Conclusions and Recommendations

The chapter presents the conclusions of the research work focussed on road traffic noise modelling studies in conjunction with passive noise control measures for its abatement. The socio-economic impact of the research work, significant contributions of the research work, limitations of the work and scope for future work is summarized. It is envisaged that present thesis work shall be helpful for government bodies like CPCB, DDA, BIS, MoEF etc. and laboratories in India engaged in Sound transmission loss testing.

9.1 Introduction

The chapter attempts to discuss the salient features of the research work done. The major achievements of the research as well as the major breakthrough of research in terms of socio-economic impact in addition to the study-wise research findings is summarized. The limitations of the present research done along with the scope of future research, that can be pursued further to achieve the underlined research objectives stated is highlighted.

9.2 Summary of Research Objectives

The objectives of this research work are summarized as:

- Development of a validated road traffic noise model helpful in conducting EIA (Environmental Impact Assessment) studies in respect of noise.
- Development of a modelling technique for time-series prediction of traffic noise levels. The developed model can serve as alternate tool to the continuous long-term noise monitoring which is quite cumbersome and involves a lot of infrastructural and economic constraints.
• Investigations on the accuracy of short-term noise monitoring strategies (continuous or random) with respect to the long-term noise monitoring.

• Investigations on passive noise control strategies for traffic noise abatement and control. The major objective of the work was to conduct experimental studies in Reverberation chambers in conjunction with analytical studies for investigating the sound insulation provided by building elements particularly the window glazing, which is considered to be the weakest part of building facades and development of best sandwich constructions that provides higher sound insulation.

• Recommendations pertaining to the ambient noise standards status in India based on analyzing the noise monitoring data of 35 sites spread across 7 major cities of India gathered in pilot National Ambient Noise Monitoring Network (NANMN) project implemented by CPCB, India.

• Recommendations pertaining to the amendment in sound regulation requirements in National Building Codes of India with inclusion of spectrum adaptation terms as per ISO 717-1 to effectively deal with the problem of traffic noise in future.

9.3 Study-wise Learning’s and Findings

The objectives and the conclusions of the individual chapters are recapitulated as:

• The literature review spanning the research contributions in modeling traffic noise and passive control measures for its abatement is presented. The various regression models developed in India in past years in various parts of the country
are summarized. The study reveals that majority of the models in Indian context have been concentrated on multiple regression approach for modelling traffic noise as a function of vehicular density, speed and distance from the road (edge or median). The various noise control programmes with an objective of accomplishing the noise abatement goal has been an initiative taken seriously in Europe. In Indian conditions, there is a lack of such studies which aims at controlling the traffic noise by passive methods. Fig. 2.2 in chapter 2 discusses the flow chart of a proposed noise abatement programme with an objective of reducing the traffic noise in Delhi city.

- A critical review of principal traffic noise models developed and implemented recently in developed nations is presented. The source model and propagation algorithms followed have been clearly identified and compared for each of these models. The implications of all these models developed recently, sources of uncertainty have been discussed. The study has been instrumental in identifying the state-of-art pertaining to the accomplishment of the research objectives. Also, some of these models have been revised in recent years, and thus it is imperative to update the earlier comparison presented by Steele (2001) based on the technical attributes as discussed in table 3.1 comprehensively.

