GIS BASED SMART NOISE MAPPING TO COMPARE ORGANIZED TRAFFIC AND UNORGANIZED TRAFFIC FOR A DEVELOPING SMARTCITY

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ABSTRACT:

One of the most pervasive environmental dangers to humans is noise. It has detrimental effects on a person's health, including tinnitus, heart attacks, cardiovascular illness, and hearing problems. A noise prediction model, traffic noise data, and 3D geographic data are all necessary for noise mapping. Smart noise mapping uses crowdsourced mobile applications to manage noise data, free satellite data to extract 3D information, and GIS interpolation to create a noise map of a given area. Roads, buildings, and land use/land cover are all planned by the city planner. Controlled traffic is provided by the proposed smart city, but healthier living conditions are not included. This paper aims to compare the benefits of organised and disorganised traffic using the criterion of noise pollution level. Google Images and a noise app were used to create a smart noise mapping approach that adjusted noise levels for various sorts of automobiles. The method is used to create noise maps of a busy crossroads in the growing metropolis of Lucknow, Uttar Pradesh, India. Before and after the junction became structured, noise maps were produced (separate lanes were designed for traffic in different directions). For three crucial traffic hours each day, it was seen that the scheduled traffic reduced noise levels by 15-20 dB or more. This paper tries to find out the advantages of organized traffic against unorganized traffic in terms of the yardstick of noise. The semantic segmentation method is used to characterise cars, making it simple to categorise various sets of vehicles into small, medium, and heavy vehicle categories. Data from several crossings in that smart city before and after the development was used to confirm the results.

1. INTRODUCTION

Day-by-Day, there are rapid appending of serious health hazards associated with noise pollution. Road traffic noise pollution is becoming to be a significant source of pain and illness for urban residents as a result of rapid rise in population and the expansion of transportation networks. Noise maps are very helpful for finding the sources of noise (Bharadwaj & Dubey, 2021; Vogiatzis & Remy, 2017). To create a noise map, Leq noise levels (equivalent sound pressure levels) must be measured and reflected on a map that depicts the impact of noise and can assist decision-makers in developing noise control and management approaches (Ausejo et al., 2011). A noise map is necessary in urban planning to study the sound properties of acoustics in a certain metropolitan zone and offer recommendations for soundscape urban design (Bharadwaj et al., 2020; Ruiz-Padillo et al., 2014). For instance, "Palma de Mallorca" (Spain) did research comparing potential noise mitigation strategies, taking into account noise reduction and the number of persons who would benefit from such measures, using a traffic noise map (Picaut et al., 2019). Other research made use of a "road stretch priority index," which weighed several factors according to how they affected traffic noise and divided roads into priority categories (Naish, 2010). The noise map research comprised a traffic noise forecasting model as well as sound propagation retardation. The Orbits-GIS software includes a noise prediction method (Picaut et al., 2019). Some methods may produce massive noise maps in two dimensions on a home computer in a matter of hours(Anderson, 2006). This post's objective was to show readers how to use ArcGIS for noise mapping. Noise data must be obtained before using the GIS, which is problematic and time-consuming in many places (Baliatsas et al., 2016; Paunović et al., 2009). Noise can be harmful to your health. Noise can affect your daily activities (sleep, conversation, work). Based on a literature search, the authors found no studies that combined noise-her mapping and exposure mapping. (Bharadwaj et al., 2022). As a result, the authors chose to focus on predicting noise maps and relating them to noise exposure and health indices. Areas with geographically and dynamically varying noise levels (Gleitman, 2012). As a result, it becomes difficult to identify the root cause of the above health problems. Governments must regularly educate people through effective advertising. In this respect, comprehensive monitoring and/or mapping of noise levels in multiple areas of a selected city is critical for proper traffic noise management. It is difficult to control the noise level all the time in large areas of a big city. Requires a lot of expensive noise or SPL meters. Noise level detection in critical areas such as B. Noise corridor roads and modeling or mapping in environments without such huge hardware resources. Furthermore, due to the use of sound level meters, it is difficult to collect accurate noise level data close to the noise source. We need to develop a cheap, efficient and convenient mapping system. Therefore, smartphones with noise maps are recommended (Rakesh Dubey et al., n.d., 2020). This article describes a deep learning-based semantic segmentation technique for detecting and classifying different types of vehicles, buildings, roads, and trees in high-resolution remote sensing photos. This allows you to explore object detection and define vehicle noise patterns. It uses a deep learning platform to train complex datasets and assess the accuracy of test data images. However, when collecting noise data, smartphone-based techniques present accuracy issues that need to be addressed. Smartphone-based solutions, when enabled, have the advantage of collecting data from a wide area while also providing comments from densely populated areas of the city (Rakesh Dubey et al., 2021). Effective crowdsourcing via the internet offers a wealth of opportunities to analyse data and map noise levels in cities (Zafar et al., 2020). Noise mapping requires the collection of noise levels, terrain parameters, and a noise level model. After the data is processed, it can be mapped as a raster, vector, or DEM in the ArcGIS platform and routes are extracted using LiDAR point cloud data (R. Dubey et al., 2021).

