Chapter 4

Heterogeneous Road Traffic Noise Modeling at Mid-block Sections of Mid-sized City in India

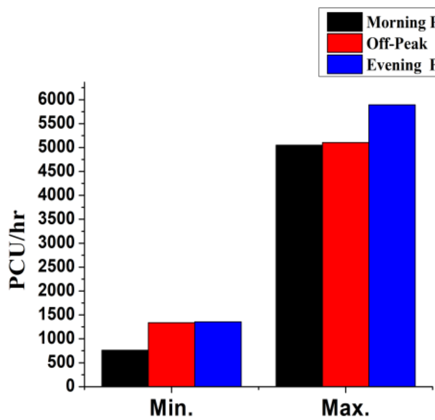
4.1 General

This research aimed to develop software that can monitor traffic noise in a mid-sized Indian city. The software would be designed to handle the varied traffic conditions (heterogeneous traffic) experienced during different times of day: morning peak hours (MP), off-peak hours (OP), and evening peak hours (EP). The focus was on mid-block sections, likely to avoid disturbances caused by intersections or traffic lights. K-Nearest Neighbor (K-NN) algorithm was adopted for traffic noise prediction modeling. Moreover, Principal Component Analysis (PCA) technique was used for the dimensionality reduction and to overcome the problem of multi-collinearity. This research resulted in a user-friendly calculator named 'Traffic Noise Prediction Calculator for Heterogeneous Traffic (TNPC-H)' was developed for the benefit of field engineers and policy planners.

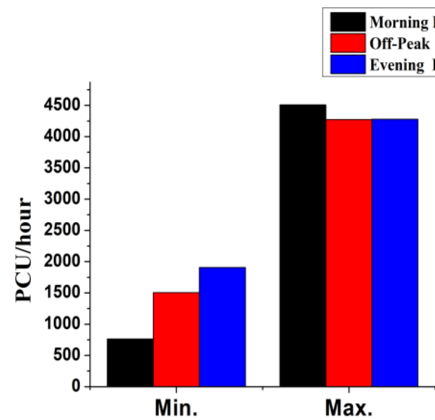
4.2 Traffic Volume, Speed and Noise Study

For comparison of traffic volume, we compared the traffic volume in Passenger car unit (PCU) per hour for different zone as shown in Figure 4.1. The city were divided into four types of zones i.e. Residential, Commercial, Industrial, Silence zone. The road width were varied from 6 to 17.8 meter. Façade distance from edge of the road were varied from 0.5m to

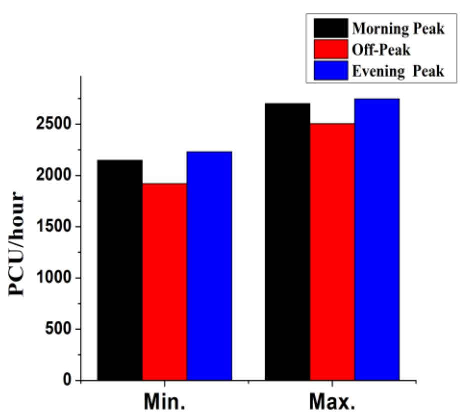
30m on same side of the road and 9.5m to 42m on opposite side of the road. The overall traffic flow ranged from 760 to 7,400 PCU/hour. The data were primarily collected on arterial roads, which were of two types: a) 4-lane divided (2-way), and b) 2-lane (2-way).



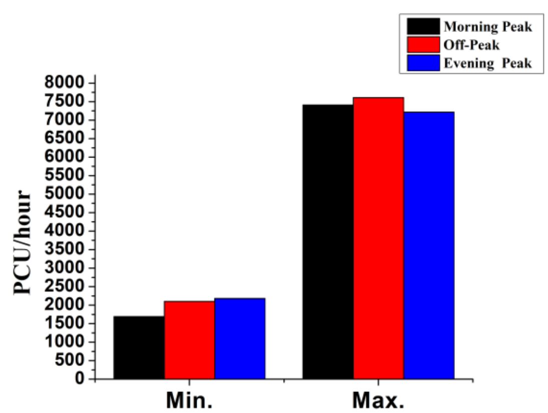
a) Silence Zone



b) Residential Zone



c) Industrial Zone



d) Commercial zone

Figure 4.1. Traffic volume plot for different zones

The maximum PCU/hour. in the commercial zone exceeded 7,000 PCU/hour, which was higher compared to other zones. In the silence zone, it was below 5,500 PCU/hour, followed by the residential zone with less than 4,500 PCU/hour, and the industrial zone with less than 3,000 PCU/hour. The maximum, minimum and average value of PCU/hour. for different location is provided on Table 4.1. Table 4.2 provides the design service volume of IRC : 106-1990. Out of 16 locations with a 4-lane divided (2-way) carriageway, 13 exceeded the design service volume specified in IRC:106-1990. Similarly, 6 out of 7 locations with a 2-lane (2-way) carriageway also surpassed the design service volume limits. The diversified pattern is achieved at different locations for different category of vehicles. The 2-wheeler (2-w), 3-wheeler (3-w), car and cycles were obtained in almost uniform pattern in many of the locations and the diversified form was obtained at few locations. While, the other class of vehicles, some locations exhibit very high number of vehicles and few are having least number of vehicles. Traffic Composition across different time periods are :

- 2-Wheelers constituted the largest share of traffic, ranging from 47–77% (average: 62%) during the morning peak, 49–74% (average: 64%) during the off-peak period, and 50–77% (average: 64%) during the evening peak.
- Passenger Cars accounted for 3–29% (average: 13%) during the morning peak, 4–30% (average: 14%) during the off-peak period, and 4–32% (average: 15%) during the evening peak.
- Non-Motorized Vehicles (bicycles and rickshaws) made up 2–26% (average: 10%) during the morning peak, 1–27% (average: 7%) during the off-peak, and 1–21% (average: 8%) during the evening peak.

- 3-Wheelers constituted less than 24% (average: 10%) during the morning peak, less than 16% (average: 9%) during off-peak, and less than 17% (average: 8%) during the evening peak.
- Heavy Vehicles (trucks and buses) accounted for less than 4% (average: 1%) during the morning peak and less than 6% (average: 1%) during both the off-peak and evening peak periods.
- Light Commercial Vehicles (LCVs) made up less than 6% (average: 2%) in the morning peak and less than 7% (average: 2%) during both off-peak and evening peak periods.
- e-Rickshaws contributed less than 9% (average: 2%) during both morning and off-peak periods, and less than 8% (average: 2%) during the evening peak.

The insight information about the traffic volume at different locations is extracted in the form of frequency plot as shown in Figure 4.2. The L_{Aeq} range were varied from 69.6 – 83.8 dB(A) for morning peak, 71.1 – 83.6 dB(A) for off peak and 69.6 – 83.8 dB(A) for evening peak. For commercial zone, during morning peak the L_{Aeq} were ranged between 72.4 – 83.6 dB(A), during off peak the range were in between 71.7 – 83.62 dB(A) and for evening peak the range were in between 72.4 – 83.8 dB(A). For residential zone, during morning peak the L_{Aeq} were ranged between 70.8 – 81.7 dB(A), during off peak the range were in between 71.9 – 81.5 dB(A) and for evening peak the range were in between 69.4 – 81.7 dB(A). For industrial zone, during morning peak the L_{Aeq} were ranged between 73.09 – 77.58 dB(A), during off peak the range were in between 73.66 – 79.44 dB(A) and for evening peak the range were in between 72.00 – 79.83. For silence zone, during morning peak the L_{Aeq} were ranged between 69.53 – 80.11 dB(A), during off peak the range were in between 71.13 – 81.49 dB(A) and for evening peak the range were in between 71.23 – 79.46 dB(A). Figure 4.3 and Figure 4.5 shows that the commercial zone experiences the highest traffic volume per hour. Additionally, the maximum noise levels were also observed in the commercial zone. According to WHO L_{Aeq} limit for commercial zone is 70 dB(A), but this level was exceeded by more than 13 dB(A). For residential and silence zone for outdoor living area the L_{Aeq} limit according to WHO is 50-55 dB(A) but it was exceeded more than 25-30 dB(A). This indicates an unhealthy environment for the well-being of people living or working nearby and necessitates proper noise mitigation measures. The traffic speed in the city were ranged between 14 -36 Km/h as per Figure 4.4 the traffic speed during the morning peak was observed to be higher compared to both the evening and off-peak periods. The range of traffic speeds for different locations and different peak times is shown in the Table 4.3 and Figure 4.4 respectively. Figure 4.5 and Figure 4.6 also highlights that there is no clear relationship of PCU/hour, speed with the noise levels; an increase in PCU/hour or speed does not necessarily result in higher noise levels. In some cases, locations with lower PCU/hour recorded higher noise levels than those with greater PCU/hour, potentially due to honking or other factors. Various parameters that can influence noise levels were considered in the modeling.