- The development of a validated road traffic noise model using the multiple regression approach and soft computing skills e.g. Artificial Neural Networks (ANN), Genetic Algorithms (GA) etc. in terms of total traffic flow and equivalent traffic flow is demonstrated. It is evident that the Artificial Neural Networks models out-perform the multiple linear regression (MLR) models developed in terms of total traffic flow and equivalent traffic flow.
The development of a road traffic noise model (RTN) based on the sound power level of vehicles is demonstrated. The model so developed is based on the acoustical characterization of source (vehicles) in terms of sound power level. The Road traffic noise model, RTN developed provides a clear distinction between the source and sound propagation model and can effectively implement ISO 9613-2. The most important benefit of these investigations lies in the fact that the framework of some widely used software’s like CadNaA, Sound PLAN etc. can easily accommodate the source model proposed in the present work for developing noise maps for any site or area in Delhi city. Consequently, it will serve the purpose of European directives 2002/49/EC to establish a uniform approach to assessment and management of environmental noise not only in Europe, but also in Indian scenario. The model is also flexible enough to include the sound propagation algorithms recommended in future in CNOSSOS-EU framework with an objective of developing a harmonized approach for noise mapping. The model so developed is in line with the approach followed in other nations and shall be helpful in conducting the Environmental Impact Assessment studies (EIA) in respect of noise for Delhi city. The work shall be helpful for carrying out EIA studies in respect of noise for new projects and development of “Smart Cities” envisaged by Government of India in NCR and nearby regions.

The thesis work reports the average $L_{\text{Day}}$ (06-22 h) and $L_{\text{Night}}$ (22-06 h) values observed under the pilot project on the establishment of National Ambient Noise Monitoring Network (NANMN) across the seven major cities in India for ascertaining the magnitude of annual average ambient noise levels, planning for
noise abatement action plans and formulation of revised ambient noise standards in Indian scenario. In accordance with the existing ambient noise standards, only 9 sites (4 commercial and 5 industrial sites) out of the 35 sites meets the ambient noise standards. Surprisingly, no site in the residential and silence zone meets the ambient noise standards. Thus, it suggests the need for revision of ambient noise standards to cope with the current situation of road traffic noise and aircraft noise pollution in India especially for areas with mixed residential and commercial activities. Day-night average sound level, DNL metrics without 10 dB night correction commonly expressed as equivalent continuous sound pressure level for 24 hours, $L_{\text{Aeq, 24h}}$ is recommended to be the noise descriptor in consideration for the revision in the ambient noise standards. It could be a relatively high value but rigidly enforced or a very low value with no legal binding whatsoever (Night noise guidelines for Europe, WHO regional office).

- The research work investigates the accuracy of short-term noise monitoring strategies with respect to the long-term noise monitoring. The difference in short-term strategies from the annual average representative values obtained from yearly noise monitoring data is quantified as error. Long-term continuous noise monitoring data in terms of monthly averages for 35 locations spread over 7 major cities of India is analyzed. The analysis shows that the error of ± 3 dB(A) from annual equivalent level is calculated with 95 % probability for $L_{\text{Day}}$ and $L_{\text{Night}}$ value by adopting one month noise monitoring strategy. For higher accuracy, the random two months strategy is recommended, whereby an error of ± 2 dB(A) is achieved with a probability higher than 90 %. The study reveals that short-term noise monitoring strategy (random monthly strategy) followed gives a reliable accuracy levels with respect to continuous long-term monitoring and thus
offers a Best Practicable and Economical option (BPEO) for noise mapping of the larger parts of the country.

- The study focused on a statistical analysis of one year continuous noise monitoring data using Autoregressive Integrated Moving Averages approach (ARIMA) and Artificial Neural Networks (ANN) approach, covering the period from September, 2013 to August, 2014 for a sample site in Delhi city. In this respect, daily mean $L_{Day}$, $L_{Night}$ in A and C-weightings, Day-night average sound level ($DNL$) and $L_{Aeq,24h}$ were used. The ARIMA models, namely $ARIMA(0,0,14)$, $ARIMA(0,0,7)$, $ARIMA(0,0,14)$, simple, $ARIMA(1,0,7)$ and $ARIMA(0,1,9)$ have been developed as the most suitable for simulating and forecasting the daily mean $L_{Day}$, $L_{Night}$ in A and C-weightings, $DNL$ and $L_{Aeq,24h}$ levels respectively. The ANN models with architecture: 8-3-1, 10-6-1, 8-4-1, 10-7-1, 10-5-1, and 6-3-1 have been developed as the most suitable for simulating and forecasting the daily mean $L_{Day}$, $L_{Night}$ in A and C-weightings, Day-night average sound level ($DNL$) and $L_{Aeq,24h}$ levels respectively. The validation and suitability of the developed ARIMA and ANN model is ascertained at various stages in the chapter. The observed and predicted values have been found to match well. The statistical parameters: stationary $R$-square, $R$-square, Root Mean Squared Error ($RMSE$), Mean Absolute Error ($MAE$) were used to test the validity and applicability of the developed ARIMA and ANN models indicating that the models fits reasonably well with the observed data series. The ARIMA and ANN methodology demonstrated in the present work can thus serve as a suitable substitute to the long-term noise monitoring and is thus indispensable for saving costs and time incurred on continuous noise monitoring. However, the ARIMA and ANN models so developed for sound level descriptors are adequate for the particular site in
commercial area of Delhi region and can’t be generalized for the other sites as well. It is obvious that for other sites, these models can be developed afresh with different $p, d, q$ values in case of ARIMA approach and different $p$ and $q$ values in case of ANN approach.

