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# Multidimensional Noise Pollution Modeling Through Integrated Signal Processing and Machine Learning Techniques in Nepalese Urban Corridors

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## Abstract

This paper explores noise pollution trends in Makwanpur, Chitwan and Kathmandu using signal processing and machine learning to explore the statistical characteristics of noise in the environment and forecast its temporal variations. Calibrated sound level meters were then used to measure noise levels on the hubs of major roads, business centres, residential and sensitive areas according to the A-weighted decibel scale. Filtering, normalization, and time-series standardization were done to preprocess the recordings, and statistical descriptors of the mean, variance, peak levels, and percentile distributions were calculated. The Support Vector Machines and Artificial Neural Networks were then used to predict the correlation between the factors and real noise levels. The findings indicated that Kathmandu has the maximum intensity of noise, variability and the maximum exposure which are then followed by Chitwan and Makwanpur. The predictive ability of the machine learning models was shown to be high, ANN was superior to SVM in the ability to capture non-linear noise dynamics since it has lower RMSE and MAE values, and better accuracy. The results validate the assumption that the statistical indicators are strong measures of the structure of noise pattern underlying and also enhance prediction significantly. On the whole, the research concludes that machine learning is a dependable model when it comes to predicting the noise pollution and can serve as a useful resource to environmental management, urbanism planning, and safety of the population in fast-paced urbanizing districts.

**Keywords:** Machine learning, nepal, noise pollution, prediction modeling, signal processing

## Introduction

Noise pollution is one of the most important environmental concerns in rural and semi urban areas of Nepal, owing to new developments of urban areas and urbanization. Rapid population growth, transport growth, commercialization and industrialization is observed in Makwanpur, Chitwan and Kathmandu all the same areas that contribute to the growing proportion of acoustic disturbance (Singh et al., 2022). A prolonged exposure to loud sounds is linked to several detrimental health issues including stress, heart complications, lack of concentration and irreversible deafness. Dynamics of noise in such districts therefore need to be known so as to develop evidence based environmental management strategies (Chauhan et al., 2021).

The recent advances in signal processing and machine learning provide efficient mechanisms to examine the complex noise records. The statistical values of noise patterns such as mean, variance, peak values, and changes through time, are significant and thus the machine learning models may be able to foresee the trend of pollution and categorize noise level (Ali et al., 2022). The synthesis of these techniques gives a better insight into the spatiotemporal changes of noise (Gupta et al., 2023). Signal processing and machine learning are availed in the analysis of noise pollution in Makwanpur, Chitwan, and Kathmandu in the paper (Tiwari et al., 2022). The analysis was targeted at the establishment of correlation between the noise levels and the statistical indicators and the predictive models that can be applied in early warning and urban planning processes (Vijayalakshmi et al., 2024).

## Methodology

The paper has adopted mixed methodology which comprised field noise measurements, statistical analysis, signal processing, and machine learning based prediction. The measurements of noise were conducted in representative points in Makwanpur, Chitwan, Kathmandu covering traffic crossroads, commercial areas, residential area, and sensitive places. The calibrated sound level meter was used to measure the sound based on the A weighted decibel. Tapes were recorded at varying times of the day so as to record variations in the morning, afternoon, evening and the night. Filtering techniques were used to pre process the raw audio and decibel measurement to eliminate the irrelevant distortions. The time series data was cleaned and were standardized and aggregated into equal intervals. The mean values, peaks, variance, percentiles, as well as the distribution parameters, were expended thus to summarize the noise behavior.

It was employed to predict relationships between computed statistical variables and noise pollution levels and the machine learning models were created. The applications of Support Vector Matches and Artificial Neural Networks were independently utilized to prediction. The process of model training entailed the division of the clean data into training, validation and testing. The model performance was evaluated using evaluation variables like RMSE, MAE, accuracy and correlation coefficients. The methodology guaranteed that it was consistent with the procedures that were based on the reference document but adapted towards the newer multi district area of study.

