Environmental and Climate Technologies
2020, vol. 24, no. 1, pp. 23–42
https://doi.org/10.2478/rtuect-2020-0002
https://content.sciendo.com

Influence of Honking on the Road Traffic Noise Generated at Urban Rotaries for Heterogeneous Traffic

Kamineni ADITYA[1], Venkaiah CHOWDARY[2]*

[1, 2]*Department of Civil Engineering, National Institute of Technology, Warangal-506004, Telangana, India*

***Abstract* – This paper presents a study conducted at major rotaries for quantifying the traffic noise levels by considering the vehicle volume and their respective honking as governing parameters for heterogeneous traffic. Traffic volume and traffic noise data was collected using a digital video camera and a class 1 sound level meter, respectively. The traffic noise data was analysed using noise tools for identifying the noise level variation. The data collected was subjected to statistical analysis for light, medium and heavy vehicles, and their contribution towards noise levels is proven to be effective with the forthright fact that, heavy vehicles and their corresponding honking were majorly affecting the equivalent noise level compared to other vehicular proportion. An equivalent noise level [LAeq (dB)] rise of 2 to 6 dB (A) is solely caused by heavy vehicles, which is an important observation to be considered for traffic noise analysis at the rotaries. Based on the obtained results from one of the rotaries, noise prediction model is developed for estimating the LAeq (dB), which is able to predict the noise levels with good precision when validated with the data collected at second rotary intersection for different vehicle volumes.**

***Keywords* – Heavy vehicles; heterogeneous traffic; honking, rotary; traffic noise.**

1. INTRODUCTION

Quietness has become an imperil species nowadays, as necessity of life is finding its existence in friction with the world. Especially, rapid road infrastructure development in many countries is resulting in high air and noise pollution levels [1]. With the globalization and the decentralized industrial growth in the last several decades, small and medium towns are experiencing a huge population growth along with heavy city traffic and pollution [2]–[5]. As an example, globalization effect was so drastic on transportation sector in such a way that, a study shows that, a 73 % of noise annoyance is from the road traffic alone [6]. Thus, there is a need for contemplation on mitigation of traffic noise by urban planners and road designers before construction of any road network [7]. This inevitable requirement led the need for taking up traffic noise studies by researchers globally including India, especially from the early 1990's, to study the core factors leading to road noise annoyance [8], [9]. With the incoming of the last decade in India, along with the vital change of demographics in urban areas, vehicles grew at a Compound Annual Growth Rate (CAGR) of 10.5 % between 2002 and 2012 [10]. This vehicle growth will automatically increase the noise pollution which is a serious threat to mankind, as noise produced by road traffic is one of the most important contributors to hearing loss, cardiovascular diseases and depreciation of the quality of life [11], [12]. Across the globe, several works recognized road traffic noise as a major pollutant

*Corresponding author.
E-mail address: vc@nitw.ac.in

affecting road side commuters and travellers, whose chances of exposure to the road noise is long-term, which is dangerous to health [13], [14]. Even with regard to the environmental impact assessment process, 70 % of the companies indicated noise as a dominant environmental aspect among all the environmental pollutants originating from Siaurine Street in Vilnius, Lithuania [15]. This shows the impact of road noise pollution on the community, which needs a thorough study. At present, with a contribution of 55 % to total urban noise, road traffic noise is becoming a major source of noise pollution in cities whose growth can take an exponential high with the present vehicle growth pattern, which can result in extreme noise pollution in the future [16], [17].

Accelerating vehicles generate more noise than vehicles travelling at constant speed and they are a major source of noise pollution in cities, particularly near intersections and rotaries/roundabouts where the driving pattern of a vehicle is likely to change. Vehicle kinematics at intersections and rotaries can cause higher noise levels compared to traffic on open roads such as highways due to temporal variations in speed and acceleration [18]. The main objective of constructing rotaries and intersections is often to improve traffic flow and safety on roads. However, the negative upshot is often diversified in the driving pattern of the vehicles, such as speed, change in acceleration or deceleration due to which noise levels tend to increase [19]–[21]. Even though the primary objective of improving traffic flow by reducing the conflict points from a safety point of view is achieved with rotaries/roundabouts, the noise level at these intervenes of urban area will severely affect the people residing nearby as most of the road stretches are passing through residential and commercial zones, where continuous noise exposure can lead to cardiovascular health hazards in humans which is a serious consideration to be made to the core for reducing noise within the limits [22]. Hence, apart from the high speed midblock sections of a highway passing through the urban area, there is a need to initiate the study on evaluating traffic noise pollution near urban units such as intersections, rotaries or roundabouts, where the traffic volumes are high and vehicle speeds are comparatively lower. Hence, the purpose of this study is to assess the road traffic noise pollution at the rotaries located in different land use sectors including residential and commercial areas, to identify the core factors affecting the noise levels, and to develop a model for prediction of traffic noise levels.

2. LITERATURE REVIEW

Major literature findings so far proved that, speed of motor vehicles on urban streets is not continuous as in highways due to heterogeneity in traffic. Thus, thorough study on urban street flow through critical units is needed before developing a traffic noise prediction model. Traffic streams at planar intersections such as linear intersections and rotaries/roundabouts are classified with respect to vehicle movement, as: decelerating while approaching the central island, accelerating while moving away from it and vehicles travelling around the island itself [23]. Thus, measuring the noise indices from a single objectifying unit is tough since there is a diversified noise occurrence in and around rotary. As multiple flows are intersecting at these junctions, noise generated by traffic is more disturbing and alleviating, and its mitigation is only possible by detailed investigation to determine the basic factors affecting the noise generation. Globally, several research works have been executed to estimate the noise levels on road network at the traffic calming sections introduced for road traffic speed control which includes road humps, traffic signals and the urban units such as roundabouts/rotaries in identifying the factors affecting noise generation. With the application of traffic calming measures, average traffic speeds will be reduced by

20 kmph [24]. Accordingly, reduction in traffic speeds would result in noise level reduction of 4 to 5 dB (A) [25]. The reduction in traffic speeds and smooth traffic flows would also result in a significant decrease in air pollution [26]. Acceleration of vehicles after a road hump has increased the noise level by about 13 dB (A), compared to the vehicle travel without a road hump [27]. Traffic noise levels increased by about 1 to 4 dB (A) with an increase in traffic volume and with the presence of a road hump [20]. These results solely are expressed by the sudden acceleration achieved by vehicles immediately after crossing the road hump.

Considering the acceleration and vehicle speed effects, several works were reported in the past on noise identification at intersections and roundabouts. Traffic volume and noise level comparison between the roundabouts and intersection show that, lesser traffic noise was generated at roundabout due to low speed of vehicles passing around the central island [18]. On the contrary, 3 dB (A) higher noise level was observed at roundabout compared to cross-intersection, due to high acceleration of vehicles while leaving the junction [21]. This is due to the fact that, compared to vehicles travelling at constant speed, accelerating vehicles generates higher noise levels due to change in driving pattern. From the past literature, traffic volume, speed and acceleration/deceleration of vehicles in traffic are observed to be the major factors affecting the noise generation near roundabouts or rotaries and linear intersections. Apart from these factors, several works in India identified honking as the major source of noise in Indian urban road network. Honking increased the equivalent noise level (Leq) from 2 to 13 dB (A) in urban highway [28], [29]. Driver's impatience, sudden breaking, and over acceleration leads to honking which increases noise levels by 2 to 9 dB (A) [30, 31].

Roundabouts, rotaries and intersections will experience increase in noise levels due to sudden acceleration and deceleration criteria due to flow of traffic while approaching the lane or while leaving the junction and due to steady speed flow during travel around the central island [18]. On the other side, several works clearly depict the effect of vehicle type, sudden braking and acceleration of vehicles which in turn leads to honking which is a major noise source from traffic especially near intersections [29]–[31]. Considering the importance of traffic volumes and honking on the generation of noise at urban intersections, the main objective of this research work is to quantify the effect of vehicle volume and honking on the traffic noise generated at a rotary intersection in an urban area. Subsequently, this study also considers development of a model for prediction of overall noise annoyance near the rotary intersection. Further, a detailed procedure is presented in this study to identify the honks within the traffic noise data.