Table 4.1. Traffic volume details of individual locations

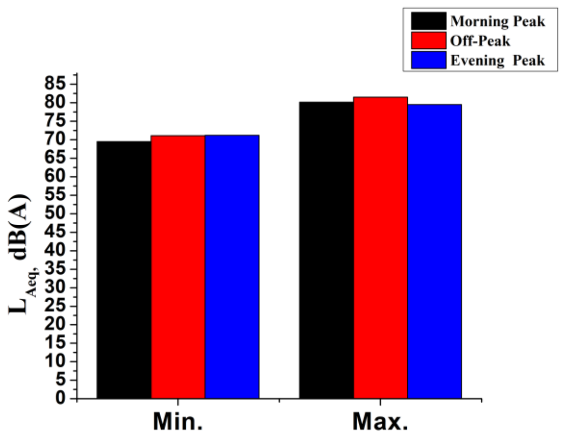
Location number	Location Name	Road type	Min PCU/hour	Avg. PCU/hour	Max PCU/hour	Avg. L_{Aeq},1h of 6 cycles
1	Mohaddipur-Asuran (Residential)	2- lane (2-way)	762	2960	3336	77.04
2	Paidleyganj (Residential)	2- lane (2-way)	3128	3975	4596	80.53
3	Tarang Bridge (Residential)	2- lane (2-way)	4573	6045	7378	79.7
4	Betiahata (Residential)	2- lane (2-way)	2683	3566	4519	80.56
5	Taramandal (Residential)	2- lane (2-way)	1504	4260	2414	78.08
6	Maya Bazar (Silence)	2- lane (2-way)	763	1572	2229	76.1
7	Arogya Bhawan (Silence)	4-lane divided (2-way)	3475	4500	5306	77.2
8	Gorakhnath Mandir (Silence)	4-lane divided (2-way)	2729	4189	5895	77.8
9	MMMUT (Silence)	4-lane divided (2-way)	2023	3074	3951	75.1
10	Mohaddipur University (Silence)	4-lane divided (2-way)	2283	4952	7332	76
11	AIIMS (Silence)	4-lane divided (2-way)	2593	3301	3705	77.7
12	BRD Medical College (Silence)	4-lane divided (2-way)	2830	3207	3486	74.5
13	GIDA (Industrial)	4-lane divided (2-way)	1920	2428	2747	75.9
14	Asuran-Padri (Commercial)	2- lane (2-way)	2058	2851	4143	77.7

15	Asuran-Padri (Commercial)	2- lane (2-way)	2058	2851	4143	77.7
16	Ganesh Chowk (Commercial)	4-lane divided (2-way)	2320	3594	4473	79.3
17	Mohaddipur (Commercial)	4-lane divided (2-way)	2566	3631	4369	76.7
18	Naushad-Rajghat (Commercial)	4-lane divided (2-way)	6065	6898	7610	80.23
19	Mohaddipur-Kunraghat (Commercial)	4-lane divided (2-way)	5527	6645	7332	78.4
20	Asuran (Commercial)	4-lane divided (2-way)	4450	5571	6169	81.12
21	Kalimata mandir (Commercial)	4-lane divided (2-way)	3143	3940	4897	80.8
22	Naushad-Mau (Commercial)	4-lane divided (2-way)	1691	2409	3154	74.2
23	SBI (commercial)	4-lane divided (2-way)	3332	4260	5398	76.9

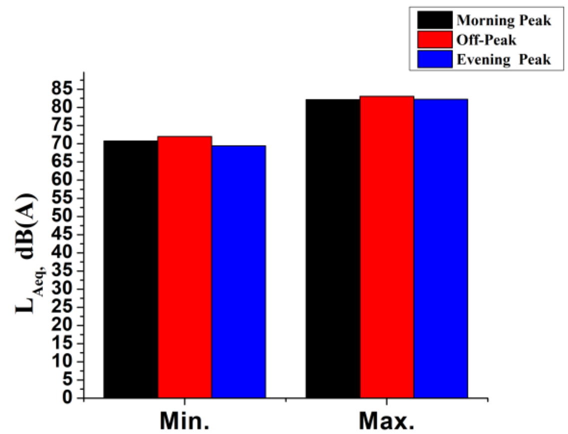
Table 4.2. Design service volume for roads

S.No.	**Types of carriageway**	**Design service volume for different categories of urban roads**		
		Arterial	Sub-arterial	Collector
1.	2-Lane (2-way)	1500	1200	900
2.	4-Lane Divided (2-way)	3000	2400	1800

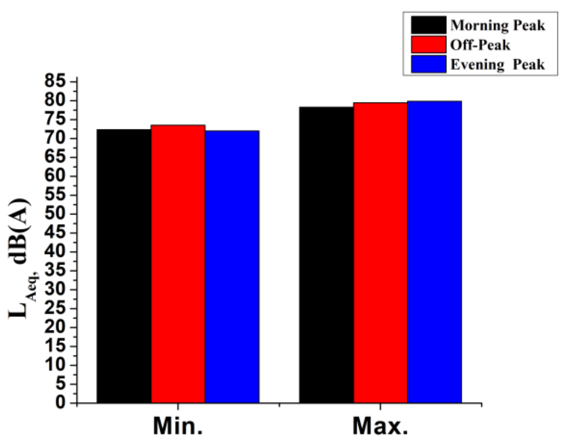
Figure 4.2. Frequency plot for traffic volume of different category of vehicles at different locations



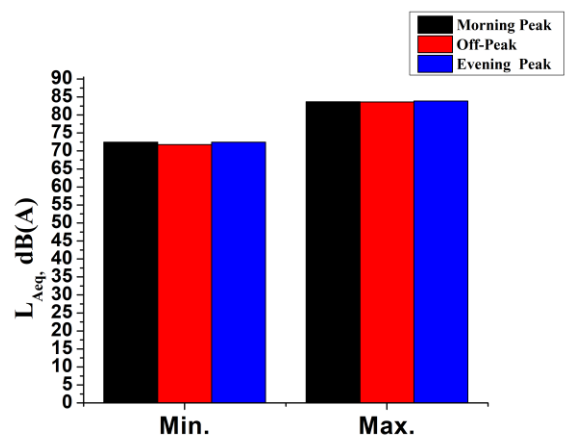
a) Silence Zone



b) Residential Zone



c) Industrial Zone



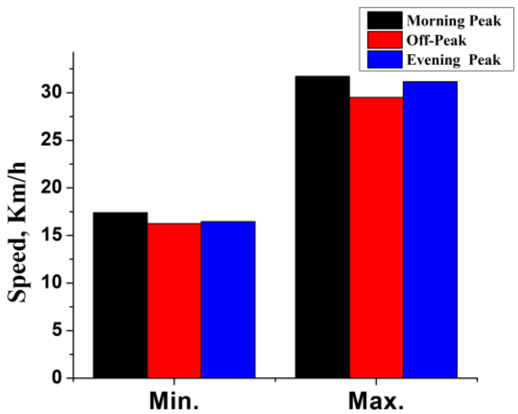
d) Commercial Zone

Figure 4.3. Noise level range for different zones

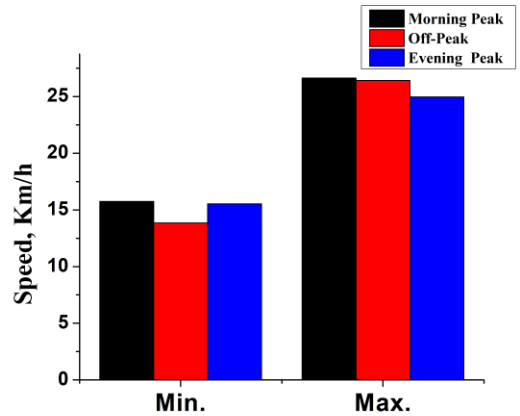
Table 4.3. Speed range for different locations

