SMARTPHONE-BASED TRAFFIC NOISE MAPPING SYSTEM

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ABSTRACT:

Noise pollution is one of the most serious environmental threats to human health. Noise is becoming more prevalent in urban areas, and it is having a negative impact on human health. The increase in noise is due to the increase in the number of vehicles that creates chaos over the road due to honking. Smart monitoring using is smartphones is required to reduce human dependency and monitor data efficiently to reduce logistical obstacles. A smartphone-based noise monitoring solution can handle the problem of monitoring noise at various traffic crossings in a metropolis. The topographical data, noise data, and noise prediction models are required for forecasting noise levels and showing them as maps. In the Indian city of Lucknow, the entire procedure is being performed by providing a map of 2D and 3D forms. The smartphone-based software tracks noise levels at three road crossings at three different times each day. The collected noise levels were calibrated against a standard noise metre to achieve correct noise levels for these sites. Following that, three noise environment types are chosen and mapped using open-source satellite images and conventional noise models through the web on the GIS platform. The anticipated noise levels on the maps were compared to recorded noise data from identical locations using a conventional noise metre for these three crossings and were found to be within 5.5 dB of accuracy. For 3D mapping, shadow height provides the Z value for point cloud DEM generation for 3D model for noise data of city of Lucknow.

1. INTRODUCTION

Noise is a widespread issue that raises serious health issues. Road traffic noise pollution is becoming a major discomfort and cause of disease for city inhabitants as a result of fast population increase and the expansion of transportation networks. Noise maps are quite beneficial to recognize the sources of noise (Shruti Bharadwaj et al., n.d.; Vogiatzis & Remy, 2017). To create a noise map, it is necessary to measure Leq noise levels (equivalent sound pressure levels) and reflect them on a map that depicts the impact of noise and can assist decision-makers in developing noise controlling and managing measures (Ausejo et al., 2011). In order to study the sound characteristics of soundscapes in a given metropolitan zone and provide recommendations for soundscape urban design, a noise map is necessary in urban planning (S. Bharadwaj et al., 2020; Ruiz-Padillo et al., 2014). For example, using a traffic noise map, "Palma de Mallorca" (Spain) undertook a study comparing different noise mitigation techniques, considering noise reduction and the number of persons who might profit from such measures(Picaut et al., 2019a). Other studies used the "road stretch priority index," in which several variables were weighted based on their influence on the traffic noise problem, as well as road segments with various priority. (Naish, 2010). A traffic noise forecasting model, as well as sound propagation retardation, were both used in the noise map analysis. Inside the Orbits- GIS software, a noise prediction mechanism was implemented (Fortin et al., 2012). Some approaches can generate noise maps in a few hours, the approach can generate enormous noise maps on a home computer, in two dimensions (Andersson et al., 2018a). This article focused on using ArcGIS for noise mapping. Before using the GIS, collection of noise data must be done and that is very difficult and time-consuming for many areas(Baliatsas et al., 2016; Paunović et al., 2009). Noises can damage health. Noise can influence everyday activities (sleep, speech, and work). Further, irritation, cognitive disability, dementia, cardiovascular disorders, as well as respiratory problems are caused by ambient noise (Andersson et al., 2018b). Numerous studies have been undertaken in the past to examine noise emissions as well as their influence on human wellbeing(Douglas & Murphy, 2016). According to recent research by the World Health Organization (WHO), 466 million individuals worldwide suffer from hearing loss, with the number expected to rise to 900 million by 2050, or one in every ten persons (*Deafness and hearing loss*, n.d.). The cumulative disability-adjusted life years lost in European nations owing to ambient noise is anticipated to somehow be 1.6 million (Burden of Disease from Environmental Noise Burden of disease from environmental noise Quantification of healthy life years lost in Europe, 2011). According to this guideline, the Ministry instructs the state government to divide the territory into four categories: quiet, domestic, commercial, and industrialized. Based on this literature review, the authors found that there is no work-relating noise mapping, with exposure mapping and health impact determination(Shruti Bharadwaj et al., 2022). So, the authors have decided to work on the prediction of noise maps and relate it with noise exposure, and health indices using spatially and dynamically varying noise levels in an area(Gleitman, 2012).

