Chapter 6

Conclusion
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Noise pollution is a significant environmental problem in the urban city centres. Various studies show that the urban road traffic is the root cause of ambient noise. However, many studies such as [Aylor, 1972-a and 1972-b, Gupta et al., 1986; Tyagi et al, 2006] suggested that other parameters like vegetation cover, road width, presence of flyover, wind velocity etc., also play a significant role in noise pollution. In the present study, an attempt has been made to develop a predictive model for different locations separately as well as to develop a model for five distinct zones, namely, residential, commercial, mixed, industrial and silence zones. Further an integrated model for entire Delhi has been developed. The different predictive multivariate regression models for different sites of different zones of Delhi are found to be as represented by equations given below:

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Zone</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site-1</td>
<td>Res 1</td>
<td>$L_{eq} = 67.78 + 0.04CJ + 0.37THW + 0.06TW$</td>
</tr>
<tr>
<td>Site-2</td>
<td>Res 2</td>
<td>$L_{eq} = 71.73 + 0.08CJ + 0.30THW$</td>
</tr>
<tr>
<td>Site-3</td>
<td>Res 3</td>
<td>$L_{eq} = 70.27 + 0.10CJ + 0.05TW$</td>
</tr>
<tr>
<td>Site-4</td>
<td>Res 4</td>
<td>$L_{eq} = 70.34 + 0.11CJ + 0.19BUS$</td>
</tr>
<tr>
<td>Site-5</td>
<td>Res 5</td>
<td>$L_{eq} = 72.02 + 0.08CJ$</td>
</tr>
<tr>
<td>Site-6</td>
<td>Res 6</td>
<td>$L_{eq} = 71.46 + 0.08CJ + 0.05TW$</td>
</tr>
<tr>
<td>Site-7</td>
<td>Res 7</td>
<td>$L_{eq} = 73.77 + 0.03CJ + 0.04TW + 0.15BUS$</td>
</tr>
<tr>
<td>Site-8</td>
<td>Res 8</td>
<td>$L_{eq} = 72.95 + 0.06CJ$</td>
</tr>
<tr>
<td>Site-9</td>
<td>Res 9</td>
<td>$L_{eq} = 73.29 + 0.06CJ + 0.22BUS$</td>
</tr>
<tr>
<td>Site-10</td>
<td>Res 10</td>
<td>$L_{eq} = 72.41 + 0.08CJ + 0.23THW$</td>
</tr>
<tr>
<td>Site-11</td>
<td>Res 11</td>
<td>$L_{eq} = 71.76 + 0.06CJ + 0.21THW$</td>
</tr>
<tr>
<td>Site-12</td>
<td>Res 12</td>
<td>$L_{eq} = 76.87 + 0.04CJ + 0.19BUS$</td>
</tr>
<tr>
<td>Site-13</td>
<td>Res 13</td>
<td>$L_{eq} = 72.29 + 0.08CJ$</td>
</tr>
<tr>
<td>Site-14</td>
<td>Res 14</td>
<td>$L_{eq} = 72.23 + 0.07CJ$</td>
</tr>
<tr>
<td>Site-15</td>
<td>Res 15</td>
<td>$L_{eq} = 71.97 + 0.09CJ$</td>
</tr>
</tbody>
</table>
Site-16  Res 16  \( L_{eq} = 76.31 + 0.02CJ + 0.15THW + 0.02TW \)
Site-17  Com 1   \( L_{eq} = 76.31 + 0.02CJ + 0.09THW + 0.03TW \)