2. LITERATURE REVIEW

2.1 Smart Mapping

With the finding of Murphy et al. it can easily be concluded that the smartphone-based noise capturing of noise data has reduced the data dependency. This is the low cost capturing of noise data. Various test is made to determine the best accuracy from the different set of phones to record the noise data. The accuracy

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depends on the quality of earphone or receiver installed in the smartphone. The author has made the anechoic chamber to determine the ability of mobile phones to assess the background noise over different set of 100 phones. The tests were carried out on cell phones running the Android and iOS operating systems, respectively. Many numbers of test were performed of around 1000 plus to distinguish in the ability of the smartphone to record the noise data. The data also reveals that there is a significant relationship between phone life and its ability to measure noise consistently, as well as the cost of ambient noise monitoring and evaluation systems (Murphy & King, 2016).
Ventura et al findings indicate that the calibration approaches in which the Ambiciti method is used must be evaluated extremely carefully. To record the noise data at this event, there are 50 sets of phones. The range, accuracy, precision, and repeatability criteria served as the foundation for the performance barriers. The experiment has given rise to technique-creating context ideas. (Ventura et al., 2017).
The research was only available on the iOS and Google platforms. In the tests, a reference microscope, a professional type level one SPL metre, and a dosimeter were used to compare the effectiveness of the apps. Four iOS applications showed mean changes of less than two dB(A) of the reference microphone, per the data (Picaut et al., 2019).

2.2 GIS-based Noise map

GIS-based mapping has expanded in popularity in recent years, with applications in nearly every field and increased geographic data availability. GIS-based noise mapping is a useful technique for minimizing noise pollution, which could be hazardous to one's health in the current environment (Esmeray & Eren, 2021). It offers both numerically generated data and software created especially for environmental noise mapping applications. It incorporates a number of acoustic theories. The geographic domain is merged with the backdrop GIS-based computation, correct visualization, and analysis. With this in mind, the writers are doing research in the city of Lucknow. When, when, and how this investigation will be conducted must be determined. It is necessary to establish how noise parameters should be handled, how to use spatial data, and how to represent noise level mapping on the ArcGIS software platform (Das et al., 2019).

2.3 Unorganised traffic flow mapping

The main objective of this study is to develop a noise prediction model for continuous traffic flow. The research area for this study has been selected to be Bangalore, Karnataka, India. The research locations were picked to represent the many zones found in a metropolitan area, including the commercial, residential, calm, and high traffic zones. For each research site, traffic noise was measured for one hour using the Leq index and an A-weighted decibel scale. A multiple regression noise prediction model was developed using field observed traffic data, taking into consideration all significant contributing components. During the model-development process, a mean standard error of 2.32 dB(A) with a r2 value of 0.82 was observed (Aumond et al., 2017).

Jain et al. investigated how to build a comprehensive highway noise prediction model for Indian environments. The model's problem is that the corrective models used in their study for volume, speed, gradient, ground cover, and barrier were clones of those used in the FHWA model (USA) and CoRTN model (UK). In light of this, it was necessary to develop an urban road traffic noise forecasting model that took into consideration India's current road traffic conditions. As a result, the main objective of this research is to develop an urban road traffic noise prediction model under continuous traffic flow conditions, taking into account all of the significant causative factors that affect outdoor noise levels (Kalaiselvi & Ramachandraiah, 2016).
The purpose of this study is to develop an empirical noise prediction model for calculating equivalent noise levels (Leq) in circumstances where traffic flow is disrupted. A new factor tendency to blow horn (A H) was introduced into the classic federal highway administration noise prediction (FHWA) model, and a comparison study was undertaken to assess the model's applicability. Leq monitoring and modelling were carried out at four Jaipur city junctions. After comparing the results, it was found that the modified FHWA model could be used well for Indian circumstances, generating results with a 3 dB variance (A). Additionally, a statistical analysis of the data is performed, which includes both measured and estimated values (Pathak et al., 2018; Tandel & Sonaviya, 2018)

3. RESEARCH GAP

The vast majority of research fails to acquire accurate noise data for unorganized road networks. The data was gathered using a crude technique that was both costly and time consuming. Through the use of open geospatial data, terrain data is made accessible on the web. Noise level maps are created by integrating noise parameter data with topographical data. A smartphone-based mapping technology will enable a crowdsourcing technique in which anyone will be invited to participate in noise management to build a noise level map for their area. The shape and color of various sets of patterns and the disorganized network make it difficult to characterize vehicles.