- The present work also compared the performance of ANN predictive model in comparison to the conventional Box Jenkins ARIMA model, which has been widely used for time-series forecasting. The findings revealed that the Artificial Neural Network (ANN) model out-performs the ARIMA model so developed. It is observed that the pattern of ARIMA forecasting models is directional and as such the time-series predictive model utilizing ANN approach demonstrated superior performance over the ARIMA model. The unique characteristics of ANNs - adaptability, non linearity, arbitrary function mapping ability thus make them useful for forecasting tasks.

- The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of various single-number ratings used for describing the sound insulation properties of partition panels is described. An laboratory investigation on a double wall partition panel combination revealed the significant dependence of STC rating on transmission loss at 125 Hz attributed to 8 dB rule. The study recommends the use of weighted sound reduction index $R_w$ in laboratory testing along with spectrum adaptation terms so as to avoid any ambiguity attributed to 8 dB rule. In Indian scenario, STC rating is widely used by some laboratories engaged on sound transmission loss testing in India, manufacturers and even acousticians. The present study provides experimental grounds towards highlighting the
anomalies with STC rating especially for partition panels with poor low frequency sound insulation.

- An investigation conducted on devising the alternative spectrums of aircraft noise, traffic noise, vehicular horn noise and elevated metro train noise as an extension to ISO 717-1 $C_{tr}$ for ascertaining the sound insulation properties of materials exclusively towards these noise sources revealed that the single-number rating $R_w+C_{tr}$ calculated using ISO 717-1 $C_{tr}$ gives the minimum sound insulation, when compared with $R_w+C_x$ calculated using the alternative spectrums of aircraft noise, traffic noise etc which means that material provides a higher sound insulation to the other noise sources. It is also observed that spectrum adaptation term $C_x$ calculated using the spectrum of noise sources having high sound pressure levels in lower frequencies decreases as compared to ISO 717-1 $C_{tr}$ owing to significant dependence of $C_{tr}$ at lower frequencies. The normalized spectra for traffic noise including horn noise component as shown in Fig. 8.5 can serve as substitute for ISO 717-1 $C_{tr}$ for adjudging the sound insulation properties of material towards road traffic noise in Indian context. The investigations conducted in the thesis justifies the use of ISO 717-1 $C_{tr}$ term for adjudging the sound insulation property of material as it represents the minimum sound insulation that a material will provide when exposed to all kinds of noise viz., air traffic, road noise, railway noise etc. Besides, it facilitates a harmonization in the description of a single-number rating for sound insulation properties of acoustical materials rather than following a country specific spectrum adaptation term $C_x$ so as to avoid any confusion or ambiguity amongst manufacturers and users.
• The research work presents experimental and analytical investigations with an objective of design and development of highly sound insulative window glazing for traffic noise abatement. Significant increase in sound insulation is observed at higher frequencies when either one glazing is double or both the glazing are double. The experimental investigations show concurrence with the previous studies on the fact that increasing the thickness of the glass pane, the coincidence dip shifts towards lower frequency and also with increasing the air gap, a significant improvement in sound insulation characteristics in both low and high frequencies is observed.