3. METHODOLOGY

The study area selected is in Karimnagar, a small sized city in Telangana state, India. The prime reason for selecting the study area in Karimnagar city is due to the growth rate in population it has experienced from 2001 to 2011, which is about 38.82 %. According to 2011 census, Karimnagar city had a population of 261 185 and its projected population by 2020 is expected to reach 375 000. This rise in population severely affects the vehicle dynamics which in turn results in vital change of noise pollution scenario in the city. Thus, noise studies are much needed in small cities like Karimnagar, which can become an essential tool for understanding the root cause and characteristics affecting the traffic noise pollution and can be used as a design aid in the future. The proposed methodology of the present study is detailed in subsequent paragraphs.

In stage 1, traffic volume and noise levels along with honking were measured at two traffic rotaries which are named with their junction names, as one town police station Chowrasta and court Chowrasta. Both the rotaries are 3-legged major intersections with 18°25'53.5"N longitude to 79°07'53.8"E latitude and 18°26'40.1"N longitude to 79°07'29.9"E latitude. Road conditions and geometric characteristics are almost the same for both rotaries with asphalt pavement surface as shown in Fig. 1 and Fig. 2, respectively.

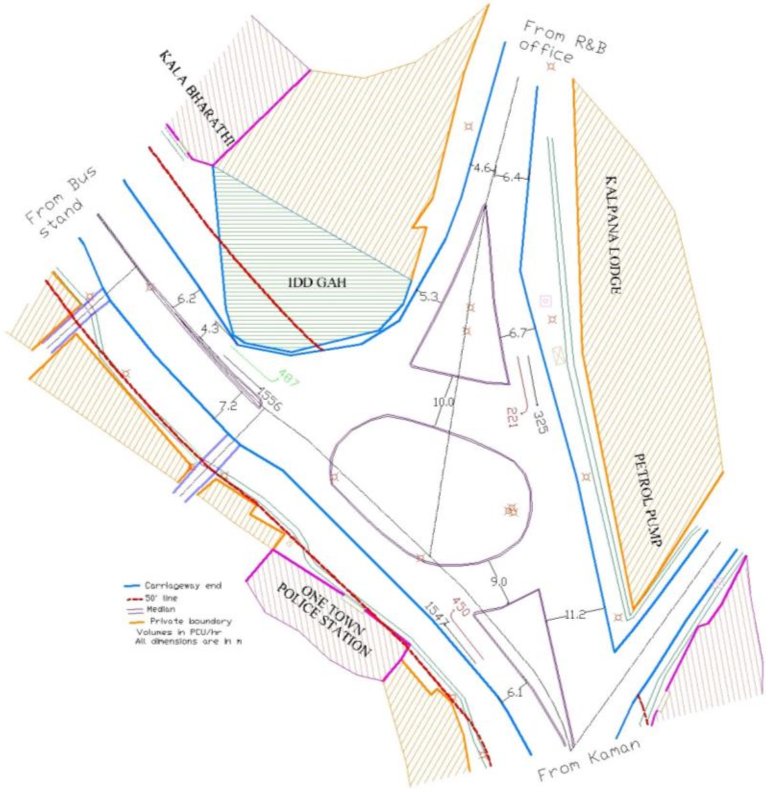

Fig. 1. One town police station Chowrasta in Karimnagar city.

Traffic volume data was collected using video cameras from 9 am to 1 pm covering the morning peak hour flows, at the selected rotaries to determine the number and type of vehicles passing through the designated sections. Vehicles are categorized as Light Vehicles (LV) (motorized two-wheeler), Medium Vehicles (MV) (auto-rickshaw, car/jeep, and light commercial vehicle) and Heavy Vehicles (HV) (bus, normal truck, dumper truck, and tractor-trailer) based on their size and noise levels [31]. Noise levels are estimated by Indian Standard (IS) methods using Cirrus Class 1 sound level meter (SLM) [32]. SLM was mounted on a tripod stand on the central island of the selected rotary at a height of 1.5 meter from the ground, which includes the island height, and is placed at a distance of 3.5 meters from the edge of the central island, where pedestrians and road side shopkeepers are experiencing the similar continuous noise exposure. Such protocol is required to avoid speech disturbance from the commuters, shop keepers, and pedestrians whose activities can affect the noise levels while capturing the road side traffic noise. SLM was kept in “A” frequency weighing for human ear response, and with data logging of 1 second interval using the fast response mode for better indication of widely changing average noise levels in an environment, and the respective equivalent noise level (LAeq (dB)) was measured [11].

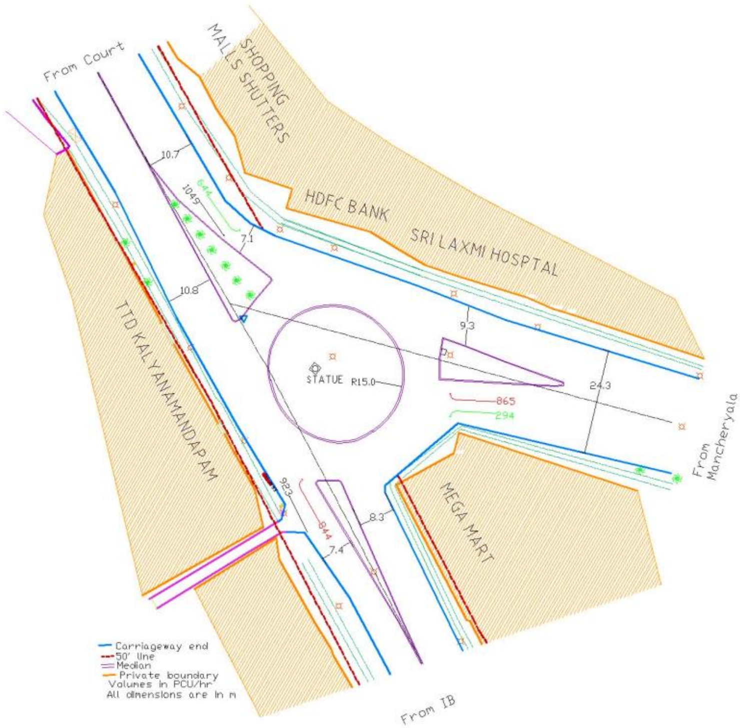

Fig. 2. Court Chowrasta in Karimnagar city.

Traffic speed was observed to be more or less the same during the study period at the rotary as the traffic is heavy, heterogenic and continuous. Considering this traffic movement, SLM was mounted at a place where vehicles are moving at constant speed around the rotary which is far from the entry, exit and leaving lanes. This protocol is required to capture the noise levels with the minimal vehicle speed variation during data logging time frame. This approach helps in capturing the vehicle volume count from the video camera which was further analysed with respect to the traffic noise levels captured by the SLM, as they share same time frame to the precision of seconds during the survey period. To avoid the effect of wind direction and speed, a wind screen was used for the microphone of the sound level meter. While extracting the data from the SLM, noise levels were estimated for each second by considering the exact time of vehicle crossing the perpendicular axis of the line joining the SLM and video camera location. This approach was needed to separate each vehicle by class and time to determine the respective honking effect on overall LAeq (dB) generation. Noise from a particular class of vehicle was further analysed for noise-class of vehicle and noise-honking response criteria.

Traffic volume was tracked for a period of four consecutive hours for identifying the peak hour in the morning. Subsequently, set of traffic volume and noise level data was analysed for a 15-minute time interval. Measured LAeq (dB) for 15 minutes was further analysed with interval of one-minute duration. The noise data was analysed from peak hour to peak

15 minutes and peak 15 minutes to minute level, keeping the objective of identifying the number of honks in a minute and their effect on noise level. For achieving this, highest and lowest minute noise in 15 minutes was further analysed with the vehicle volume from videography for each second, to identify the vehicle class and honking effect on LAeq (dB). This was done by noise tools software which can draw the data to the level of one tenth of the second where any sudden peak in noise can be clearly observed, which can be attributed to honks [33], [34]. However, the peak observed in the graph need not be due to honk every time, which is a hurdle for identifying the honks in total noise. Even though, the honks can be captured in camera microphone during videography which was placed along with sound level meter, further analysis is questioned, as even at the trivial second level in noise tools, honks from a particular vehicle can be continued beyond the second which can show the peak twice and also in a situation where two or three vehicles pass at the same instance, the count can be mismatched. To avoid such mismatch, average noise levels of vehicles passing through rotary has to be known first which is useful for identifying the honk impact in peak minute noise, due to the fact that the difference of vehicle noise and honking can be visualised graphically in noise tools by knowing the average noise from different classes of vehicles which are travelling at more or less the same speeds as traffic is heterogenic and continuous. For achieving this, least minute noise in entire survey period is analysed for each second with respect to vehicle volume at the one town police station Chowrasta and the average noise level of classified vehicles was identified. On a similar note, by knowing the average noise levels of vehicles at minute level, the major factors affecting the traffic noise can be identified.