4. OBJECTIVES

The goals are to calculate the change in noise value caused by organized and unorganized traffic for various sets of roads and timing The authors will attempt to develop a strategy for the next.

1. Collecting noise levels using smartphone app by calibrating it with standard SPL.
2. To classify the vehicles using semantic segmentation. And finding the degree of change in noise due to organized and unorganized traffic.
3. GIS based mapping using smart technique for metropolitan city.

5. METHODOLOGY

The authors chose the city of Lucknow since they were born and raised there and had seen how the traffic had changed over the years. As more segmented road corridors are built, the city's noisy traffic zone has diversified. These road corridors have organized the road network, shortened travel times, and enhanced vehicle speeds. The noise data is calibrated in an anechoic chamber using the standard SPL as data is collected using the smartphone-based NoiseCapture application. For Haniman crossing, noise data is taken at three distinct times for organized traffic. The terrain parameters required for noise mapping are obtained using publicly available topographical data. Utilizing the author's well-established methods, we extract terrain features and map. The classification of images acquired from open-sourced Google Earth is done for unorganized traffic using semantic segmentation. In this study, we provide a segment-before-detect pipeline that uses very high resolution (VHR) remote sensing data over metropolitan regions to extract and classify vehicles. Three components make up our technique, which is shown below. A fully convolutional network is used for semantic segmentation to infer pixel-level class masks. Vehicle detection is accomplished by regressing the bounding boxes of connected components, and object-level classification is accomplished using a conventional convolutional neural network. Additionally, the change in the variety of vehicle noise is identified and mapped for three-time intervals, and the mapping is done for both organised and unorganized time. The GIS platform is used for the mapping.

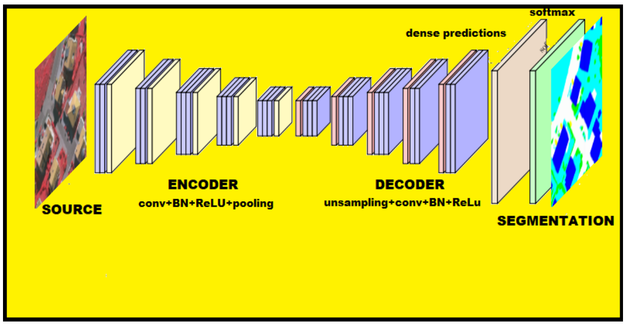

Figure 1. Semantic segmentation diagram how image is classified

5.1 Calibrating the NoiseCapture app with SPL meter

The authors can reliably predict that using iPhones and Samsung flagship phones, such as smartphones of different quality, and others, will provide better results than using other Smartphones with a high-quality microphone, based on the study's findings. The standard SPL meter CESVA SC310 is now being used in the current investigation, together with the noise app NOISECAPTURE.

5.2 Computation

The calculation was done with a number of topographical variables kept constant in mind. The presence of the noise barrier in this situation causes the noise source to be reduced or attenuated as it travels from the source to the receiver. As the noise travels, it will run into variation principles like diffraction, reflection, and refraction, which will cause the noise's real course of travel to be diverted. The following is a list of the calculations used to calculate attenuations:

$$Distance.Attenuation. = 20\,LOG10(d) + 11 \quad (1)$$

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

$$Barrier\ attenuation = 5.65 + 66N + 244N^2 + 287N^3 \quad (3)$$

Where,

d= distance between the source and the receiver

N= Fresnel number

N= path difference/(wavelength/2)

Path difference = indirect path – direct path

These calculations aid in figuring out the receiver's noise levels. The noise can be simply estimated at various locations, reducing the data reliance of gathering noise data at each and every place. The noise level map is then created using the ArcGIS software. The impediments to the straight path offer attenuation to the noise source, which in this example spans from 0 to 6.25dB(A), with higher values representing greater route loss. The building's shadow is utilized to compute its height, and a method for extracting the building's height is applied based on existing knowledge of the structure in the area. The background noise in the vicinity is estimated to range from 35.1 to 38 decibels (dB) (A), depending on the barrier encountered.

