Chapter 1

Introduction
Introduction

Last six decades have seen an increasing awareness in the world towards the surrounding environment. Apart from air, water and soil pollution, noise pollution, which we often ignore, has been perceived to be an important aspect in determining the quality of our environment and life. This environmental menace of noise pollution, mainly associated with urban and industrial areas, has attracted the attention of environmentalists all over the world. Almost all the activities of the modern civilization contribute their shares to the noise environment.

A major factor contributing to acoustic environment in cities is the transport noise which originates from road (i.e., vehicular) air and rail traffic. Road traffic noise differs from air, and rail traffic in the way that it is spread throughout the city and continuous in nature. Road traffic noise problems arose in cities due to population increase stemming from accelerated growth, internal migration, and the increasing number of vehicles, which pour into and add to the already over crowded streets.

The other major source of noise in cities is Aircraft noise. It differs from road traffic noise in the sense that it is not continuous but intermittent. There are peak noise levels when aircrafts fly overheads or take-off and land at airports. The peak frequency varies with the number and type of aircraft as well as the operational height.

Rail traffic noise also acts as a source of noise but this is not a serious nuisance as compared to Road traffic or Aircraft noise as it is generally confined to areas in the vicinity of railway tracks that run mostly through rural areas or periphery of the towns and cities. The introduction of diesel and electric locomotives has greatly reduced the rail traffic noise.
[1.1] Characteristics of traffic noise:

Of all the kinds of surface transportation noise, traffic noise is most ubiquitous. Urban road traffic noise is one of the pervasive types of noise pollution and generally considered to be more intrusive than other types of noise such as industrial noise, airport noise and community noise (Unweltbundesamt, 2000; Zannin et al., 2003, 2006). It is also intrinsically discontinuous: as a vehicle approaches an observation point, the noise level rises, reaches a maximum level and then decreases as the vehicle moves away. The actual pattern of traffic noise on a main road is complex. In general, on urban roads, there are distinct traffic peaks in the morning and evening as people travel to and from work. However, a steady flow of traffic (e.g., average or dense traffic conditions) generates an almost constant road noise, from which only the noise emitted by certain vehicles (such as heavy vehicles) consequently stands out. Thus, traffic noise is caused by a number of vehicles of different characteristics moving together under variable conditions. The noise level varies enormously according to location, type of location, density of traffic, and time of day. The mechanism of radiation of the noise to outside from a vehicle is basically different from the generation of noise inside the vehicles. None of the noise producing systems of the vehicles are fully enclosed; if any thing, they are only partially screened. Thus the noise emitted depends on the relative levels, characteristics, and the interaction of the directly radiated noises from these systems.

[1.2] Factors influencing traffic noise

Noise from motor vehicles depend partly on the vehicles themselves and partly on traffic conditions, the surroundings (vegetation, high rise buildings, etc.) and meteorological parameters (temperature, humidity, wind speed and direction) which are independent of the vehicles.

Traffic parameters:

-Speed and density
-Composition i.e. type of vehicles.
-Traffic “fluidity” (traffic lights, one way streets, etc.).

Road parameters:
-Road design (tunnels embankments etc.).
-Gradients and degree of curvature.
-Nature of road surface.
-Width.

Environmental parameters:
-Distance and height from the road of the recipient of noise.
-Presence of natural or artificial screens.
-Conditions of ground between the road and point of reception.
-Reflection of noise from high rise structures like buildings along the road.

Weather parameters:
-Humidity.
-Temperature of the atmosphere.
-Wind direction and speed.

The above parameters are not all of equal importance, some affect the observed noise significantly and others only negligibly. (Bugliarello et al., 1976)

[1.3] Sources of noise in motor vehicles
The principal source of noise in the motor vehicles can be divided into two groups of factors:
-Those related to engine speed (that is independent of vehicles speed);
-Those related to vehicle speed and how the vehicle is used;

Noise related to engine has a number of components: intake and exhaust noise, cooling-fan noise, noise emitted by the engine proper (determined by engine size, speed and payload), noise from that part of the transmission (gearbox) which rotates at engine speed and various engine accessories such as air compressors,
hydraulic pumps, electrical generators. The predominant engine noise is, in general, lies in the frequency range of 300 – 4000Hz.

