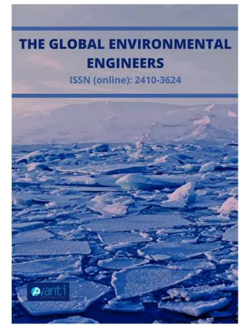
Published by Avanti Publishers

The Global Environmental Engineers

ISSN (online): 2410-3624



Prediction of Road Traffic Noise by CRTN Model in a Sub-Urban Town of India

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ARTICLE INFO

Article Type: Research Article

Keywords:
Noise model
Traffic noise
Human health
Vehicle speed
Road morphology

Timeline:
Received: August 31, 2021
Accepted: October 11, 2021
Published: October 29, 2021

Citation: Kundu S, Mondal NK, Mishra D. Prediction of Road Traffic Noise by CRTN Model in a Sub-Urban Town of India. Glob. Environ. Eng. 2021; 8: 1-13.

DOI: https://doi.org/10.15377/2410-3624.2021.08.1

ABSTRACT

The present study was undertaken for assessment of spatial characteristics of road traffic noise at varying intervals viz early morning (8-9 am), late morning (11-12 pm), afternoon (2-3 pm) and evening (6-7 pm) time at ten important locations (near school building) of G. T. Road which is passing through the Burdwan town. A digital noise meter was used for recording the traffic noise and a noise contour map was constructed by using Geographical Information System (GIS). The recorded data revealed that the highest and lowest average noises were 67.1 dB (A) and 86.9 dB (A), respectively. The results revealed that the performance of the CRTN model in both afternoon and evening time for predicting noise level near school buildings with a coefficient of determination (R2) are 0.536 and 0.544 and a mean difference of - 1.19 dB (A) and - 0.48 dB (A) between the measured and predicted values respectively. Similarly, Pearson statistics also revealed the strong correlation between measured and predicted noise level at afternoon ($r = 0.732$, $p < 0.016$) and evening time ($r = 0.744$, $p < 0.014$). However, the predicted traffic noise during early morning and late morning hours are less than 0.5. These low values are due to irregular traffic speed, traffic density and irregular building height are the appropriate reasons for low accuracy in predicting the model. Finally, it may be suggested that CRTN model can be a decision tool for predicting equivalent noise levels in a city like Burdwan.

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1. Introduction

WHO [1] recently reported that a huge population (1,00,00,000) losing their life due to traffic noise. Noise is basically a weightless pollutant and can affect both the comfort and health of the urban population [1]. Traffic noise is the major source of noise pollution in urban areas that contributes about 55% of the total noise produce in urban areas [2-3]. The fast growth of urban Centres, huge industrial development, an increase in motor vehicle population, and the spread of road networks are the main causes of noise pollution [4-6]. Vehicle noise mainly affects on the human auditory system (hearing loss, tinnitus etc.) as well as annoyance [7-8], sleep deterioration [9-10], cardiovascular disease, hypertension [11-12], ischemic heart disease, stroke, reducing work efficiency and impairment of cognitive performance in children [13-14].

In developing countries like India, the noise pollution level is associated with the fast growth of urbanisation, the rapid increase of motor vehicles and a large number of out-dated motor vehicles [15]. Interestingly, most of the Indian towns are ancient in nature which are characterized by congested roads, bad road conditions traffic jams and unplanned building patterns [16]. To reduce noise pollution, the Central Pollution Control Board, under the Ministry of Environment and Forests, Government of India, has prescribed standards of noise for various types of locations (industrial, commercial, residential, and silence zones), separately for day and night. A previous study has also pointed out that most of the Indian towns and cities are having noise levels beyond the standard prescribed by CPCB and MoEF [17]. Usually, two indicators that are mainly used for the prediction of road traffic noise are estimated L_{Aeq} or derived indicator, L_{den} [18]. Previous research [19] indicated that L_{Aeq} for road traffic noise is simple and robust and shows an excellent correlation with annoyance.

Noise mapping is the visual representation of noise level distribution of a given location and contours are coloured to represent the noise intensity [20]. According to EU noise policy group 4 on noise mapping, noise mapping includes acquisition, storage, retrieval and representation of data which related to outdoor noise levels, noise exposure, noise effects on human. Noise map is provided information for control and reduction of noise pollution to the decision maker, urban planner, public and it also shows the health risk of local inhabitants [21-22].

Numerous models based on road traffic noise were developed from all over the world, such as the American Federal Highway Administration (FHWA) model, British Calculation of Road Traffic Noise (CRTN) model, German Richtlinien für den Lärmschutz an Straben (RLS 90) model, Italian Consiglio Nazionale delle Ricerche (CNR) model, French Nouvelle Methode de Prevision de Bruit (NMPB – Routes 96) model, Scandinavian countries Nord 2000 model, Switzerland used Son Road model, European Commission developed Common NOise aSSessment methOdS (CNOSSOS-EU) and Japanese ASJ RTN 2008 model etc. [23-24]. The abetment of noise pollution is a challenging task for urban planners, environment managers as well as researchers [25]. The traffic noise prediction model is the key tool for designing environment–friendly roads and evaluating the effects of road traffic noise on the local community [26-27]. Most of the models are designed from some basic factors such as traffic volume, traffic composition, speed of vehicles, road surface characteristics, road gradient, the distance between the source of the noise and receptors [28]. The CRTN model is one of the earliest systematic road traffic noise prediction model in the world which is particularly used in UK and Hong Kong. CRTN is one of the important model for the evaluation of road traffic noise effect. Some researchers used this model in a different location in the world assessing the performance of the model [24].