• The experimental investigations on sound insulation properties of double glazing shows a pronounced dip attributed to mass-air-mass resonance consistent with theoretical formulation, which is observed when air gap is less that 30 mm in double glazing. Thus, the design target should be choosing an air gap between 30 mm to 100 mm. There has to be a trade-off in choosing the air gap as an air gap of less than 30 mm will lead to pronounced mass-air-mass resonance dip, while increasing the air space above 100 mm increases sound insulation at low frequencies more than at high frequencies as mass-air-mass resonance is lowered, but the standing wave resonances affects the high frequency sound insulation.

• The research work presents an application of Taguchi method in optimizing the sound transmission through double glazing in order to investigate the relative influence of the various parameters affecting the sound insulation characteristics for design of highly insulative facade constructions and windows for traffic noise abatement. The application of Taguchi method for optimizing sound transmission loss has been rarely reported. The work uses the results analytically predicted
using ‘Insul’ software for various double glazing configurations as desired by each experimental run in an \( L_9 \) Orthogonal Array. The relative importance of the parameters on single-number rating \( R_w \ (C, C_t) \) was evaluated in terms of percentage contributions using Analysis of Variance (ANOVA). The analysis reveals that air-gap is a prominent factor in controlling the sound insulation characteristics of double glazing and thus regression equations correlating the single-number ratings with thickness of identical glass and air-gap in a double glazing is described. The back pane thickness has higher percentage in determination of single-number rating \( R_w, R_w+C \) and \( STC \) value as compared to the front pane thickness, while front pane thickness has slightly higher contribution in case of single number quantity \( R_w+C_t \). The chapter 7 presents analytical empirical formulations (equations (7.5) to (7.12)) that can be instrumental in designing suitable double glazing’s for meeting the desired goal of sound insulation required. The regression equations can be readily used by manufacturers and architects to predict the sound transmission loss in terms of single-number rating and selection of suitable double glazing for achieving the desired Noise Level reductions.

- The research work also presents an application of well known Taguchi method in investigating the significant factors controlling the sound transmission through multi-layered constructions involving gypsum boards for their application as building facades and partition walls inside the dwellings. The key factors controlling the sound insulation characteristics of multilayered constructions comprising of concrete constructions along with gypsum board attached is the type of studs (43 \%), type of steel stud frame (22.8 \%), followed by the number of gypsum layers attached (12.8 \%) and concrete thickness (8.7 \%). The steel
stud frame plays a pivotal role in shifting the low frequency $m.a.m$ and flexural resonance. Addition of more gypsum layers can be instrumental in enhancing the sound insulation properties as well and bringing down the mass-air-mass resonance. The density and thickness of the sound absorbing material has no major role in deciding sound insulation characteristics, although it is evident that inclusion of sound absorbing material will shift the low frequency mass-air-mass resonances ($m.a.m$) and also interrupt the standing wave resonances creeping in the cavity. Double studs are the best preferred attachment followed by staggered studs, steel studs with resilient railings. The stud spacing has also been analyzed to be non critical in controlling the overall sound insulation characteristics especially when structural breaks are provided in the walls consistent with Quirt (1985) observations. Increasing the depth of cavity (deeper studs or greater separation between row of studs) is helpful in increasing the overall sound transmission loss characteristics provided standing wave resonances aren’t induced. An optimum depth of 160 mm in case of cavity unfilled and 82 mm in case of cavity filled with sound absorptive material is atleast required for $m.a.m < 50 \text{ Hz}$.

- The research work extensively reviews the airborne sound insulation criteria followed in Europe and the sound descriptors used. The work focuses on significance and need of having modified sound insulation criteria in Indian dwellings for harmonization of sound descriptors with that followed in other countries for controlling the ever increasing traffic noise. Sound regulations in terms of prescriptive and verification criteria are proposed referring to regulations adopted in Europe and recent studies conducted by Rasmussen et al., 2010 and Scholl et al., 2011. Practical implications of these regulations
particularly related to material aspects with respect to the minimum and comfort class is also discussed. A study of laboratory sound transmission characteristics of dry wall constructions and massive concrete constructions to ascertain whether these criteria could be fulfilled easily or not reveals that the drywall constructions in conjunction with massive concrete constructions are suitable for achieving the acoustic comfort in dwellings. It is envisaged that a clear definition, understanding and practical implementation of sound regulations criteria can be pivotal in controlling the outside traffic noise in Indian context.