6. RESULTS

Initially, the author calibrated the smartphone-based noise app NoiseCapture with a standard sound pressure level metre in the anechoic chamber. Both SPL and Noise apps, which were positioned at a distance of 1 metre, played and recorded several sets of tonal sounds of single frequencies. The smartphone-based app's noise measurement was 4 dB below the SPL norm. Table 1 displays the variation for each group of frequencies. Later, data is recorded using the NoiseCapture app at various crossings and mapped over the GIS platform, as illustrated in figures 3,4,5 for Haniman crossing for three days for an unorganized road stretch where vehicles are in a mixed pattern, causing pandemonium at the intersection.

Frequency (Hz)	NoiseCapture L_{eq}	SPL L_{eq}	NoiseCapture freq(dB)	SPL 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

Segmentation results:

The segment's classification of two photos from Google Earth, where there is difference in the orientation of the cars due to structured and unorganized road networks, as shown in the segment's result image of two Lucknow city locations; (b) Ground truth; (c) segment prediction.
Legend: white is road; red is building; green is vegetation; car is blue; purple truck; black is bike; skin colour is impervious surface.

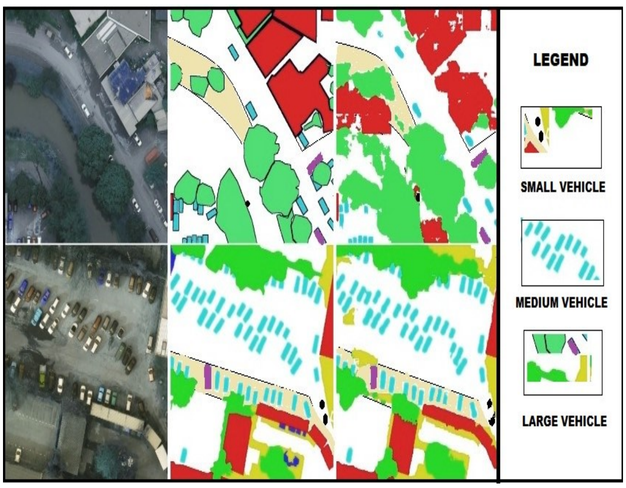

Figure 2. Semantic segmentation of vehicles on the basis of small, medium and large vehicles of google earth image classification.

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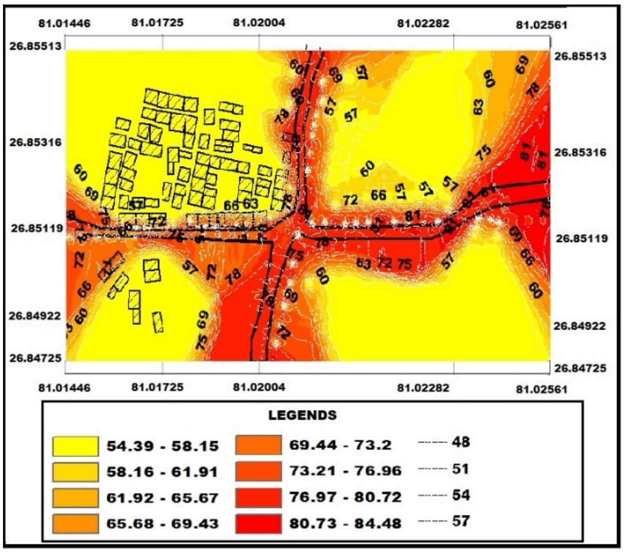

Figure 3. Noise level map of Haniman crossing for unorganized road for morning time.

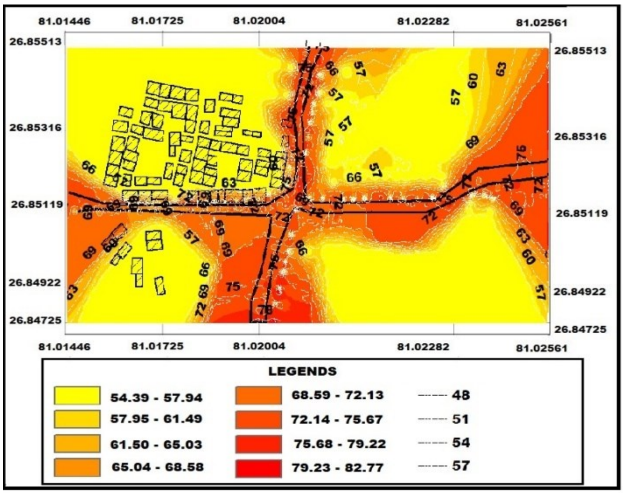

Figure 4. Noise level map of Haniman crossing for unorganized road for afternoon time.