The main objectives of our study are monitoring and assessing of road traffic noise status of various locations of Burdwan town and prepared a traffic noise contour map and perform CRTN model at Burdwan town. Burdwan is an important town of Purba Bardhaman district, West Bengal. The status of vehicle density is tremendously increased in the last five years and subsequently road traffic noise is also increasing day by day [29].

2. Material and Methods

2.1. Study Area

Burdwan town is the district headquarters of Purba Bardhaman district. Geographically Burdwan city located at 23°14'N latitude and 87°52'E longitude. This town is situated 100 km away from Kolkata. As per 2011 census the total population of the city is 347016 and population density is above 13000 per square kilometre. The mean elevation is 30 m above the mean sea level. In the last few years the Burdwan city has experienced rapid growth of motor vehicles for this reason traffic noise also increase significantly [29]. Figure **1** shows the road map of Burdwan Town and noise monitoring sites.

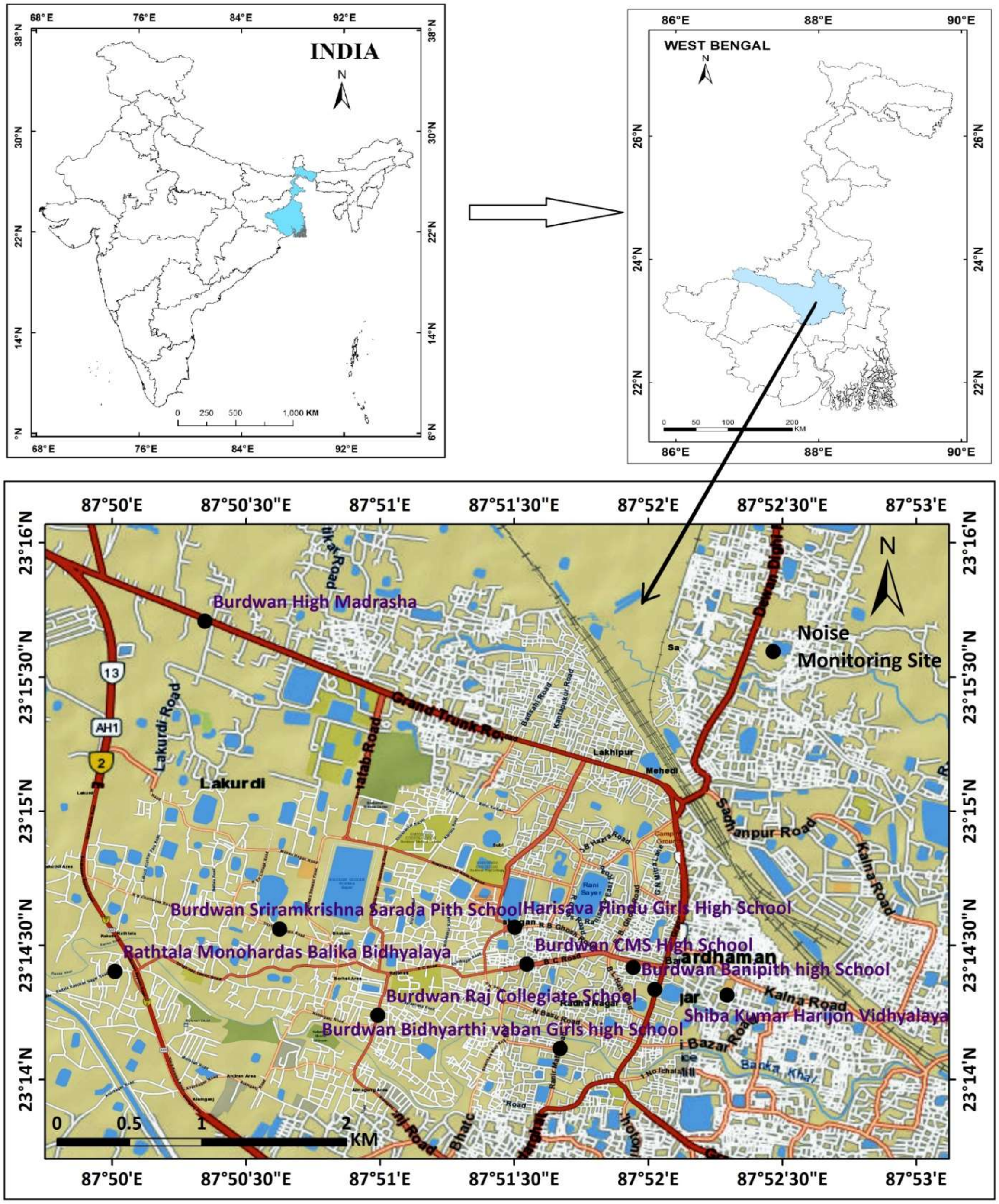

Figure 1: Location of the Study Area.

2.2. Noise Measurement

The noise was monitored by a Class 2 sound level meter (Testo 815) with ±1.0 dBA accuracy and geographical location was obtained from GPS receiver (GPS-12, Garmin). The sound level meter is set at a height of 1.2 m from the ground surface and 2 m away from the building wall to avoid reflections. Four-time session of a day was considered for noise measurement (early morning: 8-9 am; late morning: 11am-12 noon; afternoon: 2-3 pm; and evening time: 6-7 pm). Vehicle density was counted manually.