As a result, determining the true causes of the aforementioned health issues becomes difficult. The government must educate the public regularly through good advertising. In that context, detailed monitoring and/or mapping of noise resultant levels for several regions of selected cities is essential for the proper handling of noise due to traffic. It is impossible to regulate noise levels in vast regions of any city continually. It will be necessary to use a huge number of pricey noise meters or SPL meters. Detecting noise levels at important areas, such as noise corridor roads, and In the absence of such massive hardware resources, modelling or mapping them against their surroundings is required. Furthermore, due to the use of a noise level meter, obtaining precise noise level data nearer to the noise sources is difficult. A low-cost, efficient, and convenient mapping system is required. As a result, a smartphone with a noise map is considered (Dubey, Bharadwaj, & Biswas, 2020b). However, when gathering noise data, the smartphone-based approach will encounter accuracy concerns that must be solved. If successful, smartphone-based solutions will have the advantage of acquiring data from wide areas while obtaining feedback from densely populated areas in cities (Dubey et al., 2021). Effective crowdsourcing through the internet opens us with a lot of possibilities for studying observed data and mapping noise levels in cities(Dubey, Bharadwaj, Zafar, et al., 2020). Noise mapping necessitates the acquisition of noise level, terrain parameters, and a noise levelling model. Once the data has been handled, it may be mapped as a raster, vector, or DEM on the ArcGIS platform,

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and route extraction was accomplished using LiDAR point cloud data(Dubey, Bharadwaj, & Biswas, 2020a).

2. LITERATURE REVIEW

2.1 Smart Phone-based Mapping

This article details the results of tests undertaken to determine the noise which is being monitored with the applications that can be used as a low-cost alternative to traditional noise monitoring with a SPL meter. In a reverberation chamber, researchers put 100 smartphones through their paces. The ability of mobile phones to assess noise at background levels was investigated using broadband white noise, and the results were estimated to actual noise levels recorded using a calibrated sound level meter. The tests were carried out on cell phones running the Android and iOS operating systems, respectively. Each smartphone was subjected to separate testing for the top noise monitoring applications, for a total of 1472 tests. The data also suggests that there is a considerable link between phone life and its capacity to reliably assess noise, as well as the cost of ambient noise monitoring and evaluation systems(Murphy & King, 2016).

The findings of the evaluation led to the creation of a calibration technique, which was included in Ambiciti and used on over 50 devices at public events. The measurement range, accuracy, precision, and repeatability were all examined in a performance study. In-situ experiments in the context of noise sensing were carried out, and subsequent testing led to the creation of sensing context ideas (Ventura et al., 2017).

Noise exposure initiatives that are standardised in confront to the limitations such as high instrumentation costs and other issues related to field deployment. Our ongoing research evaluates the suitability of a smartphone-based alternative method: A spatial-temporal analysis of noise measurements and GPS data from mobile phones are being used to assess occupational noise exposure and measurement errors. This study describes a free field laboratory calibration approach for any noise dosimeter application on a smartphone-based device. (Dumoulin & Voix, 2013). Noise sources employed during measurement are based on the distribution of a referenced industrial noise database to ensure realistic calibration. The measurement methods and calculation of combined uncertainties associated with the measured correction values are described in detail. The authors also present the interpolation of calibration values and their implementation in an Android app.

The first research included 192 sound measuring applications that were accessible on Apple's (iOS) and Google's (Android) platforms. Only 10 iOS applications passed our functionality, measurement metrics, and calibration requirements. In the experiments, a microscope taken in reference, a professional type level one SPL meter, and a type 2 noise dosimeter were used to compare the applications' performance. Four iOS applications had mean variances of less than 2 dB(A) of the reference microphone, according to the findings(Picaut et al., 2019b). The Android-based apps lacked the powers and functionality seen in iOS apps, and app metrics varied significantly between devices. To raise awareness of noise dangers in the workplace, NIOSH and EA LAB are cooperating to develop an occupational sound monitoring app for iOS devices.

2.2 GIS-based technique for the generation of the Noise map

In recent years, GIS-based mapping has grown in popularity, with applications in practically every field and a broadening of geographic data availability. In today's environment, GIS-based noise mapping is a valuable tool for reducing noise pollution, which may be harmful to one's health(Esmeray & Eren, 2021). It provides numerically generated data as well as software designed specifically for noise mapping applications in the environment. It draws on a variety of acoustic concepts. The GIS-based computation is carried out in the background, with proper visualization and analysis, and is integrated into the geographical domain. With this in mind, the authors are undertaking a study in the city of Lucknow. It must be established when, where, and how this inquiry will take place. It is required to determine the handling of noise parameters, usage of spatial data, and modeling for noise level mapping on the ArcGIS software platform (Das et al., 2019).