4. RESULTS AND DISCUSSION

From the analysis of four-hour traffic volume, peak flows were observed between 10:15 am and 11:15 am for both one town police station Chowrasta and court Chowrasta. The respective peak hour volumes of LV, MV and HV are 1586, 1010 and 57 at one town police station Chowrasta and 1727, 705 and 68 at court Chowrasta. To evaluate the effect of traffic volume on noise levels, peak hour traffic and the respective noise levels are analysed for 15-minute time interval as shown in Fig. 3 and Fig. 4. The results at one town police station Chowrasta shows that, maximum LAeq [78.1 dB (A)] was observed for traffic volume of 651 vehicles during 11:00 am to 11:15 am and minimum LAeq [77.1 dB (A)] was observed for traffic volume of 656 vehicles. In the same peak hour, for highest vehicle volume of 711 vehicles, LAeq of 77.2 dB (A) was observed. This shows that, maximum traffic volume need not generate highest traffic noise level and vice versa. Similar analysis was done at the court Chowrasta for comparing the noise levels with the traffic volume and congruent results as above are observed. The highest LAeq [77.7 dB] was observed between 10:45 am to 11:00 am for a traffic volume of 627 vehicles and lowest LAeq [76.1 dB] was observed between 10:15 am to 10:30 for a traffic volume of 621 vehicles. These results show that there is no definite statistical relation between traffic volume and noise levels, which demands further analysis by considering other factors supplementing the rise in noise levels.

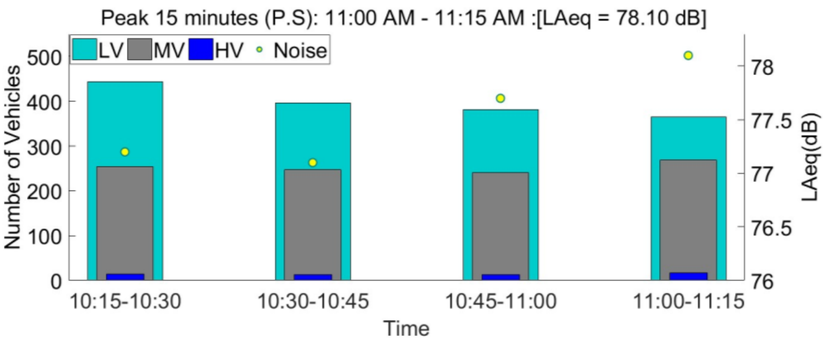

Fig. 3. Peak hour LAeq (dB) at one town police station Chowrasta.

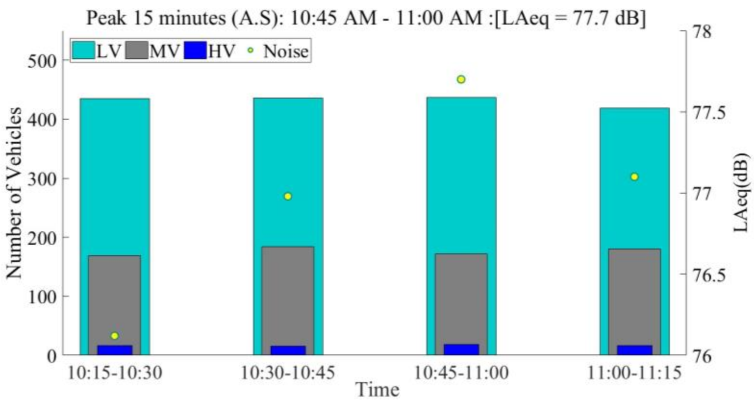

Fig. 4. Peak hour LAeq (dB) at court Chowrasta.

To pinpoint the factors liable for noise levels, analysis is further concentrated to minute level in peak 15 minutes noise data, by counting the vehicles per each minute and their exact effect on noise levels. Maximum LAeq [83.6 dB (A)] was detected in seventh minute from 11:06 am to 11:07 am and minimum LAeq [73.6 dB (A)] was detected in sixth minute from 11:05 am to 11:06 am near one town Chowrasta rotary, as shown in Fig. 5 and Fig. 6. Near court Chowrasta, maximum LAeq [80.4 dB (A)] was detected between 10:55 am to 10:56 am and minimum LAeq [75.9 dB (A)] was detected between 11:45 am to 11:46 am as shown in Fig. 7 and Fig. 8. Each sudden peak observed in noise tools is attributed to honking as shown in Fig. 5. At both the rotaries, results fall in the nature of no statistical relationship between volumes, honking and noise level, even at the minute level noise as can be clearly seen from Fig. 5–8.

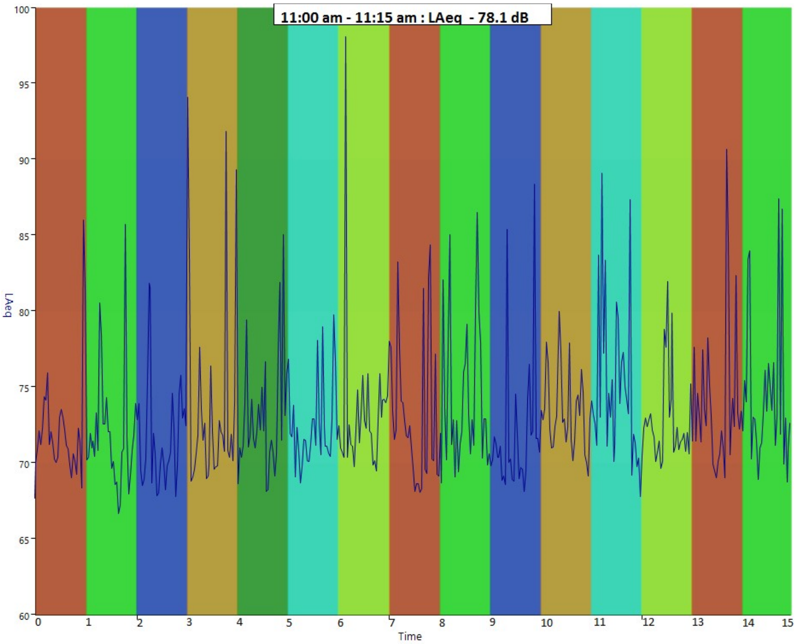

Fig. 5. Peak 15 minutes LAeq (dB) at one town police station Chowrasta in noise tools.

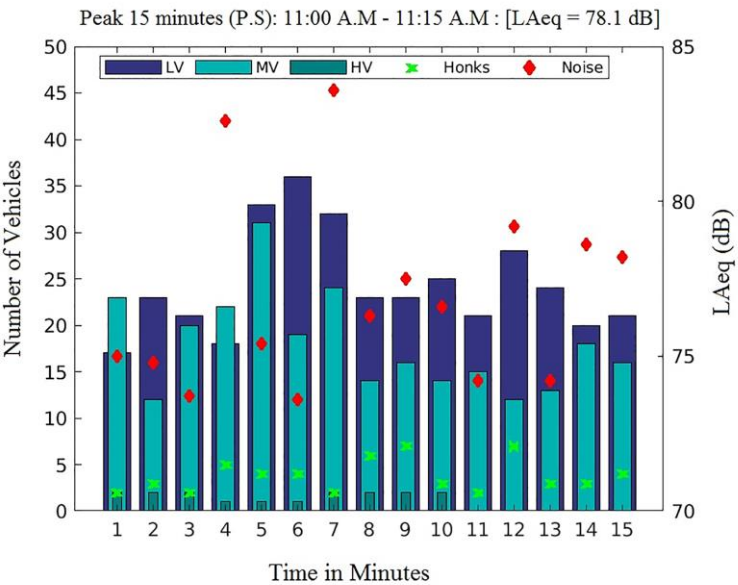

Fig. 6. Peak 15 minutes LAeq (dB) at one town police station Chowrasta.