2.3. Noise Mapping

Noise mapping was constructed using ArcGIS 10.3 software for better visualization of the noise level in the town. Contour lines were plot using IDW (Inverse Distance Weighting) interpolation method. Inverse distance weighting (IDW) is an interpolation method that gave values to unknown points that are calculated from the weighted average of the known values.

2.4. Noise Modelling

The CRTN model was originated from the transport and road research laboratory and department of transport of UK in 1988. The noise was recorded 5 ± 0.5 m away from the edge of the road and the basic hourly noise level was calculated by applying the following equation (1):

$$L_{basic} = 42.2 + 10\log_{10}q + \Delta f + \Delta g + \Delta p + \Delta d \quad (1)$$

Where, L_{basic} = basic hourly noise level, q = flow/h from a distance of 5.5 m from edge of the vehicle, Δf = traffic flow adjustment, Δg = gradient adjustment, Δp = pavement type adjustment, Δd = distance adjustment.

The adjustment of heavy vehicles and speed is calculated by the following equation (Eq. 2)

$$\Delta f = 33log_{10}\left(V + 40 + \frac{500}{V}\right) + 10log_{10}\left(1 + \frac{5P}{V}\right) + 68.8 \quad (2)$$

Where, V = the mean traffic speed as per CRTN models recommendation and p = heavy vehicles (%) applying Eq. (3)

$$P = \frac{100f}{q} \quad (3)$$

Where, f = flow of heavy vehicles/h and q = total vehicles flow/h.

Similarly, extra noise coming from the road traffic was adjusted by considering the gradient. Normally, the adjusted road gradient 0.3G (G = gradient) was considered during the application of mean speed.

$$\Delta g = 0.3G \quad (4)$$

Therefore, the basic noise level was corrected accordingly with the consideration of various parameters such as distance from the source line, surface morphology of the road, screening from all sources of the barrier which directly interfere with the noise including reflection parameters. The distance correction can be calculated by Eq. 5:

$$\Delta d = -10log_{10}\left(\frac{d'}{13.5}\right) \quad (5)$$

Where, d' is the shortest slant distance from the source position given by Eq. 6:

$$d' = \sqrt{d_2 + h_2} \quad (6)$$

d = minimum horizontal distance between the noise emission source and noise recording spot and h = vertical distance between the source spot and the noise recording spot. Here, minimum horizontal distance d was considered < 4 m.

Similarly, a proper adjustment was considered when road surface is concrete with 5 millimeter or higher deep grooving, and the adjustment is equated as Eq. (7):

$$\Delta d = 4 - 0.3\,P \tag{7}$$

where P = heavy vehicles (%).

2.5. Statistical analysis

Linear regression analysis and 't'-test were calculated from the measured noise level and model predicted noise level using statistical software (SPSS 20). The graphical presentation and maps were constructed by Origin and ArcGIS 10.3 software.

3. Results and Discussion

3.1. General Status of Noise Pollution

Noise is such a weightless pollutant that is responsible for the deterioration of both quality and comfort of the life of urban people [30]. In the present study, ten important locations near to the G. T. Road which is passing through Burdwan town were chosen and average noise level during early morning (8 - 9 am), late morning (11 - 12), afternoon (2 - 3 pm) and evening (6-7) were recorded as 77 dB (A), 78 dB (A), 76 dB (A) and 77 dB (A), respectively. As the average noise level is higher than the WHO and CPCB recommended level, the students who are present during school hours (10 am - 5 pm) and roadside habitat are equally affected by such high intense noise [31-32]. According to Table **1**, the vehicle density was recorded highest during the afternoon and lowest during the early morning. This is probably due to the carrying of goods and public transport during the late morning to afternoon [33]. So far as the variability of the vehicle is concern, medium to light vehicle concentration is very high. The result is very much the same as reported by Mondal [6] in the same study area. Very recently Arif and Gupta [[34] also endorse the same and they have applied graph theory of the transport network in the peri-urban area of Burdwan town.

Table 1: Comparison between measured and CRTN predicted noise levels of monitoring locations.

	Early Morning				Late Morning				Afternoon				Evening			
Locations	Observe value	L_{basic}	Difference	T value	Observe value	L_{basic}	Difference	T value	Observe value	L_{basic}	Difference	T value	Observe value	L_{basic}	Difference	T value
L1	86.40	78.53	7.87	p < 0.013	83.61	81.62	1.99	p < 0.255	85.41	80.20	5.21	p < 0.028	77.77	78.43	-0.66	p < 0.613
L2	86.90	80.93	5.97	p < 0.028	82.62	82.12	0.50	p < 0.586	78.98	81.94	-2.97	p < 0.070	80.96	80.92	0.05	p < 0.917
L3	81.06	78.13	2.92	p < 0.027	84.36	78.27	6.09	p < 0.019	77.37	77.69	-0.33	p < 0.863	80.86	78.21	2.66	p < 0.052
L4	76.36	76.46	-0.10	p < 0.951	78.32	76.88	1.44	p < 0.187	75.75	74.99	0.76	p < 0.057	75.42	77.30	-1.88	p < 0.139
L5	81.15	78.26	2.89	p < 0.025	84.90	77.94	6.96	p < 0.055	81.44	77.83	3.61	p < 0.082	80.75	78.26	2.49	p < 0.305
L6	69.72	76.30	-6.58	p < 0.038	68.04	77.07	-9.03	p < 0.013	67.10	75.81	-8.71	p < 0.007	73.55	76.48	-2.93	p < 0.074
L7	72.42	77.23	-4.81	p < 0.032	73.78	77.58	-3.80	p < 0.135	76.72	78.24	-1.51	p < 0.228	76.51	77.33	-0.82	p < 0.586
L8	70.88	77.55	-6.67	p < 0.001	76.82	77.14	-0.32	p < 0.861	73.62	76.41	-2.79	p < 0.229	75.21	77.69	-2.47	p < 0.084
L9	73.61	75.54	-1.93	p < 0.093	73.08	76.25	-3.17	p < 0.077	69.75	74.28	-4.53	p < 0.032	72.02	75.65	-3.63	p < 0.051
L10	70.62	69.74	0.88	p < 0.304	72.97	73.16	-0.19	p < 0.667	69.88	70.52	-0.64	p < 0.720	72.18	69.74	2.44	p < 0.187