The anticipated noise maps must be geographically compared for relative impacts Once created. Furthermore, this map must be linked to people's concerns about their health as a result of noise pollution(Kim, 2002). In a coordinated study in Bengal, the time-space and spatial noise distribution of traffic noise over the road and neighboring buildings was captured using the SPL and plotted on a web platform using the ArcGIS (Banerjee et al., 2008). In all of the areas studied, the noise level was found to be higher than the CPCB standard (Central Pollution Control Board, India). The same data was acquired and stimulated on the GIS platform in Nigeria, on the other hand(Akintuyi et al., 2014). Noise recordings were taken at three different periods of the day: morning, noon, and evening. Using spatial interpolation, multiple IDW interpolations were created for the map on the GIS platform, and the various stimulation ranges were modified according to the WHO standard for annoyances(Fritschi et al., 2011). The lowest daily average of noise across all land uses was between 67.2 dB(A) and 76.7 dB(A) Only one of the two studies that used the audiometric test to expose the noise effect was found in the connected publications. Apart from that, some people have tried methods like questionnaire surveys to determine the level of noise in a certain region.

2.3 Extracting the height of the building from the shadow

In recent years, GIS-based mapping has grown in popularity, with applications in a variety of fields, as well as in expanding access to geographic data. P.L.N. Raju et al. have estimated the height of the building by extracting using shadows utilizing high-definition satellite images with metadata information (Comber et al., 2012). The extraction of rooftops and shadows, and utilizing Rule-Based approaches, to eliminate the rooftop and shadow region manually/automatically (Raju et al., 2014). Following feature extraction, the next stage is to use the Ratio Method and the relationship between sun-satellite geometry to estimate the building's height, taking into account the rooftop with shadows. According to the results of the performance analysis, the overall mean height error for the ratio approach is 0.67m for the Rule-Based Approach. The manual Ratio Method is the best for estimating height, but it takes a long time. Because it requires more knowledge and the selection of more training samples, as well as slowing down the method's processing pace, the automated Rule-Based Approach is preferable to the Example-Based Approach for height estimation. (Benz et al., 2004).

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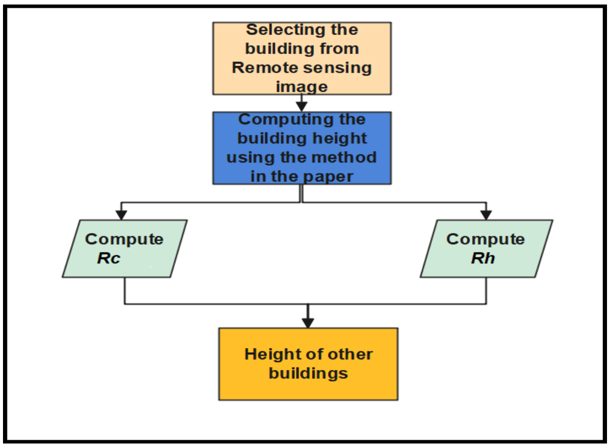

Figure 1. Height estimation of other buildings with the calculation made for the main building

