictability and precision, soft computing approaches such as fuzzy logic, Artificial Neural Network (ANN), ANFIS, and others are becoming more popular in comparison to classic statistical regression techniques. To anticipate vehicular traffic noise in metropolitan areas, Francis Cirianni et al. (2015) created a multilayer feed forward back propagation neural network. To forecast the equivalent continuous sound level (L_{eq}) in decibels(A), the proposed ANN model was applied. The regression analysis and the projected L_{eq} from the neural network approach were also compared to the actual measurement.[15] Sharaf Al Khederey et al. (2021) used an adaptive neuro-fuzzy inference system (ANFIS) to predict traffic noise levels on a Kuwaiti ring road using Count of light and heavy vehicles, vehicle noise level, average pace of both, building elevation, lane width, surface condition, and wind and pavement temperature are among the 10 factors. Machine learning was used to build a vision-based automobile detection mechanism. For the Ann based (ANFIS) traffic noise estimation method, the model was 90 % effective, with just an RMSE of 0.0022. [16] Soft computing approaches were used to identify a model produced by SL. Fortuna et al (2001) based on the utilization of several key parameters. They've suggested novel models for predicting acoustic noise that are based on soft computing approaches, specifically MLP-type neural networks, with a set of fuzzy rules generated by Sugeno's optimization method and a neuro-fuzzy network with constant consequents.[17]

Table-2 Analysis of literature on approaches

Approaches	References	Detailed approaches/tools
Parametric approaches	Maya M.S. et al. (2015)	Multiple Linear Regression Model
	Hunjae Ryu et al. (2017)	Spatial Autoregressive Model
	Sujit kumar De et al. (2017)	Adaptive Traffic Noise Model
	Deok-soon et al. (2013)	ASJ Traffic Noise Prediction Model
	Mutasem El-Fadel (2002)	FHWA Traffic Noise Prediction Model
Non-parametric approaches	N. Genaro et al. (2010)	Artificial Neural Network
	Francis Cirianni et al. (2015)	A Neural-fuzzy Logic Approach
	Sharaf Al Khederey et al. (2021)	Adaptive Neural-fuzzy Inference System
	SL. Fortuna et al (2001)	A Neural-fuzzy Logic Approach
	Cammarata (1995)	Neural technique based on a Backpropagation
	Gilani et al. (2021)	Graph Theory technique
Simulation	Bhaskar A et. al. (2004)	A hybrid approach integrating the Simulation and Traffic Noise Predictive Model along with GIS tool
	Feng Li et al. (2017)	Traffic Noise Simulation
	William H.K. Lam et al. (1998)	Monte Carlo Technique
	Bany Bossam Eldien et al. (2009)	GIS-based Noise Mapping
	Melova et al. (2014)	Descriptive Simulation
	Feng Li et colleagues (2017)	Dynamic Traffic Noise Simulation
	Alina Petrovici et al. (2020)	Traffic Microsimulation Models

The accuracy of traffic noise monitoring methodologies and noise estimations in Hong Kong were investigated by William H.K. Lam et al. (1998). To integrate the uncertainty in traffic noise estimations in Hong Kong, a simulation model using the

