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Assessment of Traffic Noise and Development of Noise Models for National Highway-06, Passing through Chhattisgarh, India

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Abstract

Background/Objectives: Traffic noise pollution is a major concern of the societies residing near the busy National highways. The recognition of this noise as the main source of environmental pollution has compelled the construction engineers & traffic planners to bring forth the models that enable us to predict noise from basic variables. These noise prediction models are very much needed as helping tools in the design of roads& traffic and in assessing frequent changes in traffic noise scenario. In India, vehicular traffic is increasing tremendously, which has given birth to overcrowded roads and simultaneously to noise pollution. Therefore, it is expected to develop noise prediction models suitable for national highways pertaining to Indian context **Methods:** This paper is the zest of a research conducted on National highway-06 with the sole purpose of setting up traffic noise models based on existing traffic conditions. Traffic noise levels have been measured by noise meter SL4023 SD by adopting standard procedure. **Findings:** In the process of observation & measurement of noise data, noise levels were found alarmingly& consistently high. After the analysis coefficient of correlation (R^2) for the developed model for Supela (Location 1) and Power house (Location 2) are found 0.78 and0.70 respectively, which is lying in acceptable range. **Applications:** It can be concluded that traffic noise prediction models so developed is theoretically acceptable and conveniently applicable for real traffic conditions of National highway-06passing through Chhattisgarh, India.

Keywords: Model, Noise, Traffic Noise Prediction

1. Introduction

Though technological advancements have brought many conveniences, it has also resulted in many bottlenecks. Pollution of various types is one of them. These include air, water and noise pollution. Noise is one of the irritating &harmful components of environmental pollution for the residents residing near the busy highways[1,2] therefore, many countries have enforced noise emission standards for vehicles and framed laws to reduce highway traffic noise[3–6]. The recognition of this fact has led planners & designers to develop models that enable us to predict traffic noise levels[7]. A number of models have been developed with the help of regression/multi regression analysis of gathered data, obtained from the basic variables such as traffic flow, speed of vehicle and sound levels[8,9]. In recent years a few developed models for prediction of road traffic noise were found suitable for that region[10–12].

1.1 Need to Predict Traffic Noise in India

Noise prediction models having varying characteristics are developed by many developed & western countries[13,14]. Few of them are based on $L_{10,}$ L_{eq} traffic noise parameters. In India, vehicular traffic has-been increasing at an average pace of 10.16% per annum over the last five years and vehicular traffic noise is contributing nearly 70

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% of total noise pollution in our environment[15,16]. These noise levels exceed the prescribed levels in most of the internal peripherals and on to the highways[17]. Hence, to assess traffic noise in its spatial temporal aspects on high ways and to formulate traffic noise prediction model for effective planning and designing of road networks its prediction is the demand of the day for the highways of developing countries like India.

1.2 Objectives of Research

- To monitor and assess highway traffic noise in its spatial temporal aspects on highways.
- To formulate traffic noise prediction model which can be more theoretically acceptable and conveniently applicable for real traffic conditions of National highways passing through Chhattisgarh.
- The model should support construction engineers in addition to traffic planners as a supplemental tool to predict traffic noise for existing and proposed highways.

1.3 Concept of Fundamental FHWA Model for Predicting Noise

The noise levels of road traffic in the proximation of roadways can be predicted on the basis of each vehicle noise levels, vehicular volume and speed, distance from the observer and is also based on other correlations[18].

The fundamental Federal Highway Administration (FHWA) model is presented here after:

$$L_{eq} = L_0 + A_{VS} + A_D + A_B + A_F + A_G + A_S$$

In the present model, L_{eq} represents hourly equivalent sound level, L_0 represents reference energy mean emission level, A_{VS} represents volume and speed correction, A_D represents distance correction and A_B represents barrier correction, A_F represents flow correction, A_G represents gradient correction and A_S represents ground cover correction.