Location number	Location Name	Road type	Min. Speed, Km/h	Avg. Speed, Km/h	Max Speed, Km/h
1	Mohaddipur-Asuran (Residential)	2- lane (2-way)	19	21	24
2	Paidleyganj (Residential)	2- lane (2-way)	14	18	29
3	Tarang Bridge (Residential)	2- lane (2-way)	18	22	25
4	Betiahata (Residential)	2- lane (2-way)	17	21	22
5	Taramandal (Residential)	2- lane (2-way)	21	27	26
6	Maya Bazar (Silence)	2- lane (2-way)	16	19	25
7	Arogya Bhawan (Silence)	4-lane divided (2-way)	21	23	26
8	Gorakhnath Mandir (Silence)	4-lane divided (2-way)	20	23	29
9	MMMUT (Silence)	4-lane divided (2-way)	21	25	29
10	Mohaddipur University (Silence)	4-lane divided (2-way)	22	27	32
11	AIIMS (Silence)	4-lane divided (2-way)	19	26	31
12	BRD Medical College (Silence)	4-lane divided (2-way)	18	22	25

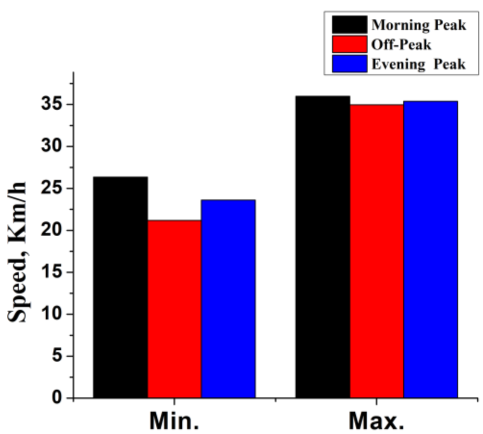
13	GIDA (Industrial)	4-lane divided (2-way)	21	31	36
14	Asuran-Padri (Commercial)	2- lane (2-way)	16	19	26
15	Ganesh Chowk (Commercial)	4-lane divided (2-way)	16	18	23
16	Golghar (Commercial)	4-lane divided (2-way)	17	21	25
17	Mohaddipur (Commercial)	4-lane divided (2-way)	21	25	29
18	Naushad-Rajghat (Commercial)	4-lane divided (2-way)	20	24	29
19	Mohaddipur-Kunraghat (Commercial)	4-lane divided (2-way)	18	27	32
20	Asuran (Commercial)	4-lane divided (2-way)	18	20	23
21	Kalimata mandir (Commercial)	4-lane divided (2-way)	18	22	24
22	Naushad-Mau (Commercial)	4-lane divided (2-way)	24	29	32
23	SBI (commercial)	4-lane divided (2-way)	20	21	24



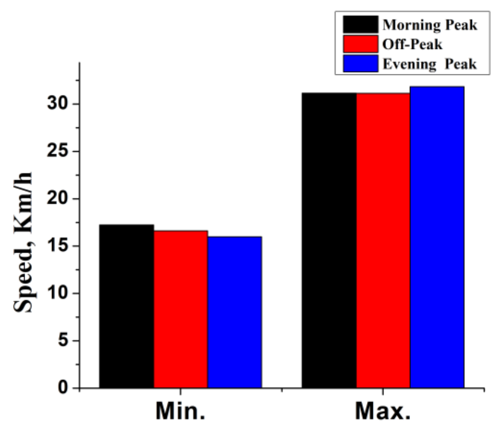
a) Silence Zone



b) Residential Zone



C) Industrial Zone



d) Commercial Zone

Figure 4.4. Traffic speed range for different zones

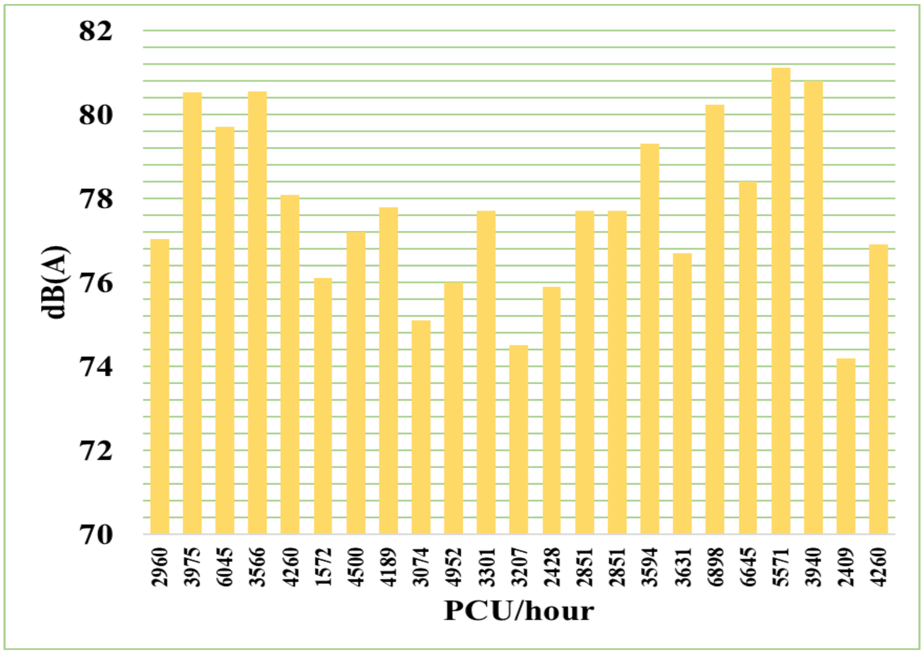


Figure 4.5. PCU/hour vs L_{Aeq} for different locations

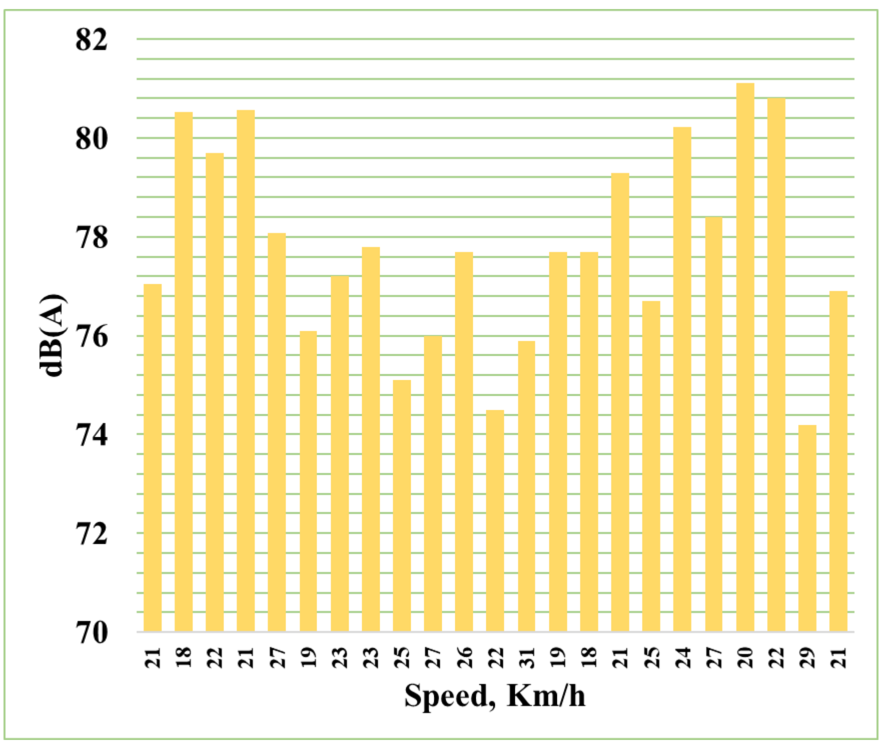


Figure 4.6. Speed vs $L_{Aeq,}$ for different locations

4.3 Statistical Visualization of Prepared Dataset

In this study, parameters like traffic volume and average speed of each category of vehicles (2-wheeler (2-w), 3-wheeler (3-w), Car, Jeep, Light Commercial Vehicle (LCV), Tractor, Bus, Truck, Rickshaw, e-rickshaw and Bicycle), percentage of Honking Contributor Vehicle (HCV), road width, Façade Same Side (FSS) distance , Façade Opposite Side (FOS) distance , Average Building Height Same Side (ABHSS), Average Building Height Opposite Side (ABHOS), International Roughness Index (IRI), observer distance (OD), L_{eq} and L_{10} were considered for analysis. Percentage of honking contributor vehicle is the sum of percentage of 3-wheeler (Auto-Rickshaw), e-rickshaw, Rickshaw and Cycle. These Auto-rickshaw, e-rickshaw vehicles drive intermittently and improperly obstruct the flow of traffic by stopping frequently to pick up and drop off passengers. Another problem is that cyclist and rickshaw drivers often travel too slowly for traffic conditions, and they often disregard traffic laws and regulations. Congestion in traffic flow is caused by all of these factors, and the resulting acceleration and deceleration of vehicles causes a honking situation. Because of these considerations, this HCV parameter is included in the Modeling process. While Average building height is the average of 5-7 building heights. The descriptive statistic values of all these parameters for MP, OP and EP is presented in Table 4.4.