9.4 Summary of Research findings: Overall Conclusions & Recommendations

The primary objective of the research work was to focus on the development of a validated model and investigations on passive noise control strategies with major emphasis on strengthening the facades. The key findings of the research are summarized as:

- A validated road traffic noise model so developed shall be helpful in conducting EIA studies in respect of noise.

- The developed road traffic noise model enables to conduct EIA studies in respect of noise for Delhi city. The model can be thus very helpful for urban planners and authorities in assessment and management of traffic noise in Delhi city with an objective of reducing the noise pollution. The work shall be helpful for carrying out EIA studies in respect of noise for the new projects and development of “Smart Cities” envisaged by Government of India in NCR and nearby regions.
Thesis work shows that the Artificial Neural Network (ANN) models out-performs the multiple linear regression model developed in terms of total traffic flow and equivalent traffic flow. Eventually, adopting a comprehensive approach with inclusion of many input variables like distances, height of building, road surface, street-aspect ratio, honking effect, vegetation, type of locality, presence of industries nearby etc. shall be helpful in developing a practical model for Delhi roads.

Thesis work has shown the suitability & applicability of ANN and ARIMA approach in for long-term sound levels predictions. It is recommended that ANN approach in conjunction with short-term noise monitoring can be instrumental in covering all the noisy hot spots in Delhi city - Best Practicable & Economic Option.

The present study recommends the use of weighted sound reduction index $R_w$ along with spectrum adaptation terms so as to avoid any ambiguity attributed to 8 dB rule used in STC rating. In Indian context, many of the leading laboratories are widely using STC in laboratory testing and certification. The research work provides a theoretical and experimental grounds for highlighting the anomalies associated with STC rating.

Sound insulation provided by building elements particularly the window glazing, which is considered to be the weakest part of building facades has been investigated and best sandwich constructions to provide higher sound insulation have been designed and tested in Reverberation Chambers. The design target should be focused for chosing an air depth between 30 mm to 100 mm for double
glazing. Significant increase in \((R_w + C_{tr})\) value is observed in sandwich constructions with either one double glazing or both are double.

- The thesis recommended a revision in sound regulation requirements in National Building Codes with inclusion of spectrum adaptation terms as per ISO 717-1 to effectively deal with problem of traffic noise in future. The thesis work also stresses on reporting the uncertainty values associated with single-number ratings like \(R_w\), \(NRC\) etc. in routine sound transmission loss and sound absorption testing which shall be helpful for manufacturers, architects and town planners in identifying the best acoustical material to be used in building constructions. The use of drywall sandwich constructions in building constructions in Indian scenario is highly recommended.

- Also, the thesis work recommends the revision in ambient noise standards, which shall be helpful in execution of noise abatement action plans for controlling the noise pollution in India.

### 9.5 Socio-Economic Impact of Research Work

The socio-economic impact of the research work is highlighted as:

- The study provides analytical models validated with experimental observations suitable for conducting Environmental Impact Assessment (EIA) studies in respect of noise.

- The study also provides a road traffic noise model based on sound power level of vehicles, which can be helpful for traffic noise predictions. Also, the model utilizes the sound propagation algorithms to account for the diffraction, air
absorption, ground effect etc. The developed model with an integrated GIS platform shall be indispensable for noise mapping of the larger parts of Indian cities. Such a model with a GIS platform can be very helpful for Central Pollution Control Board (CPCB), Delhi Development Agency (DDA), Ministry of Environment and Forests (MoEF) and Delhi Pollution Control Committee (DPCC). The model can be utilized for conducting EIA studies in respect of noise in development of “Smart Cities” project envisaged by Government of India in NCR and nearby region for controlling the traffic noise.