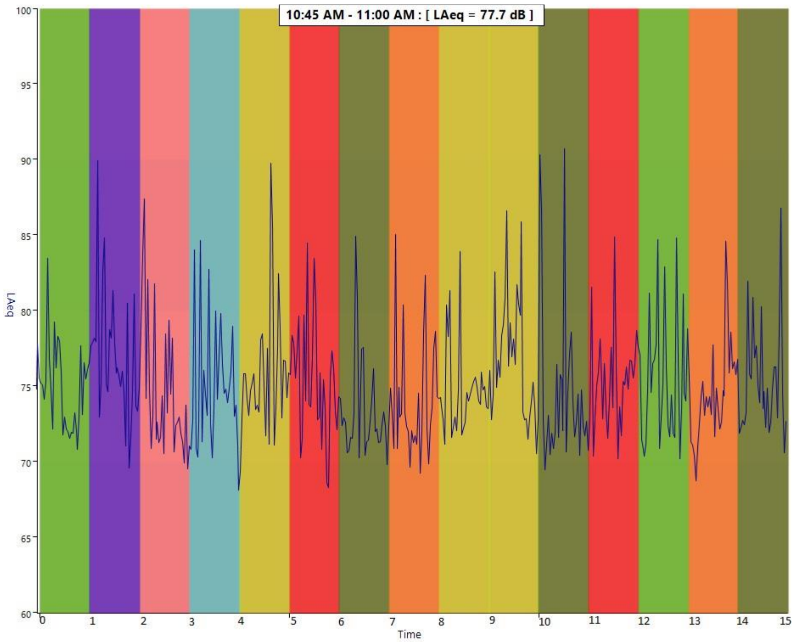

Fig. 7. Peak 15 minutes LAeq (dB) at court Chowrasta in noise tools.

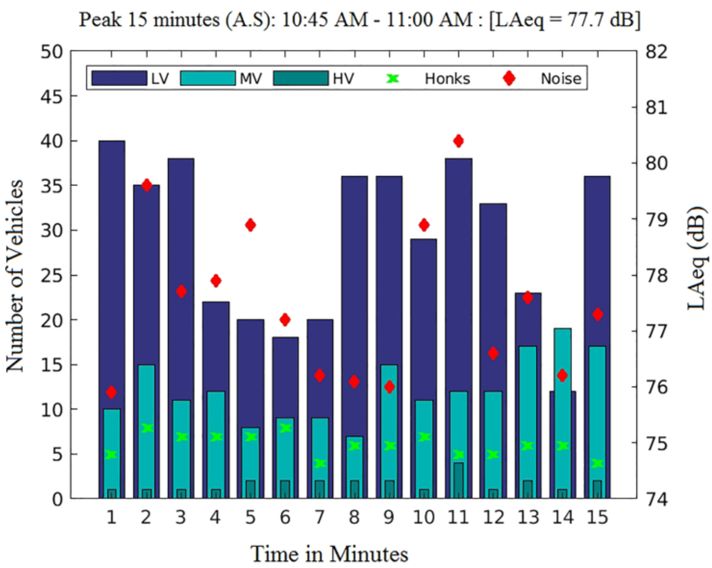

Fig. 8. Peak 15 minutes LAeq (dB) at court Chowrasta.

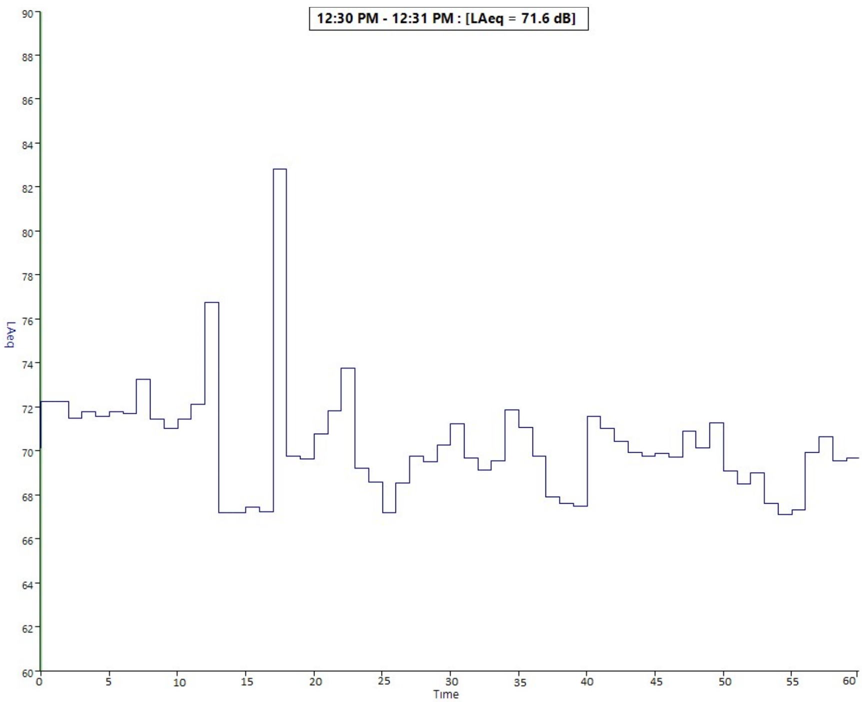

Fig. 9. Lowest LAeq (dB) minute at one town police station Chowrasta in noise tools.

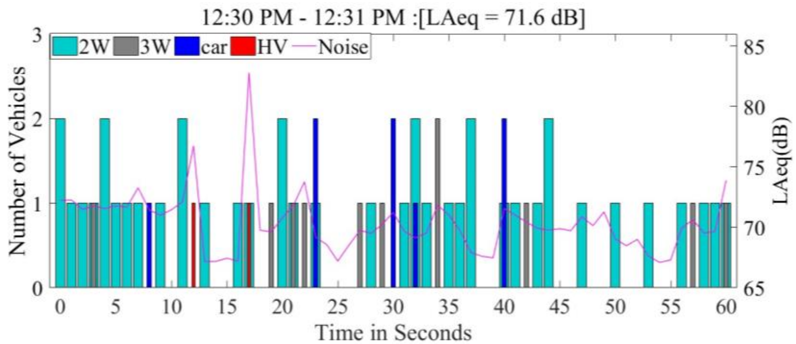

Fig. 10. Lowest LAeq (dB) minute at one town police station Chowrasta.

Data visualized in Fig. 5 and Fig. 6 are analysed in noise tools software for each second, which is used for analysing the environmental noise measurements, having the visual representation of data to the one tenth of a second. The noise levels are analysed with respect to the vehicle volume in camera and respective LAeq [dB] levels by each second in a minute which gives the exact noise generation by vehicles in each second which can identify the core factors generating the noise apart from volume and honks. There are several sudden peaks observed in the data which can be contributed by engine noise or honking which has to be identified before arriving at the conclusion. Here, noise from the vehicle is identified as mainly engine noise at lower vehicle speeds, typically below 50 kmph, as in present study at the rotary [35]. Thus, either the engine noise or the honking are the major factors responsible for noise generation at both the rotary intersections. However, vehicle engine noise will be accounted clearly in average noise levels, which can be attributed to the extreme peaks in noise levels resulting due to honking.

Thus, for analysing the sudden peaks at the second level, average noise generated by each class of vehicle at the rotary has to be known initially. For accomplishing this, irrespective of the peak hour, lowest minute noise (LAeq [71.6 dB (A)]) in entire four hours duration is observed from 12:30 pm to 12:31 pm is selected and is analysed in noise tools along with the vehicle volume for each second. Unambiguous results are observed in this minute which are shown in Fig. 9 and Fig. 10, where noise due to the light and medium vehicles are varying from LAeq [67.1 dB (A)] to LAeq [78 dB (A)], and heavy vehicles are contributing the noise levels of LAeq [76.7 dB (A)] to LAeq [82.8 dB (A)]. To further confirm this, another low noise minute (LAeq [71.8 dB (A)]) in the survey period from 12:19 pm to 12:20 pm is analyzed in Fig. 11 and Fig. 12. It is observed that, average noise levels of light and medium vehicles vary from LAeq [67.6 dB (A)] to LAeq [73.9 dB (A)] and heavy vehicles are contributing the noise of LAeq [75.38 dB (A)] to LAeq [77.24 dB (A)]. LAeq of 82.8 dB(A) observed in the 17^{th} second in Fig. 10, is mainly due to the heavy vehicle honking which can be justified by the average noise levels of heavy vehicles in the 12^{th} second of 12:30 to 12:31 minute and the 6^{th}, 18^{th} and 21^{st} seconds of 12:19 to 12:20 minute as shown in Fig. 12. This shows the impact of heavy vehicles and their honking on overall noise generation.