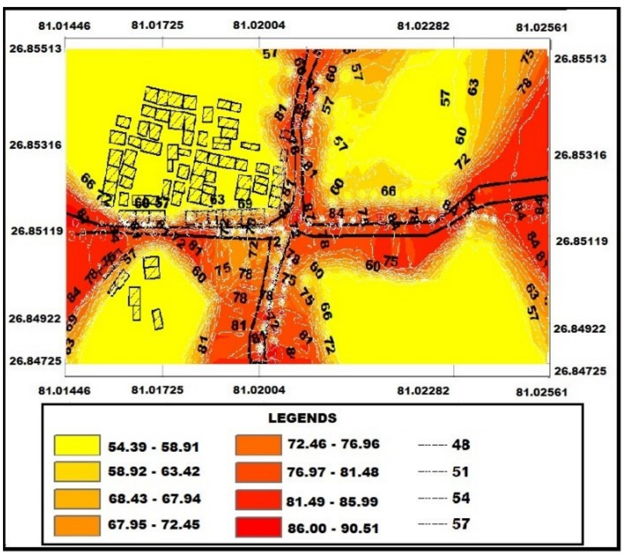

Figure 5. Noise level map of Haniman crossing for unorganized road for evening time.

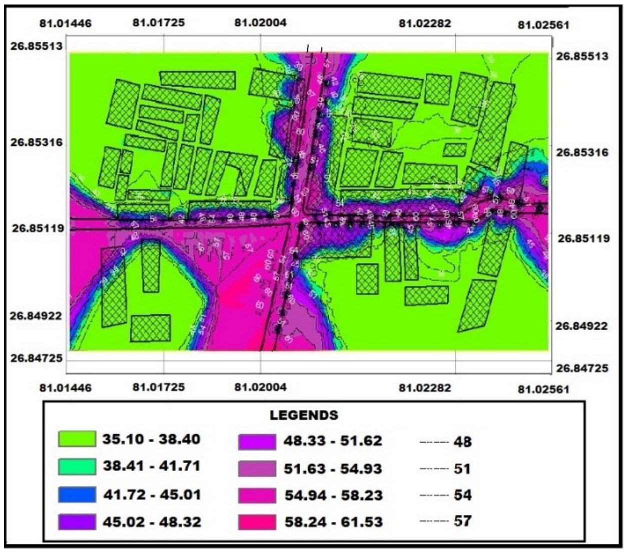

Figure 6. Noise level map of Haniman crossing for organized road for morning time.

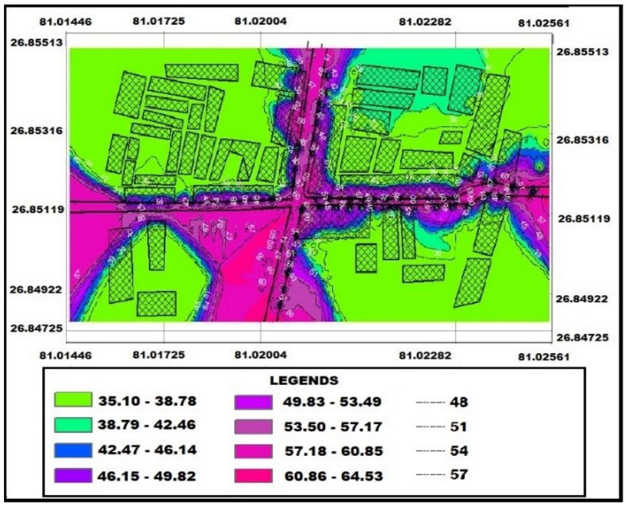

Figure 7. Noise level map of Haniman crossing for organized road for afternoon time.

