PROJECT REPORT

(Revised 12.06.2018)

NOISE MAPPING OF MYSURU CITY

AIISH Research Fund Project No. SH/CDN/ARF/27/2015 - 2016

Authors

Sreeraj Konadath

Suma Chatni

Sanction No: SH/CDN/ARF/27/2015 – 2016 dated 05.10.2015 and 23.02.2016

Personnel	Akshay M. Research Officer Department of Audiology All India Institute of Speech and Hearing Mysuru– 570 006 akshaymadakari@gmail.com
Total Fund	Sanctioned: Rs. 6,70,000/-
Project duration	15 months
Principal Investigator	Sreeraj Konadath, Lecturer in Audiology Department of Audiology All India Institute of Speech and Hearing Mysuru– 570 006
Co-Investigator:	Suma Chatni Audiologist Gr. II (on contract basis) Department of Audiology All India Institute of Speech and Hearing Mysuru– 570 006 sumachatni@gmail.com ***Present affiliation:*** Speech Therapy Department Jordanian Speech Clinic for Speech and Learning disabilities Al Ain, Abu Dhabi, U.A.E.

Acknowledgments

The investigators would like to acknowledge the Director of the All India Institute of Speech and Hearing for being pivotal in granting the funds for the study. We would like to acknowledge the HOD, Department of Audiology for allowing us to use the resources from the department for testing. We also would like to extend our appreciation to the Commissioner of Police (Law and Order) for granting permission to carry out the data collection in the city of Mysuru.

Contents

Abstract

Objective: Current study was carried out with the purpose of measuring noise levels in Mysuru city at various time frames and across land use categories. The same is represented using isopleth maps. It was also aimed to measure noise levels during the occasion of Dussehra and Deepavali festivals and compare the same with noise levels in the city on any other regular day. *Method:* Noise mapping of city involved three phases. Phase I- Identification of areas to be mapped and categorizing them into respective land use types (Residential, Commercial, Sensitive, Industrial & Mixed), Phase II- noise measurement in these areas using a calibrated sound level meter in each of the timeframe (morning, afternoon, evening & night). In phase III, Isopleth noise maps for average noise levels were generated for each of the time frame using ArcGIS software. The measured values were compared with the existing noise exposure standard (EPA, 1986). To study the effect of Dussehra on measured noise levels in the city, noise recordings were carried out in 15 locations during morning, afternoon and evening timeframe during the festival of Dussehra. Average noise levels were calculated for each time frame and compared with those obtained in same location during any other regular day of the year. Similarly noise levels were compared between Deepavali and Non-Deepavali period in evening timeframe at 27 measurement points. *Result:* Results revealed noise levels to be higher in commercial areas followed by sensitive, mixed, industrial and residential types. Significantly lesser levels of noise were recorded in night time. No significant difference was noted in noise levels measured during morning, afternoon and evening timeframe. On comparison with existing standards, it was observed that, measured noise levels clearly exceeded the prescribed limits during both day and night for all the land use types except for Industrial areas. Significantly higher levels of noise were recorded in the city during the time of Dussehra and Deepavali when compared with noise levels during any other regular day. *Conclusion:* On observation, vehicular noise was identified as the major noise source. The higher noise levels recorded in the city would bring about adverse health effects on city dwellers in the long run, thus calling for strict law enforcement related to monitoring of noise levels and keeping them in check.

Chapter I

Introduction

1.1. Definition of noise: Its auditory and non-auditory effects.

"Noise is defined as any unwarranted disturbance within a useful frequency band"(National Institute for Occupational Safety and Health, 1991). No physical difference could be noted between sound and noise. Noise is present in our day to day situations in the form of traffic noise, household noise or even when more than two people talk at simultaneously. But, usually these sounds are within safe levels of hearing which do not damage our ear's sensitive structures. Exposure to noise above the permissible limits may have auditory and non-auditory effects. Noise could result in potential annoyance and/or hearing loss.

Auditory effects of noise exposure would include Temporary Threshold Shift (TTS), Permanent Threshold Shift (PTS), poor speech perception ability and Tinnitus.Exposure to noise is one of the major preventable causes of hearing loss. There are over 1.3 billion people globally who are affected by hearing loss. Hearing loss is rated as one of the major contributor to the global years lived along with disability (Vos et al., 2013).NIHL is common type of sensory neural hearing loss, second only to presbycusis (Nandi & Dhatrak, 2008) and has a prevalence of 16% worldwide (Nelson, Nelson, Barrientos & Fingerhut, 2005).

Threshold shift recovers in the case of TTS, but remains at an elated value in PTS (Miller, Watson, & Covell, 1963). Permanent NIHL is because of the damage occurring to cochlear hair cells or to their mechano-sensory hair bundles (Liberman & Dodds, 1984). Excessive exposure to noise would bring about alterations in the functioning of central auditory system and often leads to perception of tinnitus

(Henderson, Bielefeld, Lobarinas, & Tanaka, 2011). Tinnitus often persists in majority of the individuals who are exposed to excessive level of noise. Tinnitus can affect quality of life by bringing about disturbances in sleep, difficulty in sustaining attention and often leads to depression in severe cases (Tyler, 2000).

Non-auditory effects of noise could be defined as “adverse effect on health and well-being which are caused by noise exposure, with the exclusion of effects on the hearing organ and the effects which are due to the masking of auditory information”(Stansfeld & Matheson, 2003). Non auditory effects of noise would include sleep disturbances (Öhrström, 1989; Tarnopolsky, Watkins,& Hand, 1980; Stansfeld & Matheson, 2003), impaired performances (Glass& Singer, 1972; Salame & Baddeley, 1982; Loeb, 1986), risk of cardiovascular diseases (Zhao, Zhang, Selin, & Spear, 1991; Herbold, Hense, & Keil, 1989; Green, Schwartz, Harari, & Najenson, 1991), abnormal endocrine responses (Brandenberger, Follenius, Wittersheim, & Salame, 1980;Cavatorta et al., 1987) and certain psychological issues such as changes in mood and anxiety (Basner et al., 2014).

Noise is considered as major contributor of adversity to public health and can often lead to issues pertaining to hearing, sleep, cardiovascular functioning, social handicaps, productivity, teaching and learning, drug use, and accidents. General well-being of an individual is adversely affected by noise in the same way as affected by chronic stress (Vos et al., 2012). Economic losses are incurred due to degradation of residential, social, and learning environments. Employment of noise control measures is not successful in most places. This calls for improved noise management methods which include educating public, enlightened legislation, and active implementation of noise exposure regulations by local law enforcement authorities.

Ministry of Environment and Forests, Govt. of India has formulated Noise pollution rules in the year 2000, prescribing ambient air quality standards to be followed in India. It has prescribed standards for permissible noise levels for different land use categories for two time frames: Day (06.00-22.00) and night (22.00-6.00).

There are several guidelines and standards given by Environmental Protection Agency (EPA), U.S. Department of Defense-Hearing conservation program (DOD-HCP), International Labour Organization (ILO), The Committee on Hearing, Biomechanics and Bioacoustics (CHABA), Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) for governing the effects of exposure to noise. OSHA (1982) recommends an exposure limit of 85 dB(A) for sixteen hours per day, and a 5-dB time-intensity tradeoff. To every given 5 dB increment in noise level, the permissible time to noise exposure is reduced by half and for every 5 dB decrement in noise level, the permissible noise exposure time is doubled. Similarly, NIOSH (1998) permits an exposure of 85 dB(A) for 8 hours per day, and uses a 3 dB time-intensity tradeoff.

Although a damage risk criterion has been formulated by OSHA and NIOSH, it should be noted that, both standards assume noise to be a part of work environment and consider levels of noise in non-occupational setting to be below the hazardous level. However, noise is a transient event which could be present during any time of the day. With advancement in civilization, noise is contributed by various sound sources such as road traffic, construction work and recreational activities which could span from day to night. Although noise is considered as a part of urban soundscape, there is an immediate call for its management, since it conflicts with a person's wellbeing and interfere with his daily routine (Brown & Lam, 1987). Rapid economic growth in developing countries like India has resulted in advancement in urbanization, which poses serious noise problems, with weak conformation to noise regulations contributing to it (Tandel & Tiwary, 2014). Noise could result in potential annoyance and/or hearing loss. With noise induced hearing loss being one of the leading causes of preventable hearing loss (Basner et al., 2014), there is a pressing need for an immediate action to be taken to monitor the noise levels and to keep them within the permissible limits.

Mysuru being the cultural heritage city of Karnataka and a major tourist destination, it attracts increased number of tourists during festivals like Dussehra and otherwise, further increasing the noise levels in the city. Hence, the current research was taken up to measure environmental noise levels in Mysuru city and to identify the areas with noise levels exceeding the permissible limits during festivals like Dussehra and Deepavali, and otherwise.

1.2. Objectives.

1. Identification of the areas to be mapped in the city.
2. Measurement of noise levels of the identified areas at four different time frames spanning day and night.
3. Measurement of noise levels during two major festivals in Mysuru city, namely, Dussehra and Deepavali.
4. Comparison of noise levels across different categories of areas as categorized by Environmental Protection Act (1986)and identification of the areas exceeding the permissible noise limits.
5. Generation of Isopleth maps with the data obtained.

1.3. Noise Mapping.

European Union Directive 2002/49/CE20 (2002), was prepared to address issues of environmental noise, where standards related to assessment and management of environmental noise were formulated with the target of bringing about control and reduction of sound pollution using a standard procedure and preventing the adverse effects brought about by noise exposure (Coelho & Alarcâo, 2006).

Noise mapping could be used as an excellent tool to regulate the noise levels in the community. A noise map is employedto assess noise levels in a particular area resulting from various sources like building constructions, traffic and recreation. The noise map shows the spatial distribution of noise levels in the environment. Color coding could be used to represent the level of noise and how it varies across the areas. Identification and determination of areas which are exposed to high level of noise could be done using noise mapping(Kluijver& Stoter, 2003). Using noise maps the number of citizens who are at risk of being affected by noise exposure can be determined.

Noise maps generated could be used to illustrate the level of noise in different zones, quantify the main source of noise, monitor changes in environmental noise, locate major source of noise, and provide reference for noise reduction measures and policy makers, to identify population at risk and to create public awareness (Tandel&Tiwary, 2014).

Although, several software such as LimA, CadnA, Sound PLAN, Predictor and FAA can be used for generation of noise maps, GIS has been widely used in many studies (Iaaly-Sankari, Jadayel and El-Murr, 2010; Palamuleni, 2015; Tandel & Tiwary, 2014; Lee et al., 2014). GIS is a computer based system which enables the user to collect, store, analyze and present the data spatially. As noise as a phenomenon, involves spatial distribution and is dynamic in nature, it requires a dynamic system for spatial representation of data which is supported aptly by GIS. Information can be categorized and stored in separate layers in the GIS system. Noise data obtained through the measurement process can be stored as a separate layer and can be overlapped on the existing geographical information. Tools are provided in the GIS for data storing and retrieving, transformation and representation of spatial data from the real world for a dedicated purpose (Burrough, 2015). Manipulation of data at different stages of the process can be easily tracked down using cataloguing and metadata management system of GIS (European Commission Working, 2006). These include changes in input data, interpolation techniques, calculation formulas and settings and other such factors, which potentially power the precision of the results. Visual representation of noise effects is facilitated in GIS and interpolation techniques to generate noise contours are available. Therefore, GIS is considered as a potential tool to investigate the possible effects of noise pollution.

Two approaches are being followed to develop noise maps. One is to make direct measurement of noise level for selected sites and create a map by the interpolation method. On field measurements include measurement of level of noise at the site of noise source using sound level measuring devices. It involves identification of locations, calibration and setting up of instruments, specifying duration and time frames for noise measurement. The other approach is to model noise levels by giving noise emission, propagation and reception data. Generation of noise map through calculation procedure calls for a lot of database such as noise emission data, propagation data, reception data and development of geographical model of area under the study. Various specifications have been given such as RLS 90, NMPB, CRTN, etc. for predicting level of noise through calculation procedure. Rather than stopping at the level of prediction, comparison of predicted levels are often carried out with the measured level of noise. This is done for the purpose of validation of the model. Although noise maps based on measurement procedure have been commonly used in the past, calculation methods are now being adopted widely for generation of noise maps. Review related to the study could be discussed under international and national headings.

1.3.1. International status. Obaidat (2008) measured the level of noise due to traffic conditions in the city of Jordan and map the same using GIS. Recordings were carried out at signal junctions, between signal junctions and neighborhood around the signal junctions totally at 27 locations. Measurements were carried out during three time frames: morning (07:30 to 09:00), afternoon (13:30 to 15:00) and evening (21:00 to 23:00). Noise levels were measured with the help of calibrated SLM and the distance between measured points varied from 50-100 meters. Three recordings were carried out at each location and averaged values were considered. Contour maps and spatial distribution of noise data was mapped using Arcmap GIS software. Noise levels of up to 80 dB were recorded at some signals, while the lowest was 34 dB. Noise levels exceeding the prescribed standards were noted at few signal intersections across all three time frames. The obtained data were spatially displayed on a two dimensional noise map. Authors conclude that based on such maps, level of noise for a location of the study area at any point of time could be visualized and are useful for city planners to know the boundary of annoyance noise levels in any of the land use patterns.

Iaaly-Sankari, Jadayel and El-Murr(2010) measured the noise levels in the city of El-Mina, North Lebanon. Study was carried out with an aim of generating noise map of the city, extent of perception of noise as a problem and to identify the noise source having greatest effect. The noise measurement was carried out at 350 locations within an area of 3.5 km². Distance between two measurement points varied from 50 to 150 meters depending on the population density. Measurement of noise was carried out at interval of 5 minutes for eight hours in a day at each measuring point and the average value was considered for GIS calculations. A survey was carried out using a questionnaire regarding the effect of noise on people. Geographical location of the measurement point was recorded using GPS. The obtained data was mapped onto GIS. A spatial database was developed containing information on noise level, noise source and impact of noise. Inverse Weighted Distance (IDW) technique was employed for surface interpolation of the noise levels.

Results of the present study revealed noise levels at around 68% of measured points to be in excess of 70 dB (A) which is greater than globallyrecognizedacceptable range of 60-70 dB (A). All questioned individuals in the current study were annoyed by the noise, which affected each individual differently. It was concluded that road traffic noise was the major cause of noise pollution.

Law, Lee, Lui, Yeung and Lam (2011) outline the development of advanced 3D GIS tools, information technologies and implementation of the same for the purpose of noise mapping in Hong Kong. 2-D noise mapping was inadequate in effectively portraying the noise environment in Hong-Kong due to complex terrain of the city which has close proximity of tall and differently structured buildings and complex road patterns. Hence, the 3D GIS information and computer graphic technologies were employed to present the noise levels at building facades of 3D noise mapping. French GBTT source and 'Calculation of Road Traffic Noise' (CRTN) models were employed for the calculation procedure. A 3-D digital terrain model of Hong-Kong city was developed and necessary source emission and propagation data were updated into the model. 3-D computer graphic technologies were incorporated which would create a virtual environment and allow the viewer to walk or fly through the environment and visualize the level of noise at any user defined locations. The output obtained from the model was compared with the measured values of noise levels for the purpose of verification and results showed that 90% of the predicted data fell within ±3 dB (A) of the measured values indicating a good validity. Application of 3-D information makes it more convenient for users to comprehend the noise scape better. Accuracy of the modelling results and the efficacy in the communication of noise mapping results are enhanced.