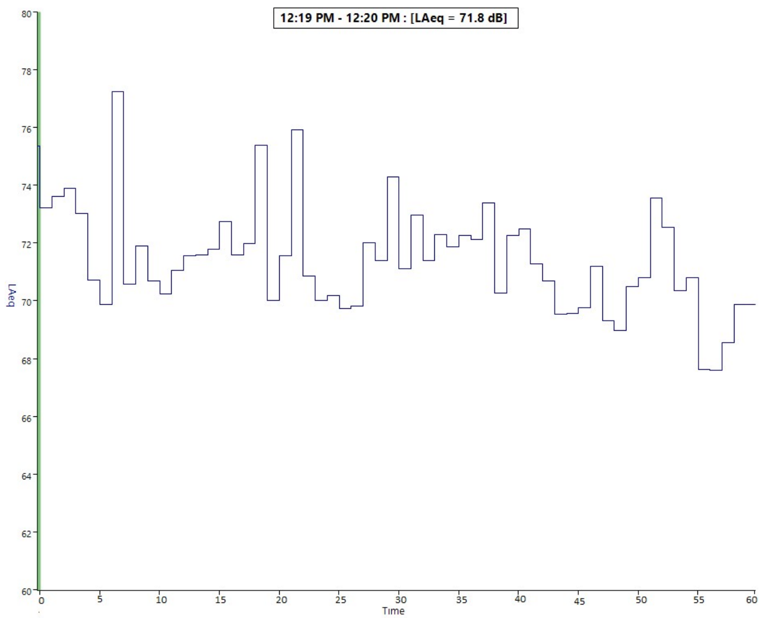

Fig. 11. Low LAeq (dB) minute at one town police station Chowrasta in noise tools.

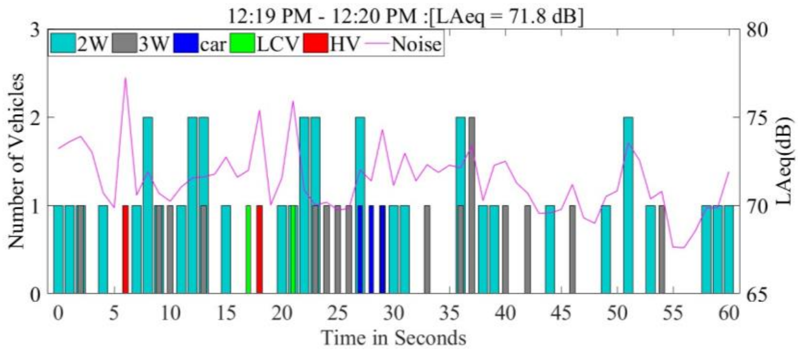

Fig. 12. Low LAeq (dB) minute at one town police station Chowrasta.

To further confirm this observation, the sudden peaks of noise were analysed for highest and lowest noise in the peak 15 minute noise data from both the rotaries using the noise tools and the details are presented in Fig. 13, 15, 17, and 19. The same data was analysed with vehicle volume count and presented in Fig. 14, 16, 18, and 20. Highest and lowest noise levels in the peak 15 minute at court Chowrasta were analysed with noise tools software by drawing down the data to one tenth of a second and each peak was observed and the resulting noise level analysed with respect to vehicle count at each second.

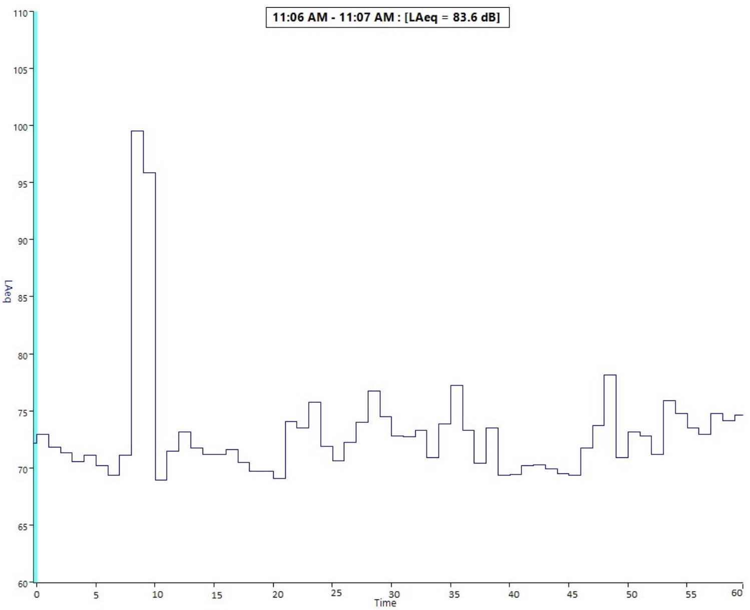

Fig. 13. Highest LAeq (dB) minute in peak 15-minute data at one town police station Chowrasta in noise tools.

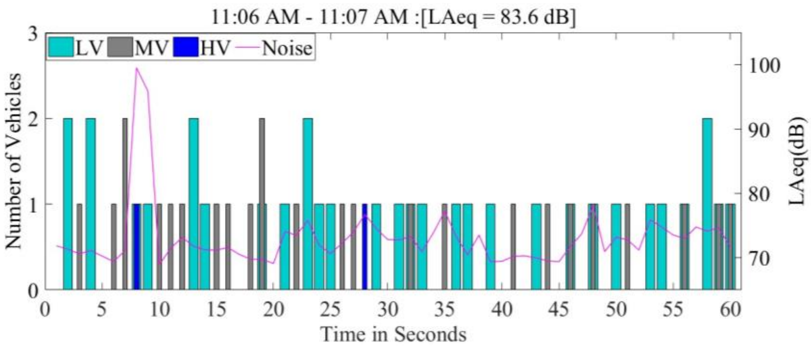

Fig. 14. Highest LAeq (dB) minute in peak 15-minute data at one town police station Chowrasta.

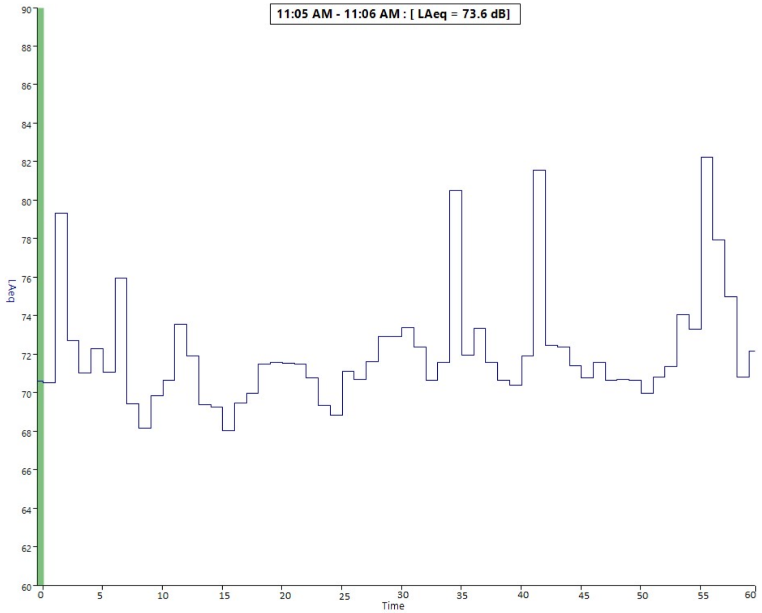

Fig. 15. Lowest LAeq (dB) minute in peak 15-minute data at one town police station Chowrasta in noise tools.

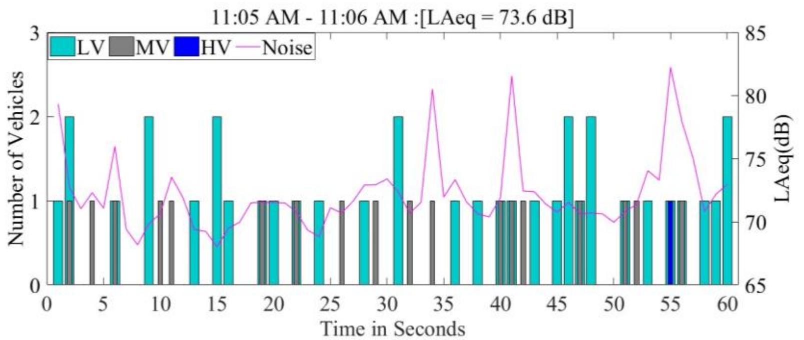

Fig. 16. Lowest LAeq (dB) minute in peak 15-minute data at one town police station Chowrasta.

