DISCUSSION
The increase of population and the consequent increase in the number of vehicles in an urban area have significantly contributed to the rise in the levels of Noise Pollution (Mansouri et al., 2006). It is affecting the quality of life in many different ways (Piccolo et al., 2005). According to the results of surveys carried out by various researchers, the noise can be consider as a stress indicator and at the same time, it appears to be a potential risk factor for human health. The most common effects of noise pollution include mental and physical health, sleep disturbance, hearing loss and cardiovascular problems (Ouis, 2001; Langdon, 1976). Keeping the seriousness of the problem in view, in most developed countries formulating standards and laws for noise and earnestly implementing them, they have become imperative to improve the quality of life of the people. However, in many cases, standards developed based on the expert’s recommendations without taking the peoples’ ideas and opinions into account. Many noise surveys conducted over the years in many cities worldwide. Many studies conducted on short-term basis and limited work has been done on long-term surveys and analysis of noise pollution. Noise pollution is now recognized as one of the constituents of overall environmental pollution. It has been established that noise not only adversely affecting the human health, but also the non-living things (Trivedi, 1999).

In India, many researchers have reported that noise levels in urban area specifically at traffic intersections are high due to soaring traffic flow along with activities such as honking, idling, gear noise, break noise, tier road noise and exhaust noise (Swain et al., 2012). According to studies of Mahandiya (2006) noise levels at traffic intersections in Delhi have increase by several times. The average annual fuel consumption for personal mobility in Delhi is far higher than any other city in the country. A similar situation has now become a reality in almost all cities including Hyderabad. The number of vehicles registered in Hyderabad in March 2011 is very high. 23, 26,028 vehicles are plying on the roads under heterogenic traffic activities. The population of the city also reached to 68, 09,970 (Census of India, 2011)

All this has resulted in a complex situation with mixed traffic flow of various vehicles that consist of trucks, buses, cars, auto-rickshaws and different types of two wheelers. This along with a snail-paced traffic like cycle rickshaws and bicycles besides
pedestrians makes the situation much more complex. This condition causes the movement of traffic flow in non-directional pattern particularly in busy centers like commercial and industrial areas. In addition, in India, research studies on traffic noise pollution on a long-term basis are very rare. Keeping this in view, the present study is aimed to develop an empirical noise prediction model for the evaluation of equivalent noise levels ($L_{eq}$) in terms of equivalent traffic density number under heterogeneous traffic flow conditions, in different environmental backdrops i.e. residential, commercial and industrial. For the present discussion, the major/metropolitan cities are referred to as Class-I cities while the other cities are Class –II cities.

**Equivalent noise levels $L_{eq}$ (L_{min} and L_{max}) variations :**

**Residential Area**

Equivalent noise level ($L_{eq}$) is defined as the steady sound level which has the same amount of acoustic energy as the fluctuating level for a prescribed period of time. The equivalent noise levels $L_{eq}$ (minimum ($L_{min}$) and maximum ($L_{max}$)) at residential areas of Marredpally in the present study varied from 40.5 - 89.5 dB (A) and an annual $L_{eq}$ average of 66.3 dB (A). A comparative analysis is made of these values obtained from various major/metropolitan cities (Class-I) of India.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bangalore</th>
<th>Chennai</th>
<th>Mumbai</th>
<th>In the present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{eq}$</td>
<td>63.3 - 74.8</td>
<td>44 - 105</td>
<td>48.5 - 88.2</td>
<td>40.5 - 89.2</td>
</tr>
<tr>
<td>($L_{min} - L_{max}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The noise levels showed minimum of 40.5 dB (A) in the present study compared to the maximum value of 105 dB (A) at Chennai (Dasarathy, 2013). While the other cities showed values higher than our study. However, similar results also recorded in other class II cities where the ambient noise levels recorded in between 45 - 118 dB (A). Vidyasagar and Rao, (2006) and Goswami et al., (2011) studied at Visakhapatnam and Balasore showed $L_{eq}$ ranging from 45 - 77 dB (A) and 70.2 - 111.8 dB (A) respectively while the
studies conducted by Chauhan and Pande (2010) at Dehradun reported a range of 55.3 - 107.6 dB (A). At our study location of Marredpally, noise levels recorded a minimum value of 40.5 dB (A) due to low traffic density of vehicles during midnight and early hours (i.e. from 23:00 to 05:00 hrs). In addition, plantation along the roadside acts as good absorber of noise in this area. The noise levels again started increasing as the day progresses with normal day to day activities like use of home appliances, movement of vehicles, activities of community etc. in this area and reached a maximum value of 89.2 dB (A). The mean also showed a high value of 66.3 dB (A). The major sources of noise in residential area is home appliances like TV, music systems, mixers and grinders, motor pumps and heating or cooling systems etc. The amplification of loud speakers in restaurants, marriage halls or public functions are also equally responsible for increase of ambient noise in this area. In addition, use of various kinds of horns also contributes high noise to environment. Thus, we can infer that the noise levels in residential area of the present study reporting high values when compared to the prescribed limits of 55 dB (A) during day time and 45 dB (A) during night time as given by CPCB (2000), India.