Table 4.4. Descriptive statistic values of parameters

	Minimum			Maximum			Average			Standard deviation		
	MP	OP	EP	MP	OP	EP	MP	OP	EP	MP	OP	EP
dB(A)	69.5	71.1	69.4	83.6	83.6	83. 8	77.6	77.7	77.7	2.6	2.58	2.62
dB(A)	69.7	71.9	70.6	84.8	83.8	84.5	78.4	78.4	78.4	2.7	2.53	2.7
HCV (%)	8.6	9.3	6.3	40.1	29.8	29.5	21.7	18.3	17.0	6.4	4.7	4.7
Road width (m)	6.0	6.0	6.0	17.8	17.8	17.8	11.8	11.9	11.9	3.2	3.2	3.17
FSS (m)	0.5	0.5	0.5	30.0	30.0	30.0	7.0	6.9	7.1	10.2	10.2	10.3
FOS (m)	9.2	9.2	9.2	42.0	42.0	42.0	21.5	21.5	21.7	6.2	6	6.3
ABHSS (m)	0.0	0.0	0.0	18.3	18.3	18.3	4.7	4.7	4.7	3.7	3.8	3.7
ABHOS (m)	0.0	0.0	0.0	20.6	20.6	20.6	5.1	5.1	5.1	4.3	4.4	4.4
IRI	1.5	1.5	1.5	3.9	3.9	3.9	2.8	2.8	2.8	0.5	0.5	0.5
O.D. (m)	3.8	3.8	3.8	8.2	8.2	8.2	5.6	5.6	5.6	1.1	1.1	1.1
Traffic volume, Veh/hour												
2-wheeler	500	1053	915	6282	5494	5628	2523	2725	2718	1180	1115	1119
3-wheeler	9	7	4	908	929	710	400	388	311	224	221	177
Car	49	82	90	1214	1235	1376	525	589	628	254	246	278
Jeep	2	2	2	51	44	27	6	6	5	8	7	5
LCV	10	15	3	341	372	290	86	86	77	61	60	52
Tractor	2	2	2	41	29	15	7	6	4	6	4	3
Bus	2	2	2	136	126	118	32	33	30	34	35	31
Truck	2	2	2	55	99	72	10	10	9	10	15	11
Rickshaw	1	2	2	327	376	228	42	52	42	64	79	58
e-Rickshaw	1	2	2	251	339	259	62	76	67	59	75	64
Cycle	43	33	15	1041	637	895	345	248	282	184	114	164

Vehicular speed, km/h												
2-wheeler	18.5	14.5	17	52.5	50.8	51.9	32.8	31.4	30.8	6.5	7	6.8
3-wheeler	15	14	13.8	43.1	43.5	42.3	27.4	26.3	26.1	6.3	6.4	6.4
Car	18.8	14	13.8	67	65	67.7	34.6	33.3	33.1	9.7	10.4	10
Jeep	10	8.3	10	43.8	34	38.8	17.9	18.0	18.3	6.8	6.1	6.4
LCV	14.3	10.5	10.8	99.5	61.1	56.2	29.2	27.6	27.2	8.9	8.4	8.4
Tractor	10.8	10.8	11.5	32.5	35.3	35.5	18.2	18.0	18.2	4.6	4.7	5
Bus	16.2	13	13	82	54.4	68.6	27.6	26.9	27.0	10.4	9.4	9.9
Truck	15.8	12.8	14.3	49	48.1	46.3	24.1	24.2	23.7	6.9	6.6	6.7
Rickshaw	2.5	7.8	7.8	43	19	24	11.1	10.9	11.2	3	1.4	1.9
e-Rickshaw	10	11.5	11.8	26	27	30.1	18.2	18.2	17.9	3.1	2.9	2.9
Cycle	7.8	7.1	8	30	19.3	24.5	13.5	13.2	13.3	2.3	2.1	2.3

4.4 Implementation of PCA

Out of large number of input parameters, it is expected that some parameters may have degree of association with output parameters (L_{Aeq} and L_{10}) on the lower side and some on higher side (as shown from Figure 4.7 to Figure 4.9). Some parameters may demonstrate inter-correlation with each other (also known as multi-collinearity), impacting the computational cost (higher) and accuracy of computational models (lower). Therefore, to avoid all these issues and to reduce the number of input parameters, the Principal Component Analysis (PCA) was adopted in this study. It generates its own new Principal Components (PCs) that defines the maximum variance in the dataset. These PCs are orthogonal to each other which helps in removing the overfitting and multi-collinearity. Considering more than 90% variance, the total number of PCs obtained were 14 for MP and OP, while they were 15 for EP. Descriptive statistic of PCs obtained for MP, OP and EP are presented in Table 4.5.