L1 = Burdwan High Madrasha, L2 = Burdwan municipal Boys high school, L3 = Harisava Hindu Girls High School, L4 = Burdwan Raj Collegiate School, L5 = Burdwan CMS High School, L6 = Burdwan Sriramkrishna Sarada Pith School, L7 = Burdwan Bidhyarthi vaban Girls high School, L8 = Rathtala Monohardas Balika Bidhyalaya, L9 = Shiba Kumar Harijon Vidhyalaya, L10 = Burdwan Banipith high School

Figure **2** depicts the noise contour map during the early morning (8 - 9 am) it has been observed that the maximum noise level 86.9 dB (A) at Burdwan Municipal Boys high school and the minimum noise level is 70.6 dB (A) at Burdwan Banipith high school during early morning hours. The study also revealed that about 40% of the studied areas are under high intense noise, $L_{eq} \geq 80$ dB (A) and the locations are Burdwan high Madrasha, Burdwan Municipal Boys high school, Harisava Hindu Girls high school, and Burdwan CMS high school. However, the other 60% of study areas are also marked as moderate noise areas having L_{eq} ≥ 69 dB (A). Therefore, it may be stated that the noise level during early morning hours is beyond the recommended level of noise as given by CPCB [30].

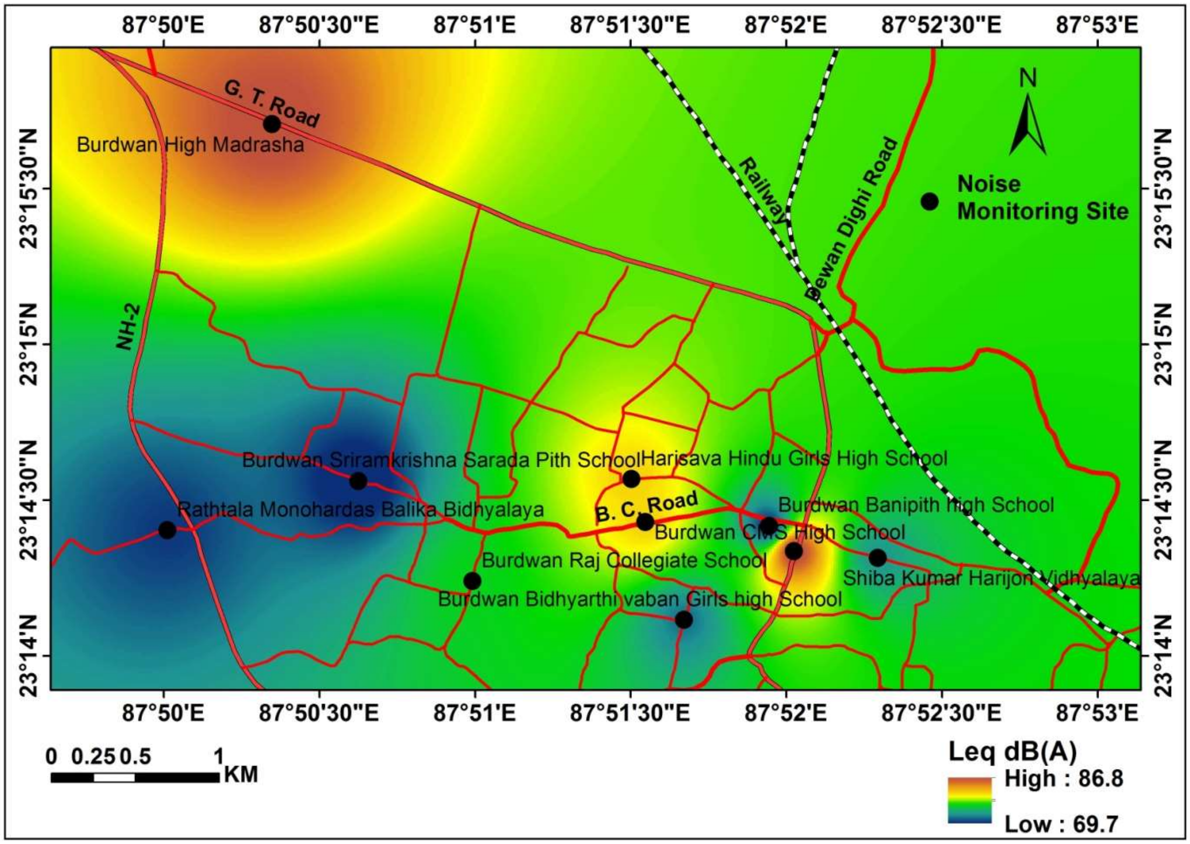

Figure 2: Noise Map of study area during early morning session (8 – 9 am).