**Commercial area**

The equivalent noise levels $L_{eq}$ (minimum ($L_{min}$) and maximum ($L_{max}$)) at mixed area of Trimulgherry and commercial area of Begumpet of the present study varied from 43.0 to 100.4 dB (A); and 50.5 to 106.2 dB (A) with an annual $L_{eq}$ average of 72.4 and 76.2 dB (A) respectively. The values were compared with the different major/metropolitan cities (Class-I) of India.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bangalore</th>
<th>Chennai</th>
<th>Mumbai</th>
<th>Jaipur</th>
<th>In the present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{eq}$ range ($L_{min}$ - $L_{max}$)</td>
<td>72.9 - 86.6</td>
<td>60 - 87</td>
<td>51.2 - 85.7</td>
<td>72.6 - 83.9</td>
<td>50.5 - 106.2</td>
</tr>
</tbody>
</table>

While in other cities, Mumbai recorded a minimum value of 51.2 dB (A) as studied by Maharashtra Pollution Control Board (MPCB) in 2009 while the maximum value of 87 dB (A) was observed at Chennai as studied by Karthik and Partheeban (2013).
Among all the Class-I cities, Mumbai showed least noise levels because of public transport and widened roads. In the present study at Begumpet also showed a minimum value of 50.5 dB (A) recorded during nighttime. This attributed to less commercial activity and less number of vehicles plying on the roads during early morning hours (03:00 - 04:00 hrs). During the daytime it showed a very high value when compared to other Class-I cities as it is one of the major commercial centers of Hyderabad and it is having a road that connects to IT hub. This is one another reason for the increase of noise levels. The other sources for increase of noise levels at Begumpet attributed to high density of population, presence of shopping malls, more vehicles plying on the roads - especially two wheelers and cars, presence of reflectors like concrete buildings and absence of absorbers like less plant growth along the roads. Similar results observed in Class-II cities where the ambient noise levels recorded in between 59.6 - 122.9 dB (A). Studies conducted by Vidyasagar and Rao, (2006) at Visakhapatnam showed a range of 70 - 90 dB (A) while the other study by Goswami et al., (2011) at Balasore showed $L_{eq}$ ranging from 88 - 122.9 dB (A). The study conducted by Bhaven Tandel et al., (2011) at Surat showed a range of 69 - 118 dB (A). Thus, we can deduce that in all Class-II cities noise levels are higher when compared to Class-I cities due to high traffic density, narrow and congested roads where the sound reverberates. In the present study, noise levels are high during daytime and above the prescribed limits of 65 dB (A) and within the permissible limit of 55 dB (A) during nighttime as prescribed by CPCB (2000), India. To control traffic noise in this area improvement of road surface is an important factor to reduce noise levels. Noise absorbing barriers are required on both sides of the road to reduce noise pollution and the height of the barrier is generally between three to seven meters. However, a systemic study is required to suggest the height of the barrier and absorbing material.

**Industrial area**

The equivalent noise levels $L_{eq}$ (minimum ($L_{min}$) and maximum ($L_{max}$)) at industrial areas of the present study varied from 53.1 - 105.7 dB (A) and annual $L_{eq}$
average of 76.9 dB (A). The present study values are more or less equal with other major/metropolitan cities (Class-I) of India.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bangalore</th>
<th>Mumbai</th>
<th>In the present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{eq}$ ($L_{min}$ - $L_{max}$)</td>
<td>62.6 - 74.4</td>
<td>58.6 - 84.9</td>
<td>53.1 - 105.7</td>
</tr>
</tbody>
</table>

$L_{eq}$ values showed minimum and maximum of 58.6 dB (A) - 84.9 dB (A) respectively at Mumbai as given by Maharashtra Pollution Control Board (MPCB) in 2009 and Bangalore recorded between 62.6 - 74.4 dB (A) as observed by Karnataka Pollution Control Board (KPCB) in 2012. In the present study at industrial area of Jeedimetla, the noise levels recorded a minimum of 53.1 dB (A) and a maximum value of 105.7 dB (A). In industrial area noise is produces in every stage by various aspects like welding, running machinery, motors, lathe machine work, moulding works, boiling and cooling of materials, fabricating, forging and compression of materials etc., which create serious large scale noise to ambient environment. The characteristic of noise vary from industry to industry and depend on specific industrial processes. Hence, noise inventory studies are required to control ambient noise from industrial areas particular in the present study area large number of industries fall under various categories including steel, plastic, pharma, machine tools etc. In addition, less vegetation along roadside and uneven roads with traffic congestion are the factors responsible for increase of noise. Similar studies reported in Class-II cities where the ambient noise levels recorded in between 62.1 - 124.3 dB (A). Studies conducted by Kisku et al., (2006) at Lucknow and Goswami et al., (2011) at Balasore showed $L_{eq}$ ranging from 72.2 - 77.2 and 70.4 - 124.3 dB (A) respectively. Another study conducted by Thangadurai et al., (2005) at Salem showed a range of 62.1 - 94.32 dB (A). The ambient noise levels reported at different metropolitan cities is less when compared to most of the class – II cities except our study location which are above the prescribed limits of 75 dB (A) during day time and 70 dB (A) during night time as given by CPCB (2000). Though Hyderabad is a Class-I city, here also the
noise levels are found to be high indicating that the development of the city is not on par with other Class-I cities.