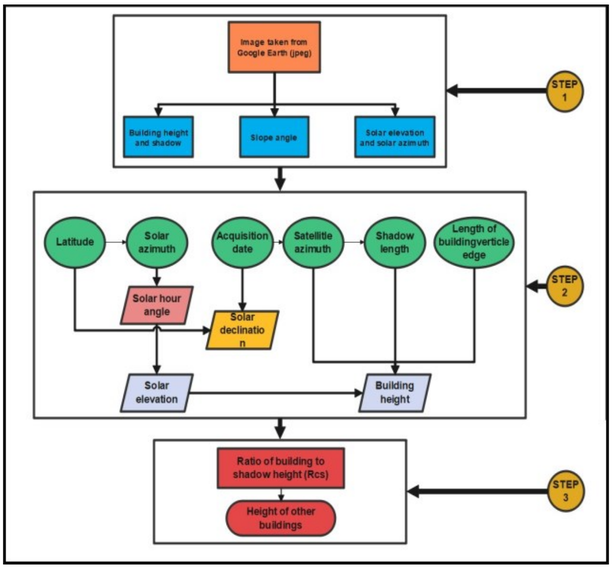

Figure 2. Flowchart of building height estimation

3. RESEARCH GAP

The collecting of accurate noise data from a large region is required for noise mapping. Researchers usually use noise data that has been limited using a costly Noise Meter. Furthermore, obtaining trustworthy noise data at various times of the day, week, and during the season becomes challenging. For the mapping, topographical data and a noise propagation model are also necessary. The noise data may be collected using a smartphone and a noise monitoring app. Terrain data is made available through web mapping using free geospatial data. By combining noise parameters data with topographical data, the noise level maps are generated. A Smartphone-based technology will enable a crowdsourcing approach for mapping, in which individuals will be invited to take part in noise handling to create a noise level map for their area.

4. OBJECTIVES

The Objectives are set out to find low-cost and easy methods for determining the degree of noise pollution in metropolitan areas. The authors will try to come up with a plan for the following.

1. Collecting noise levels using cell phones and noise-measurement applications.
2. To address the need for geographical data, employ an open-source map.
3. Use of shadow height to compute the building height for 3D noise mapping.

5. METHODOLOGY

The authors selected Lucknow as the site for noise mapping. The city has a wide range of traffic circumstances. It was developed to categorize traffic noises and then map the noise for nearby regions using the data. Noise data for three sites were obtained at different times using a smartphone-based noise level handling software (morning, afternoon, and night-time). Furthermore, the mapping will be done for the calculated noise level data for different locations. After the noise level data has been collected, it is integrated with terrain parameters data. Open-source topography data is used to obtain the terrain parameters needed for noise mapping. The author's previously established techniques are used to extract terrain attributes and map them. To calibrate the noise app on the smartphone, a standard SPL metre or sound pressure level metre is needed due to the limited precision of noise level measurement. The noise data gathered by the noise app is then utilized with the calibration settings to provide accurately measured noise level data for a defined region. The smartphone-based handling method is intended to be a simple and convenient way to collect data. The program is used to build noise maps for three different types of places, each of which has been calibrated using a standard noise meter (varying in noise character). This is done every day after using a smartphone app to measure noise levels in three separate sites in Lucknow for 10 minutes at three different intervals. The mapping is finished. Using the data collected from the App and mapped over ArcGIS.
For 3D noise mapping, the height of the building is measured using the shadow of the building and then the data collected using the NoiseCapture and height (Z) is inculcated in the model to generate the TIN for the location. Later the DEM is made over which we put the noise value to get the noise map in 3D.

5.1 Calibrating the NoiseCapture app with SPL meter

According to the findings of the research review, the authors can confidently anticipate that employing iPhones and Samsung flagship phones such as smartphones of varied quality, and others would provide better results than using other Smartphones with a high-quality microphone. The goal of the app is to acquire the noise level data. The noise levels are recorded by the Smartphone app, however, may be erroneous, which will require scaling with a conventional SPL meter (noise level meter). For calibration, both a mathematical method and a traditional one using a variety of sounds can be utilized. Due to the restricted precision of noise level measurement, a conventional noise level metre or sound pressure level metre is required to calibrate the noise app on the smartphone. Changing the tonal sound on the fly and capturing it with the smartphone and SPL. The variational change in the octave bands will be provided by this. The author might predict the variational adjustments that must be done in the program based on the data. The noise app NOISECAPTURE is now being standardized with the standard SPL meter CESVA SC310 in the present research.

5.2 Computation

Various topographical variables are computed and used to compute noise reduction or attenuation at various places surrounding noise sources, such as distance between the source and receivers' point, route loss in diffraction, and so on. At last, these characteristics are utilised to forecast receiver noise levels and display the results as a map. The numerous computations used in computing attenuations are listed below:

$$D.A. = 20\,LOG10(d) + 11 \quad (1)$$

$$L_{\Sigma} = 10log_{10}\,(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + \ldots. + 10^{\frac{Ln}{10}}) \quad (2)$$

$$B.A = 5.65 + 66N + 244N^2 + 287N^3 \quad (3)$$

where D.A.= Attenuation due to distance

L_{Σ} = logarithmic summation of different noises

B.A.= Attenuation due to barrier

d = direct route of Noise propagation

N = Fresnel number

In addition, the computation is performed for several sites, that surround the road intersections and complex buildings/obstruction to direct path of the noise, etc. Then the noise level map is made in the ArcGIS platform. The obstacles to the direct path provide attenuation to the noise source, in this case, ranges from 0 to 5.85 dB(A), where higher values are indicating greater route loss. The height of the building is calculated using the shadow being made by the building and the extraction of the building height algorithm is being used based on previous information about the same in the region. The area's background noise is believed to be 35 decibels (dB) (A). Thus, the author altered the values of distant sites (if the calculated value at the receiver location was less than 35 dB (A)) during noise mapping.