The sources of noise related to vehicles speed are that part of the transmission affected by engagement of the different gears and the rolling of the tyres which becomes predominant only at higher speed (depends both on the design of the tyre viz., the width of the tyre, dimensions and shape of the treads, the tyre pressure); at higher speed aerodynamic noise may be a factor. Certain operational factors, such as the payload, age and general condition of the vehicles and the fuel used (depends on the octane number of the fuel-more the octane number less is the noise produced), also have an influence on the noise emitted. Of all the parameters discussed above, the vehicles speed is the major factor which controls the noise. The second, in order of importance, is the effect of the road surface parameters, while the tyre design parameters have negligible effect on noise produced.(White and Walker, 1982).

[1.4] Effects of noise on human

The ear and lower auditory system of human being is continuously exposed to stimuli from the world around us. However, this does not mean that all the acoustical inputs are necessarily disturbing or have harmful effects. This is because the auditory nerve provides activating impulses to the brain that enable us to regulate the vigilance and wakefulness necessary for optimal performance. On the other hand, there are scientific reports that a completely silent world can have harmful effects, because of sensory deprivation. Thus, both too little sound and too much sound can be harmful. For this reason, people should have the right to decide for themselves the quality of the acoustical environment they live in.

Noise pollution is hazardous to human health in many ways. Noise can lead to physiological, psychological and behavioural changes in human beings. Noise is considered, a serious health hazard and inimical to efficiency and performance place of work.
In addition to its auditory effects (temporary and permanent threshold shifts, noise induced deafness, etc.), noise can also produce many non-auditory effects. It can disturb our work, rest, sleep, communication and also evoke other possibly pathological reactions. However, because of complexity, variability and the interaction of noise with other environmental factors, the adverse health effects of noise do not lend themselves to a straightforward analysis. The some of the important effects of noise on human have been briefly discussed below:-

(i) *Hearing impairment:*

Hearing impairment can either be temporary or permanent. Noise-induced temporary threshold shift (NITTS) is a temporary loss of hearing acuity experienced after a relatively short exposure to excessive noise. Pre-exposure hearing is recovered fairly rapidly after cessation of the noise. Noise-induced permanent threshold shift (NIPTS) is an irreversible loss of hearing that is caused by prolonged noise exposure. Both kinds of loss, together with presbyacusis, are the permanent hearing impairment that is attributed to the natural ageing process, can be experienced simultaneously. Noise-induced hearing impairment occurs predominantly in the higher frequency range of 3000-6000 Hz, with the largest effect at 4000 Hz.(Kryter, 1985)

(ii) *Speech interference:*

Noise tends to interfere with auditory communication, in which speech is a most important signal. In speech interference, there is simultaneous interfering noise which renders speech incapable of being understood that means it is basically a masking process. The inability to understand speech results in a large number of personal handicaps and behavioural changes. Problems with concentration, fatigue, uncertainty and lack of self confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress relations have been identified. Particularly vulnerable are the hearing impaired, the elderly, and children in the process of language and reading acquisition, and individuals who are not familiar with spoken language. Speech intelligibility in
everyday living conditions is influenced by speech level, speech pronunciation, talker to listener distance, sound level and characteristics of the interfering noise, hearing acuity and by the level of attention. Indoors speech communication is also affected by the reverberation characteristics of the room.

(iii) *Psycho-physiological and cardiovascular effects:*
Individuals exposed to noise, and in people living near airports, industries and noisy streets, noise exposure may have a large temporary, as well as permanent impact on their physiological functions. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposure to high sound levels. The magnitude and duration of the effects are determined in part by individual characteristics, lifestyles, behaviours and environmental conditions.