Monte Carlo technique was developed. [18] According to Cammarata (1995), semi-empirical methods, regression analysis, for example, does not produce particularly accurate estimations of the noise level trend. The authors employed a Back - propagation algorithm Network-based neural approach. to try to address this problem (BPN). The neural approach to the problem revealed the need for a set of auditory data in particular phases. They proposed using a cascading neural structure with two levels The learning vector quantization system is a supervised categorization network that filters data at the first stage, discarding any inaccurate data, while the BPN forecasts data at the second stage.[19] Gilani et al. (2021) used a graph theory technique to build road traffic noise models that included factors relating to the road traffic subsystem. Vehicle speed, carriageway width, traffic volume, number of heavy trucks and number of honking incidents were among the road traffic subsystem variables chosen for modelling purposes. Although the results were slightly exaggerated, the models were proven to produce satisfactory outcomes. Considering the anticipated changes in the values of the study's independent variables, the method could be useful for estimating future noise levels.[10] GIS software is also gaining popularity among urban planners. GIS-based noise mapping can provide a better understanding of current situations, allowing policymakers to develop frameworks to reduce noise pollution. Bany Bossam Eldien et al. (2009) used a Geographical Information System to conduct a study with 400 sampling points and create a noise pollution map of Suez city centre in Egypt (GIS). Noise pollution has also been discovered around major roads, according to the study [20]. After a series of lab tests, Enrico Gallo et al. (2018) created an app for signal processing and data transmission for the Regional Environmental Agency (ARPA Piemonte). The IoT Open Data platform collected hourly data for months in real time, resulting in a first exposure map for leisure noise and an annual detailed spectrum of hourly noise levels. The authors have used this data-driven method to have an impact on the political agenda, a greater positive participation of residents in focus groups, local entrepreneur engagement, and patron awareness, all in order to begin a better adaptation of open-air events to city living.[21] Melova et al. (2014) have demonstrated how traffic related noise spreads. Each road construction's explanation is explained in a straightforward manner using descriptive simulation. Projects that included a noise study simulation were found to be easier to enforce for the general public than those that did not. Vegetation growth simulation across various time periods is rapidly becoming an important part of urban transportation designs due to increasing environmental pressure. Practice shows that the design value of these simulations is increasing as the global traffic load increases [22]. Anca et al. (2015) investigated noise levels in several locations of Timisoara in order to identify the city's most vulnerable structures. Because the noise level resulting from exposure to road noise exceeds or threatens to exceed at least one of the limit values on these building facades, their identification is critical. The parameterization of traffic noise prediction models varies, and as a result, different estimations of noise levels may be produced based on the geographical context in terms of emission sources and propagation field.[23] Jibran Khan et al. (2021) compared the source and propagation characteristics of The European regulation, Common Noise Assessment Methods for European Union Member states (hereafter, CNOSSOS), Nord2000, and also the Traffic Noise Exposure (TRANEX) approach are three examples of such models. based on UK methodology. Overall, CNOSSOS and TRANEX generated similar results, with TRANEX marginally outperforming CNOSSOS in recreating Nord2000 LAeq values.[24]. Traffic noise prediction is difficult due to the complex traffic flow at road crossings. To evaluate traffic noise near roundabouts and signalised crossings, Feng Li et colleagues (2017) focused on microscopic traffic simulation, a complex traffic noise simulation technique was created. An experimental method is used to develop a vehicle noise emission model that takes into account the influence of acceleration. The model's accuracy is checked by comparing it to measured data. The effects of differing traffic volumes on traffic noise near roundabouts and signalised intersections are simulated and compared. They came to the conclusion that when traffic is light, traffic noise reaches a maximum level.[25] According to a behavioral study, the local average noise level from road traffic exceeds the national average in numerous places. Few people, on the other hand, have the adaptive capacity to ignore the influence of ambient noise pollution within reasonable bounds. Sujit kumar De et al. (2017) created an adaptive traffic noise model for a noise-prone zone's susceptible community.[26] Iphan F. Radam et al. (2018) investigated the effects of traffic on the impact of noise generated in an open space with no obstructions at distances of 0 metres, 17.5 metres, and 35 metres. According to the findings of the investigation, traffic flow has a high correlation level as a source of noise at a distance, and noise levels have a decreasing correlation level.[27]. Individual driver-vehicle-units (DVUs) and their interactions are used in traffic microsimulation models, allowing for a thorough evaluation of traffic noise utilising Common Noise Assessment Methods (CNOSSOS). Alina Petrovici et al. (2020) applied a multifractal approach to the propagation of acoustic waves. The approach's originality stems from the multifractal model's freedom, which permits the simulation of varied acoustic wave behaviours using the fractality degree. The mathematical foundation of the model is based on Cayley–Klein absolute geometries, which are periodic mappings of conventional space and the Lobacevsky surface in a variational metric.[28]. Deok-soon et al. (2013) developed a method for estimating road traffic noise for environmental assessment that took traffic volume and road surface variables into account. The ASJ model (Acoustical Society of Japan Model for Traffic Noise Prediction) utilizes statistical model for two different categories of road surfaces: permeable asphalt (PA) and dense-graded asphalt (DGA), this is determined by the sound intensity of the noise generated by the friction between the tyres and the road surface and measured sound pressure levels were found to be in good agreement.[29]

4. Discussion & Conclusion

Noise pollution is caused by a variety of factors, the most prominent of which being traffic in urban areas. Location, traffic volume, density, honking occurrences, percentage of heavy vehicles, Gradient vegetation cover, land use etc. Various studies in the subject of noise estimation and prediction models have been carried out by a number of researchers. Following tables shows the basic highlight of various approaches used for estimation of noise level.

Table-3 Approaches to Traffic Noise Models

Sr. No.	Approach	Highlights
1.	Statistical tools, regression analysis & parametric Approach	It simplifies the estimating process and, more crucially, these linear equations have an easy-to understand modular interpretation
2.	Graph Theory, Various algorithm and non-parametric Approach	Helpful tool to quantify & simplify the many components of dynamic and complex systems
3.	Soft computing techniques	(1) It made it feasible to solve nonlinear

	like Fuzzy logic, ANN etc.	problems for which mathematical models are unavailable, and (2) It introduced human knowledge such as cognition, recognition, comprehension, learning, and others into the computing domains.
4.	Software & Simulation	Variable conditions and results can be explored. Without putting oneself in danger, critical situations can be studied. It is inexpensive. Simulations can be sped up to allow for more in-depth analysis of behaviour over a longer period of time.

Every locality has its own set of traits, and the law and order in each location differs. The procedures used to estimate noise vary depending on where you are. Simple linear regression analysis is not relevant to all areas, and it has a number of drawbacks, such as the selection of independent variables that may or may not be truly independent. The complex and dynamic system can be solved using a graph theory technique. Many academics have devised various algorithms, each with its own set of advantages and disadvantages. Soft computing techniques gaining popularity can correlate human complex behavior and can give better results. Hopefully, additional research will be done in the future to improve the prediction of noise levels in metropolitan areas using artificial intelligence and soft computing technologies.

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