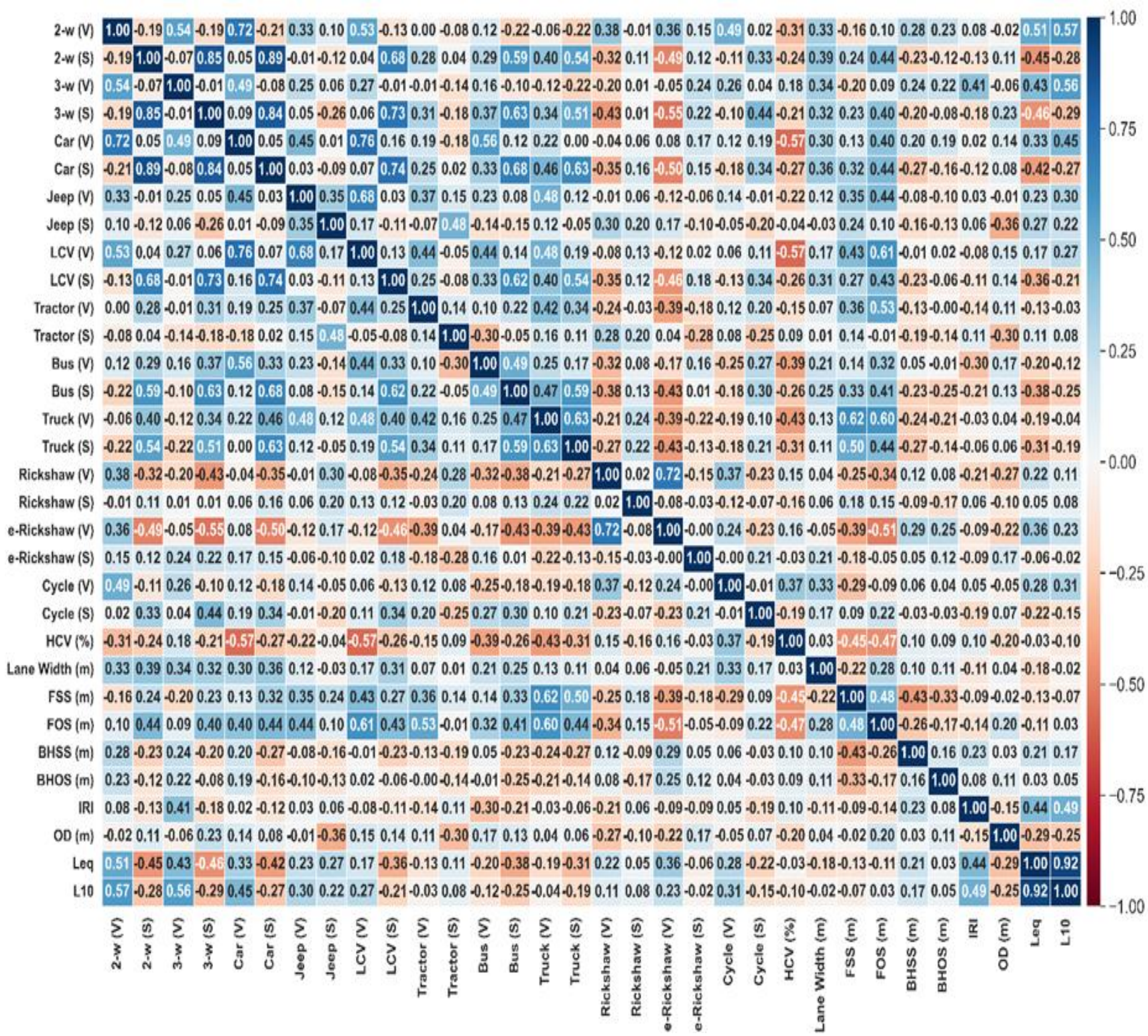


Figure 4.7. Correlation matrix for morning peak dataset

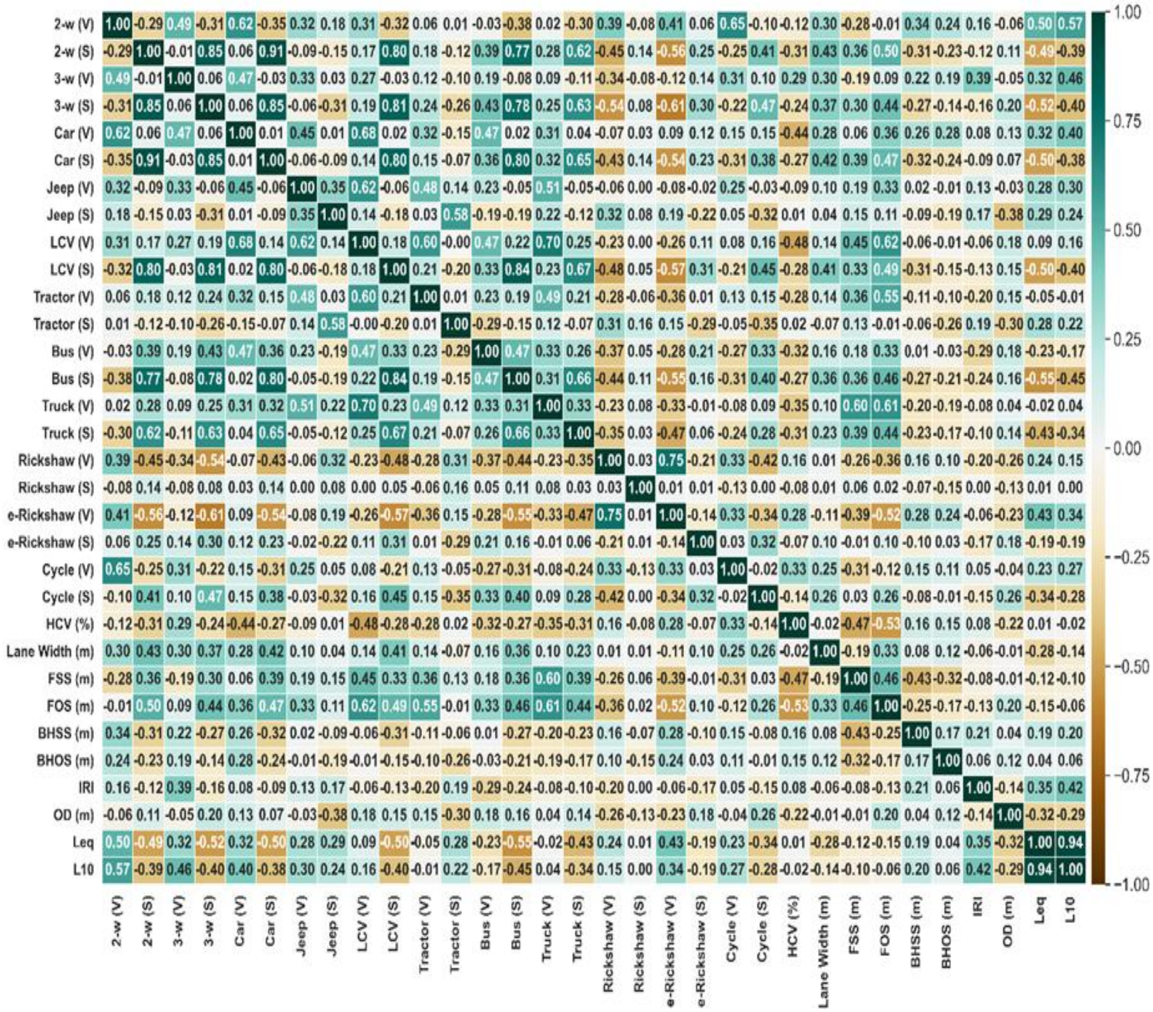


Figure 4.8. Correlation matrix for off peak dataset

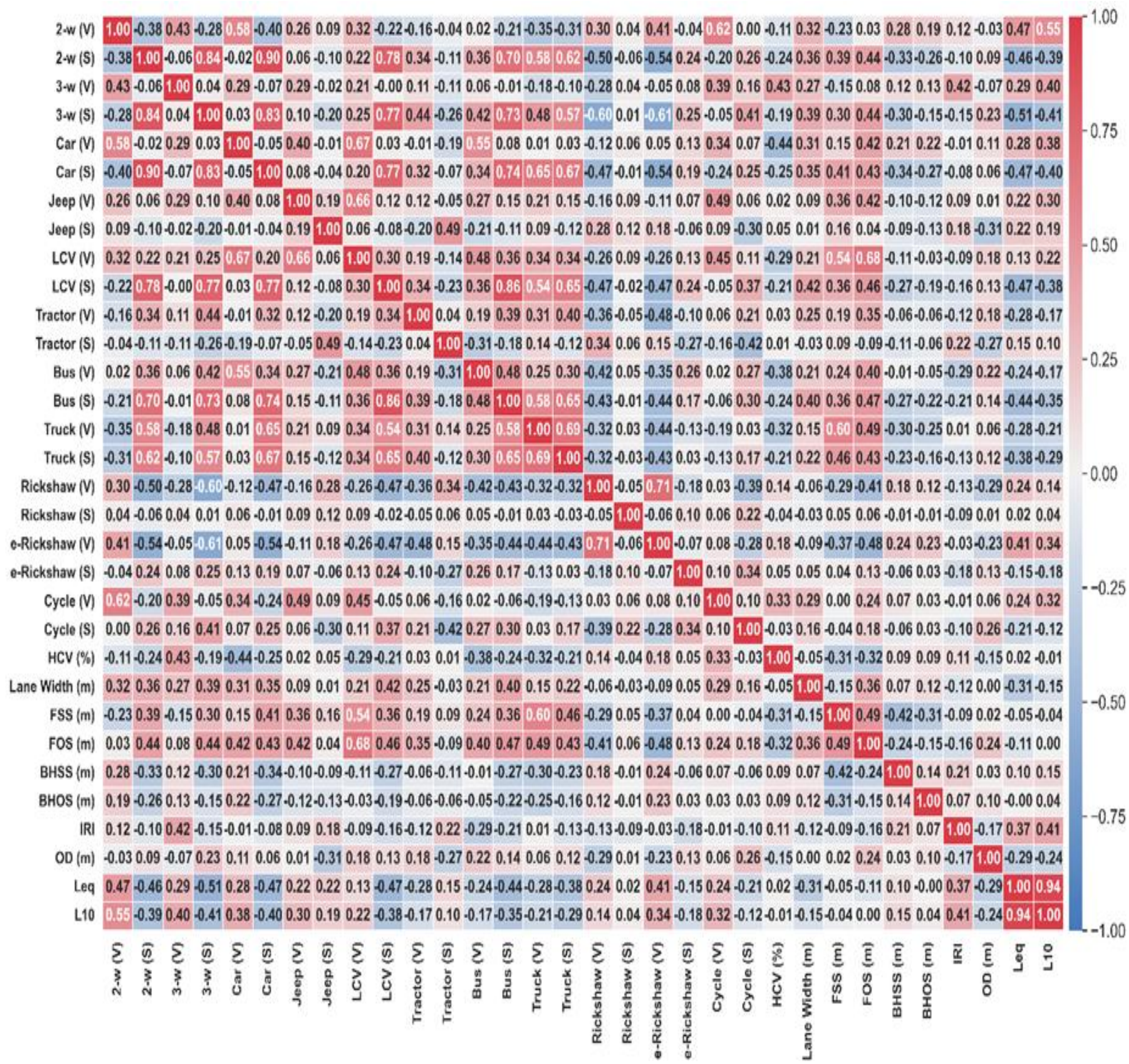


Figure 4.9. Correlation matrix for evening peak dataset

Table 4.5. Descriptive statistics of PCs obtained for MP, OP and EP hourly duration