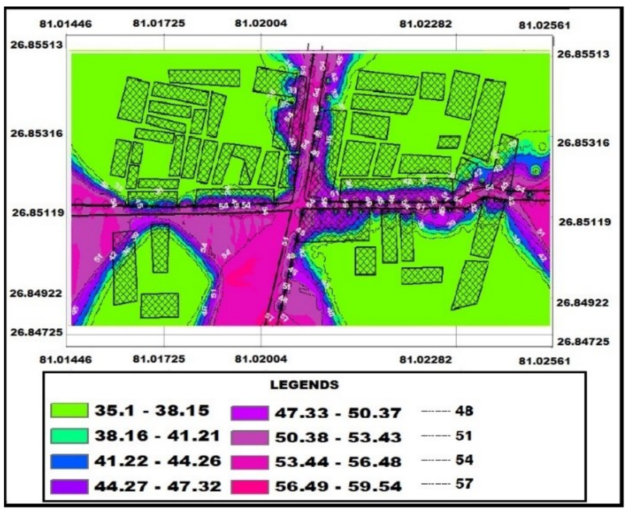

Figure 8. Noise level map of Haniman crossing for organized road for evening time.

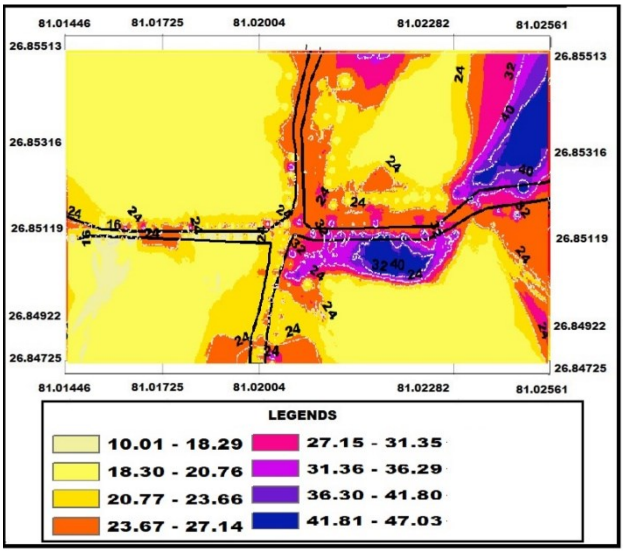

Figure 9. Noise level map of Haniman crossing showing the change in noise level of organized and unorganized traffic for morning time.

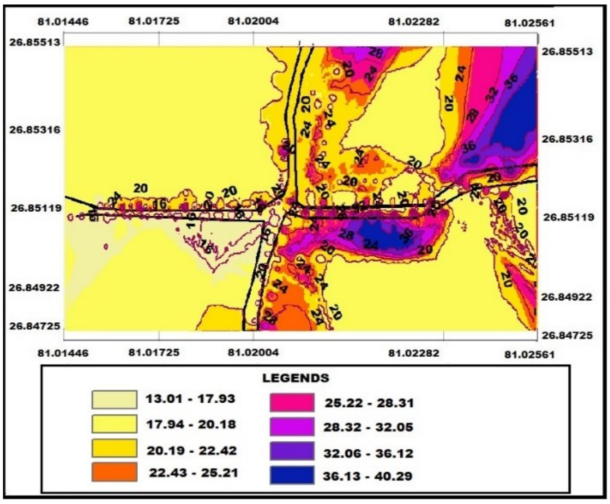

Figure 10. Noise level map of Haniman crossing showing the change in noise level of organized and unorganized traffic for afternoon time..

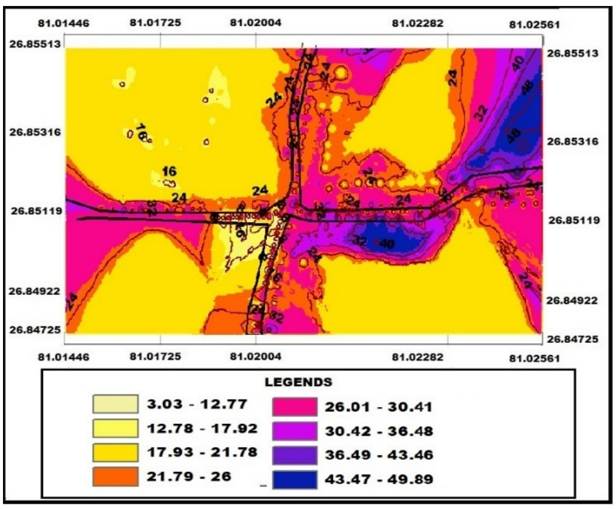

Figure 11. Noise level map of Haniman crossing showing the change in noise level of organized and unorganized traffic for evening time.