6. RESULTS

The result part essentially depicts the scaling of the smartphones with a standard SPL meter. The distance of 1.5 m in an anechoic chamber is being computed with the noise of multiple frequencies simultaneously with the Noise capture and the conventional SPL meter in order to get the exact calibrated value. The NOISECAPTURE application can capture the different tonal noise levels at 4 dB(A) lower than the average noise meter value, according to the researchers. The scaled values are also applied to the noise level of various frequencies to calculate the precise noise level data acquired by the NOISECAPTURE smartphone app. At a few traffic crossings, the police also collected individual measurements.

Frequency (Hz)	Noise capture L_{eq}	Noise meter L_{eq}	Noise capture freq(dB)	Noise meter freq(dB)
63	66-67	68.5	30	73-75
125	70	73.2	50-60	80.5
25	74.9-75.1	75.5	58-62	80.2
500	79.8	82.3	70	70.5
1000	81.7-82.0	85.1	70-75	75
2000	83.8-84.1	85.2	68-70	71
4000	79-8	78.7	58	71
10000	78-80	79.9	60-61	58

Table 1. shows the calibration done in aniqous chamber of NoiseCapture app and SPL meter

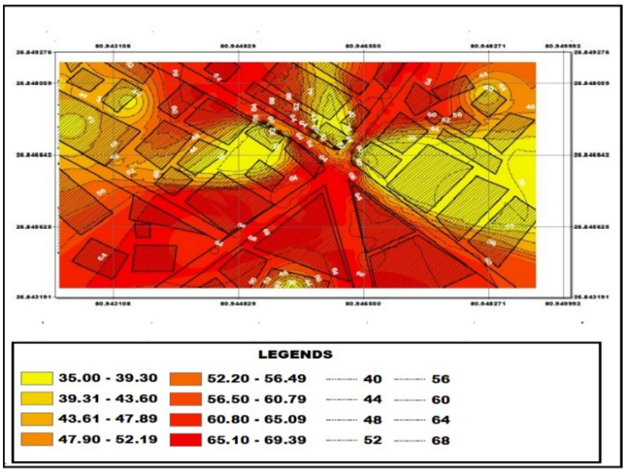

Figure 3. Noise level map of Hazartganj Intersection at morning time using NoiseCapture app scaled with standard SPL

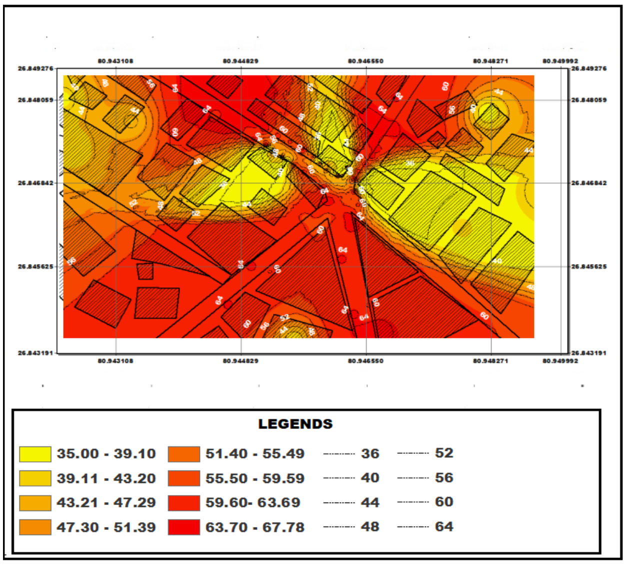

Figure 4. Noise level map of Hazartganj Intersection at afternoon time using NoiseCapture app scaled with standard SPL.