PC ID	Minimum			Maximum			Standard deviation		
	MP	OP	EP	MP	OP	EP	MP	OP	EP
PC1	-0.299	-0.283	-0.317	0.425	0.333	0.334	0.174	0.177	0.175
PC2	-0.461	-0.388	-0.399	0.359	0.449	0.410	0.166	0.171	0.175
PC3	-0.261	-0.338	-0.316	0.347	0.392	0.420	0.177	0.171	0.171
PC4	-0.452	-0.504	-0.364	0.365	0.376	0.377	0.179	0.179	0.178
PC5	-0.532	-0.537	-0.441	0.386	0.460	0.432	0.186	0.186	0.185
PC6	-0.635	-0.523	-0.285	0.440	0.626	0.631	0.183	0.185	0.184
PC7	-0.615	-0.430	-0.437	0.480	0.382	0.349	0.185	0.185	0.185
PC8	-0.262	-0.342	-0.537	0.612	0.643	0.373	0.182	0.185	0.177
PC9	-0.401	-0.317	-0.321	0.476	0.437	0.649	0.185	0.185	0.183
PC10	-0.309	-0.520	-0.417	0.515	0.314	0.417	0.185	0.185	0.186
PC11	-0.356	-0.233	-0.273	0.525	0.482	0.427	0.186	0.166	0.162
PC12	-0.259	-0.651	-0.372	0.458	0.202	0.411	0.161	0.184	0.184
PC13	-0.596	-0.438	-0.527	0.246	0.371	0.263	0.185	0.183	0.182
PC14	-0.375	-0.306	-0.409	0.571	0.693	0.337	0.186	0.186	0.185
PC15	NA	NA	-0.348	NA	NA	0.426	NA	NA	0.185

4.5 Result and Discussion

This section is particularly focused on the results achieved through developed model for MP, OP and EP.

4.5.1 Results for L_{Aeq}

Table 4.6 presents the statistical performance of L_{eq} model in TR and TS dataset of MP, OP and EP. It can be clearly observed from Table 4.6 that R^2 value obtained for TR and TS dataset of MP is 0.868 and 0.810, respectively. This means that the developed L_{eq} model is able to explain 86.8% and 81% variability in the TR and TS dataset of MP. Similarly, the variability obtained for OP is 79.9% and 77.5%, and for EP is 85.3% and 77.4% in TR and

TS dataset, respectively. The coefficient of correlation (R) value obtained for MP, OP and EP in TR and TS dataset is extensively higher than 0.80 which means that the target and predicted values are well associated with each other and prediction can be made more closely to the actual value with least amount of error. The value obtained for MAE and RMSE in TR and TS dataset of each of the peak is also least. The highest explained variability and lowest error achieved in the MP reveals that the maximum reliable prediction can be made for MP followed by EP and OP. However, the overall finding establish that the developed models are efficient in predicting the L_{eq} of a particular area, having heterogeneous traffic condition. Figure 4.10 shows the target versus predicted L_{eq} value of TR and TS dataset at MP, OP and EP. The center line denotes the 45^{o} line or line of equality whereas lower and upper line indicates the lower and upper bound which is assumed as -3% and +3%, respectively. As seen from Figure 4.10 that the dataset in the MP, OP and EP is considerably closer to the line of equality. This means that the maximum number of observations in each of the peak can be predicted within the predefined upper and lower bound limit as well as are more closely to their target L_{eq} value. Rare of the rarest dataset are outside the ±3% variation range which can also be confirmed from Figure 4.11 showing the error frequency plot for TR and TS dataset of MP, OP and EP. Almost 60% dataset for MP and 50% for OP and EP can be predicted within ±1% variation. More than 95% observations for each of the peak can be predicted within ±3% variation. Additionally, the predictive pattern achieved in the TS dataset of each of the peak is almost similar to the pattern obtained in TR dataset. Therefore, the developed models are also efficient from generalization point of view.

Table 4.6. Statistical performance of L_{eq} model in TR and TS dataset of MP, OP and EP.

Performance measurement parameters	**MP**		**OP**		**EP**	
	TR	TS	TR	TS	TR	TS
R^2	0.868	0.810	0.799	0.775	0.853	0.774
R	0.932	0.910	0.895	0.881	0.925	0.886
MAE	0.703	0.776	0.913	0.901	0.744	0.972
RMSE	0.959	1.086	1.158	1.193	1.000	1.237

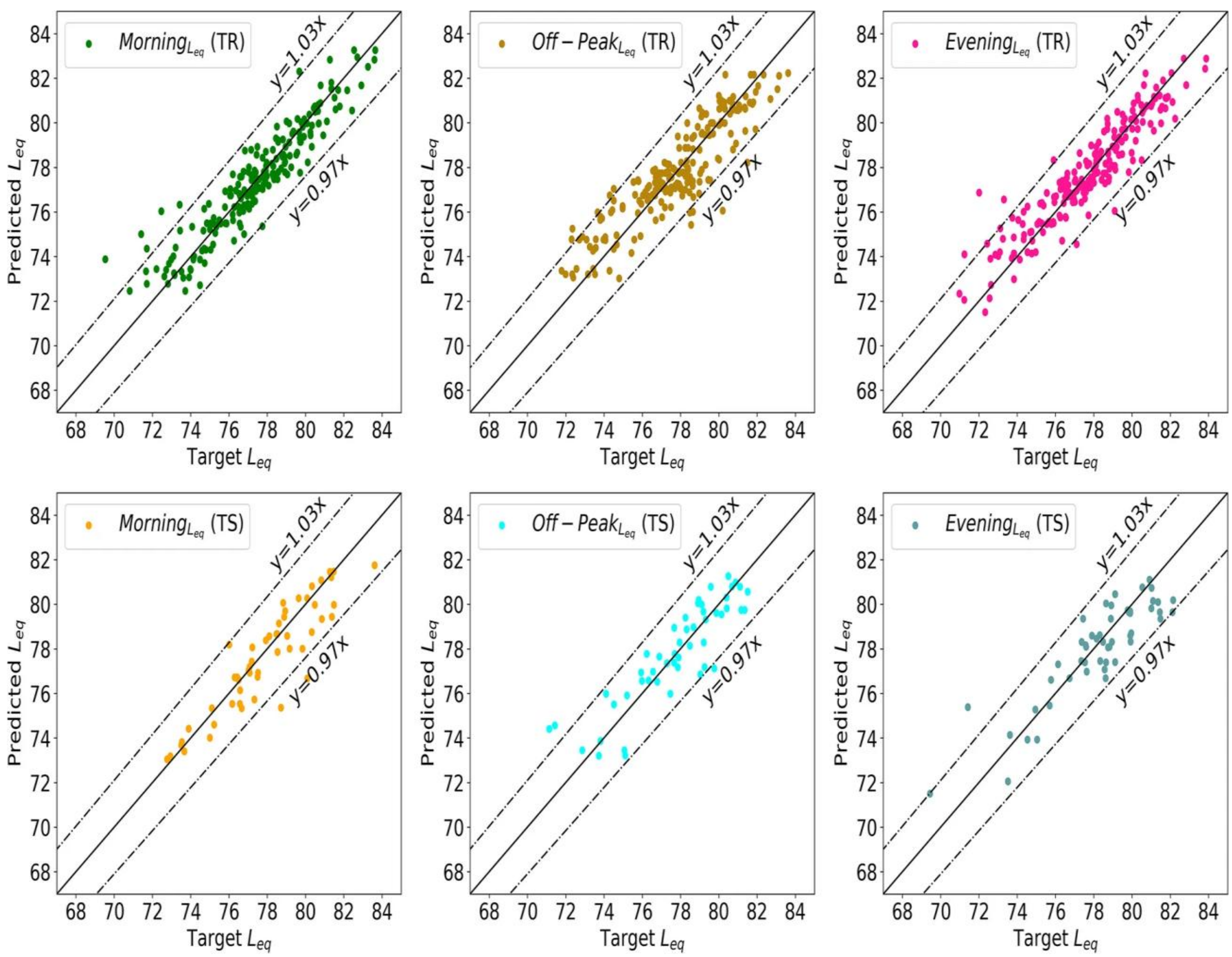


Figure 4.10. Scatter plot for L_{eq} model in the TR and TS dataset of MP, OP and EP