7. CONCLUSION

The authors have looked into the findings of numerous researchers. Using the smartphone-based application for noise prediction, which is a low-cost and practical technique of capturing noise data, noise levels are being measured. With this strategy, the problem of noisy data collection is addressed. The GIS platform is being used to forecast the map, and the technique is simple and effective for controlling traffic noise. It also uses the least amount of calculated data possible to create a noise map for the entire region. As the authors strive to modernise. The classification of Google Earth images to assess vegetation, buildings, and cars on the basis of small, medium, and large has supplied the noise map for prior years. The author has described the noise produced by individual automobiles in all conditions. The author further stated that on a planned and organised road network, when vehicle speeds are only high, honking is comparatively seldom, which lowers the noise intensity at crossings. The level of noise has significantly increased due to chaos in the quite disorganized road network. The technique identified the level of rise in noise level for Haniman crossing and fluctuation of -terrain characteristics and their application with noise level modelling t dB. The collaborative mapping, together with user health indicators, will provide an overview of the potentially harmful conditions that may present at several smart city crossings. The detailed time, season, and location-specific mapping will alert users to impending peril.

8. FUTURE SCOPE

The user was able to determine the significant repercussions at a fair amount with the aid of a noise recording software for smartphones. The user will also be able to gauge the level of noise at his or her location with the help of the classification of cars based on classifier to determine the type of vehicles. The degree of noise removal in the car can also be easily assessed. The study will also examine people's preferences for hospitals, schools, and residential areas in relation to the influence of noise on those locations. The analysis aids in infrastructure development by locating preferable areas. The idea of mixed land use pattern in developing countries can be decreased by organised traffic patterns and road networks. The entire forecast will be geospatially made in a GIS environment, with extra hints such as distance from home to hospital, distance from home to school, as well as transit availability, kind of transportation, different traffic circumstances, and so on, being weighted to discover the optimal or suitable site for perfect infrastructure with less noise.

REFERENCES

Anderson, T. L. (2006). 0.1. Failure Theories. *Fracture Mechanics – Fundamentals and Applications*, *Third Edit*, 3–10. https://mae.ufl.edu/nkim/eas4200c/VonMisesCriterion.pdf

Aumond, P., Lavandier, C., Ribeiro, C., Boix, E. G., Kambona, K., D'Hondt, E., & Delaitre, P. (2017). A study of the accuracy of mobile technology for measuring urban noise pollution in large scale participatory sensing campaigns. *Applied Acoustics*, *117*(2016), 219–226. https://doi.org/10.1016/j.apacoust.2016.07.011

Ausejo, M., Tabacchi, M., Recuero, M., Asensio, C., Pagán, R., & Pavón, I. (2011). Design of a noise action plan based on a road traffic noise map. *Acta Acustica United with Acustica*, *97*(3), 492–502. https://doi.org/10.3813/AAA.918429

Baliatsas, C., van Kamp, I., van Poll, R., & Yzermans, J. (2016). Health effects from low-frequency noise and infrasound in the general population: Is it time to listen? A systematic review of observational studies. *Science of The Total Environment*, *557–558*, 163–169. https://doi.org/10.1016/J.SCITOTENV.2016.03.065

Bharadwaj, S., & Dubey, R. (2021). RASTER DATA BASED AUTOMATED NOISE DATA INTEGRATION FOR NOISE RASTER DATA BASED AUTOMATED NOISE DATA INTEGRATION FOR NOISE. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLIII-B4-2*(July), 159–166. https://doi.org/10.5194/isprs-archives-XLIII-B4-2021-159-2021

Bharadwaj, S., Dubey, R., & Biswas, S. (2020). Determination of the best location for setting up a transmission tower in the city. *Proceedings of the 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing, ICSIDEMPC 2020*, 63–68. https://doi.org/10.1109/ICSIDEMPC49020.2020.9299612

Bharadwaj, S., Dubey, R., Zafar, M. I., Tiwary, S. K., Faridi, R. A., & Biswas, S. (2022). A Novel Method to Determine the Optimal Location for a Cellular Tower by Using LiDAR Data. *Applied System Innovation 2022, Vol. 5, Page 30*, *5*(2), 30. https://doi.org/10.3390/ASI5020030

Das, D., Ojha, A. K., Kramsapi, H., Baruah, P. P., & Dutta, M. K. (2019). Road network analysis of Guwahati city using GIS. *SN Applied Sciences*, *1*(8), 1–11. https://doi.org/10.1007/S42452-019-0907-4/TABLES/2

Dubey, R., Bharadwaj, S., Zafar, M. I., & Biswas, S. (2021). COLLABORATIVE AIR QUALITY MAPPING OF DIFFERENT METROPOLITAN CITIES OF INDIA. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLIII-B4-2021*(B4-2021), 87–94. https://doi.org/10.5194/ISPRS-ARCHIVES-XLIII-B4-2021-87-2021

Dubey, Rakesh, Bharadwaj, S., Bhushan, V., Mapping, N., Modeling, N., Phones, S., & Noise, R. T. (n.d.). *Collaborative noise mapping using smart phone*.