Site-18  Com 2   \( L_{eq} = 77.99 + 0.03CJ + 0.21BUS \)
Site-19  Com 3   \( L_{eq} = 77.21 + 0.02CJ + 0.10THW + 0.20BUS + 0.21LCV \)
Site-20  Com 4   \( L_{eq} = 78.79 + 0.02CJ + 0.14THW + 0.17BUS \)
Site-21  Com 5   \( L_{eq} = 79.18 + 0.02CJ + 0.22BUS \)
Site-22  Com 6   \( L_{eq} = 76.16 + 0.04CJ + 0.18THW \)
Site-23  Com 7   \( L_{eq} = 75.89 + 0.05CJ + 0.11THW + 0.39BUS \)
Site-24  Com 8   \( L_{eq} = 80.83 + 0.12BUS + 0.10THW \)
Site-25  Com 9   \( L_{eq} = 77.31 + 0.03CJ + 0.15BUS + 0.03TW \)
Site-26  Com 10  \( L_{eq} = 79.41 + 0.26BUS + 0.02CJ \)
Site-27  Com 11  \( L_{eq} = 76.73 + 0.02CJ + 0.05THW + 0.13BUS \)
Site-28  Com 12  \( L_{eq} = 74.59 + 0.09CJ \)
Site-29  Com 13  \( L_{eq} = 77.41 + 0.02CJ + 0.24BUS + 0.19RTV + 0.02TW \)
Site-30  Com 14  \( L_{eq} = 76.32 + 0.02CJ + 0.16THW + 0.05TW \)
Site-31  Com 15  \( L_{eq} = 74.74 + 0.08CJ + 0.05TW \)
Site-32  Com 16  \( L_{eq} = 78.46 + 0.31THW \)
Site-33  Ind 1   \( L_{eq} = 77.66 + 0.04CJ + 0.28LCV \)
Site-34  Ind 2   \( L_{eq} = 77.55 + 0.04CJ + 0.38LCV + 0.36BUS \)
Site-35  Ind 3   \( L_{eq} = 78.42 + 0.03CJ + 0.40LCV \)
Site-36  Ind 4   \( L_{eq} = 78.97 + 0.03CJ + 0.25BUS + 0.12LCV \)
Site-37  Ind 5   \( L_{eq} = 78.10 + 0.03CJ + 0.11THW + 0.18LCV \)
Site-38  Mix 1   \( L_{eq} = 76.72 + 0.06CJ \)
Site-39  Mix 2   \( L_{eq} = 77.77 + 0.04CJ + 0.10THW \)
Site-40  Mix 3   \( L_{eq} = 77.73 + 0.03CJ + 0.22BUS \)
Site-41  Mix 4   \( L_{eq} = 75.52 + 0.03CJ + 0.05TW + 0.24LCV \)
Site-42  Mix 5   \( L_{eq} = 76.73 + 0.04CJ + 0.03TW + 0.11LCV \)
Site-43  Mix 6   \( L_{eq} = 73.29 + 0.03CJ + 0.09THW + 0.25BUS \)
Site-44  Mix 7   \( L_{eq} = 75.83 + 0.03CJ + 0.03TW \)
Site-45  Mix 8   \( L_{eq} = 75.46 + 0.02CJ + 0.05TW \)
Site-46 Mix 9  \( L_{eq} = 73.51 + 0.20THW + 0.07TW \)
Site-47 Mix 10  \( L_{eq} = 77.64 + 0.04CJ + 0.16THW \)
Site-48 Mix 11  \( L_{eq} = 79.83 + 0.02CJ \)
Site-49 Mix 12  \( L_{eq} = 78.25 + 0.04CJ + 0.10THW \)
Site-50 Mix 13  \( L_{eq} = 78.36 + 0.05CJ + 0.26BUS \)
Site-51 Mix 14  \( L_{eq} = 73.51 + 0.06CJ + 0.23BUS \)
Site-52 Mix 15  \( L_{eq} = 72.40 + 0.09CJ + 0.14THW \)
Site-53 Mix 16  \( L_{eq} = 75.28 + 0.05CJ + 0.08TW \)
Site-54 Mix 17  \( L_{eq} = 76.23 + 0.06CJ + 0.08THW + 0.18BUS \)
Site-55 Mix 18  \( L_{eq} = 76.06 + 0.06CJ + 0.05TW + 0.23BUS \)
Site-56 Sil 1  \( L_{eq} = 74.31 + 0.04CJ + 0.40LCV \)
Site-57 Sil 2  \( L_{eq} = 79.69 + 0.03CJ \)
Site-58 Sil 3  \( L_{eq} = 73.66 + 0.07CJ \)
Site-59 Sil 4  \( L_{eq} = 71.00 + 0.05CJ + 0.35THW \)
Site-60 Sil 5  \( L_{eq} = 68.55 + 0.12CJ \)