The hourly distribution of traffic is being determined for a typical 24 hour day night noise levels and the traffic volume input data is adjusted to determine an equivalent hourly traffic volume. By the application of the input data and the FHWA methodology, noise levels have been obtained for existing and future conditions. According to the requirements of FHWA Model, the observations are recorded on the experimental locations. The measurements of traffic volume and speed with fixed observation distance (10 meters) from the centreline of the road have been considered for all sampling stations under consideration. The noise level observations have been taken from marked locations and a comparison has been presented between the observed and predicted noise levels using FHWA model.

1.4 Background of National Highway- 06

It lies between latitude 15°21'N and longitude 9°42'E. The length of National Highway-06 is 1949 kilometres. A number of transport& goods transport companies have their offices& godowns in Durg & Raipur, which is the focal point for the in word and out word movement of transportation vehicles. It is one of the busy highways connecting various states and their capitals, and paves path for India's commerce and industrial development.

1.5 Location Plan

This research is mainly intended to measure the noise levels on the stretch of National Highway -06, passing through Durg-Raipur region, of Chhattisgarh. The locations were so chosen so as to represent different pavement characteristics of National Highway-06.Only two locations have been presented in this paper with noise, volume & speed data for understanding the nature and level of noise & other characteristics of traffic for the development of noise models. Line plan of it is depicted in Figure 1.

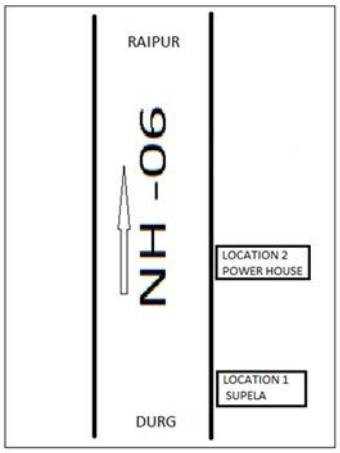

Figure 1. Line plan.

2. Materials and Working Methodology

2.1 Technique of Measurement of Noise

The sound level meter SL 4023 SD as shown in Figure 2 was mounted on a tripod at a distance of 1.5meters from the existing road corner and at an altitude of 1.2meters from the road surface[19].

Figure 2. Noise level meter SL4023 SD.

The process of noise measurement at Power House (Location 2) is depicted in Figure 3. The process measurement is carried out for typical 24 hours day night basis as per the need of FHWA model for all sampling stations under study.

Figure 3. Noise measurement in progress on National Highway -06.

Traffic volume is observed manually by forming volunteer groups at the selected locations/sites. Vehicles

Table 1. Traffic volume (in PCU/HR) for location 1, supela

Time	C/J/V	SC/MC	LCV	BUS/ TRUCK	T/T	PCU	PCU HEAVY VEHICLE	PERCENTAGE OF HEAVY VEHICLE
12:00-1:00 PM	221	37	120	33	441	852	561	65.84507042
1:00-2:00	102	15	52.5	24	175.5	369	228	61.78861789
2:00-3:00	110	4.5	30	3	319.5	467	349.5	74.83940043
3:00-4:00	66	7	25.5	3	405	506.5	430.5	84.99506417
4:00-5:00	41	20.5	24	18	315	418.5	339	81.00358423
5:00-6:00	61	53	40.5	51	405	610.5	445.5	72.97297297
6:00-7:00	61	62	64.5	84	180	451.5	244.5	54.15282392
7:00-8:00	107	78.5	64.5	105	225	580	289.5	49.9137931
8:00-9:00	615	171	66	159	27	1038	93	8.959537572
9:00-10:00	1014	440	112.5	234	4.5	1805	117	6.48199446
10:00-11:00	1420	502.5	84	201	4.5	2212	88.5	4.000904159
11:00-12:00	1252	353	66	150	22.5	1843.5	88.5	4.800650936
12:00-1:00 AM	782	315	181.5	336	18	1632.5	199.5	12.22052067
1:00-2:00	956	347.5	127.5	189	54	1674	181.5	10.84229391
2:00-3:00	1283	425	208.5	192	45	2153.5	253.5	11.77153471
3:00-4:00	1185	435	120	180	9	1929	129	6.687402799
4:00-5:00	1380	432.5	94.5	123	36	2066	130.5	6.316553727
5:00-6:00	1477	492.5	79.5	189	9	2247	88.5	3.93858478
6:00-7:00	1394	465	54	168	18	2099	72	3.430204859
7:00-8:00	933	405	78	150	9	1575	87	5.523809524
8:00-9:00	844	205	55.5	123	4.5	1232	60	4.87012987
9:00-10:00	498	105	234	84	22.5	943.5	256.5	27.18600954
10:00-11:00	665	72.5	168	42	189	1136.5	357	31.41223053
11:00-12:00	255	54.5	166.5	30	477	983	643.5	65.46286877