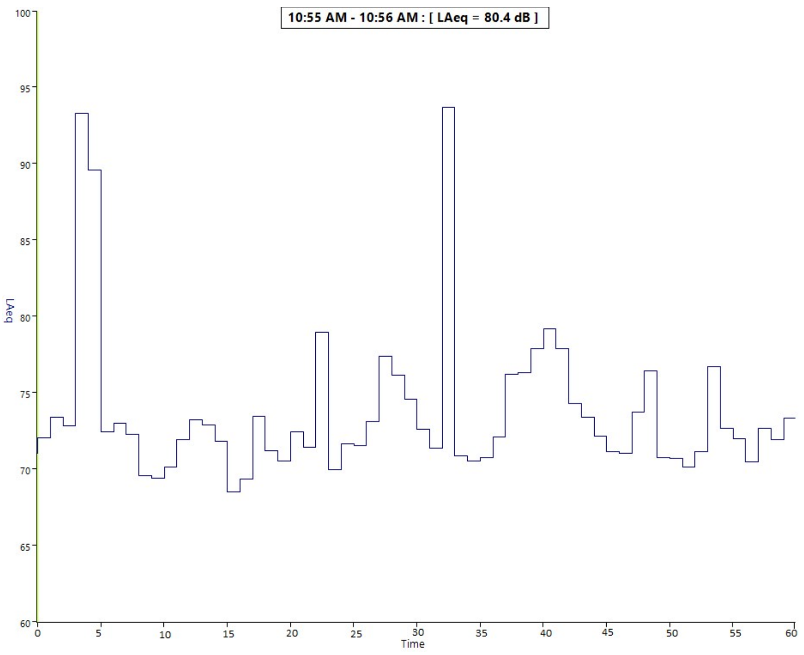

Fig. 17. Highest LAeq (dB) minute in peak 15-minute data at court Chowrasta in noise tools.

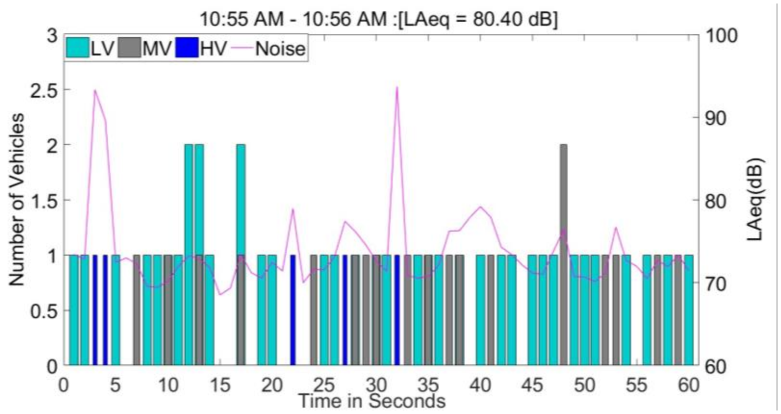

Fig. 18. Highest LAeq (dB) minute in peak 15-minute data at court Chowrasta.

In Fig. 17 highest LAeq [80.4 dB (A)] was observed between 10:55 am to 10:56 am in which heavy vehicle noise without honks are observed in the 22nd and 27th second as 77.41 dB (A) to 78.95 dB (A) and heavy vehicle with honks are observed in the 3rd, 4th and 32nd second as 93.3 dB (A), 89.52 dB (A) and 93.69 dB (A), respectively. Irrespective of the volume and honks, light and medium vehicles are generating the equivalent noise levels ranging from 68.52 dB (A) to 77.9 dB (A).

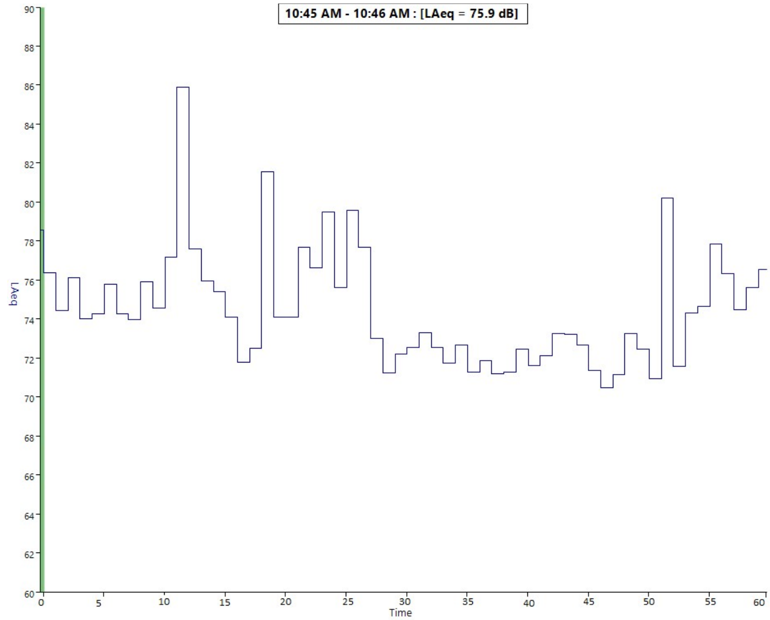

Fig. 19. Lowest LAeq (dB) minute in peak 15-minute data at court Chowrasta in noise tools.

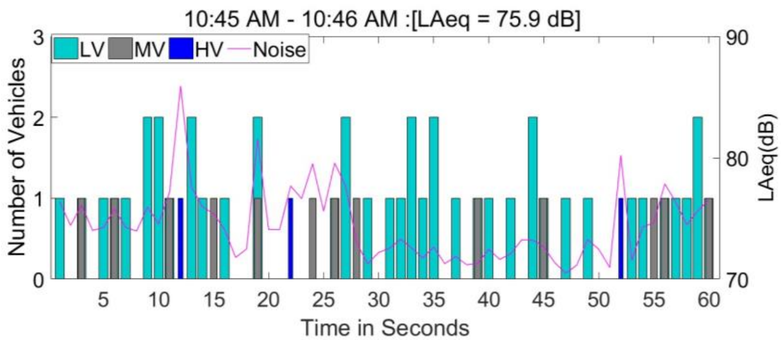

Fig. 20. Lowest LAeq (dB) minute in peak 15-minute data at court Chowrasta.

This indicates the major effect of heavy vehicle honking on overall noise generation. Thus, separating the honks from every vehicle is tedious and there can be a mismatch in the analysis as discussed elaborately in the previous section. From the above analysis, heavy vehicle presence in overall noise contribution can result in the development of a better model to predict the noise level at a rotary intersection which can only be confirmed by the following approach.

At the time frame of minute level, the noise data shows that LAeq (dB) was mainly affected by the heavy vehicle honking. However, continuous noise exposure cannot be justified at the minute level, as the noise induced over a longer period of time only leads to health hazards to people. Instead of selecting the minute in a peak hour, noise levels are analysed for a total duration of four hours where the fluctuation of honks in average noise level minutes cannot be identified just with the peak noise propagation in noise tools which might lead to poor results. Hence, taking the advantage of the prime result from minute level, heavy vehicle presence is identified in the entire survey duration for each 15 minutes at one town police station Chowrasta, and respective LAeq (dB) due to heavy vehicle is neglected and LAeq (dB) is averaged logarithmically without the presence of heavy vehicle contribution [36], [37]. The results obtained are compared with the LAeq (dB) levels including the heavy vehicle contribution using the noise tools, and the statistical significance is checked using the Statistical Package for the Social Science (SPSS) using t-test where obtained p-value is less than 0.05. This concludes that, both noise level variations are significant and the respective noise level comparison is shown in Fig. 21. The noise level comparison shows that heavy vehicles are responsible for additional noise of 3 to 6 dB (A) on overall traffic noise levels. Further, traffic noise level variation for 15 minutes LAeq (dB) for the traffic volume at one town Chowrasta was subjected to regression analysis, as shown in Table 1.

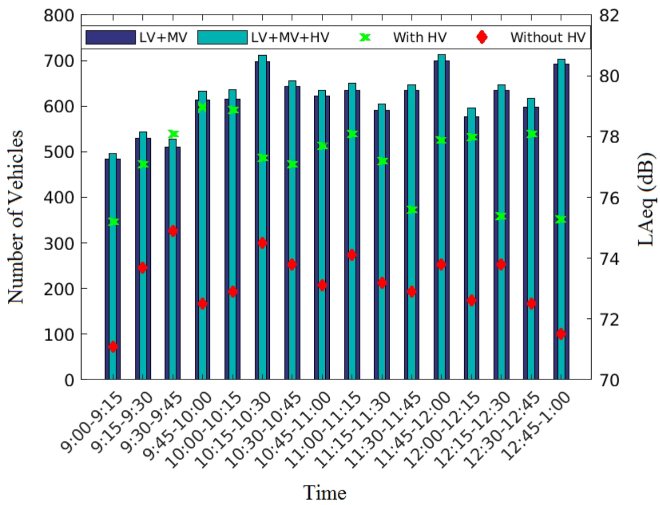

Fig. 21. Noise level LAeq (dB) comparison with and without heavy vehicles.