Models for different zones are as follows:

1. **Residential Zone:**
   (A)  \( L_{eq} = 71.294 - 0.041VEG - 0.775WV + 0.164CJ + 0.168TW + 1.737BUS + 2.589RTVs \)
   (B)  \( L_{eq} = 72.195 - 0.059VEG - 0.946WV + 0.074NON-CNG \)

2. **Commercial zone:**
   (A)  \( L_{eq} = 86.09 - 0.06VEG - 0.47TEMP + 0.11HUM - 2.21WV + 0.17CJ + 0.05THW + 1.63BUS + 0.80FLY \)
   (B)  \( L_{eq} = 78.304 - 0.019VEG - 0.026HUM + 0.053NON-CNG \)

3. **Industrial zone:**
   (A)  \( L_{eq} = 81.25 + 0.435LCV + 0.492CJ \)
   (B)  \( L_{eq} = 79.774 + 0.012NON-CNG \)
4. Mixed Zone:

(A) \[ L_{eq} = 75.287 - 0.027 \text{VEG} + 0.035 \text{CJ} + 2.383 \text{BUS} \]

(B) \[ L_{eq} = 74.886 + 0.029 \text{NON-CNG} + 0.369 \text{CNG} \]

5. Silence Zone:

(A) \[ L_{eq} = 65.915 + 0.120 \text{TW} + 7.853 \text{CJ} + 6.895 \text{FLY} \]

(B) \[ L_{eq} = 68.6 + 0.07 \text{NON-CNG} + 3.6 \text{FLY} \]

Predictive Model for Delhi:

(A) \[ L_{eq} = 72.475 - 1.569 \text{RES} + 0.954 \text{MIX} - 0.044 \text{VEG} - 0.566 \text{TEMP} + 0.056 \text{CJ} + 0.051 \text{LCV} + 1.552 \text{BUS} + 1.185 \text{THW} \]

(B) \[ L_{eq} = 74.966 - 0.057 \text{VEG} - 1.481 \text{RES} + 0.685 \text{MIX} + 0.238 \text{CNG} + 0.037 \text{NON-CNG} \]

It is evident from the models at individual locations that car/jeep (NON-CNG) plays a significant role at 56 sites out of total 60 observation sites across all the zones. Besides car/jeep (CJ), two-wheeler (TW) is another NON-CNG vehicle, which has significant contribution towards ambient noise level. It contribute significantly at 19 sites out of total 60 sites. Most of these sites, where two-wheeler also plays a significant role, pertain to residential, mixed and commercial zones.

Among CNG driven vehicles, three-wheelers (THW) and buses (BUS) are found to be significant at 23 and 21 sites out of total 60 sites, respectively.

In silence zones, buses (BUS) are not found to play any significant role at any of the 5 sites, whereas three-wheelers (THW) are found to contribute significantly at one location only.
Similarly, in industrial zones, only at two locations, buses (BUS) contribute to ambient noise whereas, three-wheelers, only at one location. LCVs and RTVs are significant contributor at very few places. RTVs are mostly confined to commercial and mixed zones. They contribute significantly only at one site each in both the zones (commercial and mixed). LCVs show their dominance at all the five industrial sites and only at two sites in mixed zones. The values of constant, which represent the background noise levels, are more than 70 dB at all the locations with the exception of site 1 or Res 1 (residential) and site 60 or Sil 5 (silence) where it is 67.78 and 68.55, respectively. Hence, it can be concluded that at all the sites the background noise exceeds the prescribed permissible limit for various categories of areas.

Close examinations of zone specific models reveal that vegetation has negative coefficient at all the sites. It indicates that at all the sites, vegetation helps in attenuating the ambient noise level. Similar observation has also been reported by Aylor, (1972-a, 1972-b), Kumar et al., (1998) and Tyagi et al., (2006). With the low coefficient value for vegetation, it can be concluded that although green belt around the noise sources reduce the ambient noise but high vegetation density will be required for any substantial noise reduction in Delhi. At residential and commercial zones, wind velocity also plays a significant role in noise reduction as indicated by its negative coefficient at these sites. At sites of other zones, it does not play any significant role. In the last 5 years, Delhi’s road infrastructure has undergone a sea change. A number of flyovers at different traffic intersections have come up. Although these flyovers ease the traffic congestions but increase the number of vehicles at the same stretch of road and hence increase the noise at those locations. It can also be inferred from the regression models of different zones that flyovers contribute significantly, towards ambient noise in silence and commercial zones.

To ascertain the impact of CNG in vehicles in Delhi on its ambient noise environment the vehicle composition was segregated into CNG and NON-CNG
vehicles and then regression analysis was carried out. The NON-CNG vehicles are found to dominate in all the five zones while CNG driven vehicles contribute significantly only at mixed zone. It can be concluded that the conversion of public transport system from petrol/diesel driven to CNG driven modes have a positive effect on noise scenario of Delhi. The models developed for entire Delhi show that the regression coefficient for CNG vehicles is 0.238 in comparison to NON-CNG vehicles, which has only 0.038 as coefficient. This is due to the fact that the number of buses and three-wheelers are noisier than that of the car/jeep which runs on petrol or diesel. But it is to be noted that the CNG buses and three-wheelers are less noisy than that of the diesel or petrol driven buses and three wheelers. This implies that the noise level per unit vehicle decreased significantly, after the induction of CNG vehicles in Delhi. Hence, we can say that CNG vehicles have a positive effect as far as noise pollution scenario in Delhi is concerned. This study has policy implications as far as noise pollution management is concerned. In the present scenario with rapidly increasing population of Delhi, more buses, three-wheelers and other modes of transport will be required in near future. In such a condition, CNG vehicles with rattle free body and proper sound mufflers, can be beneficial for noise pollution control in Delhi. Further, enhancement of vegetation cover in between the roads as well as at the pavements would go a long in protecting the people of Delhi from the adverse impacts of noise.