Dubey, Rakesh, Bharadwaj, S., & Biswas, D. S. (2020). Intelligent Noise Mapping using Smart Phone on Web platform. *Proceedings of the 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing, ICSIDEMPC 2020*, 69–74. https://doi.org/10.1109/ICSIDEMPC49020.2020.9299597

Dubey, Rakesh, Bharadwaj, S., Zafar, M. I., Mahajan, V., Srivastava, A., & Biswas, S. (2021). GIS Mapping of Short-Term Noisy Event of Diwali Night in Lucknow City. *ISPRS International Journal of Geo-Information 2022, Vol. 11, Page 25*, *11*(1), 25. https://doi.org/10.3390/IJGI11010025

Esmeray, E., & Eren, S. (2021). GIS-based mapping and assessment of noise pollution in Safranbolu, Karabuk, Turkey. *Environment, Development and Sustainability*, *23*(10), 15413–15431. https://doi.org/10.1007/S10668-021-01303-5

Gleitman, H. (2012). *Environmental protection department*. https://www.epd.gov.hk/epd/noise_education/web/ENG_EPD_HTML/m1/intro_5.html

Kalaiselvi, R., & Ramachandraiah, A. (2016). Honking noise corrections for traffic noise prediction models in heterogeneous traffic conditions like India. *Applied Acoustics*, *111*, 25–38. https://doi.org/10.1016/J.APACOUST.2016.04.003

Murphy, E., & King, E. A. (2016). Testing the accuracy of smartphones and sound level meter applications for measuring environmental noise. *Applied Acoustics*, *106*, 16–22. https://doi.org/10.1016/J.APACOUST.2015.12.012

Naish, D. (2010). A method of developing regional road traffic noise management strategies. *Applied Acoustics*, *71*(7), 640–652. https://doi.org/10.1016/J.APACOUST.2010.02.009

Pathak, S. S., Lokhande, S. K., Kokate, P. A., & Bodhe, G. L. (2018). *Assessment and Prediction of Environmental Noise Generated by Road Traffic in Nagpur City, India*. 167–180. https://doi.org/10.1007/978-981-10-5792-2_14

Paunović, K., Jakovljević, B., & Belojević, G. (2009). Predictors of noise annoyance in noisy and quiet urban streets. *The Science of the Total Environment*, *407*(12), 3707–3711. https://doi.org/10.1016/J.SCITOTENV.2009.02.033

Picaut, J., Fortin, N., Bocher, E., Petit, G., Aumond, P., & Guillaume, G. (2019). An open-science crowdsourcing approach for producing community noise maps using smartphones. *Building and Environment*, *148*, 20–33. https://doi.org/10.1016/J.BUILDENV.2018.10.049

Ruiz-Padillo, A., Torija, A. J., Ramos-Ridao, Á., & Ruiz, D. P. (2014). A methodology for classification by priority for action: Selecting road stretches for network noise action plans. *Undefined*, *29*, 66–78. https://doi.org/10.1016/J.TRD.2014.04.002

Tandel, B., & Sonaviya, D. (2018). *"A Quick review on Noise propagation models and software." February*, 6.

Ventura, R., Mallet, V., Issarny, V., Raverdy, P.-G., & Rebhi, F. (2017). Evaluation and calibration of mobile phones for noise monitoring application. *The Journal of the Acoustical Society of America*, *142*(5), 3084. https://doi.org/10.1121/1.5009448

Vogiatzis, K., & Remy, N. (2017). Soundscape design guidelines through noise mapping methodologies: An application to medium urban agglomerations. *Noise Mapping*, *4*(1), 1–19. https://doi.org/10.1515/NOISE-2017-0001

Zafar, M. I., Bharadwaj, S., Dubey, R., & Biswas, S. (2020). DIFFERENT SCALES of URBAN TRAFFIC NOISE PREDICTION. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *43*(B2), 1181–1188. https://doi.org/10.5194/isprs-archives-XLIII-B2-2020-1181-2020