TABLE 1. ANALYSIS OF NOISE LEVELS BASED ON VEHICLE VOLUME FOR HV, AND LV + MV

Noise coefficients				
Independent variable	Unstandardized coefficients		*t*	*p*-value
	Values	Std. Error		
Constant	69.990	1.839	38.05	0.00
HV (15 min)	0.333	0.047	7.10	0.00
LV + MV (15 min)	0.004	0.003	1.41	0.18

As shown in Table 1, the "*p*-value" is less than 0.05 for heavy vehicles and "*p*-value" is greater than 0.05 for combination of light and medium vehicles. This shows that there is a notable impact of heavy vehicles on response of equivalent noise level [LAeq (dB)] from traffic [Confidence Interval (CI) 95 %]. Moreover, the data in the current study shows that light and medium vehicles are generating the equivalent noise levels ranging from 68.52 dB (A) to 77.9 dB (A) as can be observed from Fig. 17. Whereas, heavy vehicle presence is increasing the LAeq (dB) by 80.4 dB (A) to 93.69 dB (A). The dominance of heavy vehicles is quite evident throughout the entire survey period as shown in the Fig. 5 to 21. This shows that, average engine noise generated by the light and medium vehicles at low vehicle speeds is very much less than the average noise generated from heavy vehicles. Thus, at the 15-minute time frame of data logging, heavy vehicle presence alone is clearly depicting the average LAeq (dB) excluding the light and medium vehicles. A similar observation of heavy vehicle dominance over light and medium vehicles in noise generation on highways was clearly observed in the heterogenic traffic noise in India [29]. Hence, a new regression equation is developed by dropping the vehicle volume of low and medium classes and a linear model is developed for a 15-minute time interval for estimating the equivalent noise level [LAeq (dB)] by using the heavy vehicle volume alone for four-hour traffic noise data at one town police station rotary as shown by Eq. (1). As shown in Table 2, the "*p*-value" is less than 0.05 for heavy vehicles. Thus, there is notable impact of heavy vehicles on response of equivalent noise level [LAeq (dB)] from traffic [Confidence Interval (CI) 95 %].

$$\text{LAeq}\,(\text{dB})(15\,\text{min.}) = 72.37 + 0.32 \cdot HV\left[R^2 = 0.765\right] \quad (1)$$

TABLE 2. ANALYSIS OF NOISE LEVELS BASED ON VEHICLE VOLUME FOR HV ALONE

Noise coefficients				
Independent variable	Unstandardized coefficients		*t*	*p*-value
	Values	Std. Error		
Constant	72.37	0.743	97.43	0.00
HV (15 min)	0.320	0.047	6.73	0.00

The model developed is validated for the traffic data collected at court Chowrasta rotary and the comparison between observed and predicted noise levels is shown in Fig. 22. Statistical test of significance (*p*-value obtained is 0.318 which is greater than 0.05) was checked using the Bland Altman method in *Microsoft Excel* tool *XLSTAT*. Analysis shows that, the model can be used effectively for predicting traffic noise levels for the rotaries with similar geometrical and traffic characteristics.

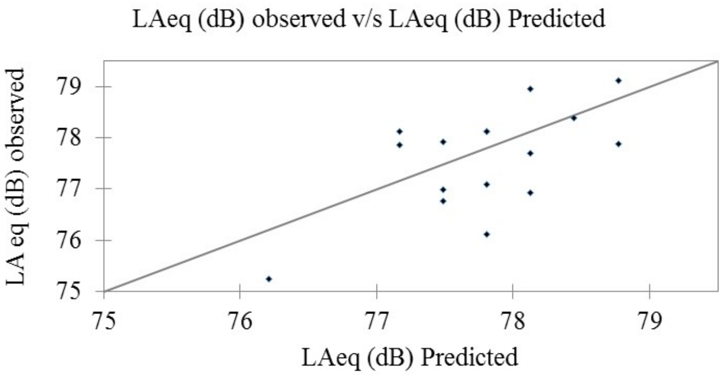

Fig. 22. Observed v/s predicted noise level LAeq (dB) for the model.

5. Conclusions

Several works done in the past on urban highway networks for separating honking from the total traffic noise by separating the frequency octave bands falling in honking response and subsequent logarithmic addition of remaining frequency bands, observed the effect of heavy vehicles, speed and honking on noise generation. It was concluded that, honking alone can increase the noise levels by 2 to 13 dB [29]–[31]. However, no work focused on estimating the noise levels at the rotaries/roundabouts which are most commonly located near the residential and commercial areas unlike the major highway network situated away from the residential areas in most cases. Thus, there is a high chance for extreme noise levels due to the large number of vehicular compositions passing continuously through these urban structural units, where heterogeneity of traffic may lead to extreme honking resulting in the severe effects on health to the people residing nearby. Moreover, the traffic noise level generated from the vehicles moving around the central island cannot be estimated exactly by using the regular standard procedures such as statistical pass-by method, for which the method described in this research study is shown to estimate with good precision for the selected rotary intersection.

Present study ascertains that, even though traffic calming can be achieved with reduced speeds and steady flows at rotaries, heavy vehicles in the traffic stream can affect the noise levels to a greater extent with their honks and high engine noise at lower speeds. At the minute level, average heavy vehicle noise varied around 78.95 dB (A) and reached the maximum with honking where the peak noise is 93.3 dB (A). This shows the severity of heavy vehicle honks on noise generation and in turn the heavy vehicle effect on overall noise generation in the hourly data, where 3 dB (A) to 6 dB (A) of noise level increase has been clearly observed for a 15-minute time interval. Throughout the survey period, traffic noise levels exceeded the day-time noise limits prescribed by the Central Control Pollution Board [38]. The regression model developed in this study gives better prediction of noise levels which can be used for finding average traffic noise levels at rotaries with similar geometrical and traffic characteristics.

Acknowledgement

The authors gratefully acknowledge the support of Karimnagar Police Commissioner and Karimnagar Municipal Commissioner for their support in collecting both the traffic volume and the traffic noise data. The authors also acknowledge the support provided by the following team members from National Institute of Technology, Warangal for the traffic data collection: Mr. P. Yugendar, Research Scholar, Dr. K.V.R. Ravi Shankar, Assistant Professor, and Dr. C.S.R.K. Prasad, Professor.

References

[1] Zandberga A., Lieplapa L., Blumberga D. The analysis of noise level on Saulkrasti bypass, Latvia. *Environmental and Climate Technologies* 2009:3(3):135–141. https://doi.org/10.2478/v10145-009-0018-3

[2] Costa S. B., Lourenco R. W. Geoprocessing Applied to the Assessment of Environmental Noise: a Case Study in the City of Sorocaba, Sao Paulo, Brazil. *Environmental Monitoring and Assessment* 2011:172(1–4):329–337. https://doi.org/10.1007/s10661-010-1337-3

[3] Korfali S. I., Massoud M. Assessment of community noise problem in greater Beirut area, Lebanon. *Environmental Monitoring and Assessment* 2003:84(3):203–218. https://doi.org/10.1023/A:1023322507415

[4] Bajcinovci B. Environment quality: Impact from Traffic, Power Plant and Land Morphology, a Case Study of Prishtina. *Environmental and Climate Technologies* 2017:19:65–74. https://doi.org/10.1515/rtuect-2017-0006

[5] Pinto F. A. N. C., Mardones M. D. M. Noise mapping of densely populated neighborhoods – example of Copacabana, Brazil: Rio de Janeiro. *Environmental Monitoring and Assessment* 2009:155(1–4):309–318. https://doi.org/10.1007/s10661-008-0437-9