King, Roland-Mieszkowski, Jason and Rainham (2012) assessed the effect of land use pattern on the level of noise in the environment. For the purpose of the study, two areas in Halifax Regional Municipal Corporation, city of Scotia were selected. One area was exclusively residential (Area 1), while the other had a mixed commercial-residential land use pattern (Area 2). Both the study areas were divided into 6 identical cells with the help of GIS. Noise recordings were carried out at each cell for a duration of 45 minutes at four different time frames namely morning (06:00–12:00), afternoon (12:00–18:00), evening (18:00–24:00) and night (24:00–06:00) leading to an overall measurement duration of 3 hours.

Noise measurement was carried out using a Center 322 Logging SLM and a Marantz PMD-660 Solid State Digital Recorder. The SLM and sound recorder were placed at a height of 1.5m from the ground level with the help of tripod stand. The noise recording was averaged at every one second and the results were computed in terms of equivalent continuous sound pressure level in dB (Leq) and day–evening–night composite whole-day rating level (LRden) values. Results of the present study indicated that Leq values ranged from 44.70 - 76.80 dB (A) in the exclusive residential area, whereas that in mixed commercial-residential area varied from 55.40 - 72.20 dB (A). A greater variability in Area 1 was noted compared to Area 2 which was attributed to variation in the traffic flow in Area 1 and greater level of continuous background noise in Area 2. It was concluded that both the study areas exceeded the noise limit when compared against WHO guidelines.

Noise mapping study was carried out by Akintuyi, Raji, Adewuni and Wunude (2014), where a GIS based assessment and mapping of noise pollution was carried out in Nigeria. Measurements were carried out at 31 different locations classified under residential, commercial, educational and traffic land use patterns. Noise recordings were carried out during three time frames namely: morning, afternoon and evening. Across all the land uses, lowest daily average of noise ranged between 67.2 dB(A) and 76.7 dB(A). Among the land use patterns, lowest values were recorded in residential areas while higher values were detected in commercial and traffic areas. The computed noise index showed that all the area covered in the study had high index of above 55 dB(A) when compared with WHO standard. Thus, a strict design of noise index was called for, for the safety and sustainable environmental development.

Lee et al (2014) assessed road traffic noise exposure in the metropolitan Seoul, Republic of Korea. Noise levels in the city were modeled using SoundPLAN V.7.1 software. Topographical data and road traffic data were fed into the NMPB model to predict the level of noise. The population exposed to noise was calculated using 3-D façade noise map which estimated the exposed population using average residential area per person. Findings of the present study were compared with major cities in EU. Results indicated that the average percentages of the population being exposed to exceeding daytime and night time noise standards in Seoul and the EU were 16.6%/34.8% and 13.0%/16.1%, respectively.

Zannin and Bunn (2014), measured noise levels generated by passing trains in the residential area of city of Curtibia. A calibrated Sound level meter (B & K 2270, Type I) was used to measure Laeq, LAFmin and LAFmax in ten locations identified as measurement points. Noise levels were measured at the railroad crossing and also inside the home of the neighborhood residents in three conditions: Train passing without honking, train passing blowing the horn and ambient noise levels in the absence of passing train. Along with this, noise levels generated by train were simulated by using 'Soundplan' software. Interview survey was carried out to assess the annoyance caused by the noise levels generated. Results indicated that, noise levels in the measured points clearly exceeded the prescribed limit of 55dB(A) and 45dB(A) for day time and night time frame respectively. Irritability, sleep disturbances, inability to concentrate and headache were the major negative reactions noted in the noise exposed residents and the severity aggravated during night time. Difference between the measured and calculated noise levels were below the prescribed limits of 4.6dB.

Palamuleni (2015) measured the noise levels in Ibadan and Ile-Ife city of Nigeria and evaluated the relationship between level of noise and land use pattern. Noise levels were measured using android mobile phones equipped with a calibrated noise meter. Measurement was carried out for 10 minutes with 30 sec intervals in A-weighted frequency network. A total of 20 recordings were obtained at a particular location and this was repeated in three time frames namely: morning (07.00 - 09.00), afternoon (12.00 - 14.00) and evening (17.00 - 19.00). The noise measurements were carried out at 20 different locations categorized under commercial, residential, educational and transportation land use type. Results revealed noise levels to higher than the prescribed limits in both the cities. The obtained results were also studied to see the relationship between level of noise and the land use pattern. Greater level of noise was noted in transportation sector in the city of Ibanda, whereas, in Ile-Ife, commercial land use had greater level of noise. A statistically significant relationship [F(3,34) = 15.13, $p = 0.000$] was noted between land use type and level of noise.

Karina, Maria and Rui (2015) conducted a cross sectional study to evaluate the effect of exposure to noise in six urban soundscapes: areas exposed to high and low level of noise in the situations of work, leisure and home. The study involved measurement of noise level with generation of noise maps followed by health related enquiries on 180 individuals. 60 individuals assigned to each scenario were divided equally into two groups: one being exposed to high level of traffic noise and the other being exposed to lower levels. The study was conducted in city of Porto. Noise maps were developed to assess the level of exposure to noise in both the areas. Noise maps were based on Lden indicator for work and leisure scenario and home scenario was indicated by Ln (overall level of annoyance). Development of noise map was a three stage process: preparation, modeling and calibration. In the preparation stage, identification of noise source, measurement and counting. The soundscape modeling was carried out with the help of Cadna-A software and Lden and Ln were computed as per calculations prescribed in Road traffic noise prediction (NMPBRoutes-96). Validation of the predicted levels by the software was carried out in calibration stage by comparing with the measured levels of noise in the area. Measurements were carried out with the help of calibrated SLM placed at height of 1.20 meters from the ground level. Noise was recorded for 20 minutes in each of the three periods:

morning, evening and night. The difference between Leq measured and obtained was less than 4.6 dB.

In the further part of the study, evaluation of perception of noise source and the annoyance was carried out in all three scenarios. Results showed that, in the scenario of leisure time 65% of interviewees mentioned perception of noise source among which 20% reported presence of annoyance. No statistically significant association between exposure to noise, perception of noise and annoyance. Noticing of noise source in work environment was reported by 85% of the interviewees out of which 48.3% reported of annoyance. Statistically significant association was noted between noise exposure and perception of noise source (p=0.01) and also for annoyance due to noise source (p=0.07). Among the interviewees 60% reported noticing of noise source among which 56.7% reported of annoyance. Statistically significant association was noted between exposure and considering home a noisy location and also for annoyance due to noise source. Authors concluded that, the study carried out enlightens the information on relationship of urban noise with non-auditoryeffects on health and factors that are associated with annoyance, by assessing the exposure to urban noise in different scenarios.

1.3.2.National status. Chakrabarthy, Santra and Mukharjee (1997), measured road traffic noise level in the city of Calcutta. Measurements were carried out in 24 traffic junctions during morning (7 a.m. to 10 p.m.) and night (10 p.m. to 7 a.m.) time frames. The measurement points were classified into five zones depending on the land use patterns: Residential, commercial, residential-commercial, residential-industrial and office complex. A calibrated SLM (SL-4001) was used to carry out A-weighted SPL measurements in selected points. A total of 1800 recordings were carried out during morning time frame with an interval of 30seconds. Similarly, 1080 recordings were carried out during night time. At each location, microphone was placed at a height of 1.2m from the ground level and at a distance of 1m from façade of building. Following noise indices were computed at all the measurement sites: LAeq, Ldn, TNI and exceedence levels. Results of the present study indicated noise levels to be exceeding the prescribed limits in all the measurement locations. The increased noise levels were attributed to poor town planning and poor lane discipline.

Banerjee, Chakraborty, Bhattacharyya and Gangopadhyay (2008),measured level of road traffic noise in Asansol town of East India. 35 locations were selected in the city to measure the noise level. The study area was classified into residential, commercial, industrial and silence/sensitive zones based on the land use pattern. A Type 2 Digital Sound Level Meter (SLM), with a frequency range of 31.5Hz to 8000 Hz and measuring range between 0 - 150 dB, was used for the study. Calibration of the SLM was carried out using a 'B & K' (Bruel&Kjaer) acoustic calibrator (Model: 4226). Microphone was placed at a height of 1.5 meters from the ground level and all the recordings were done using 'A-Weighting' frequency network, and time weighting kept at 'fast' mode. All the noise measurements were recordedon working days and under appropriateweather conditions. The following Noise Indices were computed for analysis: LAeq (Hourly A-weighted equivalent sound level), Ldn (Day-Night average sound level), Lmax and Lmin.

Isopleth maps were generated for the data obtained. From the noise level assessment carried out in the study, it was evident that the level of noise was higher than the recommended standards in all the four different land zones. The authors conclude that noise emission and transmission depend on landscape, geographical features and topography. Further, possible suggestive control methodologies are prescribed to monitor the level of noise.

Goswami (2009), measured levels of road traffic noise in the city of Balasore, Orissa. A calibrated sound level meter was used for the purpose of noise measurement. Locations identified for the purpose of noise measurement were of residential and commercial types. Totally, six locations were identified. Measurements were carried out at four different spots in each of the locations. And at each spots, measurements were obtained for 16 times during day time. The levels of noise measured at all the measurement points exceeded the prescribed standard for road traffic noise of 70dBSPL. Exceedence of noise levels in the city has been attributed to increased traffic flow in the city with two wheelers being the major contributors.

Bhosale, Late, Nalwade, Chawan and Mule (2010) measured traffic noise levels in Aurangabad city. Six different locations were identified and noise levels were measured during peak hours (Morning: 8.00-11.00, Afternoon: 13.00-16.00 and Evening: 17-20.00 hours) in both working days and holidays. LAeq, LAFmin and LAFmax levels were measured at all the measurement points. Results indicated that the noise levels measured at all the points were greater than 75dBSPL, clearly exceeding the prescribed limit by CPCB. Although not significant, greater level of noise was recorded during evening time frame followed by morning and afternoon peak hours. It was also noted that noise levels were higher during working days when compared to non-working days with differenced being up to 2-3dBSPL. Vehicular traffic was identified as the significant contributor to the noise levels.

Kalaiselvi and Ramachandraiah (2010) carried out noise mapping study in the city of Chennai, India. Data was obtained through calculation and measurement procedures. Correlation analysis was carried out among the same for validation. In the calculation method applied, a road traffic noise model was built for three-dimensional digital representation of noise levels associated with emission, propagation and reception of traffic noise. The emission data (vehicle flow rate, percentage of heavy vehicles, etc.), propagation data (distance between receiver and source, characteristics of propagation surface, etc.) and reception data which included location, height and angle of impact of receiver were built into the model. The area selected was modeled in accordance with the methodology prescribed in RLS 90 specifications. The RLS 90 specifications rate the level of noise at the location of the receiver for day (06.00 - 22.00) and night (22.00 - 06.00) time frame to evaluate the impact. Point source method is employed in RLS90 and takes into consideration ground attenuation, screening and reflection. The standard is made up of two separate models namely source model and propagation model. Traffic data is updated in the source model which predicts the reference level of noise at a distance of 25 meters and four meters above the ground. Average emission for day and night and noise levels calculated in previous phase is considered as an input for propagation model. Noise maps were generated using other specifications such as Calculation of Road Traffic Noise (CRTN), Federal Highway Administration (FHWA) and Statens Planwerk.

For field study and data collection 6 locations were considered for measurement. Norsonic SLM was placed on a tripod at a height of 1.2 meters above the ground level and the measurement was carried out. Measurement duration was for 15 minutes and data was obtained during both working and non-working days. Results of the present study showed a difference of about 10 dB(A) with measured noise being greater than calculated levels. A correlation value (R^2) of 0.847 was obtained. Authors attributed the difference, to the assumption of homogeneity of traffic conditions in the standards prescribed, which is not the case in the city of Chennai. With greater variability in dimensions of vehicles, heterogeneous traffic conditions and lack of lane discipline, honking becomes inevitable leading to greater noise in the environment.

Wani and Jaiswal (2010), assessed noise levels in the city of Gwalior, Madhya Pradesh. A calibrated sound level meter SL4010 was used for the purpose of noise measurement. The measurement sites included of residential, commercial and sensitive areas and at each point, a total of six recordings were taken and averaged. At each site, six recordings were taken at an interval of 45minutes. LAeq, LAFmax and LAFmin were computed for the analysis. The obtained values were compared to the standards prescribed by the Central Pollution Control Board. Results revealed a higher level of noise in all the land use types considered under the study with greater levels of noise being noted in commercial land use type. Increase in noise levels in the city has been attributed to increased traffic flow in the city ranging from two wheelers to trucks. Various mitigation measures have been suggested by the authors to keep the noise levels within the prescribed limits.

Tandel and Tiwary (2014), measured noise levels at different locations in the city of Surath, in morning (9.30 a.m. to 12.00 p.m.), afternoon (2.00p.m. to 4.00p.m.) and evening (5.30 p.m. to 8.00p.m.) time. Measurement was carried out only during working days. ArcGIS software was used to map the obtained values for data representation. Results indicated that greater than 30% of the study zone was susceptible to high levels of noise (79 dB(A)-86 dB(A)), 40% area was having modest noise levels (73 dB(A)-77 dB(A)) and around 30% area was open to lower levels of noise (60dB-65 dB). Levels of noise higher than 50dB(A) were noted in sensitive zones in all the time frames. The noise levels exceeded the prescribed norms in all the major roads in all the time frames. Noise levels exceeded the limits in all the minor roads as well during morning and afternoon time frame posing threat to wellbeing of the city dwellers.

Ambika, Nitesh and Payal (2015) conducted a study to noise map the roads of Mumbai City. A calibrated sound level meter was used to measure noise levels at different places in the city. Noise levels were recorded by pointing the microphone towards the ongoing traffic. Average, minimum and maximum levels were recorded at each of the site. The data obtained was used to segregate the city into different noise sectors. The authors calculated the Leq, noise pollution levels and the noise climate and cartographic maps were used to display the data. Results revealed the noise levels to be beyond 80dBSPL in all the measurement points clearly exceeding the prescribed noise limits. Greater levels of noise were attributed to the thick density of the traffic flow. The authors suggested that increasing public awareness is required to keep the noise levels within check.