have been divided into five categories such as Car/Jeep/Van, LCV, Bus/Truck and Tractor/Tralya. Sum total of vehicles passing in each category, in one hour for a total period of 24 hours is recorded& tabulated in terms of vehicles/hour and then converted to a single entity called Passenger Car Unit (P.C.U.) equivalent values. In normal practice, spot speed is measured by Doppler Radar Gun, But due to the non-availability of Doppler Radar Gun, manual method of spot speed measurement is practiced in the present study. Two points are ear marked with a known distance of 75 meters on the road at the sampling site for this purpose. Then with the help of stop watch the time taken by the vehicle to cross that earmarked distance is recorded. Dividing that distance with the time taken in crossing the distance, is being calculated, which gives the speed in Kilometres/hour for that vehicle & in this way the speed is found out for each class of vehicle for every hour of study[20].

2.2 Traffic Data Compilation on National Highway -06

2.2.1 Location 1(Supela)

A traffic data compilation programme was chalked for classified traffic volume& presented in Table 1.

A traffic data compilation programme was chalked for speed and presented in Table 2.

2.2.2 Location 2 (Power House)

A traffic data compilation programme was chalked for classified traffic volume& presented in Table 3.

A traffic data compilation programme was chalked for speed and presented in Table 4.

Table 2. Average traffic speed for location 1, supela

Time	C/J/V	SC/MC	LCV	BUS/TRUCK	T/T	AVG. SPEED
12:00-1:00 PM	39.65	41.7	32.1	37.5	36.7	37.53
1:00-2:00	42.65	40.2	42	40.9	40.7	41.29
2:00-3:00	40.5	39.92	33.8	38	34.5	37.344
3:00-4:00	40.35	42	36.5	34.1	32.5	37.09
4:00-5:00	45	39.65	44.5	44.1	31.2	40.89
5:00-6:00	44.45	43.9	33.8	38.75	39	39.98
6:00-7:00	41.05	43.6	36.3	54.6	39.8	43.07
7:00-8:00	46.45	46.85	36.9	35.45	39.82	41.094
8:00-9:00	41.35	41.05	41.5	37.4	36.31	39.522
9:00-10:00	45.76	43.34	36.43	38.27	40.62	40.884
10:00-11:00	46.15	46.25	37	35	42.1	41.3
11:00-12:00	49.08	50.04	40.38	45	40.8	45.06
12:00-1:00 AM	48.34	44.08	46.27	40.23	48	45.384
1:00-2:00	41.28	36.62	38.08	43.11	44.15	40.648
2:00-3:00	64.73	44	41.8	43.01	37.75	46.258
3:00-4:00	38.82	35.33	36	41.25	38.66	38.012
4:00-5:00	59.91	45.62	40.21	48	41.16	46.98
5:00-6:00	53.5	52.1	59.5	43.72	63	54.364
6:00-7:00	53.5	49.84	43	50.5	50.24	49.416
7:00-8:00 AM	56.26	44.66	49.8	46.5	57	50.844
8:00-9:00	40.16	38.6	40.2	35.8	34.5	37.852
9:00-10:00	37.75	37.45	29.2	35.1	34	34.7
10:00-11:00	45.75	42.9	32	36.1	42	39.75
11:00-12:00	46.15	45.45	40.8	41.4	45	43.76