(iv) *Sleep disturbance:*
The major effect of environmental noise is a sleep disturbance. Uninterrupted sleep is known to be prerequisite for good physiological and mental functioning of healthy persons. It may cause primary effects during sleep, and secondary effects that can be assessed the day after night-time exposure. The primary effects of sleep disturbance are difficulty in falling asleep, awakenings and alteration of sleep stages or depth, increased blood pressure, heart rate etc. The secondary, or after effects the following morning or day(s) are reduced perceived sleep quality, increased fatigue, depressed mood or well being and decreased performance.

(v) *Annoyance:*
Noise annoyance may be defined as the feeling of displeasure evoked by noise. The annoyance inducing capacity of noise depends upon its physical characteristics, including the sound pressure level, spectral characteristics and variations of these properties with time. However annoyance is not necessarily directly related to these parameters. It may be influenced by a number of subjective factors (such as familiarity and personal attitudes) and by some physical
factors (such as microclimate). Annoyance caused by noise is partly an individual response and varies with persons and situations.

(vi) Performance:
It has been shown, mainly in workers and children that noise can adversely affect performance of cognitive tasks. Although noise induced arousal may produce better performance in simple tasks in the short term, cognitive performance substantially deteriorates for more complex tasks. Reading, attention, problem solving and memorization are among the cognitive tasks most strongly affected by noise. Noise can also act as a distracting stimulus and impulsive noise events may produce disruptive effects as a result of startle responses. Mental activities involving high load in working memory, such as sustained attention to multiple cues or complex analysis, are all directly sensitive to noise and performance suffers as a result.

(vii) Fatigue:
For long time, it has been suspected that noise can induce fatigue in exposed peoples, but it is not easy to prove that employees become more tired working in a noisy environment than in a quiet one. Fatigue may result from having to talk more loudly or from the extra effort caused by misunderstandings.

(viii) Mental health effects:
The association between exposure to high noise levels and the impairment of mental health is still a controversial one. It has often been suggested that noise is not a direct cause of mental illness, but it may accelerate the development of latent neurosis. Research in recent years has shown the lack of association between the noise exposure and mental morbidity. However, a greater prevalence of mental disorders among those who had reported that they were very annoyed by the noise has been confirmed by recent research (Bluhm et al., 2004).
effects on social behaviour

The effects of environmental noise may be evaluated by assessing the extent to which it interferes with different activities. For many community noises, interference with rest, recreation and watching television seem to be the most important issues. However, there is evidence that noise has other effects on social behaviour: helping behaviour is reduced by noise in excess of 80 dBA; and loud noise increases aggressive behaviour in individuals predisposed to aggressiveness. The school children exposed to high levels of chronic noise could be more susceptible to helplessness.

[1.5] Literature review

Vehicular traffic is the most dominant source of noise pollution in urban areas. A number of surveys on traffic noise have been conducted in various cities of the world, viz., Madrid (Paez, 1968), London (Perkin et al., 1968; Fisk et al., 1974), Washington (Safeer and Knerr, 1971), Great Vancouver (Price, 1972), New York (Senko and Krishan, 1972), Madison Massachusetts (Webster, 1973), Rome (Cannelli, 1974), Sydney (Burgess, 1977), Hong Kong (Ko, 1978), Victoria (Don and Rees, 1985), Gothenburg (Bjorkman, 1988), Tokyo (Mochizuki and Imaizumi, 1967; Ishiyama et al., 1991; Yoshida, 1994; Yamaguchi et al., 1992 and 1992), Gothenberg (Bjorkman and Rylander, 1997), Eastern Nigeria (Onuu, 2000), Cairo (Ali and Tamura, 2002, 2003), South Caceres (Morillas et al., 2002), Valencia (Gaja et al., 2003; Ramis et al., 2003), Beijing (Li et al., 2002, Li and Tao, 2004), Curitaba, (Zannin et al., 2002, 2006, Filho et al., 2004), Messina (Piccolo et al., 2005), Amman (Hammad, 1987; Jamrah et al., 2006). In India, surveys on road traffic noise levels have been carried out in Bombay (Dixit et al., 1982), Delhi (Bhanot, 1974; Kumar and Jain, 1991; Singh and Jain, 1995; Kumar et al., 1998), Calcutta (Prabhu and Chakrabarty, 1978; Pancholy et al., 1978; Chakraborty et al., 1997).
Individual vehicular noise pollution in urban areas have been investigated by various workers (eg., Pride, 1967; Mill and Aspinall, 1968; Lewis, 1973; Raff and Perry, 1973; Favre et al., 1977; Jones and Hothersall, 1980).