In India, noise mapping is a fairly new concept with very few studies aiming to identify the areas with noise levels exceeding the permissible limits and its management. Measuring noise levels at the city level and plotting the noise maps throws light on the hazardous areas causing noise pollution and the population most affected by noise exposure, so that they can be catered to with immediate effect. From the above review of literature, it has been found that the noise levels in most Indian cities exceed the permissible limits as prescribed by Central Pollution Control Board and Ministry of Environment and Forest, Govt. of India, 2012 (Naik&Purohit, 1999;Mohan, Dutta & Sarai 2000; CPCB, 2012; Ambika& Payal, 2012).

With Mysuru, being one of the major tourist attractions in the country, the authorities shall focus on keeping noise levels in the city within the prescribed limits.

However, there are no scientific studies carried out measuring the noise levels in the city across different land use patterns. A scientific study of the prevailing noises would help the authorities to chalk out an action plan. Such a study would also help to create awareness among the citizens in the respective areas, so that they can also contribute to the cause of reducing noise pollution.

Chapter II

Method

The current research was carried out with an aim to measure noise levels across different land use patterns in the city of Mysuru during morning, afternoon, evening and night time frames, representing the same using Isopleth maps and comparing the noise levels measured with the prescribed noise standards.

2.1. Material.

(i) Sound level meter (B & K model 2270) with wind shield
(ii) Tripod stand
(iii)SLM Calibration unit (Piston phone)

2.2. Procedure.

The study was conducted in following three phases:

2.2.1. Phase I: Identification of various areas in Mysuru city to be mapped. Mysore is situated at 76°12' (East) longitude and 12°18' (North) latitude. It is the second single largest city in the state of Karnataka, with an average population about of 887,446 as per 2011 provisional census figures. The city has a healthful weather and the temperature varies from 12° C to 35° C. It has an average annual rainfall of about 798 mm. The city is spread out across an area of 128.42 sq. kms. (Shankar & Vidya, 2013).

The study area was confined within the outer ring road as this covers all the major roads of Mysuru city, areas near railway tracks, residential areas, commercial areas, and silent zones. Equidistant allocation of measurement point within the study area was carried out with the help of ArcGIS Desktop software. This yielded a total of 216 points in the study area with distance between two measurement points being approximately 500 meters. The identified measurement points were coded with numbers for the purpose of noise mapping. Longitude and latitude of all the measurement points were noted down. The study areas were classified into respective categories (Residential, Commercial, Industrial, Sensitive and Mixed commercial residential) based on local land development authority’s definition of land use patterns. Areas up to 100 meters around premises such as hospitals and educational set ups are referred to as ‘Sensitive zones’ (EPA, 1986). Area No.22 was not considered for the purpose of noise measurement as entry to the area was restricted during night hours (within the university campus). Majority of the industrial set up in the city is established outside the outer ring road. Number of measurement points in industrial category was very minimal (5 Nos.) whenonly the areas within the outer ring road were considered. Hence, Hootagalli industrial area and Hebbal industrial area were considered for noise mapping although they were located outside the ring road. Radial distance of Hootagalli industrial area and hebbal industrial area from outer ring road is approximately 2.0 and 1.5 KMs respectively. Once again, equidistant allocation of measurement points was carried out with two measurement points being approximately 500 meters apart. This yielded additional 19 points, summing up to a total of 235 measurement points. Details are as follows: Residential

– 83, Commercial – 48, Sensitive – 30, Mixed commercial residential – 50 and Industrial – 24. Permissions were obtained from the concerned authorities to measure the ambient noise levels in various public places. Longitude and latitude of all the measurement points were entered into ‘Google Earth’ by giving colour code to each category for categorical representation of measurement points (Figure2.1).

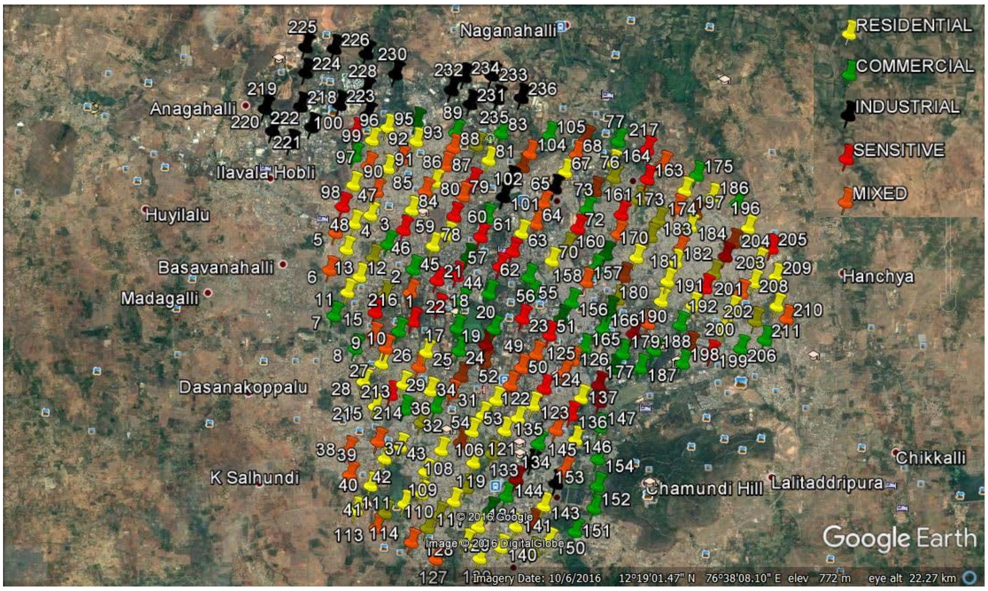

Figure 2.1. Categorical representation of measurement points.

It could be seen from the above figure that, the majority of the land in the city has been devoted for residential purposes. Commercial areas were majorly concentrated in the city center whereas, major industrial set up was outside the outer ring road. Residential, sensitive and mixed land use types were spread throughout the city.

2.2.1. Phase II: Noise measurement in the identified areas. All the measurements were carried out during working days and under suitable weather conditions, in following time frames: Morning (07:00-12:00hrs), Afternoon (12:00-17:00hrs), Evening (17:00-22.00hrs) and Night (22.00-23.00hrs) & (04.00-07.00hrs). The measurement during the above mentioned time frame was carried out using a calibrated sound level meter (SLM) mounted on a tripod stand with the microphone placed at a height of 1.5 meters from the floor of the measurement loci. A Brüel&Kjær type 2270 was employed which is a class I SLM (tolerance level of ±0.7dB) which performs sound intensity measurements as per IEC61043 standards with a frequency range of 4.2 Hz to 22.4 KHz and measuring range of 16.6 to 140.6 dB(A). All the measurements were carried out using 'A' weighting network and in 'fast' mode response as this is simulated as 'Human ear listening response' (Banerjee et al, 2008). A wind shield was used to cover the microphone during noise measurement and appropriate corrections were employed. The following noise indices were computed: LAeq, LAFmax, LAFmin and Exceedence level L90.

LAeq gives the average level of noise over measured period of time. The value at L90 indicates that, the noise levels were higher than the obtained L90 value for 90% of the time, giving information about general background activity of the area under concern.LAFmin and LAFmax gives information about the minimum and maximum noise levels recorded during the measurement period. The L_{eq} (Level Equivalent), LAF_{max}, $LAF_{min\ and}$ L90 was measured over the period of the above mentioned time frames. For each of the time frame, measurement was done at a site for a duration of 15 minutes and the same was repeated for three times, which later was averaged to obtain final average values for that particular time frame. Similarly, measurement was carried out at four different time frames at each of the measurement points. (A total of 12 recordings in each point. Three measurements in each of the time frame: morning, afternoon, evening and night, thus yielding a total of 2820 recordings).

2.2.1. Phase III: Generation of Isopleth noise maps and noise report. Isopleth map refers to a colour coded map where in different colours indicate different noise levels present in various areas of the city under the study. Here, information on noise levels is super imposed as a layer, on the existing geographical map which could be used to visualize the level of noise in different parts of the city.

Step 1: Coordinates (Longitude and Latitude) of all the measurement points were entered into the base map, which is the Local Planning Area (LPA) boundary of the Mysuru city using ArcGIS software.

Step 2: Data on average noise levels (LAeq) in dBSPL at each of the 235 measurement points was fed into the ArcGIS. This procedure was repeated for all the four time frames. Therefore, each measurement point on the map contained information regarding geographical coordinates and average noise levels.

Step 3: As noise measurements were carried out only at predetermined points, surface interpolation was employed to predict noise levels at non measured locations. The surface area of the map was divided into many grid cells. Surface interpolation uses all or a defined set of samples to estimate the final output of each grid (Iaaly, Jadayel,&Murr, 2010). Kriging interpolation method was used to map the noise levels where noise levels at known points influenced the interpolated values depending on the distance from the output point.

Following formulae was employed for Kriging interpolation:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where:

$Z(s_i)$ = the measured value at the *i*th location

λ_i = an unknown weight for the measured value at the *i*th location

s_0 = the prediction location

N = the number of measured values

Average level of noise obtained at each of the land use types was compared to prescribed standards given byEPA (1986).

2.3. Noise level measurement during Dussehra and Deepavali.

For the purpose of noise measurement during Dussehra, 15 different locations were identifiedwhich included city's major roads, Dussehra procession path and measurement points near major tourist attraction spots such as Mysuru city palace, Zoological garden and food exhibition. LAeq, LAFmax, LAFmin and L90 were measured at all the 15 sites during morning, afternoon and evening time frame. Noise level measurement in night time frame was not carried out as no Dussehra related events would be occurring during this time frame. Procedure as explained in the previous section was employed for the purpose of noise measurement. Averaged values were obtained for each of the time frame. A total of 135 recordings were obtained for this purpose (3 recordings in each time frame for 15 points: 15x3x3=135). Similarly, noise measurements were carried out in these 15 points during non-Dussehra time (135 recordings). The values obtained during Dussehra were compared with the values obtained in same measurement points during non-Dussehra time of the year as to study the increase in noise levels due to Dussehra.

Noise measurements were carried out in the city during the time of Deepavali. 27 different residential points across the city were considered for the purpose of data collection. These points were selected from the previously identified residential points. Previously mentioned measurement procedure was employed for noise measurement. Same noise indices were measured during the evening time frame. As bursting of crackers is prohibited during night time (22.00-06.00hrs) in the city, and crackers would majorly be fired during evening times, measurements were compared only for evening time frame. Noise levels measured in these residential areas during non-Deepavali time were compared to those obtained during the time of Deepavali to study the increase in noise levels due to the occasion. A total of 81 recordings (27x3) were obtained during Deepavali and previously obtained recordings in these residential points served as the control.

2.4. Statistical procedures.

Data obtained for all the conditions were tabulated.Statistical Package for Social Sciences (SPSS), version.20 was employed to carry out descriptive and inferential statistics. Prior to the inferential statistics, the data were checked for the assumptions of parametric statistics. The normality of distribution was tested using Shapiro-Wilk test and Levene test was carried out to assess homogeneity of variance. Depending on the results of the above tests, appropriate statistics was chosen for data analysis.

Chapter III

Results

The current study was carried out with the aim of measuring noise levels in the city of Mysuru across different land use patterns at four different timeframes. It was also intended to study the effect of occasions such as Dussehra and Deepavali on measured noise levels. Results of the present study are discussed under the following headings.

3.1. Measurement of noise levels of the identified areas at four different time frames.

Prior to the inferential statistics, the data were checked for the assumptions of parametric statistics. The normality of distribution was tested using Shapiro-Wilk test. Results showed non-normal distribution of data in majority of the conditions ($p<0.05$). Levene test was carried out to assess homogeneity of variance and results showed that the variances were significantly different ($p<0.05$) indicating that assumption of homogeneity of variance was violated. Hence, non-parametric statistics was chosen for analysis.

Results of noise levels measured in all five categories and in four different time frames were subjected to descriptive statistics to obtain the mean and standard deviation (SD). The same is tabulated in the Table 3.1. From the table, it could be noted that greater levels of noise were recorded in commercial areas, followed by mixed, sensitive and industrial areas. Least amount of noise was recorded in residential areas. This trend was observed for all the noise indices measured in all the four different time frames. LAeq, LAFmax, LAFmin and L90 did not vary greatly as a function of time of measurement for morning, afternoon and evening time frame.

However, a clear and drastic reduction in noise levels was noted during night time frame and this trend was observed to be present in all the land use categories.

Average noise levels in different land use types across all the time frames are represented in Figure 3.1.

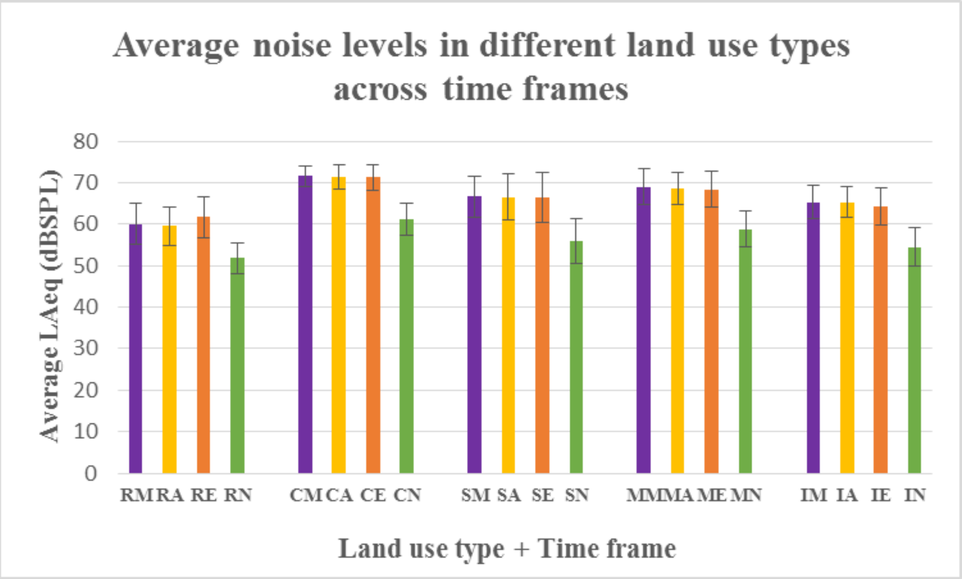

Figure 3.1. Average noise levels (LAeq) in the city of Mysuru across different land use types at four different time frames.

Note: RM: Residential Morning, **RA:** Residential Afternoon, **RE:** Residential Evening, **RN:** Residential Night, **CM:** Commercial Morning, **CA:** Commercial Afternoon, **CE:** Commercial Evening, **CN:** Commercial Night, **SM:** Sensitive Morning, **SA:** Sensitive Afternoon, **SE:** Sensitive Evening, **SN:** Sensitive Night, **MM:** Mixed Morning, **MA:** Mixed Afternoon, **ME:** Mixed Evening, **MN:** Mixed Night, **IM:** Industrial Morning, **IA:** Industrial Afternoon, **IE:** Industrial Evening, **IN:** Industrial Night.

Table 3.1.