Similarly, Figure **3** also highlighted the noise contour map during late morning (11-12 pm) and it is revealed that the maximum noise level 84.9 dB (A) at Burdwan CMS high school and the minimum noise level is 72.9 dB (A) at Burdwan Banipith high school during the late morning session. The study also revealed that about 40% of the studied areas are under high intense noise, L_{eq} ≥ 80 dB (A) and the locations are Burdwan CMS high school, Harisava Hindu Girls high school, Burdwan high Madrasha, and Burdwan Municipal Boys high school. However, the other 60% of study areas are also marked as moderate noise areas having L_{eq} ≥ 72 dB (A). Therefore, it may be concluded that the noise level during late morning sessions is beyond the recommended level of noise as given by CPCB and this higher level of noise definitely impacted school children [35].

On the other hand, during the afternoon (2 - 3 pm) noise contour map (Figure **4**) shows that the maximum noise level 85.4 dB (A) at Burdwan high Madrasha school and the minimum noise level is 67.1 dB (A) at Burdwan Sriramkrishna Sarada Pith school during the afternoon period. The study also suggests that about 20% of the studied locations are under high intense noise, L_{eq} ≥ 80 dB (A) and the locations are Burdwan High Madrasha School and Burdwan CMS high school. However, other 80% locations are also marked as moderate noise areas having L_{eq} ≥ 69 dB (A). Therefore, it may be inferred that the noise level during the afternoon session is beyond the prescribed level of noise as given by CPCB.

In the evening time (6 - 7 pm) noise contour map (Figure **5**) clearly revealed that the maximum noise level 80.9 dB (A) at Burdwan Municipal high school and the minimum noise level is 72 dB (A) at Shibkumar harijon Vidhyalaya during the evening period. The study also suggests that about 30% of the study sites are under high intense noise, L_{eq} ≥ 80 dB (A) and the locations are Burdwan CMS high school, Harisava Hindu Girls high school,

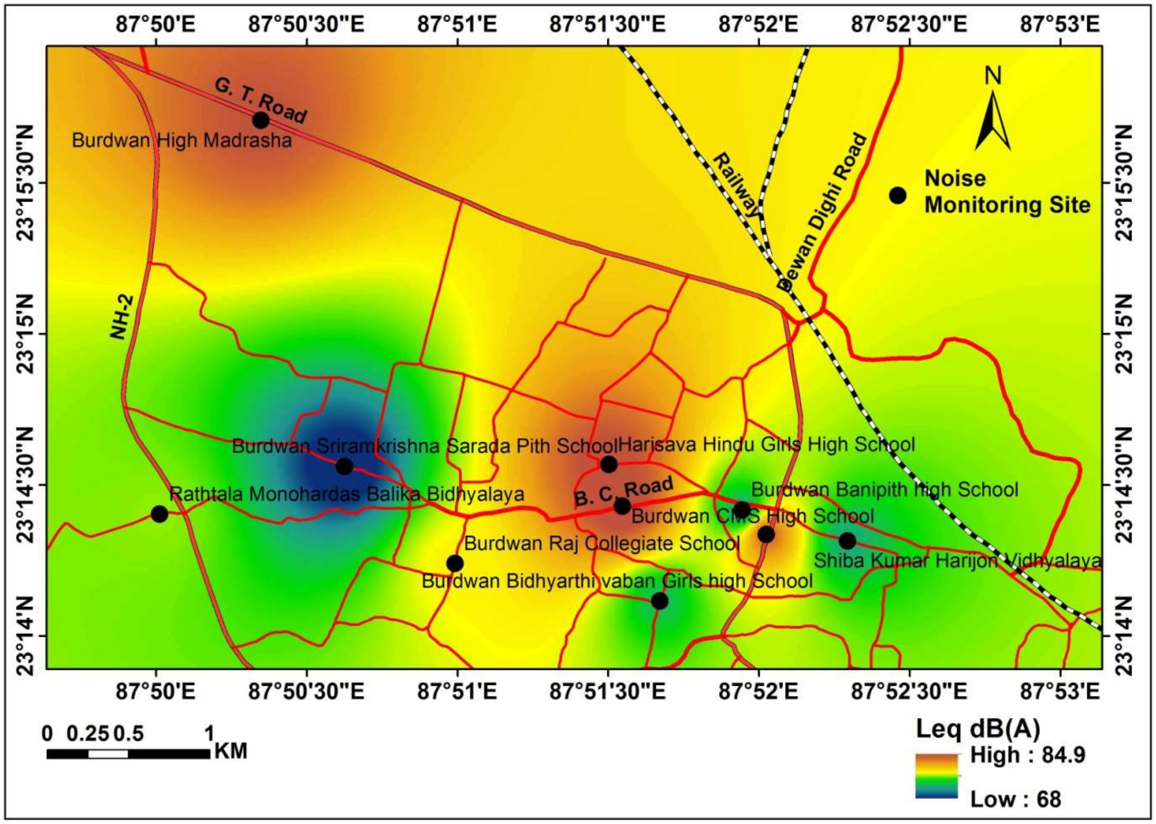

Figure 3: Noise Map of the study area during the late morning session (11 am – 12).