- The research work recommends about the short-term noise monitoring strategy to be a good trade-off between the accuracy and costs incurred. Thus, short-term noise monitoring strategies in conjunction with ANN approach offers a Best Practicable and Economical option (BPEO) for noise mapping of the larger parts of the country.

- The laboratory investigations in reverberation chamber reveals that STC rating may create an ambiguity in judgment of the sound insulative characteristics of partition wall panels having poor low frequency performance. The thesis work thus recommends the use of weighted sound reduction index, $R_w$ along with spectrum adaptation terms calculated as per ISO 717-1. These investigations shall be very helpful for premier testing agencies like National Physical Laboratory, Delhi; Automotive Regulatory Authority of India (ARAI), Pune; Naval Physical Oceanographic Laboratory (NPOL), Kochi etc. for using $R_w (C, C_t)$ rating in routine testing.

- The research work provides an experimental and theoretical database on various aspects related to the design and development of window glazing, which can be
helpful for manufacturers and acousticians for achieving the desired noise levels reduction. These investigations shall be helpful in saving costs and time incurred on trial-and-error approach followed by manufacturer’s currently in developing various window glazing’s for investigating their suitability for desired noise level reductions.

- The thesis recommended a revision in sound regulation requirements in National Building Codes with inclusion of spectrum adaptation terms as per ISO 717-1 to effectively deal with problem of traffic noise. The present work also recommends the revision in ambient noise standards which shall be helpful in execution of noise abatement action plans for controlling the noise pollution in India. These recommendations can be helpful for Central Pollution Control Board (CPCB), India; Panel for Acoustics, Sound Insulation and Noise Control, CED 46:P15 of Bureau of Indian Standards (BIS); Delhi Development Authority (DDA) and National Committee for Noise Pollution Control (NCNPC), India for reviewing the National Building Codes and National ambient standards of India and considering the recommended amendments.

Overall, the thesis work shall be very helpful for noise modeling and planning for abatement measures, which can be helpful for avoiding the health hazards from traffic noise pollution in metropolitan cities of India.

9.6 Limitations of the Research Work

The limitations in the present work are summarized as follows:-

- The present study considers the total sound power level of the vehicles and doesn’t further segregate them as propulsion noise and rolling noise. However,
with advanced instrumentation facility, the further division of rolling and propulsion noise shall present a comprehensive view in diagnosing the source noise and shall be instrumental not only in enhancing the accuracy of traffic noise model, but also shall be helpful in predicting the noise levels at traffic intersections etc.

- The present study utilizes a calibrated laser speed gun to measure the speed of vehicles. However, the use of video camera based instrumentation facility for obtaining the kinematics data of each vehicle run shall further enhance the accuracy of speed measurements and traffic noise model so developed.

- The development of road traffic noise model employing the road surface corrections shall be helpful in increasing the accuracy and reliability of road traffic noise model so developed. Thus, appending validated road surface corrections from extensive experimental investigations in Indian context can further improve the accuracy of the model so developed.

- The present study doesn’t address the issue of high measurement uncertainty associated with sound transmission loss measurements at low frequencies beyond 100 Hz and reporting of sound transmission loss results in low frequency range of 50 Hz to 80 Hz. These investigations shall be helpful in not only reducing the reproducibility associated with single-number ratings e.g. $R_{w}+C_{tr}$, $R_{w}+C$ calculated for the frequency range 50 Hz to 3.15 kHz, but also enable better harmonization of sound descriptors used for routine testing and certification and in sound regulation requirements in National Building Codes.
• More emphasis has to be given to the low frequency noise and its abatement. Thus, future studies focused on analyzing the ambient noise levels at various sites in India in 1/3rd octave bands shall be indispensable in diagnosing the low frequency noise sources and its abatement.