Table 3. Traffic volume(in PCU/HR) for location 2, power house

Time	C/J/V	SC/MC	LCV	BUS/TRUCK	T/T	PCU	PCU HEAVY VEHICLE	PERCENTAGE HEAVY VEHICLE
12:00-1:00 PM	990	760	141	444	40.5	2375.5	484.5	20.39570617
1:00-2:00	1110	544	165	540	13.5	2372.5	553.5	23.32982086
2:00-3:00	1100	487.5	100.5	420	54	2162	474	21.92414431
3:00-4:00	1080	517.5	111	363	54	2125.5	417	19.6189132
4:00-5:00	1175	587.5	126	612	31.5	2532	643.5	25.41469194
5:00-6:00	1220	682.5	93	828	22.5	2846	850.5	29.88404779
6:00-7:00	1326	544	45	540	4.5	2459.5	544.5	22.13864607
7:00-8:00	1466	609.5	34.5	732	4.5	2846.5	736.5	25.8738802
8:00-9:00	1738	657.5	33	447	4.5	2880	451.5	15.67708333
9:00-10:00	1620	507.5	57	351	4.5	2540	355.5	13.99606299
10:00-11:00	1075	467.5	94.5	291	13.5	1941.5	304.5	15.68374968
11:00-12:00	860	274	100.5	108	40.5	1383	148.5	10.73752711
12:00-1:00 AM	825	282.5	63	27	49.5	1247	76.5	6.134723336
1:00-2:00	205	121	13.5	42	4.5	386	46.5	12.04663212
2:00-3:00	90	33	43.5	9	76.5	252	85.5	33.92857143
3:00-4:00	67	16.5	75	18	130.5	307	148.5	48.3713355
4:00-5:00	105	60	76.5	57	112.5	411	169.5	41.24087591
5:00-6:00	155	125.5	96	45	36	457.5	81	17.70491803
6:00-7:00	220	210.5	454.5	69	99	1053	168	15.95441595
7:00-8:00 AM	211	418	94.5	393	40.5	1157	433.5	37.46758859
8:00-9:00	571	587.5	138	471	58.5	1826	529.5	28.99780942
9:00-10:00	585	687.5	70.5	732	67.5	2142.5	799.5	37.31621937
10:00-11:00	560	649	133.5	414	54	1810.5	468	25.84921292
11:00-12:00	1130	515	109.5	411	22.5	2188	433.5	19.81261426

Table 4. Average traffic speed for location 2, power house

Time	C/J/V	SC/MC	LCV	BUS/TRUCK	T/T	AVG. SPEED
12:00-1:00 PM	42.28	43	36.56	38.17	40	40.002
1:00-2:00	41.5	39.11	38.17	40.17	30	37.79
2:00-3:00	39.61	40.94	35	36.67	38	38.044
3:00-4:00	39	42.72	35.89	34.06	39	38.134
4:00-5:00	51.5	48.94	35.67	32.72	32.2	40.206
5:00-6:00	52.42	44.26	40.31	36.52	35.4	41.782
6:00-7:00	46.94	44.77	39.72	31.62	33.26	39.262
7:00-8:00	49.72	44.55	43.44	43.77	30.14	42.324
8:00-9:00	47.33	46.94	40.15	43.38	30	41.56
9:00-10:00	46.22	42.44	39.38	45.44	30	40.696
10:00-11:00	43.11	32.08	38.86	41.06	32	37.422
11:00-12:00	45.11	42.22	42.77	41.88	35	41.396
12:00-1:00AM	47	44.33	43.4	49.33	41.66	45.144
1:00-2:00	46.6	34.5	41.1	40.22	34.66	39.416
2:00-3:00	38.5	44.66	30	40	49	40.432
3:00-4:00	42.2	40.33	42.8	34	34	38.666
4:00-5:00	45.83	39.8	47.6	37	43.25	42.696
5:00-6:00	45.57	41.18	46	39	44.25	43.2
6:00-7:00	45.22	43.88	44.44	42.28	41.25	43.414
7:00-8:00 AM	40.12	42.55	46	42.83	44.66	43.232
8:00-9:00	41.9	43.11	34.29	39.67	30	37.794
9:00-10:00	42.28	43	36.56	38.17	40	40.002
10:00-11:00	41.5	39.11	38.17	40.17	30	37.79
11:00-12:00	39.61	40.94	35	36.67	38	38.044