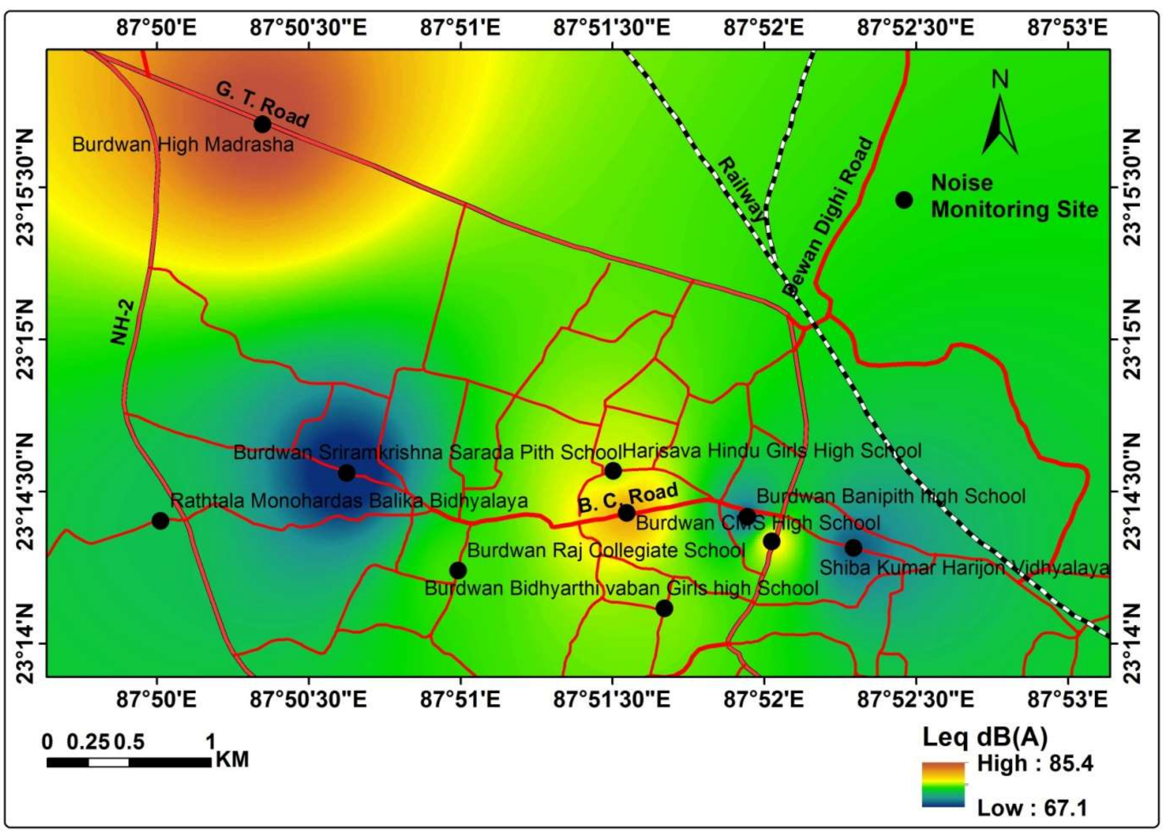

Figure 4: Noise Map of study area during afternoon session (2-3 pm).

and Burdwan Municipal Boys high school. However, the other 70% of sites are also marked as moderate noise areas having $L_{eq} \geq 72$ dB (A). Therefore, it has been stated the noise level during the evening time is above the noise level as prescribed by CPCB and the inhabitant of this particular location will be under the threat of high risk of hypertension which is directly associated with the release of catecholamines and circulation of some specific hormones [36].