Mean and standard deviation of LAeq, LAF min, LAF max and L90 for different land use patterns across four time frames

		LAeq (dBSPL)				LAFmin (dBSPL)				LAFmax (dBSPL)				L90 (dBSPL)			
	Time Frame	Morning	Afternoon	Evening	Night	Morning	Afternoon	Evening	Night	Morning	Afternoon	Evening	Night	Morning	Afternoon	Evening	Night
Residential (N=83)	Mean	59.96	59.55	61.65	51.75	43.84	41.02	45.41	32.70	84.94	83.91	84.34	74.07	47.52	47.92	49.35	39.32
	SD	4.94	4.65	5	3.66	4.04	3.45	3.87	3.65	5.93	5.85	6.32	5.43	4.61	4.38	5.28	3.67
Commercial (N=48)	Mean	71.64	71.42	71.28	61.22	54.81	54.60	55.14	38.53	92.48	93.02	92.25	82.99	61.91	61.33	61.76	46.35
	SD	2.47	2.97	3.09	3.78	4.19	4.30	3.86	6.26	8.53	4.77	4.17	4.31	3.65	3.93	3.41	5.11
Sensitive (N=30)	Mean	66.6	66.43	66.31	55.91	49.07	48.18	48.83	34.83	89.99	89.40	88.46	78.07	57.70	54.81	55.44	42.10
	SD	5.05	5.56	6.01	5.32	5.01	5.04	6.09	3.76	4.37	6.10	6.52	5.09	5.65	6.32	7.13	4.39
Mixed (N=50)	Mean	68.98	68.52	68.4	58.85	49.94	49.73	50.69	36.38	91.86	91.53	90.09	80.16	57.46	56.66	57.73	44.15
	SD	4.24	3.88	4.4	4.4	5.42	5.22	4.62	5.73	4.99	4.50	5.31	4.45	5.88	5.50	4.98	4.74
Industrial (N=24)	Mean	65.25	65.23	64.31	54.45	46.59	45.86	46.38	34.76	87.41	87.48	86.96	76.61	51	51.48	50.80	40.15
	SD	3.99	3.74	4.52	4.56	4.64	4.65	4.18	4.73	4.35	4.33	4.29	5.48	4.72	4.93	4.44	3.75

To study the main effect of land use categories on measured noise levels, Kruskal Wallis test was carried out on all the noise indices across different time frames. For example; LAeq obtained in morning time frame (LAeqM) was compared across different land use patterns (Residential, Commercial, Industrial, Sensitive and Mixed). Similarly, other noise indices were examined to see how they varied across land use patterns. The parameters subjected for examination were: LAeq morning **(LAeqM)**, LAeq afternoon **(LAeqA),** LAeq evening **(LAeqE)**, LAeq night **(LAeqN)**, LAFmin morning **(LAFminM)**, LAFminafternoon **(LAFminA)**, LAFmin evening **(LAFminE)**, LAFmin night **(LAFminN)**, LAFmax morning **(LAFmaxM)**, LAFmax afternoon **(LAFmaxA)**, LAFmax evening **(LAFmaxE)**, LAFmax night **(LAFmaxN)**, L90 morning **(L90M)**, L90 afternoon **(L90A)**, L90 evening **(L90E)** and L90 night **(L90N)**. Category was the grouping variable. Results of the test revealed that all the noise indices measured, varied significantly across land use categories. The same is being represented in Table 3.2.

Table 3.2.

Test statistics for comparison of LAeq, LAF min, LAF max and L90 at different time frames across different land use patterns

Noise parameter	Chi-square (χ^2)
LAeqM	132.13*
LAeqA	138.66*
LAeqE	101.71*
LAeqN	107.41*
LAFminM	125.19*
LAFminA	139.71*
LAFminE	95.30*
LAFminN	34.78*
LAFmaxM	78.48*
LAFmaxA	84.33*
LAFmaxE	59.51*
LAFmaxN	80.93*
L90M	135.48*
L90A	125.97*
L90E	126.20*

L90N	68.19*

*significant at $p<0.05$

As all the noise parameters compared varied significantly across land use categories, Mann-Whitney U test was followed up for pair wise comparisons. A Bonferroni correction was applied to limit the type I error, by dividing critical value of 0.05 by 10 (number of test run for comparison). Hence, all the effects are reported at 0.005 level of significance. Results are tabulated in the Table 3.3.

From the results, it could be seen that residential areas were significantly different from commercial, mixed and sensitive areas for all the noise parameters measured, indicating greater level of noise in these areas compared to residential. Effect size >0.5 is considered as large effect, <0.3 as medium effect (Andy Field, 2009). A large effect size (>0.5) was seen for all the parameters on comparing residential areas with commercial type indicating noise levels to be significantly high in commercial areas compared to residential. However, the difference in noise levels appeared to be comparatively lesser during night time frame. Similar effect size was obtained on comparing residential with mixed type except for LAFmin at night (LAFminN) which showed medium-large effect ($0.3<r<0.5$). Medium effect size was seen for comparison between residential and sensitive type. On comparing residential with industrial areas, significant difference in noise levels was noted for all the noise parameters measured during morning and afternoon time frame except for LAFmaxM. There was no significant difference noted for noise levels measured during other time frames indicating similar noise levels in these two land use types during evening and night time frame.

Significant difference was noted in all the noise parameters measured, except for LAFminN on comparing commercial areas with industrial type indicating greater levels of noise present in commercial areas and the effect of land use type was large (0.5 and above). Similar results were obtained on comparing commercial with sensitive areas where significantly higher level of noise was noted in commercial type for all parameters except for LAFminN and LAFmaxE. Although greater level of noise was seen in commercial for these two parameters as well, the difference was not significant.

Significantly higher levels of noise in following parameters were noted in commercial areas compared to mixed land use types: LAeqM, LAeqA, LAeqE, LAeqN, LAFminM, LAFminA, LAFminE, LAFmaxN, L90M, L90A and L90E. A moderate to strong (0.3-0.5) effect size was seen indicating the degree of effect of land use type to be moderate to strong.

No significant difference in any of the noise indices were noted between mixed land use types and sensitive areas. Similarly, no significant difference was noted for comparison of sensitive and industrial areas indicating similar level of noise in areas considered for comparison.

Table 3.3.

Results of pairwise comparison of various noise parameters across different time frames

Land use category comparison		LAEqM	LAEqA	LAEqE	LAeQN	LAFminM	LAFminA	LAFminE	LAFminN	LAFmaxM	LAFmaxA	LAFmaxE	LAFmaxN	L90M	L90A	L90E	L90N
R	C	U=37 z=-9.33 r=-0.81	U=57 z=-9.24 r=-0.80	U=192 z=-8.59 r=-0.75	U=148 z=-8.80 r=-0.76	U=91.5 z=-9.07 r=-0.79	U=52.5 z=-9.26 r=-0.80	U=189 z=-8.61 r=-0.75	U=892 z=-5.25 r=-0.45	U=451 z=-7.36 r=-0.64	U=416 z=-7.52 r=-0.65	U=543 z=-6.91 r=-0.60	U=337 z=-7.90 r=-0.69	U=40.5 z=-9.32 r=-0.81	U=93.5 z=-9.06 r=-0.79	U=24.5 z=-9.39 r=-0.82	U=526.5 z=-7.00 r=-0.61
	M	U=348 z=-8.02 r=-0.69	U=253.5 z=-8.46 r=-0.73	U=565.5 z=-7.01 r=-0.60	U=454.5 z=-7.52 r=-0.65	U=501.5 z=-7.31 r=-0.63	U=315.5 z=-8.17 r=-0.70	U=793 z=-5.95 r=-0.51	U=1243 z=-3.86 r=-0.33	U=751.5 z=-6.14 r=-0.53	U=617.5 z=-6.77 r=-0.58	U=946 z=-5.24 r=-0.45	U=741 z=-6.19 r=-0.53	U=409.5 z=-7.73 r=-0.67	U=431 z=-7.63 r=-0.66	U=378 z=-7.88 r=-0.68	U=852 z=-5.61 r=-0.48
	S	U=450.5 z=-5.16 r=-0.48	U=383 z=-5.60 r=-0.52	U=673 z=-3.71 r=-0.34	U=683 z=-3.65 r=-0.34	U=352 z=-5.80 r=-0.54	U=334 z=-5.92 r=-0.55	U=835 z=-2.66 r=-0.25	U=836 z=-2.65 r=-0.25	U=613 z=-4.10 r=-0.38	U=639.5 z=-3.93 r=-0.36	U=818 z=-2.77 r=-0.26	U=757.5 z=-3.17 r=-0.29	U=419 z=-5.37 r=-0.50	U=466 z=-5.06 r=-0.47	U=631 z=-3.99 r=-0.37	U=774 z=-3.06 r=-0.28
	I	U=411 z=-4.36 r=-0.42	U=349.5 z=-4.32 r=-0.41	U=719 * z=-2.06 r=-0.19	U=663.5 * z=-2.48 r=-0.23	U=472.5 z=-3.91 r=-0.37	U=371 z=-4.66 r=-0.45	U=862.5 * z=-.99 r=-0.09	U=713.5 * z=-2.11 r=-0.20	U=734 * z=-1.35 r=-0.13	U=633 z=-2.71 r=-0.26	U=809 * z=-1.39 r=-0.13	U=715 * z=-2.09 r=-0.20	U=628.5 z=-2.74 r=-0.26	U=599 z=-2.96 r=-0.28	U=800 * z=-1.46 r=-0.14	U=863 * z=-.99 r=-0.09
C	M	U=710.5 z=-3.47 r=-0.35	U=582 z=-4.39 r=-0.44	U=696.5 z=-3.37 r=-0.34	U=803 z=-2.82 r=-0.28	U=542.5 z=-4.67 r=-0.47	U=537 z=-4.71 r=-0.47	U=558.5 z=-4.55 r=-0.46	U=957.5 * z=-1.72 r=-0.17	U=1019 * z=-1.28 r=-0.12	U=917.5 * z=-2.00 r=-0.20	U=962.5 * z=-1.68 r=-0.16	U=756 z=-3.15 r=-0.31	U=578 z=-4.42 r=-0.44	U=533 z=-4.74 r=-0.47	U=644 z=-3.95 r=-0.39	U=934.5 * z=-1.88 r=-0.19
	S	U=291 z=-4.40 r=-0.49	U=316 z=-4.15 r=-0.46	U=336 z=-3.94 r=-0.44	U=318.5 z=-4.12 r=-0.46	U=264 z=-4.68 r=-0.53	U=226.5 z=-5.06 r=-0.57	U=293 z=-4.28 r=-0.48	U=480.5 * z=-2.46 r=-0.27	U=423.5 z=-3.04 r=-0.34	U=451 z=-2.76 r=-0.31	U=474 * z=-2.52 r=-0.28	U=342 z=-3.88 r=-0.43	U=211.5 z=-5.22 r=-0.59	U=273.5 z=-4.28 r=-0.48	U=347 z=-3.83 r=-0.43	U=392.5 z=-3.96 r=0.44
	I	U=87 z=-5.84 r=-0.68	U=99.5 z=-5.69 r=-0.67	U=129 z=-5.34 r=-0.62	U=147.5 z=-5.11 r=-0.60	U=116.5 z=-5.48 r=-0.64	U=106.5 z=-5.60 r=-0.66	U=86 z=-5.85 r=-0.68	U=387.5 * z=-2.25 r=-0.26	U=177 z=-4.76 r=-0.56	U=193 z=-4.57 r=-0.53	U=217 z=-4.28 r=-0.50	U=215 z=-4.31 r=-0.50	U=36 z=-6.45 r=-0.76	U=65 z=-6.10 r=-0.71	U=24 z=-6.59 r=-0.77	U=183.5 z=-4.68 r=-0.55
M	S	U=531.5 * z=-2.17 r=-0.24	U=535 * z=-2.13 r=-0.23	U=184.5 * z=-1.64 r=-0.18	U=508.5 * z=-2.50 r=-0.27	U=682.5 * z=-.671 r=-0.07	U=652 * z=-.974 r=-0.10	U=604 * z=-1.45 r=-0.16	U=634 * z=-1.15 r=-0.12	U=565.5 * z=-1.83 r=-0.20	U=571.5 * z=-1.77 r=-0.19	U=631 * z=-1.18 r=-0.13	U=589.5 * z=-1.59 r=-0.17	U=530 * z=-2.18 r=-0.24	U=619 * z=-1.30 r=0.14	U=618.5 * z=-1.30 r=-0.14	U=560.5 * z=1.88 r=-0.21
	I	U=293 z=-3.54 r=-0.41	U=325 z=-3.17 r=-0.36	U=392 z=-3.55 r=-0.41	U=299.5 z=3.47 r=-0.40	U=377 z=-2.57 r=-0.29	U=332 z=-3.09 r=-0.35	U=298 z=-3.48 r=-0.40	U=517 * z=-.958 r=-0.11	U=279 z=-3.70 r=-0.43	U=274 z=-3.76 r=-0.43	U=344 z=-2.95 r=-0.34	U=394.5 z=-2.37 r=-0.27	U=231.5 z=-4.25 r=-0.49	U=289.5 z=-3.58 r=-0.41	U=180 z=-4.85 r=-0.56	U=301.5 z=-3.44 r=-0.4
S	I	U=305 * z=-0.95 r=-0.12	U=309 * z=-.88 r=-0.11	U=281 * z=-1.37 r=-0.18	U=300* z=-1.03 r=-0.14	U=263 * z=-1.68 r=-0.22	U=256.5 * z=-1.80 r=-0.24	U=284.5 * z=-1.31 r=-0.17	U=357.5 * z=-0.44 r=-0.05	U=238.5 * z=-2.11 r=-0.28	U=287.5 * z=-1.26 r=-0.17	U=290.5 * z=-1.21 r=-0.16	U=313 * z=-0.818 r=-0.01	U=226* z=-2.32 r=-0.31	U=250 * z=-1.90 r=-0.25	U=220 * z=-2.42 r=-0.32	U=269 * z=-1.57 r=-0.21

* indicates difference not to be significant (p>0.005). Note: R- Residential, C-Commercial, I-Industrial, S-Sensitive, M-Mixed land use type.

To study the effect of time frame of noise measurement on measured noise levels, Friedman test was carried out for each of the land use categories. Comparisons were made in following set: LAeq for morning, afternoon, evening and night (LAeqM, LAeqA, LAeqE and LAeqN). Similarly, it was carried out for LAFmin, LAFmax and L90 parameters in different timeframes. Results are tabulated in Table 3.4.

Table 3.4.