From the above studies it can be summarized that the equivalent noise levels $L_{eq}$ range is higher in Class-II cities when compared to Class-I cities due to increasing population which in turn leads to increasing vehicular growth, narrow roads, less public transport facility resulting in more usage of private vehicles, speed of vehicles, ill planning and heavy vehicles flow. All these factors lead to traffic congestion (Prabat and Nagarnaik, 2007). Lack of awareness in people, less plantation along the roadside and driving behavior together with absence of proper civic sense - all these parameters influence the increase in noise levels in Class-II cities.

**Noise Indices $L_{10}$, $L_{50}$ and $L_{90}$**

A complete statistical description of the noise, which provides the major information, indicates the fact that very often the following descriptors $L_{eq}$, $L_{10}$, $L_{50}$ and $L_{90}$ are calculated. These four values, which give the range of noise levels, specified effectively for most purposes. $L_{10}$, $L_{50}$ and $L_{90}$ are the most commonly used percentile exceeded sound levels (Rao and Rao, 1992 and 1991; Peterson, 1980). Similar studies made by other researchers in different cities in India with different backdrops compared with the present study.

The minimum and maximum values of noise indices for different areas is shown in table below

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Residential</th>
<th>Mixed</th>
<th>Commercial</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{10}$</td>
<td>52.6 - 84.4</td>
<td>58.7 - 90.3</td>
<td>63.8 - 94.3</td>
<td>66.5 - 93.9</td>
</tr>
<tr>
<td>$L_{50}$</td>
<td>47.5 - 77.1</td>
<td>52.9 - 83.4</td>
<td>57.8 - 85.1</td>
<td>60.0 - 85.8</td>
</tr>
<tr>
<td>$L_{90}$</td>
<td>42.1 - 66.5</td>
<td>46.7 - 75.5</td>
<td>53.3 - 76.4</td>
<td>56.2 - 75.1</td>
</tr>
</tbody>
</table>
The $L_{10}$ is the level exceeded for 10% of the time. It is found for many years a useful descriptor of noise as it correlates relatively well with the disturbance people feel close to busy roads in urban and industrial areas. The present study at residential area of Marredpally the $L_{10}$ is ranging between 52.6 - 84.4 dB (A) and annual average is 69.5 dB (A). Studies conducted at Chidambaram as given by Balashanmugham et al., (2013) $L_{10}$ ranged between 71 - 75 dB (A) having an average of 72.66 dB (A) while in another study at Rohtak city of Harayana as studied by Chandraprabha and Jitender (2013), it is ranging between 37 to 78.3 dB (A). At our study location at Marredpally, $L_{10}$ was minimum at 52.6 dB (A) during night time due to less residential activity and growth of plants along road side while it was more during day time as it was a single line congested roads and traffic is not systematic leading to factors like honking and frequent traffic jams due to narrow roads. These are the factors which are responsible for the increase of $L_{10}$ (higher noise levels) value of 84.4 dB (A) during daytime and also thereby increasing the annual average value of 69.5 dB (A) but less when compared to other study at residential area.

In the present study of both mixed and commercial areas of Trimulgherry and Begumpet, $L_{10}$ values ranged between 58.7 - 90.3 dB (A) and 63.8 - 94.3 dB (A) respectively with annual averages of 76 and 80 dB (A) respectively. Studies conducted by Agarwal and Swami, (2011) in Jaipur in commercial areas $L_{10}$ range is 77.3 - 88 dB (A) with an average of 82.84 dB (A). The $L_{10}$ values showed maximum values of above 90 dB (A) at both locations due to mixed flow of vehicles, frequent traffic congestion due to increase of private vehicles, increasing commercial activities thereby increasing the annual average $L_{10}$ to 76 and 80 dB (A) respectively. Our study showed much higher values when compared to studies conducted by other different researchers.

In the Industrial area of Jeedimetla $L_{10}$ varied between 66.5 - 93.9 dB (A) and annual average is 80.8 dB (A). The $L_{10}$ showed less value of 66.5 dB (A) during night time and reached a maximum value of 93.9 dB (A). Three-wheeler is unconditional goods carrier, which produce more noise along with movement of heavy vehicles in this area and showed a high $L_{10}$ annual average of 80.8 dB (A). In our present study the annual averages of $L_{10}$ showed maximum values of 94.3 dB (A) and 93.9 dB (A) at commercial
area of Begumpet and industrial area of Jeedimetla respectively and a minimum of 52.6 dB (A) at residential area.