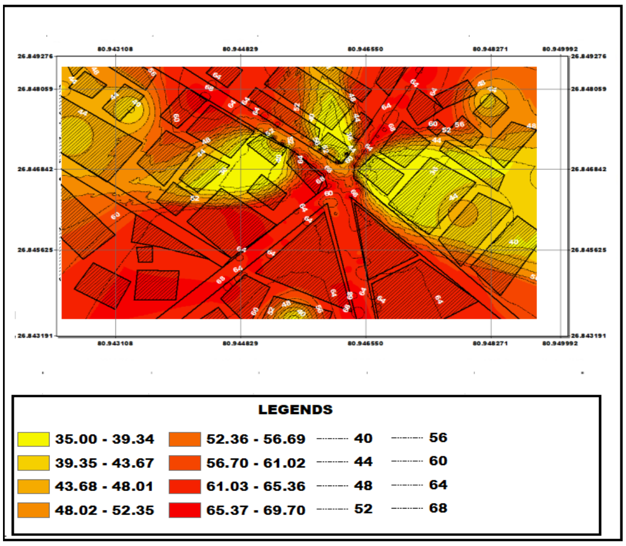

Figure 5. Noise level map of Hazartganj Intersection at morning time using NoiseCapture app scaled with standard SPL.

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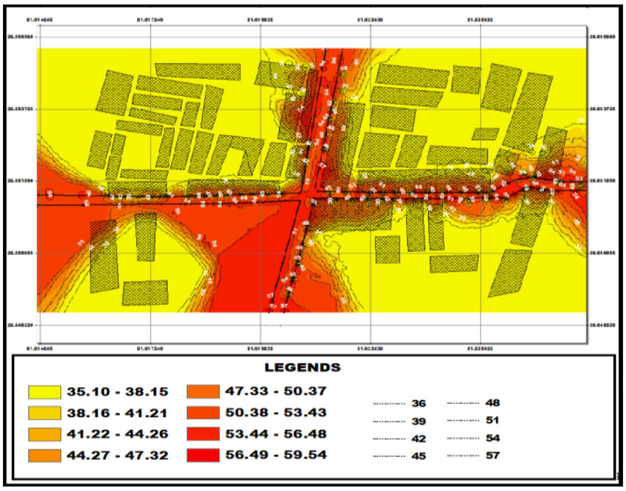

Figure 6. Noise level map of Haniman at morning time using NoiseCapture app scaled with standard SPL.

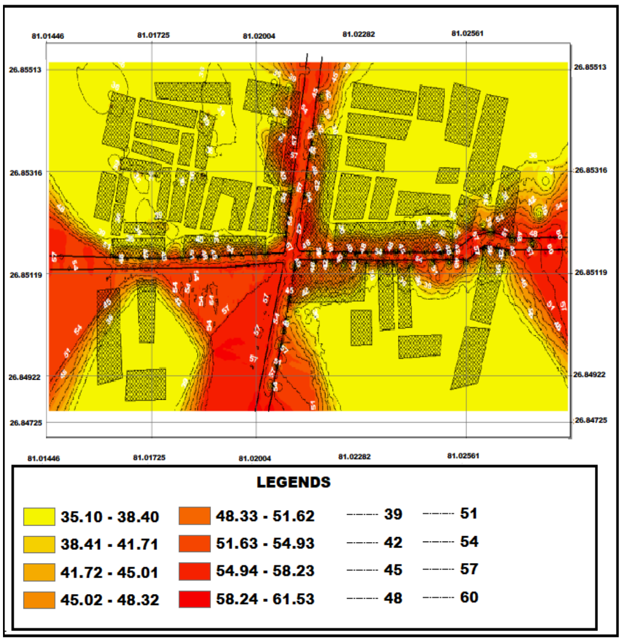

Figure 7. Noise level map of Haniman at afternoon time using NoiseCapture app scaled with standard SPL