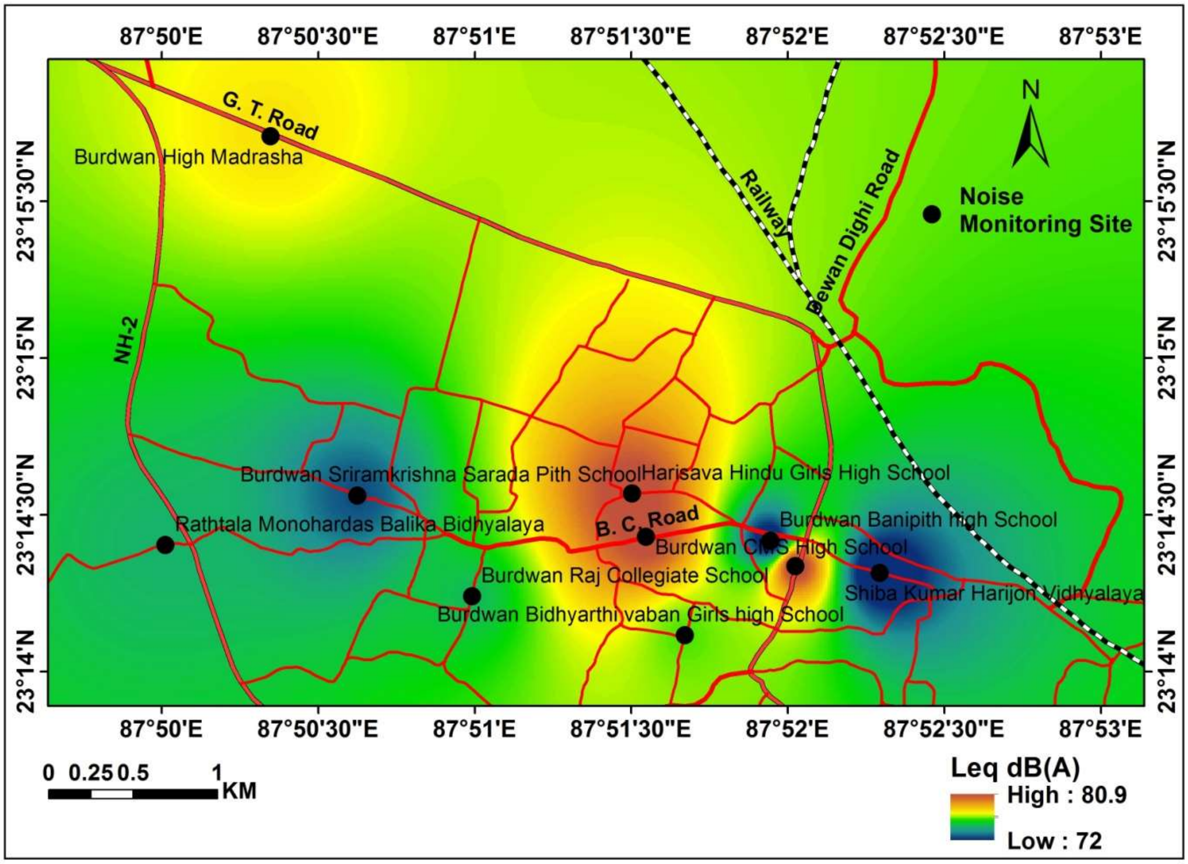

Figure 5: Noise Map of study area during evening session (6-7 pm).

3.2. Road Traffic noise Prediction by CRTN model

The regression analysis between measured noise and model outcome noise level has been demonstrated in Figure **6(a-d)**. Figure **7a** depicts the regression of noise level in the early morning with a moderate regression coefficient value (R^2 = 0.453). On the other hand, $L_{predicted}$ was calculated from the CRTN model through the application of the following equations (8-9):

$$L_{Predicted} = 0.3004\ L_{basic} + 53.767; \qquad R^2 = 0.453 \tag{8}$$

Putting the values of L_{basic} in Equation (8), the general form of eq. (9) will be:

$$L_{Predicted} = 3log_{10}q + 9.91log_{10}\left(V + 40 + \frac{500}{V}\right) + 3log_{10}\left(1 + \frac{5P}{V}\right) + 45.77 \tag{9}$$

The result reveals that the variation of noise level from – 6.67 to + 7.87 dbB (A) when compared with measured noise and model predicted noise level and almost similar as recorded from linear regression (0.453). Almost similar differences between predicted and measured levels of noise were reported by [37]. From the Table **1** it has been also observed that the deviation at two receptors did not exceed 1.5 dB (A). However, deviations of more than 1.5 dB (A) were found at the eight highest receptors. This may be due to the high volume of light vehicles and rapid fluctuation of speed/hour [28]. However, Steel [23] highlighted that the traffic volume, speed, heavy vehicle

(%) and gradients are extremely important for the prediction of traffic noise. Moreover, the results of the verification of the designed model in this study revealed the mean of predicted Leq was 76.87 ± 2.92 dB (A).

$$L_{Predicted} = 0.2751\ L_{basic} + 56.386; \qquad R^2 = 0.395 \tag{10}$$

Putting the values of L_{basic} in Equation (10), the general form of eq. (11) will be:

$$L_{Predicted} = 2.75 log_{10} q + 9.08 log_{10}\left(V + 40 + \frac{500}{V}\right) + 2.75 log_{10}\left(1 + \frac{5P}{V}\right) + 49.07 \tag{11}$$

Similarly, in late morning hours, the linear regression coefficient is very weak (R^2 = 0.395) and the mean difference was calculated as 0.05 dB (A). Table **1** (Eq. 10-11) also reflected that the deviation at four receptors did not exceed 1.5 dB (A) for both late morning and afternoon sessions. However, deviations of more than 1.5 dB (A) were found at the six and seventh-highest receptors late morning and afternoon sessions respectively. This observation is again attributed to the huge density of light vehicles [38]. Moreover, the results of the verification of the designed model in this study revealed the mean of predicted Leq was 77.80 ± 2.56 dB (A). However, afternoon and evening sessions showed good consistency between measured and model outcome results and the linear regression coefficients 0.536 and 0.554 were recorded at afternoon and evening sessions, respectively (Eq. 12 and 14)

$$L_{Predicted} = 0.4134\ L_{basic} + 45.54; \qquad R^2 = 0.536 \tag{12}$$

Putting the values of L_{basic} in Equation (12), the general form of eq. (13) will be:

$$L_{Predicted} = 4.13 log_{10} q + 13.64 log_{10}\left(V + 40 + \frac{500}{V}\right) + 4.13 log_{10}\left(1 + \frac{5P}{V}\right) + 34.54 \tag{13}$$

The results from measured and model-predicted data suggested that the noise levels range between – 8.71 to + 5.21 dB (A) with the coefficient of determination (R^2) is 0.536. The mean difference was calculated as – 1.19 dB (A). From the Table **1** it has been also suggested that the deviation at three receptors did not exceed 1.5 dB (A). However, deviations of more than 1.5 dB (A) were found at the seven highest receptors. This may be due to the high volume of light vehicles and rapid fluctuation of speed/hour. Moreover, the results of the verification of the designed model in this study revealed the mean of predicted L_{eq} was 76.79 ± 3.20 dB (A). Similarly, high values of linear regression coefficient were recorded by Sharma et al. [39] their study where the equivalent vehicle speed is > 30 kmh and without traffic where practically no honking was recorded. Earlier researchers [40-42] also showed the consistent result.

$$L_{Predicted} = 0.6214\ L_{basic} + 29.444; \qquad R^2 = 0.554 \tag{14}$$

Putting the values of L_{basic} in Equation (14), the general form of eq. (15) will be:

$$L_{Predicted} = 6.21\ log_{10} q + 20.5\ log_{10}\left(V + 40 + \frac{500}{V}\right) + 6.21\ log_{10}\left(1 + \frac{5P}{V}\right) + 12.91 \tag{15}$$

The results have been also specifying that measured and model-predicted noise levels range between – 3.63 to + 2.66 dB (A) with a coefficient of determination (R^2) is 0. 554. The mean difference was calculated as - 0.48 dB (A). Table 1 has been also showing that the deviation at three receptors did not exceed 1.5 dB (A). However, deviations of more than 1.5 dB (A) were found at the seven highest receptors. This may be due to the high volume of light vehicles and rapid fluctuation of speed/hour. Moreover, the results of the verification of the designed model in this study revealed the mean of predicted L_{eq} was 77.00 ± 2.90 dB (A).