$L_{50}$ is the level that exceeded for 50% of the time and statistically the midpoint of the noise readings and represents the median of the fluctuating noise levels. In the present study at the residential area of Marredpally, $L_{50}$ is ranging from 47.5 - 77.1 dB (A) with an average of 63.1 dB (A). Studies at Chidambaram as studied by Balashanmugham et al., (2013) $L_{50}$ ranged from 60 - 64 dB (A) with an average of 62.33 dB (A). The median levels of noise $L_{50}$ at our study location of Marredpally, a residential area, showed minimum value 45.1 dB (A) due to lesser vehicular activity and less reflectors along the road side and maximum value showed a value of 77.1 dB (A) due to continuous uninterrupted traffic flow conditions keeping the median $L_{50}$ levels increasing and the annual average showed a average of 63.1 dB (A) which is more when compared to observations made in other studies.

The mixed area of Trimulgherry in the present study, $L_{50}$ ranged between 52.9 - 83.4 dB (A) having an average of 69.8 dB (A) which is much higher compared to the study at mixed area of Kolhapur as studied by Mangalekar et al., (2012) $L_{50}$ which showed an average of 62.2 dB (A). In the present study $L_{50}$ values showed a minimum of 52.9 dB (A) at mixed area of Trimulgherry due to less vehicular activity and some absorbers like plants along road side and maximum value of 83.4 dB (A) due to regular movement of tempos and seven seater autos which further increased the annual average of median $L_{50}$ showing a value of 69.8 dB (A).

The present study at commercial area of Begumpet, $L_{50}$ showed ranged between 57.8 - 85.1 dB (A) with an average of 73.3 dB (A) while the other city of Jaipur as reported by Agarwal and Swami, (2011) at commercial area $L_{50}$ range was 72.5 - 82.7 dB (A) and an average of 77.98 dB (A). Industrial area of Jeedimetla $L_{50}$ ranged from 60 - 85.8 dB (A) with an average of 74 dB (A). In both commercial and industrial areas median $L_{50}$ values showed minimum values nearby 58 dB (A) when due to less vehicular activity and maximum $L_{50}$ showed value above 82 dB (A) because of regular vehicle flow.
due to commercial and industrial activities and presence of reflectors like tall building which always keep this median $L_{50}$ to higher value and annual average of both areas showed above 73 dB (A) and these values are less when compared to other study conducted by Agarwal and Swami,(2011) at Jaipur city. The median of noise levels $L_{50}$ in present study showed a minimum value of 47.5 dB (A) at residential area of Marredpally and maximum of 85.8 and 85.1 dB (A) at industrial area of Jeedimetla and commercial area of Begumpet.

$L_{90}$ is the level exceeded for 90 % of the time and is generally represented as background or ambient levels of noise environment. In the present study at the residential area of Marredpally, the background noise $L_{90}$ is ranging from 42.1 - 66.5 dB (A) with an average of 56.2 dB (A). Balashanmugham et al., (2013), Chandraprabha and Jitender (2013), reported $L_{90}$ was between 58 - 59 dB (A) and 30.2 - 70.1 dB (A) respectively at Chidambaram and Rohtak cities. The present study at residential area of Marredpally the background noise levels $L_{90}$ showed the minimum value of 42.1 dB (A) due to presence of sound absorbers like trees along the road sides making this area less noisy when compared to other areas of our study and maximum value of 66.5 dB (A) which is more though comparable. This is due to regular residential activity like vendors shouting, regular traffic during daytime and the annual average also showed a value of 56.2 dB (A). The background noise levels $L_{90}$ showed medium values when compared to other studies.

The present study at mixed area of Trimulgherry, $L_{90}$ varied from 46.7 - 75.5 dB (A) with average of 62.9 dB (A) and Kolhapur as studied by Mangalekar et al., (2012) recorded an average of 59 dB (A). The present study at mixed area showed $L_{90}$ values of minimum 46.7 dB (A) due to less vehicular activity and the presence of some vegetation along roadside and maximum value of 75.5 dB (A) which is almost equal to commercial and industrial areas of the present study due to regular vehicular and commercial activity and the annual average showed a value of 62.9 dB (A) which is higher when compared to other studies conducted by Mangalekar et al., (2012) at Kolhapur city.