Effect of time frame on LAeq, LAFmin, LAFmax and L90 in different land use categories

Land use category	LAeq (dBSPL)	LAF min (dBSPL)	LAF max (dBSPL)	L90 (dBSPL)
	Chi-Square (χ^2)	Chi-Square (χ^2)	Chi-Square (χ^2)	Chi-Square (χ^2)
Residential (N=83)	135.84*	169.13*	124.23*	138.33*
Commercial (N=48)	86.98 *	82.27*	81.81*	87.45*
Mixed (N=50)	81.56*	81.61*	86.18*	92.61
Sensitive (N=30)	47.16*	54.36*	43.04*	54.28*
Industrial (N=24)	41.35*	39.89*	36.35*	42.03*

*Significant at $p<0.05$

It could be seen from the results of Friedman test that, there was a clear effect of timeframe of noise measurement on all the noise parameters, i.e. LAeq, LAFmin, LAFmax and L90. This was noted for all the land use patterns under the study. Hence, these results were followed by pairwise comparison using Wilcoxson signed ranks test to check among what timeframes did the difference exists for noise parameters. This was carried out for all the five land use categories. A Bonferroni correction was applied to limit the type I error, by dividing critical value of 0.05 by 6 (number of comparison run). Hence, all the effects are reported at 0.008 level of significance.

Table 3.5.

Time wise comparison of LAeq across different categories

*significance at p<0.008

Land use category	LAeqM v/s LAeqA		LAeqM v/s LAeqE		LAeqM v/s LAeqN		LAeqA v/s LAeqE		LAeqA v/s LAeqN		LAeqE v/s LAeqN	
	Z	Effect size (r)	Z	Effect size (r)	z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	z	Effect size (r)
Residential (N=83)	0.95	0.07	2.90*	0.22	7.82*	0.60	3.43*	0.26	7.82*	0.60	7.83*	0.60
Commercial (N=48)	0.79	0.07	0.610	0.06	6.03*	0.60	0.303	0.03	6.03*	0.60	6.03*	0.60
Mixed (N=50)	2.19	0.21	0.950	0.95	6.09*	0.60	0.405	0.40	6.13*	0.61	6.06*	0.60
Sensitive (N=30)	0.10	0.01	0.04	0.005	4.78*	0.61	0.165	0.02	4.67*	0.60	4.74*	0.61
Industrial (N=24)	0.18	0.02	1.100	0.15	4.28*	0.61	1.583	0.22	4.28*	0.61	4.22*	0.61

Table 3.6.

Time wise comparison of LAFmax across different categories

*significance at p<0.008

Land use category	LAFmaxM v/s LAFmaxA		LAFmaxM v/s LAFmaxE		LAFmaxM v/s LAFmaxN		LAFmaxA v/s LAFmaxE		LAFmaxA v/s LAFmaxN		LAFmaxE v/s LAFmaxN	
	Z	Effect size (r)	Z	Effect size (r)	z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	z	Effect size (r)
Residential (N=83)	2.04	0.15	1.07	0.08	7.81*	0.60	0.524	0.04	7.82*	0.60	7.64*	0.59
Commercial (N=48)	0.65	0.06	1.61	0.16	5.53*	0.55	1.40	0.14	5.79*	0.57	6.02*	0.60
Mixed (N=50)	1.15	0.11	2.27	0.22	6.09*	0.60	0.405	0.04	6.13*	0.61	6.06*	0.60
Sensitive (N=30)	0.44	0.05	1.29	0.16	6.11*	0.78	1.62	0.20	6.15*	0.79	6.01*	0.77
Industrial (N=24)	0.14	0.02	0.671	0.09	4.22*	0.60	.371	0.05	4.25*	0.61	4.22*	0.60

Table 3.7.

Time wise comparison of LAFmin across different categories

*significance at $p<0.008$

Land use category	LAFminM v/s LAFminA		LAFminM v/s LAFminE		LAFminM v/s LAFminN		LAFminA v/s LAFminE		LAFminA v/s LAFminN		LAFminE v/s LAFminN	
	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)
Residential (N=83)	3.41*	0.26	5.27*	0.40	7.87*	0.61	6.52*	0.50	7.85*	0.60	7.91*	0.61
Commercial (N=48)	0.79	0.07	1.65	0.16	6.03*	0.60	0.86	0.08	6.01*	0.60	6.02*	0.60
Mixed (N=50)	0.975	0.097	1.829	0.18	6.02*	0.60	2.18	0.21	6*	0.60	6.08*	0.60
Sensitive (N=30)	1.29	0.16	0.175	0.02	4.78*	0.61	0.54	0.6	4.78*	0.61	4.78*	0.61
Industrial (N=24)	1.27	0.18	0.137	0.01	4.25*	0.61	0.829	0.11	4.22*	0.60	4.28*	0.61

Table 3.8.

Time wise comparison of L90 across different categories

Land use category	L90M v/s L90A		L90M v/s L90E		L90M v/s L90N		L90A v/s L90E		L90A v/s L90N		L90E v/s L90N	
	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)	Z	Effect size (r)
Residential (N=83)	1.08	0.08	3.52*	0.27	7.73*	0.60	3.05*	0.23	7.86*	0.61	7.90*	0.61
Commercial (N=48)	1.80	0.18	0.153	0.015	6.03*	0.60	0.603	0.060	6.02*	0.60	6.03*	0.60
Mixed (N=50)	2.47	0.24	0.16	0.01	6.04*	0.60	2.95*	0.29	6.15*	0.61	6.15*	0.61
Sensitive (N=30)	0.216	0.02	1.131	0.14	4.78*	0.61	0.854	0.11	4.78*	0.61	4.78*	0.61
Industrial (N=24)	0.821	0.11	0.143	0.02	4.25*	0.61	1.67	0.24	4.28*	0.61	4.28*	0.61
Industrial (N=24)	0.821	0.11	0.143	0.02	4.25*	0.61	1.67	0.24	4.28*	0.61	4.28*	0.61

*significance at $p<0.008$

As it could be seen from Table 3.5, average noise level LAeq was significantly less during night time when compared with morning, afternoon and evening. A large effect size was seen which was >0.5. No significant differences were noted among morning, afternoon and evening time frame. This trend was observed for all the land use categories except for residential type where LAeq in evening was significantly greater than the LAeq obtained during morning and afternoon timeframe with a moderate effect size (<0.3). And also, like all other categories, noise level LAeq in night was significantly lesser when compared with other time frames. Similar results were obtained for LAFmin parameter as well (Table 3.7).

On studying the effect of time frame of noise measurement on LAFmax values (Table 3.6), it was found that, the LAFmax values obtained during night time were significantly lesser compared to those obtained during morning, afternoon and evening timeframe. A large effect size (>0.5) was noted indicating a clear effect of time frame. However, LAFmax values obtained during morning, afternoon and evening did not vary significantly with each other.

L90 recorded during night time frame was significantly lesser to those recorded during morning, afternoon and evening time. No significant difference among morning, afternoon and evening time frame was noted indicating background activity to be at consistent levels throughout the day. This was true for all categories except for residential and mixed where significantly higher values were recorded during evening time frame when compared with afternoon time frame (Table 3.8). As with other land use categories, L90 during night time frame was significantly lesser compared to other time frames.

3.2. Comparison of noise levels measured during Dussehra and other period of the year (Non-Dussehra).

Data obtained inset for all conditions were tabulated. Descriptive and inferential statistics were carried out. Prior to the inferential statistics, the data were checked for the assumptions of parametric statistics. The normality of distribution was tested using Shapiro-Wilk test. Results showed normal distribution of data in all the conditions ($p>0.05$). Levene test was carried out to assess homogeneity of variance and results showed that the variances were not significantly different ($p>0.05$) indicating that assumption of homogeneity of variance was maintained. Hence, parametric statistics was chosen for analysis. Results of noise levels measured during Dussehra and non-Dussehra in three different time frames, were subjected to descriptive statistics to obtain the mean and standard deviation (SD). The same are tabulated in the Table 3.9.

Table 3.9.

Comparison of noise levels obtained during Dussehra and Non-Dussehra

	Dussehra		Non-Dussehra	
	Mean	SD	Mean	SD
LAeqM	74.92	3.18	72.90	2.37
LAeqA	77.29	4.44	73.30	2.11
LAeqE	80.15	2.32	73.28	2.38
LAFminM	61.24	4.19	59.39	3.07
LAFminA	63.46	4.77	60.44	2.88
LAFminE	66.70	3.27	59.51	3.85
LAFmaxM	93.50	3.56	92.53	4.04
LAFmaxA	96.20	5.30	92.34	5.12
LAFmaxE	99.26	2.89	94.32	3.71
L90M	66.48	3.75	64.19	3.41
L90A	68.91	4.36	65.46	2.32
L90E	71.76	2.80	64.43	3.26

It could be noted from the above table that higher levels of noise were recorded during Dussehra across all the timeframes. All the noise parameters exhibited higher values during Dussehra. During Dussehra, greater levels of noise were recorded in evening timeframe, followed by afternoon and morning. Whereas, during Non-Dussehra period similar levels of noise were noted across all the timeframes. This was true for all the noise parameters under the study (LAeq, LAFmin, LAFmax and L90). Average noise levels (LAeq) across different timeframes are reported for Dussehra and Non-Dussehra in the Figure.3.2.

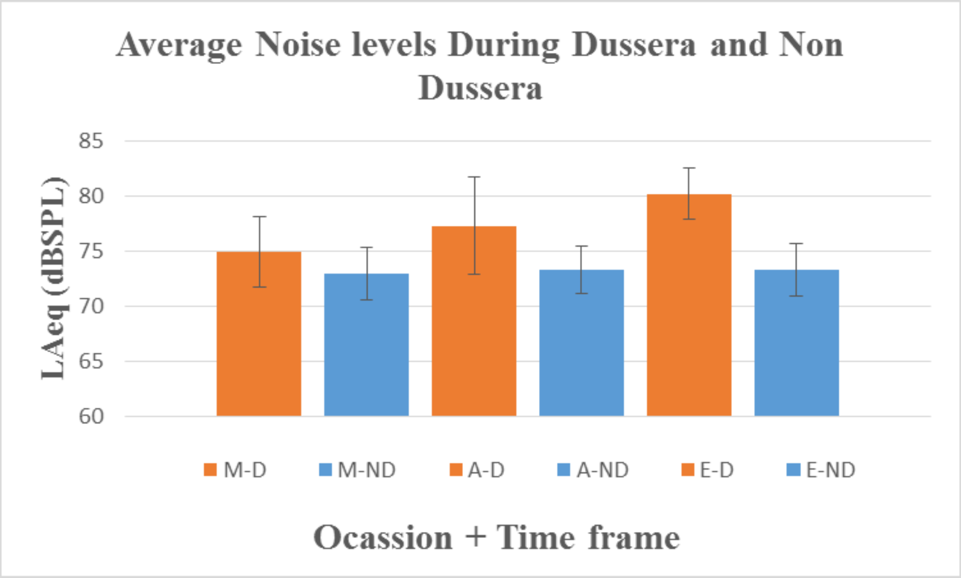

Figure 3.2. Average noise levels (LAeq) in the city of Mysuru during Dussehra and Non-Dussehra at three different time frames.

Note: M-D: Morning Dussehra, **M-ND:** Morning Non-Dussehra, **A-D:** Afternoon Dussehra, **A-ND:** Afternoon Non-Dussehra, **E-D:** Evening Dussehra, **E-ND:** Evening Non-Dussehra.

Repeated measure analysis of variance (R-ANOVA) was conducted with occasion (Dussehra v/s Non-Dussehra) and time frame of noise measurement (Morning v/s Afternoon v/s Evening) as within subject factors for each of the noise parameter (LAeq, LAFmin, LAFmax and L90). Results revealed a significant main effect of occasion and time for all the noise parameters indicating noise levels to be significantly higher during the time of Dussehra.

LAeq: Occasion - $F(1,14)=31.674.p<0.05$, $r=0.693$, Time - $F(2,28)=59.014.p<0.05$, $r=0.536$, Interaction - $F(2,28)=7.843.p<0.05$, $r=0.359$.

LAFmin: Occasion - $F(1,14)=31.916.p<0.05$, $r=0.695$, Time - $F(2,28)=8.242.p<0.05$, $r=0.371$, Interaction - $F(2,28)=7.249.p<0.05$, $r=0.341$.

LAFmax: Occasion - $F(1,14)=7.725.p<0.05$, $r=0.356$, Time - $F(2,28)=10.324.p<0.05$, $r=0.424$, Interaction - $F(2,28)=1.960.p>0.05$, $r=0.123$.

L90: Occasion - $F(1,14)=49.464.p<0.05$, $r=0.779$, Time - $F(2,28)=9.172.p<0.05$, $r=0.396$, Interaction - $F(2,28)=7.335.p<0.05$, $r=0.344$.

It could be noted that, interaction effect was seen for all the noise parameters except for LAFmax.

Given the main effect of time, Bonferroni post hoc analysis was carried out for both the occasions. No significant difference was noted between morning, afternoon and evening time frame during Non-Dussehra for any of the noise parameters. However, a significant difference in noise levels across timeframes was noted during Dussehra. Higher levels of noise were recorded during evening time frame. Results are as follows:

LAeq: Noise levels were significantly different from one another in all the time frame (Morning v/s Afternoon v/s Evening) at $p<0.05$ with evening showing the highest values.

LAFmin: Noise levels in morning was significantly lesser compared to afternoon and evening ($p<0.05$). No significant difference was noted between afternoon and evening ($p>0.05$).

LAFmax: Noise levels in evening was significantly higher when compared with morning and afternoon ($p<0.05$). No significant difference in noise levels was noted between morning and afternoon.

L90: Noise levels in morning was significantly lesser compared to afternoon and evening ($p<0.05$). No significant difference was noted between afternoon and evening ($p>0.05$).

As interaction between occasion and time frame of noise measurement was noted for all the noise parameters except for LAFmax, pairwise comparison between two occasions was carried out across timeframes, so as to see how the difference between two occasions varied significantly as a function of timeframe of noise measurement. Results are tabulated in Table 3.10.

Table 3.10.

Results of Dependent t-test for comparison between Dussehra and Non-Dussehra

Pairs compared	‘t’ value (df=14)	Significance value	Effect size ‘r’
LAeqMD v/s LAeqMND	2.351	0.34	0.532
LAeqAD v/s LAeqAND	2.894	0.12	0.610
LAeqED v/s LAeqEND	8.690	0.00	0.910
LAFminMD v/s LAFminMND	2.086	0.56	0.486
LAFminAD v/s LAFminAND	2.493	0.26	0.554
LAFminED v/s LAFminEND	5.980	0.00	0.847
LAFmaxMD v/s LAFmaxMND	0.610	0.552	0.160

LAFmaxAD v/s LAFmaxAND	1.933	0.074	0.458
LAFmaxED v/s LAFmaxEND	3.578	0.03	0.691
L90MD v/s L90MND	2.777	0.015	0.594
L90AD v/s L90AND	2.959	0.010	0.620
L90ED v/s L90END	7.309	0.000	0.890

Note: MD: Morning Dussehra, MND: Morning Non-Dussehra, AD: Afternoon Dussehra, AND: Afternoon Non-Dussehra, ED: Evening Dussehra, END: Evening Non-Dussehra.