4. Conclusion

Noise prediction models are commonly needed for proper prediction of intensity of traffic noise with association of various terms such as L_{eq}, L_{10}, L_{50}, L_{90} etc. Therefore, present model outcomes could be utilized to manage road traffic noise and subsequently reduction of health burden of the busy roadside inhabitant. Moreover, this may also regulate the driving patterns by installing speed breaker in appropriate distance.

However, other measures such as banning of air horns, systematic parking of vehicles, spot fine of high noise producing vehicles, proper plantation near roadside etc. Finally, from the present outcome, it may be concluded that the selected locations of the Burdwan town are found to be exceeding the noise limits as recommended by CPCB [43].

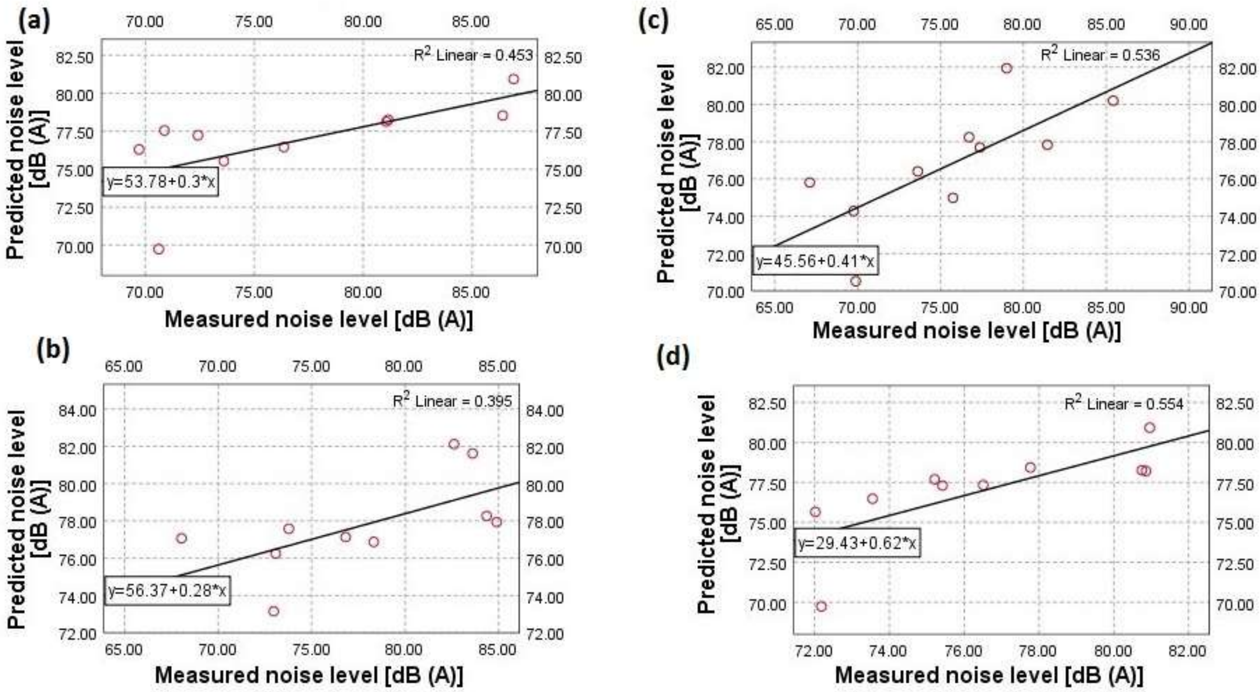

Figure 6: Association between measured noise level and model predicted noise level of Early Morning (a), Late Morning (b), Afternoon (c) and Evening (d) session.

Acknowledgment

The authors express their sincere gratitude to all the faculty members and staff in the Department of Environmental Science, The University of Burdwan, for their moral support and valuable suggestions in preparation of this manuscript.

Declarations

Ethics Approval and Consent to Participate

None

Consent for Publication

None

Availability of Data and Material

Detail data will be provided by the corresponding author

Competing Interests

The authors declare that they have no competing interests

Funding

This research work was financially supported by the funding agency ICSSR, Govt. of India under IMPRESS scheme vide Memo No: IMPRESS/P1115/552/SC/2018-19/ ICSSR dated 20.09.2019. The fund was used for purchase of instruments and scholar's fellowship.

Authors Contributions

SK: entire field work, data recording, GIS and ArcGIS 10.3 software using IDW interpolation NKM: The experimental design, statistical calculation and manuscript drafting, DM: Typing & Editing the MS. Moreover, all authors have read and approved the present manuscript.

Ethics Approval

Not applicable

Abbreviations

FHWA = American Federal Highway Administration

CPCB = Central Pollution Control Board

dB = Deci Bel

CRTN = Calculation of Road Traffic Noise

EFA = European Economic Area

IDW = Inverse Distance Weighting

GIS = Geographic Information System

SPSS = Statistical Package for the Social Sciences

WHO = World Health Organization

Reference

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