Commercial area of Begumpet and industrial area of Jeedimetla in the present study the ambient noise levels $L_{90}$ ranged from 53.3 - 76.4 dB (A) and 56.2 - 75.1 dB (A)
respectively having an average above 65 dB (A) at both study locations. While in Jaipur L\textsubscript{90} ranged from 68.6 - 77.9 dB (A) with an average of 74.17 dB (A) as reported by Agarwal and Swami, (2011). The present study at commercial area of Begumpet and industrial area of Jeedimetla showed minimum value of ambient noise levels L\textsubscript{90} around 53 dB (A) due to less commercial and industrial activity and less traffic movement and maximum value of above 75 dB (A) which is high due to increase in continuous vehicular traffic movement and less absorbers like trees and more reflectors like buildings on either side of roads making these areas much noisier when compared to other study locations of the present study. The value of ambient or background noise levels L\textsubscript{90} is less in our study at commercial area of Begumpet when compared to Jaipur city as studied by Agarwal and Swami, (2011). The ambient or background noise levels L\textsubscript{90} in present study showed a minimum value of 42.1 dB (A) at residential area of Marredpally and maximum at 76.4 dB (A) at commercial area of Begumpet.

**Noise Parameters TNI, NC and L\textsubscript{np}**

These noise parameter TNI was proposed by Griffiths and Langdon in 1968 (Schultz, 1972) and Traffic Noise Index (TNI) is used to estimate the annoyance response due to traffic noise. This noise parameter Noise Pollution Level (L\textsubscript{np}) was developed by Robinson in the late 60’s (Schultz, 1972) and describes community noise, which employs the equivalent continuous (A-weighted) sound level and the magnitude of the time fluctuations in levels and Noise Climate (NC) gives how sound levels will be fluctuating in an interval of time and is a best indicator of physiological and psychological impact of noise and all these parameters depend on noise indices.

The minimum and maximum value of noise parameters for different areas is shown in table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Residential</th>
<th>Mixed</th>
<th>Commercial</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNI</td>
<td>54.2 - 108.1</td>
<td>64.4 - 105.3</td>
<td>64.6 - 121.7</td>
<td>67.4 - 120.4</td>
</tr>
<tr>
<td>NC</td>
<td>10.1 - 17.9</td>
<td>10.2 - 15.7</td>
<td>10.0 - 20.1</td>
<td>10.3 - 18.8</td>
</tr>
<tr>
<td>L\textsubscript{np}</td>
<td>59.8 - 100.3</td>
<td>67.2 - 101.8</td>
<td>70.1 - 110.4</td>
<td>72.1 - 110.5</td>
</tr>
</tbody>
</table>
In the present study, TNI range for different areas i.e. residential area of Marredpally, 54.2 - 108.1 dB (A), mixed area of Trimulgherry 64.4 -105.3 dB (A), commercial area of Begumpet 64.6 - 121.7 dB (A) and the industrial area of Jeedimetla showed a range of 67.4 - 120.4 dB (A). In the present study TNI showed minimum value of 54.2 dB (A) at residential area of Marredpally and maximum value of greater than 120 dB (A) at both commercial area of Begumpet and at industrial area of Jeedimetla. The annual average of TNI showed a minimum value of 79.6 dB (A) and maximum value of 96.7 dB (A) at industrial area of Jeedimetla. At all the study locations the TNI values showed are high above the threshold values of 74 dB (A) (Scholes and Sargent, 1971; Schutz, 1972; Ma et al., 2006) because of the increasing traffic noise due to more vehicular growth due to increase in population in urban areas which further causes annoyance to the people living nearby roads causing health problems to humans like hypertension and cardio vascular diseases. Similar study conducted by Agarwal and Swami, (2011) and Kartheek and Partheeb (2013) in commercial area of Jaipur and Chennai showed TNI are varying between 73.3 - 88.6 dB (A) respectively with same average value of 79.15 dB (A). The TNI at our present study location in commercial area showed higher values when compared to other studies conducted at different cities.

The Noise Climate (NC) range in the present study for different areas i.e. mixed area of Trimulgherry 10.2 - 15.7 dB (A), residential area of Marredpally 10.1 - 17.9 dB (A), commercial area of Begumpet 10 - 20.1 dB (A) and industrial area of Jeedimetla 10.3 - 18.8 dB (A). The NC showed a minimum value of 10 dB (A) at commercial area of Begumpet and maximum value of 18.8 dB (A) at industrial area of Jeedimetla, while the annual average showed a minimum of 13.1 dB (A) at mixed area of Trimulgherry and maximum of 15.3 dB (A) at industrial area of Jeedimetla. The noise climate gives the best indication of health effects of physiological and psychological like frequent irritation and mental behavior. Studies conducted by Mangalekar et al., (2012) in Kolhapur a mixed area the NC is ranging between 5 - 6.7 dB (A). In our study all the areas showed NC values above 10 dB (A) which is more when compared to the other study at mixed area in Kolhapur by Mangalekar et al., (2012).
In the present study the L_{eq} showed ranges of 59.8-100.3 dB (A) at residential area of Marredpally 67.2 - 101.8 dB (A), mixed area of Trimulgherry, 70.1 - 110.4 dB (A) commercial area of Begumpet and industrial area of Jeedimetla showed 72.1 - 110.5 dB (A). All the study areas showed higher values more than 100 dB (A) which is more than threshold values of 72 dB (A) (Scholes and Sargent, 1971 and Schutz, 1972). In the present study L_{eq} showed minimum value of 59.8 dB (A) at residential area of Marredpally and maximum value of greater than 110 dB (A) at both commercial area of Begumpet and at industrial area of Jeedimetla. The annual average of L_{eq} showed a minimum of 79.5 dB (A) at residential area of Marredpally and maximum of 93.3 dB (A) at industrial area of Jeedimetla. The Similar study conducted at Jaipur in commercial area by Agarwal and Swami, (2011) the L_{eq} is ranging between 64 - 73.8 dB (A), while the average is 69.81 dB (A). In all areas of the present study the L_{eq} values showed higher values when compared to other study conducted by Agarwal and Swami, (2011) in Jaipur city. These high values of community noise leads to health problems. These high noise levels which cause annoyance can be reduced by increasing vegetation and we need to plant special trees along the roadside to reduce the noise and more important cost effective on the basis of air pollution (Agarwal and Tiwari, 1997; Kumar and Paulsany, 2006; Paulsanmg and Latha, 2000).