From the table, it could be noted that, a significant difference was seen in LAeq across all the timeframes. However, this difference was more pronounced during evening timeframe (larger effect size). There was no significant difference in LAFmin values between two occasions when measured during morning timeframe. Significant difference in LAFmax values was noted only in evening timeframe. L90values varied significantly across all the timeframes with evening producing maximum difference.It could be concluded that, the noise levels measured during Dussehra was significantly higher when compared with Non-Dussehra time and this difference was more pronounced during evening timeframe.

3.3. Comparison of noise levels measured during Deepavali and other period of the year (Non-Deepavali).

Obtained data was checked for the assumptions of parametric statistics. The normality of distribution was tested using Shapiro-Wilk test. Results showed normal distribution of data in all the conditions (p>0.05). Levene test was carried out to assess homogeneity of variance and results showed that the variances were not significantly different (p>0.05) indicating that assumption of homogeneity of variance was maintained. Hence, parametric statistics was chosen for analysis. Results of noise levels measured during Deepavali and non-Deepavali in evening time frame, were subjected to descriptive statistics to obtain the mean and standard deviation (SD). The same are tabulated in the Table 3.11.

Table 3.11.

Comparison of noise levels obtained during Deepavali and Non-Deepavali

	Deepavali		Non-Deepavali	
	Mean	SD	Mean	SD
LAeq	81.07	8.02	61.87	5.25
LAFmin	46.78	4.50	43.87	3.27
LAFmax	106.73	8.21	85.44	6.96
L90	53.81	6.16	48.55	4.30

It could be noted from the above table that, higher levels of noise were recorded during Deepavali across all the noise parameters. Average noise levels (LAeq) up to 20dBSPL higher was seen during the time of Deepavali. The same is being represented in the Figure 3.3 below.

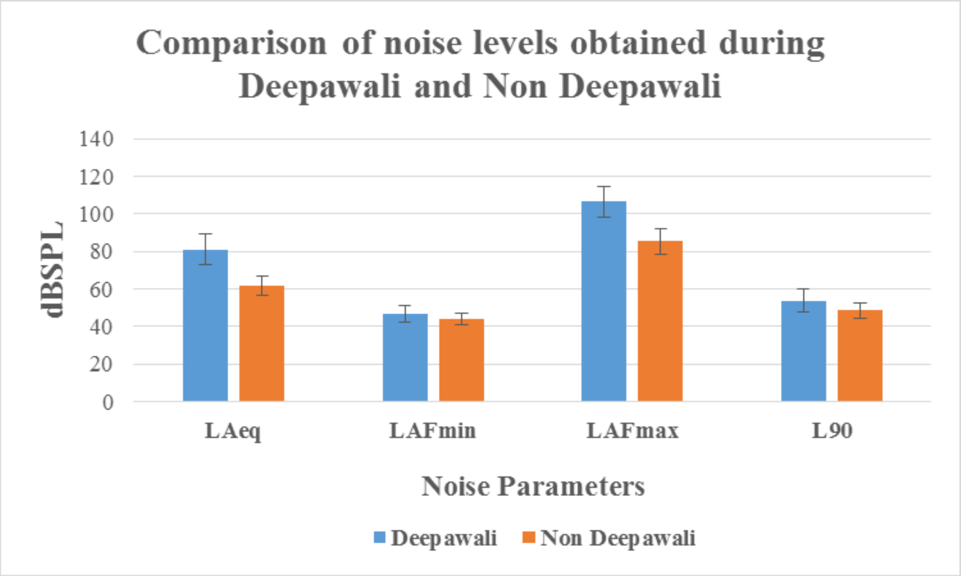

Figure 3.3. Measured noise levels in the city of Mysuru during Deepavali and Non-Deepavali.

Independent t-test was carried out to study the difference between noise levels measured during Deepavali and Non-Deepavali in evening timeframe. Results indicated, noise levels to be significantly higher during Deepavali period for all the noise parameters studied. Results were as follows: **LAeq:** $t(52)= 10.401$, $p<0.05$, r= 0.821, **LAFmin:** $t(52)= 2.712$, $p<0.05$, r= 0.352 **LAFmax:**$t(52)= 10.267$, $p<0.05$, r= 0.6696, **L90:** $t(52)= 3.627$, $p<0.05$, r= 0.4493. A large effect size (>0.5) could be noted for LAeq and LAFmax indicating greater influence of the occasion on the measured parameters compared to LAFmin and L90 which showed a medium-large effect size (0.3-0.5).

3.4. Comparison of measured noise levels across time frames with prescribed standards.

Noise levels measured in the city of Mysuru across different land use pattern and different timeframes were compared with the prescribed noise limits given by Environmental Protection Agency (EPA), 1986. EPA, 1986 has prescribed standards for permissible noise levels for different land use categories for two time frames: Day (06.00-21.00) and night (21.00-6.00). However, in the current study 07.00-22.00 was considered as day time, and 22.00-23.00 & 04.00-07.00 were considered to be night.

Table 3.12.

Comparison of measured and prescribed LAeq values across different land use categories

Land use type	Day time (dBSPL)		Night time (dBSPL)	
	Prescribed	Measured	Prescribed	Measured
Industrial area	75	64.93	70	54.45
Commercial area	65	71.44	55	61.22
Residential area	55	60.38	45	51.75
Silent zone	50	66.44	40	55.91

As it could be seen from the above comparison, noise levels in Mysuru city exceeded the prescribed limits in all the categories except for Industrial land use type. This was true for both the timeframes. Similar pattern of deviation was observed in both the time frames for commercial, residential and silent zones.

Chapter IV

Discussion

Excessive noise levels in the surrounding environment have been one of the major complaints in most of the urban settlements in recent days. Disturbance arising from such noises has been noted in contributing to altered work and sleep patterns and affecting urban inhabitants in their daily life. With gradual increase in noise levels in the environment, a pressing need has been developed to monitor noise levels and thereby, drawing the attention of environment researchers. The current research was carried out with an aim of measuring noise levels across different land use patterns in the city of Mysuru during morning, afternoon, evening and night time frames, representing the same using Isopleth maps and to compare measured noise levels with the prescribed noise standards (EPA, 1986). It was also aimed to measure noise levels in the city during the occasion of Dussehra and Deepavali and compare it with noise levels during any other regular day.

4.1. Effect of land use type on measured noise levels.

Noise levels measured in the city were compared across categories of land use (as defined by local authority of land development), so as to study how noise varied as a function of land use type. It was noted that higher levels of noise were recorded in commercial areas followed by mixed commercial-residential, sensitive, industrial and residential land use types. It was seen that, the measured levels exceeded the prescribed noise limits across all the land use categories except for industrial areas. Similar results were reported by Banerjee et al., (2008), where noise levels exceeded the prescribed limits across all the land use patterns. Although majority of the lands in the city have been denoted towards residential purposes, being an urban settlement, the city encompasses numerous commercial settings varying from isolated settings to clustered ones. The increased noise levels in the commercial set up could be attributed to narrow roads and tall commercial buildings bringing about a canyon effect (King et al, 2012). It was also noted that most of the commercial set up was established in the city center, where a greater vehicular density on road was observed. Average noise levels greater than 75 dBSPL was measured in some of the major commercial streets of the city such as DevarajUrsu road, Sayyaji Rao road, Shivarampet road and Kali Temple Street (KT Street). Road traffic noise was majorly contributed by two wheelers and public transport system such as auto rickshaws, vans and buses. Poor lane discipline, pedestrian path occupied by vendors leading pedestrians on to roads ends up causing severe noise emission due to honking. With noise levels being higher than the prescribed limits, people working in these areas are at greater risk for adverse effects of noise.

Mixed land use type comprises of commercial and residential set-up coexisting in the same locality. In the current study, there were 50 such points. Average noise levels recorded in mixed land use type were 66.5 dBSPL and 55.9 dBSPL for morning and afternoon respectively. Although no prescribed noise standards have been given for mixed land use type, the levels measured could be assumed to be greater than the desirable levels, as they exceed the limits for a completely commercial land use type which is 65 dBSPL and 55 dBSPL for morning and afternoon respectively. Major noise source in such kind of land use type was from activities in commercial establishments such as markets, shopping complexes and from road traffic noise.

In the current study, areas up to 100 meters around set ups like educational institutions and health care centers were considered as sensitive zones. Noise levels in these areas were beyond prescribed limit of noise exposure. Excessive noise levels in sensitive zones (areas within 50 meters of an educational/hospital set-up), could be attributed to poor land use planning with respect to placement of the set up. Most of the sensitive zones have been placed amongst the commercial set up where higher levels of noise become inevitable. Lack of adequate ‘No honking’ signs and minimal awareness among common citizens has contributed to poor ambient noise levels.

Nearly 50% of land use in the city planning has been attributed to residential purposes. Although least levels of noise were recorded in residential land use type, the levels recorded were however, greater than the prescribed noise limits. The average noise levels measured in residential area was 60.38 and 51.75 dBSPL for morning and afternoon respectively, with vehicular noise being the major contributor. Two different kinds of residential set ups were observed in the study area. One being, with ample space among the residential structures, well vegetated and with thick green belt, where as tall and crowded residential infrastructures with minimal vegetation were noted in other categories. Higher levels within residential land use were noted in such crowded residential infrastructures, with their residences being more prone to adverse effects of environmental noise.

Majority of the industrial areas in the city of Mysuru have been established outside the outer ring road. The industrial area located outside the ring road has been dedicated solely for industrial activities with no residences located in the premises. Noise levels measured in the industrial area is below the prescribed limits for noise exposure both during day and night time frame. Averaged noise levels measured in the industrial area were 64.93 dBSPL and 54.45 dBSPL for day and night respectively. In majority of the industrial set ups, it was observed that working machineries were located at the center of the setup if not always; and a large area was left open between the main building and the outer compound wall, thereby increasing the distance between the noise source and the site of measurement. Level of noise emitted due to industrial set up was minimal and noise levels measured in industrial areas were majorly contributed by vehicular noise.

4.2. Effect of timeframe of noise measurement on measured noise levels.

In the current study, noise levels were measured across four different timeframes in each of the land use type. The timeframe in which noise measurements were carried out was, morning (07.00-12.00), afternoon (12.00-17.00), evening (17.00-22.00) and night (22.00-23.00 & 04.00-07.00). It was observed that noise levels measured exceeded the prescribed standards during both day and night time for all the land use categories, except for industrial areas. On comparing noise levels across timeframes in each of the land use category, it was observed that noise levels measured during night time were significantly lesser when compared with those measured during morning, afternoon and evening in all land use types. There was no significant difference noted in the levels of noise measured during morning, afternoon and evening time in commercial, sensitive, mixed and industrial type indicating noise levels to be similar across time frames. Similar findings were reported by Plicollo, Plutino and Canistraro (2005). However, significantly higher levels of noise in evening time were noted in residential areas when compared with morning and afternoon timeframe.

As observed, the major noise source that contributed to overall noise levels in the city was vehicular traffic noise. This was seen for all the land use types under the study. Similar results were reported by Ambika and Payal (2012). The reduction in noise levels during night time could be attributed to lesser vehicular density in the city when compared with morning, afternoon or evening time. And also, commercial set ups such as malls, shopping complexes and hotels don’t often function beyond 22.00 hours in the night and open before 9.00 hours in the morning.

Although not statistically significant, higher levels of noise were measured during morning timeframes when compared with afternoon and evening. This was noted for all land use categories except for residential areas where, greater level of noise was seen during evening timeframe. Greater levels of noise in morning timeframe could be attributed to the general morning rush seen in the city where people would be travelling to their workplace during this time, school vans and autos picking up children and such activities contributing to it. Greater levels of activity were noted in evening time in residential area when compared to any other time. This could be due to the factor that, public in general, would be occupied with work in morning and afternoon timeframe thereby bringing greater scope for recreational tasks to occur during evening timeframes. The general recreational activities would involve children playing, orchestra events and other such events. It was also observed that greater vehicular movement occurred during this time. This all would have contributed to the increased noise levels in residential areas during evening time.

With obtained data on averaged noise levels, Isopleth noise maps were generated for all the time frames.

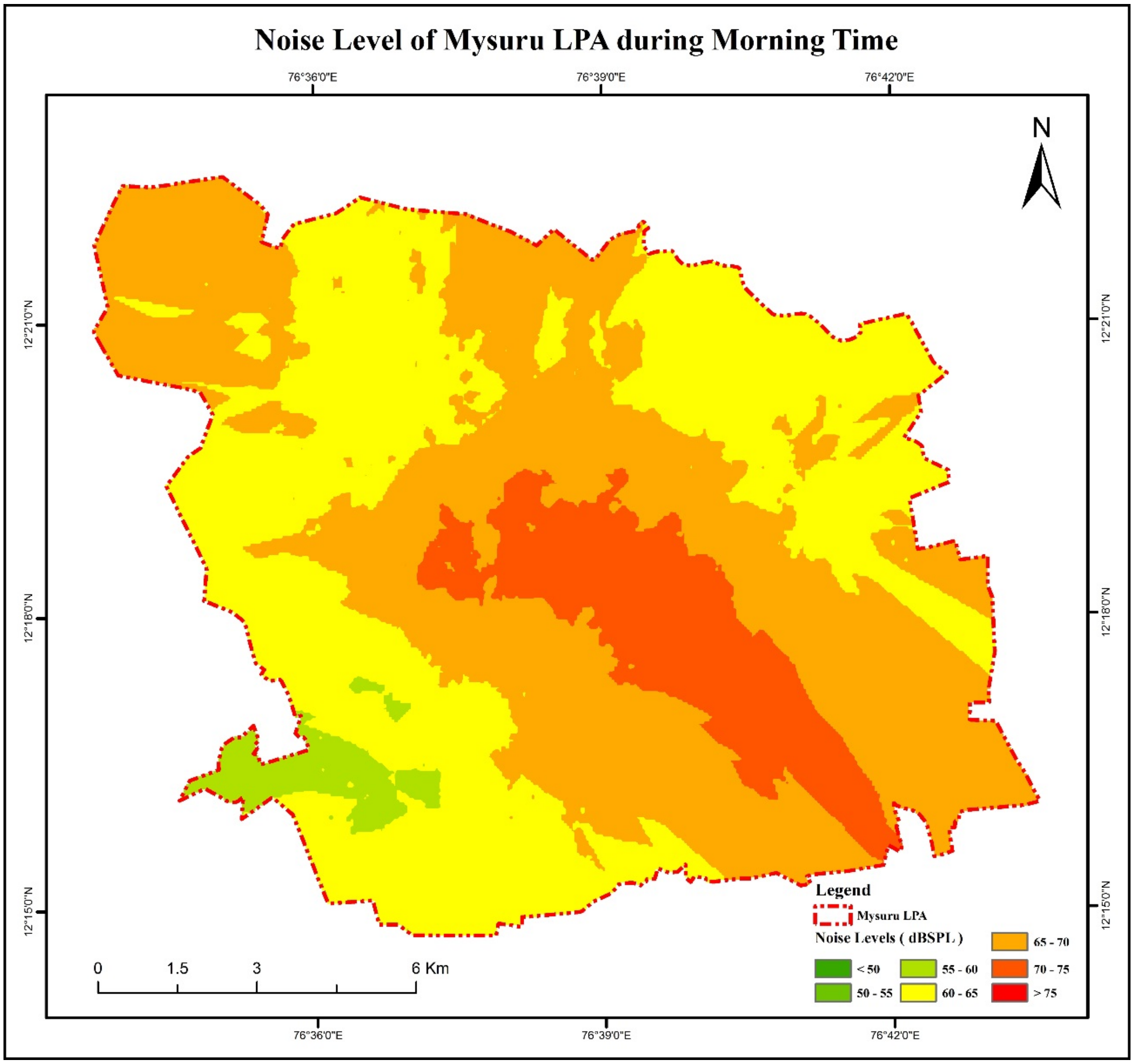

Figure 4.1. Isopleth noise map of averaged noise levels for Mysuru city during morning time frame.