The other important subject to research, concerning traffic noise, which has not been looked into so extensively, is the examination of the nature and levels of noise inside various types of vehicles. Early investigations of spectral distribution of noise levels inside vehicles were made by Tempest and Bryan (1972) and Williams and Tempest (1975). In India, Sanyogita et al., 2004), investigated the noise and its spectral characteristics inside various types of transport running on Compressed Natural Gas fuel in Delhi. The study revealed a significantly lower noise levels inside the CNG driven public modes of transport compared to those found inside diesel and petrol driven vehicles.

Air traffic is also a source of noise pollution in the residential areas especially in the vicinity of airports. Consequently a number of studies have been carried out on aircraft induced noise in urban areas (e.g., Kryter, 1959; Bishop, 1966; Rylander et al., 1980); In India, Upadhyay and Jain, (1999) measured the aircraft induced noise at four residential areas along the landing path of aircrafts near Indira Gandhi International Airport, Palam, New Delhi. The measured noise levels were found to correlate well with public response in terms of annoyance obtained from the results of social survey.

In addition to above mentioned sources of noise, the community activities such as religious functions, musical shows etc. also contribute to noise in residential areas. Existence of nearby commercial complexes too adds to this problem. Industrial machineries too contribute to noise pollution in industrial areas. Several studies of noise in the residential, commercial and industrial areas have been carried out by a number of workers (e.g., Perkin, 1964; Keighley, 1966; Donley, 1969; Fisk, 1975; Langdon, 1976; Singh and Jain, 1995).
A number of studies have also been performed on assessing the community response to noise pollution in terms of annoyance, speech interference, disturbance in sleep and other adverse effects on human health (e.g., Richards, 1975; Schultz, 1978; Field 1979; Brown, 1994; Hirmastu et al., 2004; Ali and Tamura, 2002). Recently, Prakash et al., (2006) have studied the annoyance due to different modes of transport in Delhi. The study revealed that RTVs are the most annoying followed by buses, auto rickshaws (three wheeler), and taxis. Zaheeruddin et al., 2003 carried out fuzzy modelling of human work efficiency in noisy environment.

A number of studies have been conducted on the effect, mitigation and perception of traffic noise due to vegetation (e.g., Avlor, 1972-a and 1972-b; Price et al., 1986; Huddart, 1990; Watts et al., 1999; Sala et al., 2006). In India, Tyagi et al., (2006) studied the spectral characteristics of traffic noise reduction by vegetation belts in Delhi and found that attenuation generally increases with frequency.

A number of studies have been conducted on the effect of high rise buildings on the noise levels in urban areas. Heutschi, (1995), presented a new method to evaluate and predict the increase of traffic noise emission level due to buildings. Chew, (1992), also studied the façade effects of buildings parallel to the expressways. Chew, (1995) gave the method to reduce the effect of high rise buildings and found that noise can be reduced by inclining the buildings, the reason being the reduction in the multiple reflections and reduction in the energy diffusion. Thorsson et al., (2004, 2005) gave a simple model to predict the road traffic noise levels in areas not directly exposed, such as areas behind buildings and courtyards.