[6] Calixto A., Diniz F. B., Zannin P. H. T. The Statistical Modeling of Road Traffic Noise in an Urban Setting Cities (London, England). *Urban Policy and Planning*2003:20(1):23–29. https://doi.org/10.1016/S0264-2751(02)00093-8
[7] Shafaghat A., Manteghi G., Keyvanfar A., Lamit H. B., Saito K., Ossen, D. R. Street geometry factors influence urban microclimate in tropical coastal cities: A review. *Environmental and Climate Technologies* 2016:17:61–75. https://doi.org/10.1515/rtuect-2016-0006
[8] Braj B. S., Jain V. K. A comparative Study of Noise Levels in Some Residential, Industrial and Commercial Areas of Delhi. *Environmental Monitoring and Assessment* 1995:35(1):1–11. https://doi.org/10.1007/BF00552571
[9] Guite K. Road Transport Year Book. New Delhi: Ministry of Road Transport and Highways, 2017.
[10] Skarlatos D., Drakatos P. Environmental noise – Annoyance in Patras, Greece. *Environmental Monitoring and Assessment* 1988:11(2):171−178. https://doi.org/10.1007/BF00401728
[11] Abbate C., Concetto G., Fortunato M., Brecciaroli R., Tringali M. A., Beninato G., Arrigo G., Domenico G. Influence of Environmental Factors on the Evolution of Industrial Noise-Induced Hearing Loss. *Environmental Monitoring and Assessment* 2005:107(1–3):351–361. https://doi.org/10.1007/s10661-005-3107-1
[12] Heritier H., Vienneau D., Frei P., Eze C., Brink M., Probst-Hensch N., Roosli M. The Association between Road Traffic Noise Exposure, Annoyance and Health-Related Quality of Life (HRQOL). *Journal of Environmental Research and Public Health* 2014:11(12):12652–12667. https://doi.org/10.3390/ijerph111212652
[13] Leong S. T., Laortanakul P. Monitoring and Assessment of Daily Exposure of Roadside Workers to Traffic Noise Levels in an Asian City: A Case Study of Bangkok Streets. *Environmental Monitoring and Assessment* 2003:85(1):69–85. https://doi.org/10.1023/A:1023305216910
[14] Mutairi N. Z., Attar M. A., Rukaibi F. S. Traffic-Generated Noise Pollution: Exposure of Road Users and Populations in Metropolitan Kuwait. *Environmental Monitoring and Assessment* 2011:183(1–4):65–75. https://doi.org/10.1007/s10661-011-1906-0
[15] Dagiliute R., Juozapaitiene G. Stakeholders in the EIA Process: What is Important for Them? The case of Road Construction. *Environmental and Climate Technologies* 2018:22:69–82. https://dx.doi.org/10.1186%2Fs40201-015-0164-4
[16] Zannin P. H. T., Diniz F. B., Giovanini C., Ferreira J. A. C. Interior noise profiles of buses in Curitiba. *Transportation Research Part D-Transport and Environment* 2003:8(3):243–247. https://doi.org/10.1016/S1361-9209(03)00019-1
[17] Prascevic M. R., Mihajlov D. I, Cvetkovic S. C. Measurement and Evaluation of the Environmental Noise Levels in the Urban Areas of the City of Nis (Serbia). *Environmental Monitoring and Assessment* 2014:186(2):1157–1165. https://doi.org/10.1007/s10661-013-3446-2
[18] Chevallier E., Can A., Nadji M., Leclercq L. Improving Noise Assessment at Intersections by Modeling Traffic Dynamics. *Transportation Research Part D* 2009:14(2):100–110. https://doi.org/10.1016/j.trd.2008.09.014
[19] Guarnaccia C. Analysis of Traffic Noise in a Road Intersection Configuration. *WSEAS Transactions on Systems* 2010:1(8):865–874.
[20] Rosli N., Hamsa A. K. Evaluating the Effects of Road Hump on Traffic Volume and Noise Level at Tamankeramat Residential Area, Kuala Lumpur. *Proceedings of the Eastern Asia Society for Transportation Studies* 2013:10(2013):1171–1188. https://doi.org/10.11175/easts.10.1171
[21] Covaciu D., Florea D., Timar J. Estimation of the Noise Level Produced by Road Traffic in Roundabouts. *Applied Acoustics* 2015:98:43–51. https://doi.org/10.1016/j.apacoust.2015.04.017
[22] Oyedepo O. S., Saadu A. A. A Comparative Study of Noise Pollution Levels in Some Selected Areas in Ilorin Metropolis, Nigeria. *Environmental Monitoring and Assessment* 2009:158(1–4):155–167. https://doi.org/10.1007/s10661-008-0570-5
[23] Lewis P. T., James A. Noise Levels in the Vicinity of Traffic Roundabouts. *Journal of Sound and Vibration* 1980:72(1):51–69. https://doi.org/10.1016/0022-460X(80)90707-5
[24] Hydén C., Svensson A. Traffic Calming in India: report on the theory of traffic calming and empirical trials in the city of Jaipur. Department of Technology and Society, Lund University, Bulletin 252, 2009.
[25] Pharoah T. M., Russell J. R. Traffic calming: policy and evaluations in three European countries. London: South Bank Polytechnic, 1989.
[26] Litman T., Traffic calming: benefits, costs and equity impacts. Victoria: Victoria Transport Policy Institute, 1999.
[27] Rylander R., Bjorkman M. Road traffic noise influenced by road bumps. *Journal of Sound and Vibration* 2002:250(1):157–9. https://doi.org/10.1006/jsvi.2001.3893
[28] Kalaiselvi R., Ramachandraiah A. Environmental noise mapping study for heterogeneous traffic conditions. *Applied Accoustics* 2010:23–27. https://doi.org/10.1016/j.apacoust.2016.04.003
[29] Kalaiselvi R., Ramachandraiah A. A noise mapping study for heterogeneous road traffic conditions considering horn sounds. *Journal of Acoustical Society of America* 2011:129(4):2380–2380. https://doi.org/10.1121/1.3587712
[30] Doshi P., Halani P., Jasoliya V., Jain M., Vinaya S. Honking with reduced effect on noise pollution. *International Journal of Advanced Research in Computer and Communication Engineering* 2015:4(10).
[31] Vijay R., Sharma A., Chakrabarti T., Gupta R. Assessment of honking impact on traffic noise in urban traffic environment of Nagpur, India. *Journal of Environmental Health Science & Engineering* 2015:13(1):10. https://doi.org/10.1186/s40201-015-0164-4

[32] Indian Standard, IS: 3098. Noise emitted by moving road vehicles, measurement. Indian Standards Institution 2015:13(10). https://doi.org/10.1186/s40201-015-0164-4
[33] Chowdhury K. A., Debsarkar A., Chakrabarty S. Critical assessment of day time traffic noise level at curbside open-air microenvironment of Kolkata City, India. *Journal of Environmental Health Science & Engineering* 2015:13(1):65. https://doi.org/10.1186/s40201-015-0219-6
[34] Cirrus Research Plc. Noise Tools. [Online]. [Accessed 15.06.2017]. Available: https://www.cirrusresearch.co.uk/library/software/
[35] Hammer E., Egger S., Saurer T., Buhlmann E. Traffic noise emission modelling at lower speeds. Conference Proceeding ICSV 2016:1–8.
[36] Cirrus Research. Energy Averaging of Noise Levels. [Online]. [Accessed 06.04.2017]. Available: https://www.cirrusresearch.co.uk/blog/2013/01/noise-data-averaging-how-do-i-average-noise-measurements/
[37] Cirrus Research. Fast and Slow Impulse Weightings. [Online]. [Accessed 15.06.2017]. Available: http://www.cirrusresearch.co.uk/blog/2015/01/fast-slow-impulse-time-weightings/
[38] The Noise Pollution (Regulation and Control) Rules (2000). [Online]. [Accessed 09.06.2017]. Available: http://cpcbenvis.nic.in/noisepollution/noise_rules_2000.pdf

Kamineni Aditya received M.Tech degree in Transportation Engineering from National Institute of Technology Warangal (NITW) in the year 2013. He is presently working for his PhD degree in the Transportation Division, Department of Civil Engineering, NITW, India. He works in the area of road traffic noise modelling. His publications include two international journal papers and two conference papers.
ORCID iD: https://orcid.org/0000-0001-9218-6292

Venkaiah Chowdary is an Associate Professor in the Department of Civil Engineering, National Institute of Technology, Warangal, Telangana, India. He has 12 years of teaching and research experience. He is a member of Association of Asphalt Paving Technologists, USA, International Society for Asphalt Pavements, USA, and Indian Roads Congress. He is a regular reviewer for several international journals and conferences. He has published his research works in various national and international journals and conferences of repute. He works in the area of traffic noise modelling, and characterization of asphalt binders and mixtures.
ORCID iD: https://orcid.org/0000-0003-4929-7055