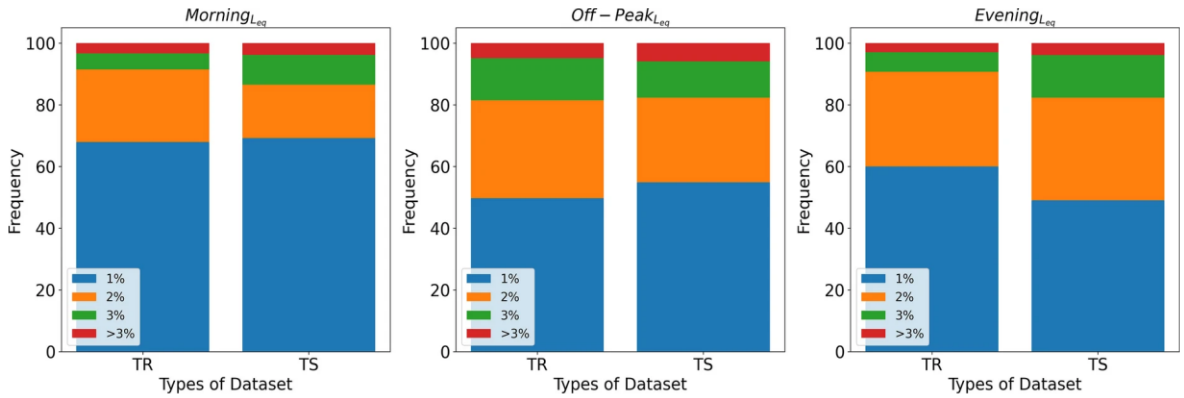


Figure 4.11. Error frequency plot for L_{eq} model in the TR and TS dataset of MP, OP and EP

4.5.2 Results for L_{10}

The statistical performance of L_{10} model in TR and TS dataset is shown in Table 4.7. As seen from Table 4.7 that the developed L_{10} model can explain 89.3%, 81.6% and 86.3% variability in TR dataset of MP, OP and EP, respectively. Similarly, variability explained in TS dataset is 85.8%, 80.4% and 84.3% for MP, OP and EP, respectively. The predicted L_{10} values are prominently closer to the actual value as the R value obtained for each of the model is significantly higher than 0.80. The above findings and the MAE and RMSE value demonstrate that the L_{10} value can be predicted more efficiently in MP which is followed by EP and OP. However, the overall findings establish that the developed models are adequate in predicting the L_{10} value at MP, OP and EP time for a vicinity of heterogeneous traffic condition.

Figure 4.12 depicts the scatter plot for the TR and TS dataset at MP, OP and EP of L_{10} model. The congestion of the number of observations toward the line of equality is maximum in the MP followed by EP and OP. Therefore, the L_{10} value of MP can be predicted more efficiently as compared to another peak interval. However, except some sporadic dataset, the L_{10} value in each of the peak can be predicted within ±3% variation which can also be confirmed from Figure 4.13 showing the error frequency plot for TR and TS dataset of MP, OP and EP. Moreover, the error pattern achieved in TS dataset at each of the % variation is almost similar to the TR dataset pattern; therefore, the developed models are also adequate from generalization point of view. Ultimately, the developed L_{10} models are able to predict more than 95% observations within ±3% variation.

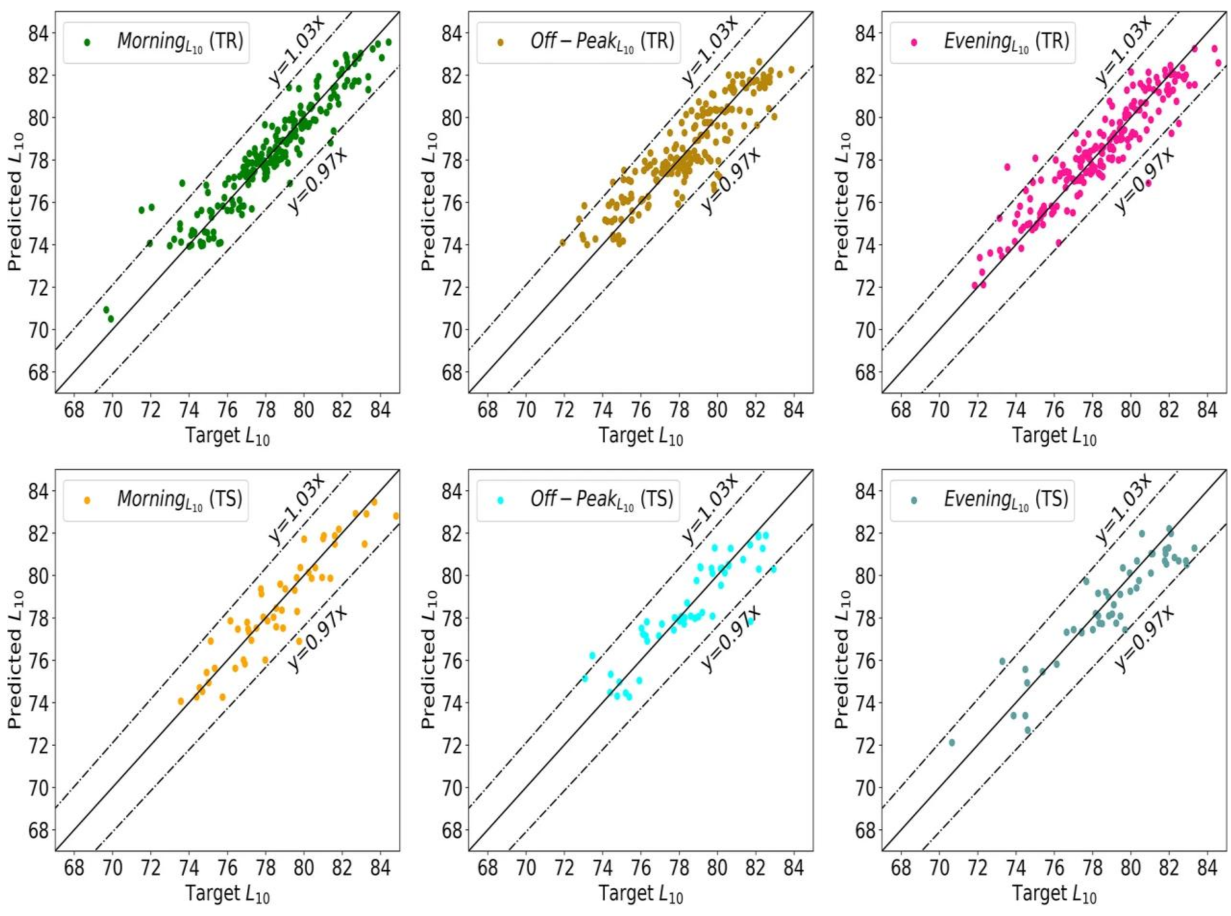


Figure 4.12. Scatter plot for L_{10} model in the TR and TS dataset of MP, OP and EP

Table 4.7. Statistical performance of L_{10} model in TR and TS dataset of MP, OP and EP

Performance measurement parameters	**MP**		**OP**		**EP**	
	TR	TS	TR	TS	TR	TS
R^2	0.893	0.858	0.816	0.804	0.863	0.843
R	0.945	0.928	0.904	0.898	0.930	0.928
MAE	0.647	0.751	0.836	0.816	0.720	0.876
RMSE	0.890	0.993	1.080	1.122	0.982	1.115