**Noise Levels (L_{eq}) during Peak Hours**

The peak hours of Traffic during morning (8:00 - 11:00 hrs) for Marredpally and (9:00 -12:00 hrs) for all other study locations and evening (17:00 - 20:00 hrs) for all locations in the present study. The average equivalent noise levels L_{eq} values for the peak hour during morning at our present study recorded a minimum of 74.2 dB (A) at residential area of Marredpally and maximum of 85.1 dB (A) at commercial area of Begumpet during morning. While the other area of Trimulgherry (mixed) the value is 81.2 dB (A). Similar study conducted by Anirban et al., (2012) at Kolkata at four important traffic intersections and sampling locations were mainly comprised of residential, mixed and commercial areas during morning peak hours i.e. (9:00 - 10:00 hrs) showed average noise level L_{eq} value of 79.78 dB (A). During evening peak hours i.e. (17:00 - 20:00 hrs)
in our present study both industrial of Jeedimetla and commercial area of Begumpet recorded the same $L_{eq}$ value of 85.6 dB (A), while the mixed area of Trimulgherry showed a value of 83.2 dB (A) and minimum is recorded at residential area of Marredpally having a value of 74.4 dB (A). Similar study conducted at three corridors in commercial area at Surat by Bhaven Tandel et al., (2011) showed the average values of $L_{eq}$ was varying between (92-98) dB (A) during evening peak hours (17:00 - 20:00 hrs). The equivalent noise levels $L_{eq}$ are higher in all the areas of the present study during morning and evening peak hours are due to more vehicular flow, traffic jams leading to congestion, people using their own vehicles for going to offices and other places due to lack of public transport, unwanted use of horns creating annoyance, drivers behavior, road and vehicle conditions and lack of plantation along the roads in most places.

**Correlation between Annual Average Noise Level $L_{eq}$ and Total Vehicles Count**

The total number of vehicles consists of two wheelers, three wheelers, four wheelers (light vehicles) like cars and heavy vehicles like buses and trucks. The vehicle noise is a major source of noise pollution. Heavy vehicles cause more noise but the noise from the others vehicles cannot be neglected as their contribution to the total count of vehicles is much more especially two wheelers like scooters and motorcycles which play a significant role in increasing vehicular traffic noise pollution. The regression equations for total sum of all vehicles were plotted against observed equivalent noise levels $L_{eq}$ for different areas.

<table>
<thead>
<tr>
<th>Study Locations</th>
<th>Regression Equation</th>
<th>$R^2$</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marredpally</td>
<td>0.002x+43.191</td>
<td>0.982</td>
<td>0.991</td>
</tr>
<tr>
<td>Trimulgherry</td>
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<td>0.963</td>
<td>0.981</td>
</tr>
<tr>
<td>Begumpet</td>
<td>0.0009x+19.379</td>
<td>0.989</td>
<td>0.994</td>
</tr>
<tr>
<td>Jeedimeta</td>
<td>0.0009x+45.958</td>
<td>0.988</td>
<td>0.993</td>
</tr>
</tbody>
</table>

The basic elements of traffic noise model are the traffic source inputs and the propagation or reduction of sound between the traffic and receiver. The source inputs
include volume of the vehicle types, speed and roadway characteristics (surface, gradient and length of roadway with line of sight of the receiver location). Propagation related inputs include the acoustic characteristics of the ground, number of lanes, site geometry and topography and the any barriers or buildings present. Some of the models also consider meteorological conditions like the prevailing wind and temperature and interrupted traffic flow.