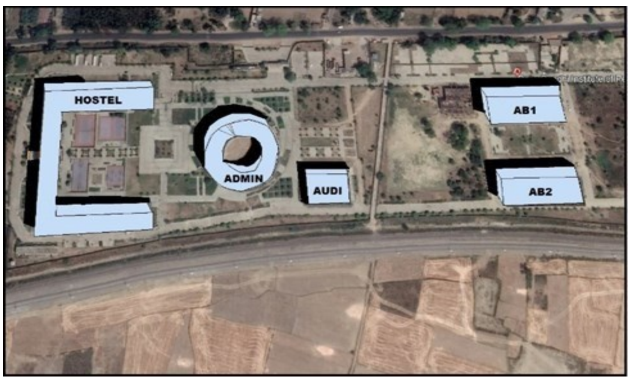

Figure 8. Rgipt google image for estimating height through shadow. for reference

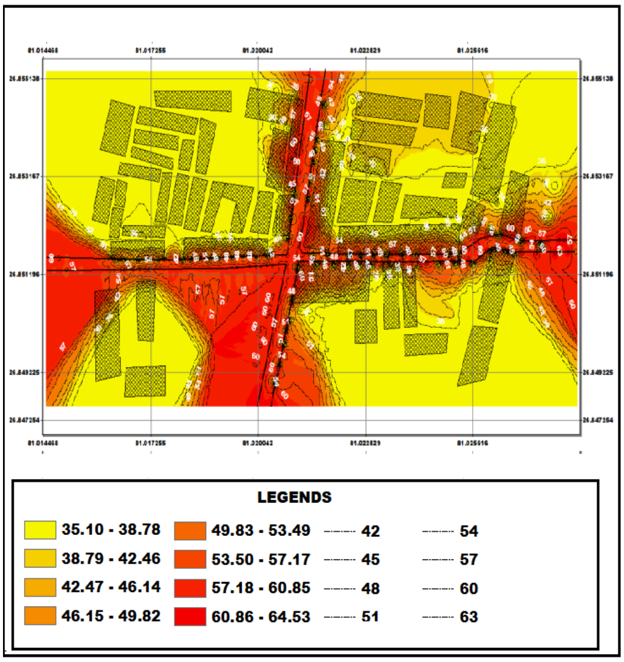

Figure 8. Noise level map of Haniman at evening time using NoiseCapture app scaled with standard SPL.

Calculate the height using the technique of shadow to calculate the height of the building. Here in this, the author has taken the example of the RGIPT campus in Uttar Pradesh (India). In which the difference in the sum of the shadow of the building and the building height with calculated height will provide the actual height.

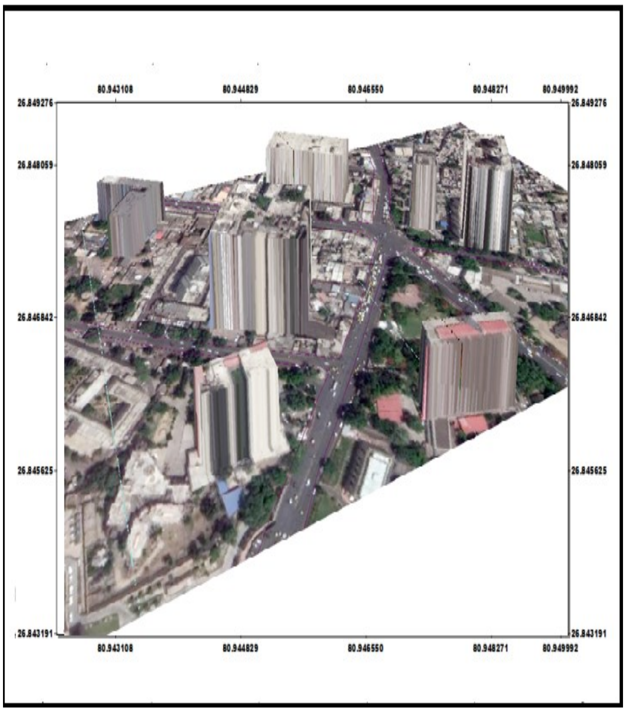

Figure 10. 3D view of Hazartganj intersection where the algorithmic model is been used to get the elevation and thereafter the noise values is been calculated over different buildings around the crossing.

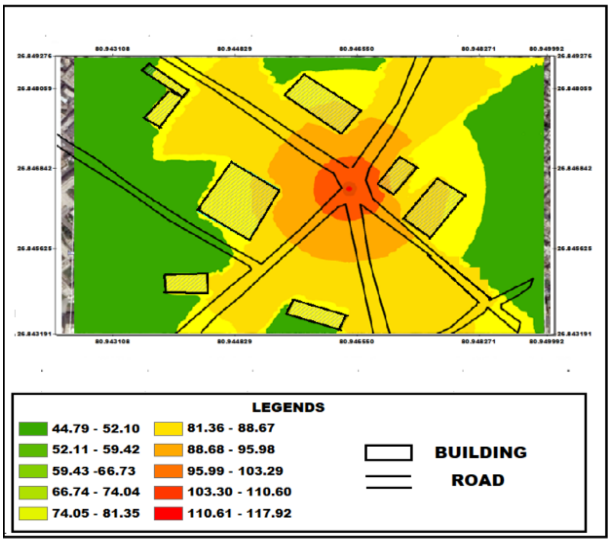

Figure 11. 2D Noise level map of Hazartganj Intersection (noise level lies in between 44.79 to 117.92 dB(A)) from single point source and it's the instantaneous noise that has been monitored and mapped.