Noise map for morning time frame was produced from the average noise levels measured during 07.00-12.00 hours. It could be noted that greater level of noise (70-75dBSPL) was recorded in the city center, where majority of the land has been devoted for commercial purposes. This increased noise levels could be due to inherent commercial activities in the area and greater vehicle density in these regions. It could be seen that, the level of noise reduced as the site of measurement shifted from center towards the peripheral regions of the city. These areas are occupied by residential, mixed, isolated commercial settings and industrial areas.

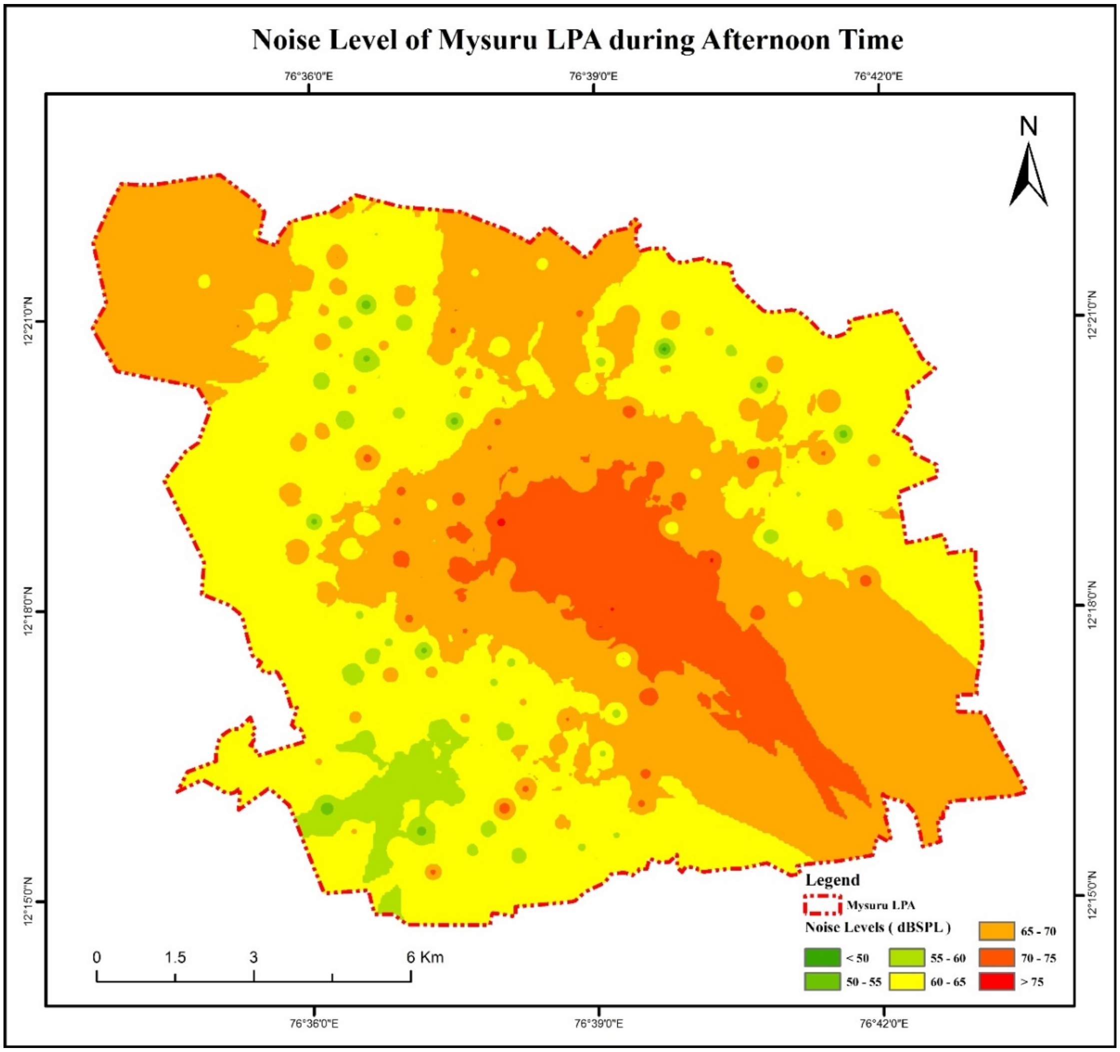

Figure 4.2. Isopleth noise map of averaged noise levels for Mysuru city during afternoon time frame.

Noise map for afternoon time frame was produced from the average noise levels measured during 12.00-17.00 hours. Similar pattern was observed in the map, where higher level of noise was measured in city center and it gradually reduced towards the outer portions of the city. Noise levels in the city center ranged from 70-75dBSPL while noise levels in surrounding regions ranged from 65-70dBSPL.

`

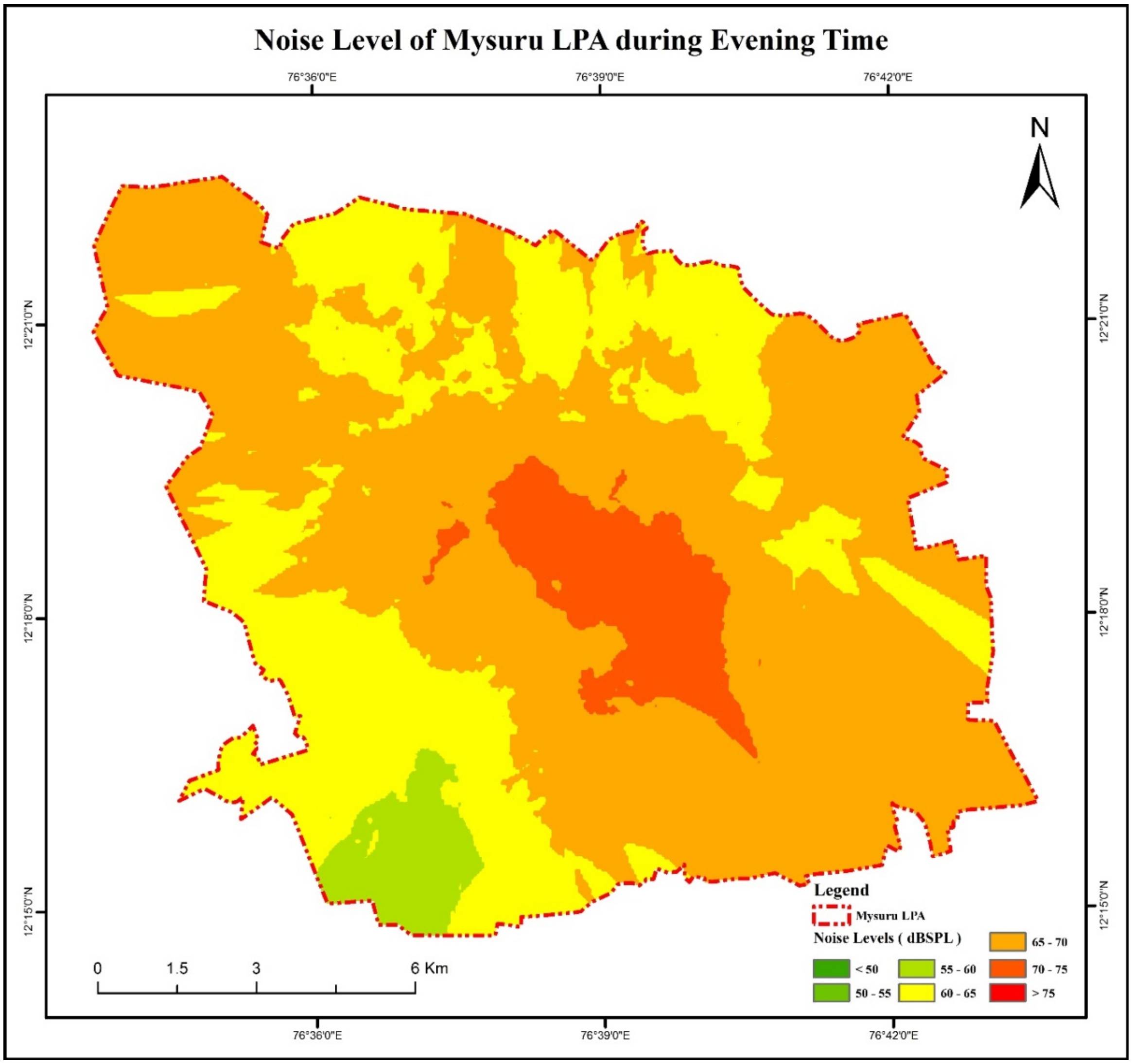

Figure 4.2. Isopleth noise map of averaged noise levels for Mysuru city during evening time frame.

Noise map for evening time frame was produced from the average noise levels measured during 17.00-22.00 hours. Average noise levels of 65-70dBSPL were noted in most portions of the city. However, highest noise levels were recorded in the city center. Similar pattern of geographical noise distribution was noted for morning, afternoon and evening time frames.

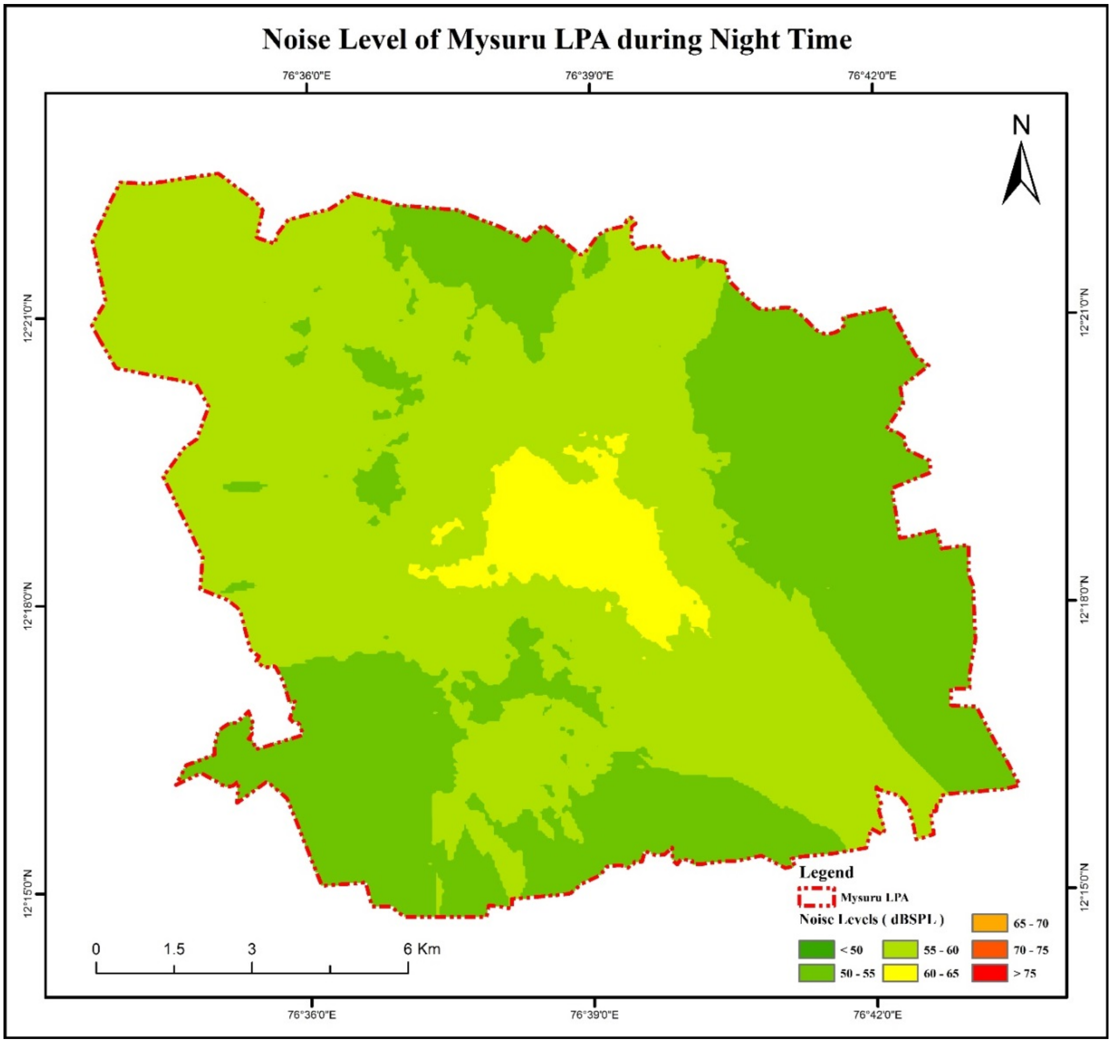

Figure 4.4. Isopleth noise map of averaged noise levels for Mysuru city during night time frame.

Noise map for night time frame was produced from the average noise levels measured during 22.00-23.00 & 04.00-07.00 hours. It could be noted that, the level of noise in the city was greatly reduced during night time when compared to morning, afternoon and evening timeframes. This was majorly due to minimal traffic movement and commercial activities occurring during this time frame. As observed in previous maps, greater levels of noise (60-65 dBSPL) were noted in city center. Noise spread throughout the rest of the city was below 60 dBSPL.

4.3. Comparison of noise levels during Dussehra and Non-Dussehra.

The study also aimed to measure noise levels in the city during the occasion of Dussehra and to comparethe same with noise levels measured during any other regular day. Upon the comparison, two following prominent findings were observed:

(i) Noise levels in the city during Dussehra was significantly higher in all the timeframes of noise measurement,

(ii) During the occasion of Dussehra, noise levels measured in evening timeframe were significantly higher (80.15 dBSPL) compared to those measured during morning (74.92 dBSPL) and afternoon (77.29 dBSPL).

With Mysuru being the cultural heritage city of Karnataka and a major tourist destination, it attracts increased number of tourists from across the globe during festivals like Dussehra. The increased visitors’ inflow to the city, large crowd gatherings and increased traffic flow often leaves the city overly crowded, thereby contributing to greater levels of noise. It was also noted that, noise levels in the city during Dussehra were greater during evening time compared to morning and afternoon. Major tourist attractions in the city during Dussehra arelight illumination of Ambavillas palace, lightings of city’s major road and circles, food fest and many crowd gathering events such as Yuva Dussehra. As all these events occurred during evening timeframe, crowd gathering was large and traffic flow was greater in comparison with morning and afternoon thereby leading to greater noise levels in evening period during Dussehra.