**Model**

In order to obtain the proper mathematical models that are able to predict in a satisfactory manner, the equivalent and statistical noise levels it is necessary that the models should be simple enough so that they can be used by those responsible for urban planning, requires only easily obtained data for calculating noise levels and incorporating accurate results according to the subjective perception of the noise. The models, such as FHWA model and STAMINA which are used in USA and for the calculation of road traffic noise prediction model, (CoRTN) in the UK, can be found in the review by Steele, (2001). Noise prediction models due to traffic are very important in designing schemes for highways and non highways. They take into account, the changing traffic conditions (Givaris and Mohmoodi, 2007; Steele, 2001). Various models to predict noise have been developed basing on traffic characteristics as well as geometry of roads. There is no standard number for the levels of noise pollution (Golmohammadi et al., 2007; Jamrah et al., 2006; Zannin et al., 2006; Theebe, 2004; Bjorkman and Rylander, 1996). Different models for noise pollution are given as under. For instance, Lam and Tam, (1998) designed a noise prediction tool by Monte Carlo technique which accounted for the fluctuations in noise predictions. Suksaard et al., (1999) designed a model to predict noise in Thailand. A GIS-based model was developed by Li et al., (2002). Calixto et al (2003) predicted noise due to traffic in urban areas. Abo and Alhiary (2004) studied the effect of distance from road intersection on developed traffic noise levels. Research on noise pollution in India is backward when we compare with other developed countries. In urban areas, narrower, over-crowded, and medium to heavy congested road network conditions create interrupted traffic flow condition (Rajakumara and Gowda, 2008; Parida et al., 2003).
Calixto Model

The total sum of vehicles is combined of both light vehicles like motorcycles, auto-rickshaws and cars and heavy vehicles, even though light vehicles play a significant part in increasing noise levels but heavy vehicle makes stronger noise when compared to light vehicles under speed consideration. So this Calixto model is used as a model for calculating/predicting equivalent noise levels $L_{eq}$ for the present study a factor, $n$, has been considered for such vehicles, so that an equivalent value could have been achieved for the traffic flow, $Q_{eq}$. By considering $Q$ as the real hourly vehicle flow, $VP$ as the percentage of heavy vehicles and $n$ as the weighting factor, we get:

$$Q_{eq} = Q(1 + n \times \frac{VP}{100}). \quad (1)$$

So, the term $10 \log(Q_{eq})$ will be transformed into $10 \log(Q (1+n\times VP/100))$.

The factor value, $n$, will have to have a certain value that results in the largest correlation coefficients between the noise levels and this factor $10\log(Q(1+n\times VP/100))$. By varying the factor from 4 to 10, the largest correlation coefficients between $L_{eq}$ and the above term

Mathematically, the curve can be represented by:

$$Y=a \times x + k \quad (2)$$

By applying the variables on the straight line equation, we get:

$$L_{eq} = a \times 10\log(Q(1+n\times VP/100)) + k \quad (3)$$

Where ‘$n$’ is the weighting factor and the values of constants ‘$a$’ and ‘$k$’ can be found after the statistical methods of linear regression.

As it is seen from the above discussions that any mathematical model which is to be used for calculated or predicted $L_{eq}$ level must include the following parameters:

- Total vehicle volume/hr
- Percentage of heavy vehicles
- The distance of the measurement point from the roadway
- Average vehicle speed
Inclusion of vehicle speed as a parameter may be a difficult task and many models do not include this.

Road traffic noise is a major concern for the people living in the surrounding areas of roads in urban areas. The coefficient of determination \( R^2 \) between the predicted and observed noise levels \( L_{eq} \) by some empirical models showed that the recommended model has the higher value of \( R^2 \) compared to earlier traffic models, as studied by Chakrabarty et al., 1997 on Kolkata city road traffic noise was measured and regression equation was developed for calculating noise levels by using equivalent number of light/heavy vehicles per hour and distance from the travelling centerline. Another study by Kumar (2000) by calibrating FHWA model another model was developed for Indian road conditions and the predicted value gave a regression coefficient of 0.793, Study conducted by Parida et al (2003) a metropolitan traffic noise prediction model in Delhi for typical Indian conditions of interrupted and heterogeneous traffic flow was developed using an analytical approach. Rajakumara and Gowda developed a regression noise prediction model under interrupted traffic flow conditions by using two systematic lane approaches (acceleration and deacceleration). Study conducted by Kumar (2011) developed a road traffic noise prediction model using regression analysis and the data collected was computed and compared with values predicted by Calixto model and the model showed good results for the Indian road conditions and showed good value of correlation coefficient \( R^2 \) and all the other models except Calixto model showed the adequacy of model for Indian road conditions. Finally we can conclude that suggested Calixto model is the simplest model for predicting noise levels in the present study at Hyderabad city, when compared to other models as it requires total vehicle count and percentage of heavy vehicles as the heavy vehicles generate more noise compared to light vehicles and it doesn’t require any other parameters like road dimensions, building heights and exact speed. A weighing factor ‘n’ (varying from 4 to 10) is calculated by largest correlation and in the present study ‘n’ is taken as 9.5, then this predicted noise levels \( L_{eq} \) derived from model is compared with observed noise levels \( L_{eq} \) and regression analysis to correlate different traffic parameters a new noise prediction model for road transportation is developed for Indian road conditions. Therefore this study
reveals by using Calixto model, traffic noise levels can be reduced and so the health problems for the people nearby roads and calibrating this model by regression analysis has led to raise in accuracy of predicted traffic noise. The regression equations between the observed and calculated/predicted $L_{eq}$ for different areas of the present study is shown below.