9.7 Scope for Future Work

Although the present research work is a broad study conducted with a blend of analytical, computational and experimental investigations pertaining to noise modelling and abatement, yet there is a good scope for future research, which may lead to enhanced accuracy of the traffic noise model developed. Also, in case of passive noise control measures, there is a good scope for development of best sandwich constructions for enhancing the sound insulation of building facades. The laboratory testing facilities have also to be improved so as to reduce the measurement uncertainty in sound transmission loss testing and the reverberation time measurements especially at low frequencies beyond 100 Hz. Some of these aspects to be focussed are as follows:

• There’s a need for enhancing the accuracy of developed source model and widening its applicability by further investigations on sound power level characteristics of vehicles on different pavements. Thus comprehensive investigations focused on including the road surface corrections, varied source heights, development of linear sound emission law for propulsion and rolling noise exclusively as demonstrated in HARMONOISE model and integrated Geographic information system (GIS) interfacing using a suitable software platform shall enhance the accuracy, reliability and usability of the RTN model. Also, the validation of RTN model with large real time data observed from noise
monitoring shall be indispensable in evaluating the prediction uncertainty of the model under moderate downwind conditions.

- The development of a frequency based sound power level characterization of vehicles for determination of traffic noise levels at various frequencies (1/1 octave & 1/3\textsuperscript{rd} octave band) shall be indispensable for planning noise abatement measures.

- An iterative scenario projection process based on the interaction of GIS and RTN model is proposed for future work with an objective of assessing the significance of abatement measures for reducing road traffic noise in Delhi city.

- The multiple regression models developed are generalized model based on the field measurements from 8 sites in Delhi and thus should not be interpreted as a site-specific model. A large database gathered from various sites shall be instrumental for developing generic empirical formulations for calculating road traffic noise in Delhi city. It is imperative to further extend these studies for developing a validated model which can be very helpful in predicting the noise levels and identification of noisy hot spots.

- Research studies should be focused with an objective of reducing the measurement uncertainty in low frequency sound insulation measurements in Reverberation Chambers

- Traffic noise control with various design and shapes of noise barriers should be explored considering the cost/benefit analysis in Indian Context.
There’s an urgent need to focus on studies on multi-layered building facades for accomplishing the targets for Noise Level Reduction (NLR) required.

9.8 Concluding Remarks

The thesis work has been a comprehensive study with broad research objectives carried out for the first time in Indian conditions based on exhaustive literature survey. The awareness towards the health effects of noise pollution has considerably increased in recent years as there have been many public litigations filed in Delhi High Court pertaining to the disturbance from metro trains; traffic noise and vibrations and aircraft noise in areas near runway 29 in Delhi. The research findings of the study shall be helpful not only for CPCB, DDA, Ministry of Environment and Forests (MoEF) etc. and testing laboratories in India, but also lay a foundation for future studies in Indian context. The amendment in sound regulation requirements with inclusion of low frequency sound insulation is essential to fight against the transportation noise in future. There is also a need for setting a noise abatement goal as followed in the developed nations. A noise abatement goal in line with the Nordic and Dutch perspectives of decreasing the number of houses exposed to a noise level > 70 dB (A) by 100 % and number exposed to a noise level > 65 dB (A) by 90 % by next decade is to be strictly adopted for tackling the adverse effects of alarming increase in population and vehicular density in Indian scenario.

Thus, formulation and enforcement of noise legislations, noise control policies for controlling the noise emitted from the domestic appliances, motor vehicles, construction equipments, loudspeaker noise, crackers noise, noise emitted by Diesel Gensets etc. and enforcement of ambient noise standards shall be indispensable in
controlling the noise pollution in India. It is envisaged that awareness of general public in maintaining a “noise free society” is must. Organizing “Noise Awareness Campaigns”; Noise Pollution Control Day (“Dhwani Pradushan Niyaman Diwas”) and integrating “Noise Pollution Control Mission” as a part of the ongoing “Swatch Bharat Mission” introduced by the Government of India in year 2014 shall be indispensable in controlling the noise pollution in India and development of “Smart Cities” concept envisaged by Government of India.