Table 5. Observed vs. predicted noise levels

Location 1,Supela		Location 2,Power House	
Leq observed	Leq predicted	Leq observed	Leq predicted
90.8698	87.2834	84.0400	82.9130
86.2376	83.2947	86.4630	83.2550
90.8757	85.8712	86.9420	82.8300
92.4227	86.9667	85.1770	82.2130
90.0977	86.0284	86.3940	83.1950
92.2068	86.8138	87.8950	84.4070
88.4338	84.1418	84.5300	81.6910
89.0562	84.5826	87.6970	85.0540
84.5922	80.0048	86.9110	83.6130
85.9969	80.9996	86.3310	83.1440
84.1848	81.1326	84.4860	81.6550
87.4965	82.0616	83.7320	81.0400
86.1514	82.5254	84.0560	80.5010
85.7932	82.2718	75.4670	74.3750
88.4628	84.1623	81.8600	79.5350
85.2910	80.4997	85.4230	82.4110
87.3483	83.3730	82.7410	81.8610
86.9258	83.0739	80.6110	78.5270
87.0142	83.1365	85.1720	83.0160
85.3241	81.9395	84.7240	82.6540
82.1830	78.2986	83.7440	83.4780
85.1733	78.2917	88.8070	84.3350
90.3581	84.0882	85.3610	83.1690
91.0965	87.4439	85.3610	81.9160

2.3 Noise Data Measurement on National Highway -06

The noise levels have been measured from two selected locations (Supela & Power House) and a comparison has been presented between the observed and predicted noise levels (which are obtained by applying adjustments to the fundamental FHWA model.) as presented in Table 5.

3. Discussion

3.1 Steps in Model Development

In normal practise, the relationship is generally exist amongst two or more variables, when this relationship has to be represented in mathematical form by developing an equation connecting the variables, the following steps are to be adopted.

(1) Determining all the possible variables which could be taken into consideration for the development of predictive models;

(2) Fix the dependent and independent variables.

There are various independent variables which may affect the characteristics of traffic noise parameters although, in the present research the parameters like hourly traffic volume, percentage heavy vehicles & average traffic speed (in kmph), were taken as independent variables.

The general form of mathematical model for highway traffic noise prediction is mentioned below.

$$Y = m_0 + m_1 y_1 + m_2 y_2 + m_3 y_3 + \cdots m_n y_n$$

In the above modelY is traffic noise parameter i.e., L_{eq}, whereas m_0 is a constant.

$_{Y1}$, y_2, y_3 .....y_n are the variables affecting the road traffic noise like, volume, average speed & Percentage heavy vehicle.

Whereas m_1, m_2, m_3 ..... m_n are the coefficients to be identified by adopting multiple linear regression.

3.2 Fundamental Assumptions

In the process of developing the strategic planning of highway noise pollution modelling a few key but fundamental assumptions are taken into consideration, within the application of its practical limit without making any loss in its generality. For the present research the below mentioned assumptions have been taken into consideration.

1. Traffic volume is a positive integer number & can never be taken less than 1.

2. The model developed for a free flow of traffic or for an average traffic flow speed is always be greater than zero.

3. The highway patch should be flat & straight and the road should be levelled with a remarkably good surface condition so that, effect of variation in road alignment & a surface condition is excluded.