4.4. Comparison of noise levels measured during Deepavali and other period of the year (Non-Deepavali).

Noise levels in residential areas of the city was measured during the occasion of Deepavali and compared with the noise levels during any other regular day. All the measurements were carried out during evening timeframe as bursting crackers occurred majorly during this period. Upon comparison, it was noted that, average noise levels (LAeq) were up to 20 dBSPL higher during the time of Deepavali. This was due to burst of crackers occurring during the occasion. It could be noted that L90 parameter, which talks about general background activity occurring in the area, although significantly different between two occasions, the amount of difference was much less (5dBSPL) when compared to the difference in LAeq levels. This indicates that, the general background activity in the area was similar in two occasions. However, the transient high intensity acoustic event of cracker bursting occurring randomly, increased the average noise levels in the area for the measured period. Maximum sound pressure levels (LAFmax) of 125dBSPL and average noise levels (LAeq) up to 94dBSPL were noted during the time of Deepavali due to cracker bursting which is potential enough to bring about permanent and temporary threshold changes in hearing on repeated exposure.

Chapter V

Summary and Conclusions

Aim of the research was to measure noise levels in the city of Mysuru across land use categories (Residential, Commercial, Sensitive, Industrial & Mixed) during different timeframes (morning, afternoon, evening & night) and represent the same using Isopleth noise maps. It was also aimed to measure noise levels in the city during the occasion of Dussehra and Deepavali and compare the same with noise levels in the city on any other regular day.

This study was carried out in three phases where, first phase involved identification of areas (measurement point) to be mapped. This was carried out using ArcGIS software which produced an equidistantly allocated 235 points. They were categorized as commercial, residential, sensitive, industrial and mixed land use types. In the second phase of the study, noise measurements were carried out in the identified points using a calibrated sound level meter. For every identified measurement point, noise levels were recorded three times in each of the timeframe; thereby giving a total of 12 recordings at each site. The following noise indices were recorded: LAeq, LAFmin, LAFmax and L90. Phase three was concerned with generation of Isopleth maps. In phase three, information regarding geographical coordinates of measurement points were fed into base map of the city. Once the measurement points were plotted, noise maps were obtained by feeding information on average noise levels at each of the point using the ArcGIS software. This was done for each of the timeframe separately,to represent the changes in the noise levels with respect to time. As noise measurements were carried out only at predetermined points, surface interpolation was employed to predict noise levels at non-measured locations. The noise levels obtained were compared with the existing Indian standard for noise exposure limit (EPA, 1986).

For the noise measurement during Dussehra, 15 different locations were identifiedwhich included city’s major roads, Dussehra procession path and measurement points near major tourist attraction spots such as Mysore city palace, Zoological garden and food exhibition. LAeq, LAFmax, LAFmin and L90 were measured at all the 15 sites during morning, afternoon and evening time frame. Procedure as explained in the previous section was employed for the noise measurement where 3 recordings were obtained for each of the time frame. Averaged values were obtained for each of the time frame. Similarly, noise measurements were carried out in these 15 points during non Dussehra time (135 recordings). The values obtained during Dussehra were compared with the values obtained in same measurement points during non Dussehra time of the year as to study the increase in noise levels due to Dussehra.

Noise measurements were carried out in the city during the time of Deepavali. 27 different residential points across the city were considered for data collection. These points were selected from the previously identified residential points. Same noise indices were measured during the evening time frame. Noise levels measured in these residential areas during non-Deepavali time were compared to those obtained during the time of Deepavali to study the increase in noise levels due to the occasion. A total of 81 recordings (27x3) were obtained during Deepavali and previously obtained recordings in these residential points served as the control. Appropriate statistics was employed to study the results.

Results revealed noise levels to be higher in commercial areas followed by sensitive, mixed, industrial and residential types. Significantly lesser levels of noise were recorded in night timeframe. No significant difference was noted in noise levels measured during morning, afternoon and evening timeframe, indicating noise levels to be similar throughout the day. On comparison with existing standards (EPA, 1986), it was observed that, measured noise levels clearly exceeded the prescribed limits during both day and night for all the land use types except for Industrial areas. Significantly higher levels of noise were recorded across all the 3 timeframes in the city during the time of Dussehra when compared with noise levels during any other regular day. It was also noted that, during the occasion of Dussehra, noise levels were higher in evening timeframe compared with morning and afternoon. Noise levels recorded at the time of Deepavali were significantly higher when compared to noise levels during any other regular day. Upon comparison, it was noted that, average noise levels (LAeq) were up to 20 dBSPL higher during the time of Deepavali. Maximum sound pressure levels (LAFmax) of 125dBSPL and average noise levels (LAeq) up to 94dBSPL were noted during the time of Deepavali due to cracker bursting.

Vehicular noise was identified as the major noise source, with increase in number of private vehicles contributing to it. Strict rules are needed to be employed on limits of noise generated by vehicles, as alterations of automobile silencers emitting greater noise has grown as a trend. Increase in green belts could be used as an effective strategy in noise controlling, which acts as a noise barrier in the path of transmission. The higher noise levels recorded in the city would bring about adverse health effects on city dwellers in the long run, thus calling for strict law enforcement related to monitoring of noise levels and keeping them in check.

References

Akintuyi A. O.,Raji S. A.,Adewuni D, &Wunude,E. O. (2014). Gis-based assessment and mapping of noise pollution in Bariga area of Lagos state, Nigeria.*Sokoto journal of the Social Sciences*, *4(1)*, 154-168.

Ambika N. Joshi, Nitesh C. Joshi, and Payal P. Rane(2015). Noise Mapping in Mumbai City, India. *International Journal of Innovative Science, Engineering & Technology*, Vol. 2 (3), 380-85.

Ambika N. Joshi, &Payal P. Rane(2012). Monitoring noise levels of vehicular traffic on Mumbai roads. *International journal of research 40(3)*, 413-425.

Banerjee, D., Chakraborty, S. K., Bhattacharyya, S., & Gangopadhyay, A. (2008). Evaluation and analysis of road traffic noise in Asansol: an industrial town of eastern India. *International journal of environmental research and public health*, *5*(3), 165-171.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet*, *383*(9925), 1325- 1332.

Bhosale, B. J., Late, A., Nalawade, P. M., Chavan, S. P., & Mule, M. B. (2010). Studies on assessment of traffic noise level in Aurangabad city, India. *Noise and Health*, *12*(48), 195.

Brandenberger, G., Follenius, M., Wittersheim, G., Salame, P., Siméoni, M., & Reinhardt, B. (1980). Plasma catecholamines and pituitary adrenal hormones related to mental task demand under quiet and noise conditions. *Biological Psychology*, *10*(4), 239-252.

Brown, A. L., & Lam, K. C. (1987). Urban noise surveys. *Applied Acoustics*, *20*(1), 23-39.

Burrough, P. A., McDonnell, R., McDonnell, R. A., & Lloyd, C. D. (2015). *Principles of geographical information systems*. Oxford University Press.

Cavatorta, A., Falzoi, M., Romanelli, A., Cigala, F., Ricco, M., Bruschi, G., &Borghetti, A. (1987). Adrenal response in the pathogenesis of arterial hypertension in workers exposed to high noise levels. *Journal of hypertension. Supplement: official journal of the International Society of Hypertension*, *5*(5), S463-6.

Centers for Disease Control and Prevention. (1991). National Institute of Occupational Safety and Health. *National traumatic Occupational Fatalities Database*.

Chakrabarty, D., Santra, S. C., Mukherjee, A., Roy, B., & Das, P. (1997). Status of road traffic noise in Calcutta metropolis, India. *The Journal of the Acoustical Society of America*, *101*(2), 943-949.

Contaminants, A. (1980). Occupational Safety and Health Administration 29 CFR 1910: 1000, 1982. Documentation of the Threshold Limit Values. In *American Conference of Governmental Industrial Hygienists: Cincinnati, OH*.

Coelho, J. B., &Alarcão, D. (2006). Noise mapping and noise action plans in large urban areas. *Technical Acoustica*, 1039-1044.

CPCB. (2012). Ambient Air and Noise Pollution Levels - Deepavali. Delhi.

Directive, E. U. (2002). Directive 2002/49/EC of the European parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise. *Official Journal of the European Communities, L*, *189*(18.07), 2002.

Environmental Protection Act, 1986 http://moef.gov.in/citizen/specinfo/noise.html

European Commission Working Group. Assessment of Exposure to Noise (WG-AEN)(2006). *Good practice guide for strategic noise mapping and the production of associated data on noise exposure*.

Field, A. (2009). *Discovering statistics using SPSS*. Sage publications.

Glass, D. C., & Singer, J. E. (1972). Urban stress: Experiments on noise and social stressors.

Goswami, S. (2009). Road traffic noise: A case study of Balasore town, Orissa, India. *International Journal of Environmental Research, 3*(2), 309-318.

Green, M. S., Schwartz, K., Harari, G., &Najenson, T. (1991). Industrial noise exposure and ambulatory blood pressure and heart rate. *Journal of Occupational and Environmental Medicine*, *33*(8), 879-883.

Henderson, D., Bielefeld, E. C., Lobarinas, E., & Tanaka, C. (2011). Noise-induced hearing loss: implication for tinnitus. In *Textbook of Tinnitus* (pp. 301-309). Springer New York.

Herbold, M., Hense, H. W., &Keil, U. (1989). Effects of road traffic noise on prevalence of hypertension in men: results of the Luebeck Blood Pressure Study. *Sozial- und Präventivmedizin*, *34*(1), 19-23.

Iaaly-Sankari, A., Jadayel, O., El-Murr, N., & Center, G. I. S. (2010). Urban noise mapping: the case of the city of El-Mina, North Lebanon. In *Proceedings Middle East & North Africa Users Conference ESRI*.

Kalaiselvi, R., & Ramachandraiah, A. (2010, August). Environmental noise mapping study for heterogeneous traffic conditions. In *Proceedings of 20th International Congress on Acoustics, ICA* (pp. 23-27).

Karina Mary de PaivaVianna, Maria Regina Alves Cardoso1 and Rui Manuel Calejo Rodrigues. (2015). *Noise & Health*, Volume 17:76, 125-33.

King, G., Roland-Mieszkowski, M., Jason, T., &Rainham, D. G. (2012). Noise levels associated with urban land use. *Journal of Urban Health*, *89*(6), 1017-1030.

Kluijver, H., & Stoter, J. (2003). Noise mapping and GIS: optimising quality and efficiency of noise effect studies. *Computers, Environment and Urban Systems*, *27*(1), 85-102.

Law, C. W., Lee, C. K., Lui, A. S. W., Yeung, M. K. L., & Lam, K. C. (2011). Advancement of three-dimensional noise mapping in Hong Kong. *Applied Acoustics*, *72*(8), 534-543.

Lee, J., Gu, J., Park, H., Yun, H., Kim, S., Lee, W., ...& Cha, J. S. (2014). Estimation of populations exposed to road traffic noise in districts of Seoul metropolitan area of

Korea. *International journal of environmental research and public health, 11*(3), 2729-2740.

Liberman, M. C., & Dodds, L. W. (1984). Single-neuron labeling and chronic cochlear pathology. III. Stereocilia damage and alterations of threshold tuning curves. *Hearing research*, *16*(1), 55-74.

Loeb, M. (1986). *Noise and human efficiency*. John Wiley & Sons.

Miller, J. M., Watson, C. S., & Covell, W. P. (1963). Deafencing Effects of Noise on the Cat. *Journal of Occupational and Environmental Medicine*, *5*(11), 555.

Mohan, S. Dutta, N. and Sarai, S. (2000). Subjective Reaction to Road Traffic Noise of Resident Living in Delhi City. *Pollution Research.* 19, 353-56.

Naik, S. and Purohit, K. (1999).Traffic noise pollution at Bondamunda of Rourkela Industrial Complex. *Pollution Research*.18, 475- 78 .

Nandi, S. S., &Dhatrak, S. V. (2008). Occupational noise-induced hearing loss in India. *Indian journal of occupational and environmental medicine*, *12*(2), 53.

Nelson, D. I., Nelson, R. Y., Concha-Barrientos, M., & Fingerhut, M. (2005). The global burden of occupational noise-induced hearing loss. *American journal of industrial medicine*, *48*(6), 446-458.

Obaidat, M. T. (2011, November). Spatial mapping of traffic noise levels in urban areas. In *Journal of the transportation research forum* (Vol. 47, No. 2).

Öhrström, E. (1989). Sleep disturbance, psycho-social and medical symptoms—a pilot survey among persons exposed to high levels of road traffic noise. *Journal of Sound and Vibration*, *133*(1), 117-128.

Palamuleni, L. G. (2015). A comparative land use-based analysis of noise pollution levels in selected urban centers of Nigeria. *International journal of environmental research and public health*, *12*(10), 12225-12246.

Piccolo, A., Plutino, D., &Cannistraro, G. (2005). Evaluation and analysis of the environmental noise of Messina, Italy. *Applied Acoustics*, *66*(4), 447-465.

Salame, P., & Baddeley, A. (1982). Disruption of short-term memory by unattended speech: Implications for the structure of working memory. *Journal of verbal learning and verbal behavior*, *21*(2), 150-164.

Shankar, B & Vidhya, D. (2013). Changing Dynamics of Land Use in Residential Neighbourhood of VaniVilasaMohalla¸ Mysore. *Int. J. Modern Engineering Research, 3(2),* 678-684.

Stansfeld, S. A., & Matheson, M. P. (2003). Noise pollution: non-auditory effects on health. *British medical bulletin*, *68*(1), 243-257.

Tandel, B. N., & Tiwari, K (2014). A GIS based approach for mapping of urban road traffic noise.http://www.civil.iitb.ac.in/tpmdc/PAPERS/254.pdf (accessed on 20/11/2015).

Tarnopolsky, A., Watkins, G., & Hand, D. J. (1980). Aircraft noise and mental health: I. Prevalence of individual symptoms. *Psychological medicine*, *10*(04), 683-698.

Tyler, R. S. (2000). *Tinnitus handbook*. United Nations Publications.

Vos, T., Flaxman, A. D., Naghavi, M., Lozano, R., Michaud, C., Ezzati, M., & Abraham, J. (2013). Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, *380*(9859), 2163-2196.

Wani, K. A., &Jaiswal, Y. K. (2010). Assessment of noise pollution in Gwalior MP India. *AdvBiores*, *1*(1), 54-60.

Zannin, P. H. T., & Bunn, F. (2014). Noise annoyance through railway traffic-a case study. *Journal of Environmental Health Science and Engineering*, *12*(1), 1.

Zhao, Y. M., Zhang, S. Z., Selvin, S., & Spear, R. C. (1991). A dose response relation for noise induced hypertension. *British Journal of Industrial Medicine*, *48*(3), 179-184.