A number of studies have also been focused on development of models to predict the noise levels in urban areas due to the road traffic. The early models (e.g., Johnson and Sounders, 1968; Fisk, 1973; Nelson, 1973; Delany et al., 1976; Burgess, 1977; Mulholland, 1979; Farve et al., 1983; Zhang, 1993) developed for the prediction of traffic noise were empirical in nature. A few attempts have also
been made to develop multiple linear regression models of noise (e.g., Attenborough et al., 1974; Baverstock et al., 1991; Ohta et al., 1995; To et al., 2002). In the United Kingdom, Baverstock et al. (1991) developed an area-based prediction model based on considerations of land use and road traffic that have been validated and found to be robust and reliable. Suksaard et al. (1999) have developed a road traffic noise prediction model for environmental impact assessment in Thailand. Kokowski and Makarewicz (1997) and Makarewicz et al. (1999) developed a model for interrupted road traffic noise. Li et al. (2002) used the Geographical Information System (GIS) to develop a road traffic noise prediction model and found it to be in good agreement with the field measurement. Calixto et al. (2003) developed a statistical model of road traffic noise in an urban setting.

In the Indian context, empirical models for the prediction of road traffic noise have also been developed for few Indian cities of Visakhapatnam (Rao and Rao, 1990, 1991) and Calcutta (Prabhu and Chakrabarty et al., 1978) and Delhi (Kumar et al., 1998). A linear multiple regression model for the city of Calcutta was developed by Prabhu and Chakrabarty (1978). Kumar et al. (1998) have developed a predictive model for Delhi. Though the model is quite satisfactory for prediction, its main limitation is that traffic density and vegetation were assumed to be binary variables i.e. they assigned value 1 or 0 depending on the existence or absence of the attribute. Also the meteorological parameters (temperature, relative humidity, wind speed and direction) were not considered in the above study. The study however revealed that noise levels in various places in Delhi are mainly determined by traffic density.

Concerned about the rising pollution levels in Delhi, the Supreme Court on 28 July, 1998, ordered the state government of Delhi to improve the air quality by reducing vehicular pollution in Delhi. The directives of SC to move public transport to CNG has been implemented in Delhi since April 2001. Delhi now boasts of a completely CNG driven bus fleet, three-wheelers (auto-rickshaws) and
RTVs. Also significant fraction of taxis on Delhi roads are driven by CNG. In a case study of the impact of CNG implementation on the air quality in Delhi, it has been found that concentration of air pollutants has been reduced considerably (Goyal et al., 2003). No attempts however have been made till date to assess the impact of CNG on the noise environment in Delhi. Since traffic density is the main contributing factor of ambient noise levels, there is reason to believe that the noise environment in Delhi, after CNG implementation might have undergone significant change.

This has prompted us to undertake the present study and developing multiple linear regression models where explanatory variables corresponding to vegetation and traffic density have the real graded values (in percentage) and not 1 or 0. The study also tries to establish the effects of meteorological parameters and flyovers on the ambient noise levels.

Objectives:

The present work aims to study the impact of CNG in public transport system on the ambient noise levels in Delhi. The broad objectives of the study are:-

1. Measurement of Equivalent Sound Pressure Levels ($L_{eq}$), the background levels ($L_{90}$) and peak levels ($L_{10}$) during 9 hours/day period (9A.M. to 6P.M.) at different locations (residential, commercial, industrial, mixed and silence) in Delhi

2. Simultaneous measurement of meteorological parameters (viz. temperature, relative humidity, wind direction and speed).

3. Simultaneous measurement of vehicular composition in the vicinity of the measurement location.

4. Based on measurements made above, mathematical models for individual locations, for different zones and for entire Delhi were developed.
The Basic concepts of noise pollution and the characteristics of CNG fuel are given in Chapter 2. Theoretical details of multiple linear regression modelling approach are discussed in Chapter 3. Methodology and Experimental details are given in Chapter 4. Results and Discussion are presented in Chapter 5 and Conclusion is given in Chapter 6.