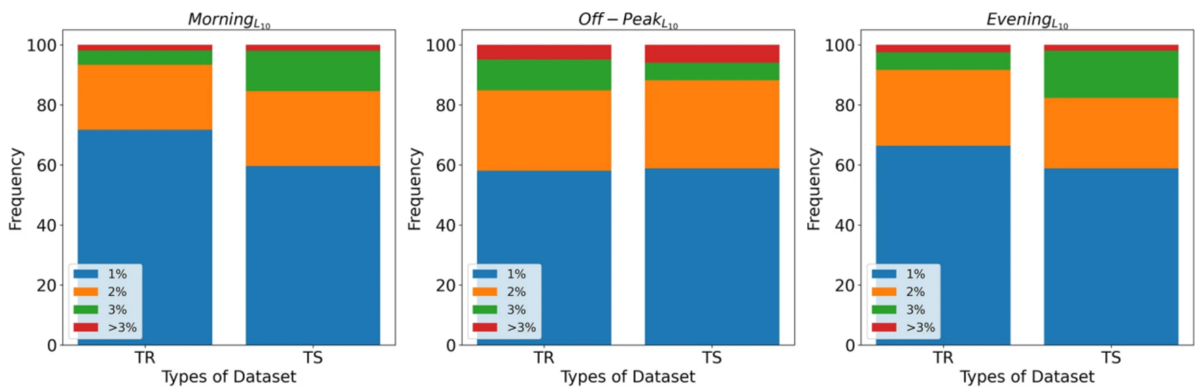


Figure 4.13. Error frequency plot for L_{10} model in the TR and TS dataset of MP, OP and EP

For L_{eq}, the R^2 values for OP and EP phases are quite similar (0.799–0.775 for OP and 0.853–0.774 for EP. This suggests that the model captures a similar percentage of the variability in traffic noise during both the OP and EP periods. The L_{eq} metric represents the cumulative energy of noise over a time period, meaning it is sensitive to the continuous presence of noise. Since the key factors influencing L_{eq}, such as overall traffic flow and ambient conditions, do not drastically change between OP and EP, the variability explained by the model remains stable. Thus, there is no significant improvement in the model's explanatory power when transitioning from OP to EP.

For L_{10}, the explanatory power between MP and EP phases is comparable, as reflected in the similar R^2 values (0.816–0.804 for MP and 0.863–0.843 for EP). L_{10}, being a metric that focuses on peak noise events (such as honking or sudden traffic spikes), is more influenced by the transient, high-intensity noise events that occur during specific times, particularly during the MP phase. These events are already well-represented and captured during the morning rush hour (MP), where peak traffic and noise levels are at their highest. As a result, the model captures the dominant peak noise events during MP, and the explanatory power remains relatively stable when the model is applied to the EP phase. The variability in L_{10} during EP does not provide a significant increase in explanatory power because the peak noise events in the EP phase do not introduce much additional variance compared to the MP phase.

4.6 Developed Computer-based Software for Predicting the Traffic Noise

In this study a computer-based interface was designed to predict the traffic noise of a region masked with heterogeneous traffic conditions. For this purpose, the Graphical User Interface (GUI) was used which is a system of representing the required features visually in the form of computer software and tool. The designed interface was titled as "Traffic Noise Prediction Calculator for Heterogeneous Traffic (TNPC-H)". Figure 4.14 shows the structure of the designed software. Once all the dataset is entered appropriately then Submit button shows a 'Successful' pop-up message. After clicking 'Ok' the Run button is activated and by clicking it provide the predicted L_{eq} and L_{10} value for a particular time period. The Reset button could be used for initializing the model and input parameters value. The designed software is not only user friendly but also beneficial for the planning engineers.

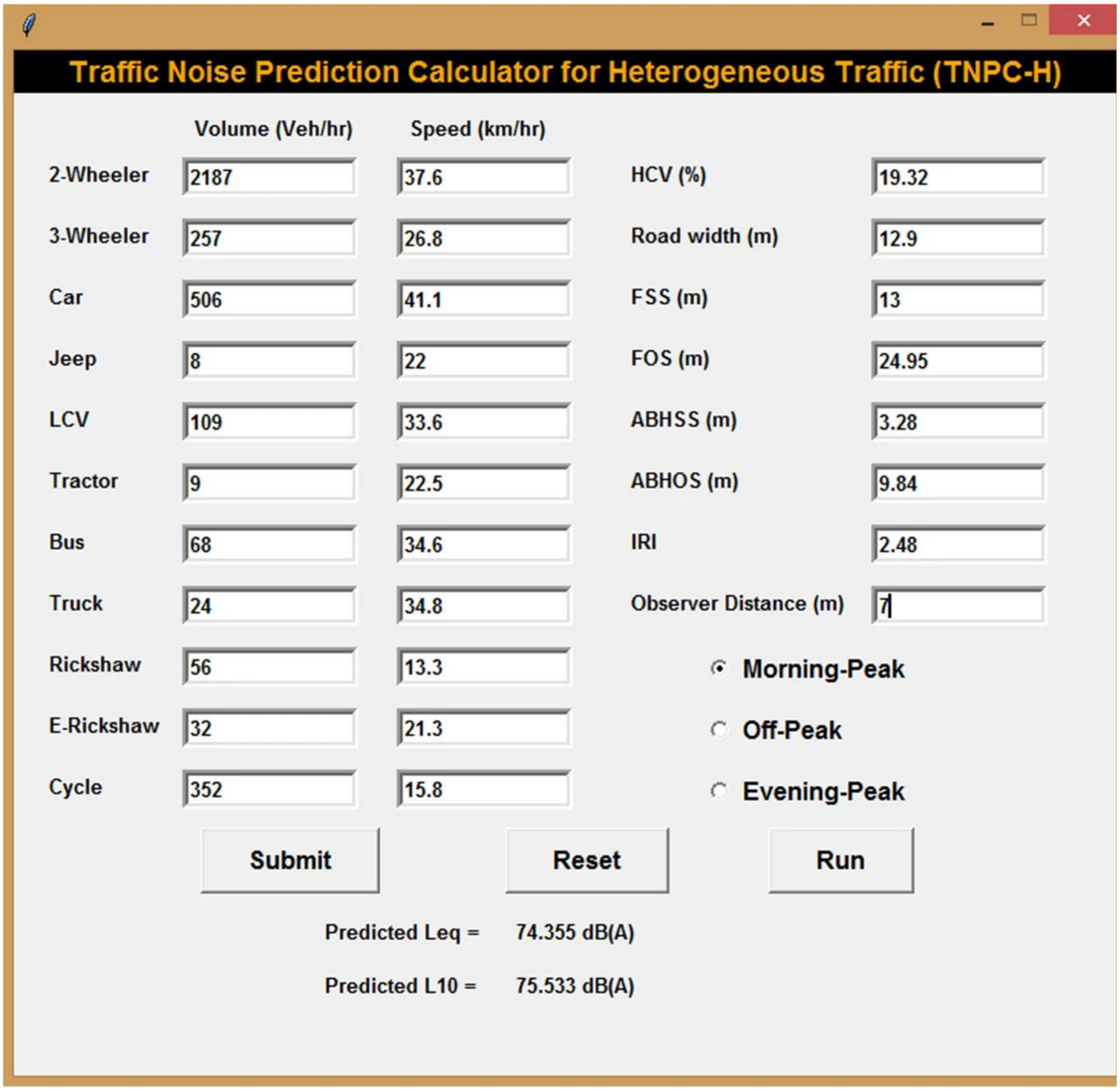


Figure 4.14. Software for predicting L_{eq} and L_{10} of MP, OP and EP

4.7 Conclusion

Traffic engineers and transportation planners always come across with many difficulties in estimating the traffic noise of an area masked with mixed traffic flow condition. This study aimed to develop a computer-based software for predicting the traffic noise of heterogeneous traffic condition at MP, OP and EP interval. Almost 776 number of datasets were occupied from 23 locations of Gorakhpur city of state Uttar Pradesh in India. Out of which, 264 observations belong to MP, 256 for each OP and EP. The developed PCA based K-NN model was sufficient to explain 81%, 77.5% and 77.4% variability in the MP, OP and EP, respectively, in terms of L_{eq}, whereas, 85.8%, 80.4% and 84.3% in terms of L_{10} value. Moreover, the proposed models were found to predict more than 94% observations within ±3% variations. Lastly, the developed computer software was found useful for the future convenience to the transportation planner and design engineer in predicting the traffic noise for a particular region under heterogeneous traffic condition.

4.8 Applicability and Limitation of Software

The developed software is applicable to all areas with uninterrupted mixed traffic flow in plain areas. The noise transmission should be free-field and with no barrier between the source and the receiver. The software is calibrated to weather conditions existing in the Indian tropical plains with wind speed not exceeding 4 m/s. The condition of the topography being plain area with mixed traffic, free-field transmission of noise signals and no barriers between the source and receiver are its limitations. Subject to the above limitations, the software is replicable in all areas of mixed traffic flow with tropical climate since the data was collected for sustained period of time covering four seasons (summer, spring, winter and monsoon).