4. Model is tested under a normal climatological / meteorological condition.

5 It is assumed that, there is no noise barrier (either natural or manmade) between the observer and the source of noise, i.e., traffic flow etc.

6. In the context of referring various literature surveys, it has been observed that in many of the developed & western countries higher L_{10} or L_{eq} traffic noise parameters are generally referred as traffic noise parameters. But, in Indian context the permissible standards are available for L_{eq}. By keeping this information into consideration, the model for mathematically predicting L_{eq} has been tried in present research.

4. Result

4.1 Predictive Model

By the application of available statistics a new traffic noise model have been developed for Indian conditions in MS-Excel, for National Highway- 06, for two different locations. (by performing multiple regression analysis among three variables such as hourly traffic volume in PCU/HR, percentage heavy vehicles & average traffic speed) .

4.1.1 Location 1

Regression Output

R Square (R^2) = 0.7874.
Standard Error = 1.3542
Constant = 76.926
Independent 1 (PCU/HR) - 0.00277
Independent 2 (Percentage Heavy vehicle) - 0.1302
Independent 3 (Average speed) – 0.720
No of Observations – 24
Noise Model

$$L_{eq} = 76.926 + .00277 * PCU/HR + .1302 * PERCENTAGEHEAVY\ VEHICLE + .072 * AVG.SPEED$$

4.1.2 Location 2

Regression Output

R Square (R^2) = 0.746935
Standard Error = 1.198805
Constant = 66.908
Independent 1 (PCU/HR) - 0.002173
Independent 2 (Percentage Heavy Vehicle) - 0.118
Independent 3 (Average Speed) – 0.213
No of Observations – 24
Noise Model

$$L_{eq} = 66.908 + 0.002173 * PCU/HR + 0.118 * PERCENTAGEHEAVYVEHICLE + 0.213 * AVG.SPEED$$

5. Conclusion

The observed noise levels for two sampling locations (presented in Table 5.) clearly indicates that the observed noise levels along National Highway-06, is alarmingly high as compared to Central Pollution Control Boards standards. Therefore, controlling measures needs to be adopted to curb the ill effects of traffic noise on to the nearby dwellers and passengers frequently travelling onto it. Further the noise models developed gives the coefficient of correlation(R^2) values between 0.7 to 1.0 which is in the acceptable range. (R^2) Value1.0 indicates excellent co-relation among variables. It is a well-established fact that the noise prediction is essential element of environment impact assessment, for highway development works, Therefore, the noise models developed for national highway-06 in this research can be applied for noise prediction for the current busy highway. The model so develop should also support construction engineers & traffic planners as a supplemental tool to predict traffic noise for existing and proposed national highways.

6. Scope for Future Research

- In the present work vehicle speed was measured manually which can be done more precisely by the use of hand held Doppler radar gun.
- In the present work only three traffic parameters were

included i.e., PCU/HR, percentage heavy vehicles and Average speed .Apart from that geometric parameters, observer distance can also be included to obtain more accurate and precise results.

- In this research work the highway patch is selected without median. But nowadays, road constructions are carried out with providing ample medians. Hence, this may be given due considered for future research work.
- The current research is applicable for uninterrupted free flow traffic, but the characteristics of noise will differ for an interrupted traffic flow situation. Hence, this traffic flow situation may be taken into account for future study.
- This research took place in flexible pavement. The noise characteristics will be totally different in case of rigid payment. Hence there is sufficient scope to compare the levels of noise for rigid surface under study.
- It is very much required to construct noise barriers at locations where noise levels are exceeding prescribed standards. Studies can also be carried out for providing barriers of variable height, thickness and material type.
- The noise generated from heavy transport vehicles is of utmost concern for environmental engineers; therefore, ways and means has to be devised to ensure that these vehicles should also confirm the prescribed emission standards of central motor vehicle act.

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