<table>
<thead>
<tr>
<th>Study Locations</th>
<th>Regression Equation</th>
<th>$R^2$</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marredpally</td>
<td>0.8175x+12.106</td>
<td>0.8175</td>
<td>0.904</td>
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<tr>
<td>Trimulgherry</td>
<td>0.9139x+6.236</td>
<td>0.9139</td>
<td>0.955</td>
</tr>
<tr>
<td>Begumpet</td>
<td>0.8273x+13.159</td>
<td>0.8273</td>
<td>0.909</td>
</tr>
<tr>
<td>Jeedimetla</td>
<td>0.9178x+6.3195</td>
<td>0.9178</td>
<td>0.958</td>
</tr>
</tbody>
</table>

In the present study correlation coefficient $R^2$ values for industrial area of Jeedimetla showed the highest correlation of 0.917 whereas the mixed area of Trimulgherry also showed the best results of $R^2$ value of 0.913, whereas the commercial area of Begumpet showed a $R^2$ value of 0.827 and the residential area of Marredpally shows least correlation coefficient $R^2$ value of 0.817. Similar model was studied by Kumar et al., (2011) in India and found the correlation coefficient of 0.927. The correlation coefficient $R^2$ value of 1.0 is considered to be the best fit, where as values above 0.7 is considered to be good. This shows that in all the areas the correlation is very good and the value of $r$ also shows good results. From this we can conclude that the Calixto model is good for Indian road conditions.

Since the vehicular noise plays an important part in increasing road traffic noise pollution and there by overall increase in ambient noise in urban and industrial areas and constant exposure to these high values of noise leads to health problems to humans such as hypertension, frequent irritation, hearing loss and cardiovascular diseases. So some recommendations are made to reduce these noise levels and thereby creating good environment which further leads to good health.
Recommendations

Most of the cities in India are encountering problems due to rapid urbanization which is a direct result of increase in population. Hyderabad is one of the most populated cities in Telangana state due to availability of more opportunities for livelihood because of the presence of more industries and IT hub. People migrate here from different places to earn their living. Due to this high population, the vehicular usage has also increased steeply. The major contributors to noise pollution are the vehicles. The lack of public transport system, especially during peak hours of traffic, leads to the use of more number of personal vehicles which is highly undesirable. This is a major problem for the increase in noise pollution. The use of individual/private vehicles coupled with the lack of proper wide roads has lead to the traffic congestion.

Steps to reduce noise pollution

1. Control of noise of the respective vehicles can be done at individual level by ensuring proper maintenance and fitting a suitable muffler or silencer which can reduce sound. Use of unwanted horns should be avoided and using of honking horns (hydraulic) should be banned as they cause annoyance to other people travelling.
2. Plantation of a variety of trees along the roadside is one easy cost-effective way to reduce levels of noise pollution. Vegetation buffers zones should be created at different places of the city.
3. Awareness programs should be conducted for people and vehicle drivers regarding the consequences of noise pollution as well as the ways to encounter the problem effectively.
4. Parallel lane system should be followed for all the vehicles to avoid traffic congestion. Streamlining of roads and improving parking facilities are also equally important because of the increasing number of shopping malls, theaters and function halls in the prime areas. Vendors should stay away from the main roads and parking slots making the roads more congested and leading to more noise.
5. Restricting heavy vehicle movement in the city during the daytime and providing separate lanes for them if they are allowed can also prove to be effective to reduce
traffic congestion and the resultant noise levels. Special drives should be done to check the vehicles and over-aged vehicles, which make more noise, should be eliminated.

6. The windows of the houses which are nearby roads should be double glazing which can reduce the levels up to 20 dB.

7. Taking the services of NGOs, researchers, professionals and students will also help significant in creating awareness and minimizing the ill effects of noise pollution.

8. There should be an increase in public mass transport especially during peak hours to avoid usage of individual vehicles which can reduce the traffic and thereby decrease the noise pollution.

9. Road surface gradient (design), road usage and development of adjacent roads are also some ways that influence the traffic noise.

10. Modern technology can be used in the form of installing automatic traffic signals and setting up surveillance systems at all the junctions. These can help us to make sure that both the pedestrian and vehicle driver abide by the rules. Creating silent zones near the schools and hospitals and penalizing the culprits who violate the rules may be another effective method.

11. Making people aware of use of bicycles rather than using vehicles for smaller distances saving fuel as well as making it pollution-free. Promotion of more eco-friendly vehicles will also go a long way in reducing noise.