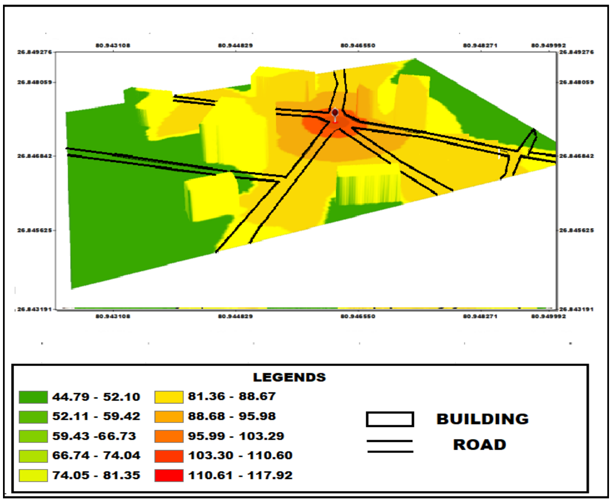

Figure 12. The instantaneous noise level has been measured and plotted in a 3D noise map of Hazartganj Intersection with values ranging from 44.79 to 117.92 dB(A) from a single point source. The attenuation of barriers and distances is also estimated and mapped.

According to the aforementioned findings, the author must do a 0-5 dB(A) addon in the value which is being measured using the NoiseCapture app for the specific level of frequencies. This is being done to get the accurate calibrated value which is lacking in the smartphone-based noise monitoring. Furthermore, based on the map's varied color patterns, the author may decide that Intersection is located in the high-risk noise zone and the low-risk noise zone, respectively on the basis of the color zone they are being coming in after the mapping as the red zone is the noisiest of all with green being the lowest. The noise levels recorded using a normal noise metre at the three sites were also compared to the noise levels plotted (sound pressure level meter). The changes were determined to be between 5 and 7 decibels at various test sites (A)

7. CONCLUSION

The authors investigated the work of many noise mapping researchers. A smartphone-based noise capture device is being used to try to tackle the problem of noise level data handling for large regions of cities. Using the noise model, the authors sought to forecast the noise map on an online platform. The method was divided into two parts: easy and effective traffic noise handling and the creation of a noise map for the whole region using minimum calculated data. As the authors work toward modernisation, they've addressed the demand for a creative, simple, and low-cost method to noise data gathering and mapping. A smartphone-based noise level calculation app was used to obviate the requirement for a pricey SPL or Noise metre. In addition to landscape data, crowdsourcing has been advocated for acquiring noise data via web platforms. The demand for web-based noise maps will be met by the extraction of terrain characteristics and their use with noise level modelling techniques. The ESRI's ArcGIS web platform allows you to anticipate noise levels for various areas in the metropolitan environment and display the findings as colourful maps. The extraction of building height from the shadow inculcated in the algorithm to get the height to get the 3D map ease the mapping using the conventional method of 3D noise mapping. The collaborative mapping, in conjunction with user health indicators, will offer an overview of the potentially dangerous circumstances that may exists at several city crossings. Users will be notified of impending risk thanks to the detailed time, season, and location-specific mapping.

8. FUTURE SCOPE

Using a mobile phone, consumers will be able to easily determine the similar consequences at a reasonable amount. As a result, it can be used in any desired area. Unlike traditional techniques, people can obtain extensive information on a location's noise ambiance and relate it to potential noise problems. The study will also look into people's preferences for hospitals, schools, and residential areas in relation to the noise impact on those locations. This will provide the optimal or most preferable places for noise-sensitive infrastructure. The described data help in transcript which place is best suited to have a hospital, complex or the school. In the country like India where the land use pattern is mixed, we need a solution to rectify the problem of noise pollution. The entire prediction will be geospatially made in a GIS environment, with additional clues such as distance from home to hospital, home to school, etc., as well as the availability of transportation, the kind of transportation, different traffic conditions, and so on, being weighted to determine the optimal or suitable location for perfect infrastructure with less noise.

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