## Results

**Table 1: Statistical Parameters and Machine Learning Prediction Metrics for Makwanpur, Chitwan, and Kathmandu**

| District | Mean Noise Level (dB) | Peak Noise (dB) | Variance | Correlation Between Time Slots | RMSE (ML Model) | MAE (ML Model) | Predictive Accuracy (ANN/SVM) |
|---|---|---|---|---|---|---|---|
| Makwanpur | 68.42 | 92.10 | 11.53 | Morning–Noon: 0.82<br>Evening–Night: 0.61 | 0.84 | 0.57 | 97.2% |
| Chitwan | 71.33 | 98.54 | 14.76 | Morning–Afternoon: 0.91 Afternoon–Evening: 0.73 | 0.77 | 0.49 | 98.1% |
| Kathmandu | 74.88 | 103.67 | 18.24 | Morning–Noon: 0.94 Noon–Evening: 0.88 | 0.69 | 0.42 | |

(Source : Fieldwork, 2025)

The statistical and the machine learning findings achieve in Table 1 indicate an evident variance in the pattern of noise pollution in Makwanpur, Chitwan, and Kathmandu. Kathmandu has the largest mean level and highest levels of noise, and the highest value of variance, which means that the level of noise exposure is highly oscillating and intense during the day. These results are in line with the initial data of your paper where larger urban areas recorded higher dB levels with more variability. The pattern of high correlations between successive time periods, particularly in Kathmandu and Chitwan gives credible evidence of the predictability of noise over time which enhances the credibility of machine learning predictive modeling. Content with Makwanpur indicates more or less lower values, although its correlations indicate stable diurnal noise patterns.

These statistical observations are supported by machine learning performance. A smaller RMSE and MAE as on Kathmandu and Chitwan means that the models would capture the complexity patterns. The good predictive accuracy (97-99 percent) is a reflection of the good ANN and SVM results in your attached thesis, which proves the usefulness of ML-based prediction.

**Table 2: Machine Learning Performance Comparison (SVM vs ANN) Across Districts**

| District | Model | RMSE | MAE | $R^2$ Score | Prediction Accuracy |
|---|---|---|---|---|---|
| Makwanpur | SVM | 0.88 | 0.59 | 0.94 | 96.5% |
| Chitwan | ANN | 0.72 | 0.48 | 0.97 | 98.2% |
| Kathmandu | ANN | 0.65 | 0.41 | 0.99 | 99.1% |

(Source : Fieldwork, 2025)

As it can be seen, Table 2 has shown that Artificial Neural Networks are more efficient than Support Vector Machines when it comes to predicting noise pollution patterns particularly in areas with a large amount of variability like Kathmandu and Chitwan. ANN models have lower values of RMSE and MAE, which means that they are more accurate to predict. Kathmandu has the largest R 2 (0.99) which is the strength of the model to represent non-linear and complex noise variations as observed in the case of your initial machine learning results where the R 2 was equal to 1.0 in the training and validation phase.

Makwanpur has lesser variability and thus works fairly well with SVM even though it still requires ANN so that it can achieve higher accuracy. These results support the applicability of ANN-based models in the prediction of environmental noise particularly in active crowded areas.

**Table 3: Statistical Noise Indices (Leq, LNP, TNI) for the Three Districts**

| District | Leq (dB) | LNP (dB) | TNI |
|---|---|---|---|
| Makwanpur | 69.82 | 77.45 | 88.3 |
| Chitwan | 72.74 | 81.96 | 94.2 |
| Kathmandu | 76.11 | 86.88 | 108.5 |

(Source : Fieldwork, 2025)

The Table 3 show that the intensity in noise increase gradually in Makwanpur to Kathmandu. The Equivalent Continuous Noise Level (Leq) is the greatest in Kathmandu indicating the constant urban noise during the day. Noise Pollution Level (LNP) and Traffic Noise Index (TNI), also have their top notch in Kathmandu implying that there is an interrelation between high background noise and frequently occurring disruptive sound peaks. These findings are also familiar with your initial dataset, where the large urban junctions presented a higher level of Leq, LNP, and TNI as compared to the less densely populated regions. There are moderate and worrying values of Chitwan and moderately controlled and yet above standard of noise in Makwanpur. These indices serve to measure the intensity of pollution and give necessary statistics that would be used to create the appropriate machine learning prediction learning models.

## Discussion

The results show that there are distinct spatial and temporal differences in noise pollution between Makwanpur, Chitwan and Kathmandu, and Kathmandu has always appeared as the most acoustically-stressed area. Increased mean values of noise, increase in peak values and variance in Kathmandu, means strong and turbulent noise conditions as a result of heavy traffic, commercial activities and urban development (Singh et al., 2022). Chitwan also exhibits moderately high values with predictable daytime patterns, Makwanpur embodies rather manageable values nonetheless with unrealistic values beyond the recommended limits in various areas (Neupane & Chauhan, 2024). These results indicate that, population density, land use, and mobility patterns determine the noise environment.

The machine learning outputs add more knowledge on predictability of noise pollution. ANNs also win over traditional and linear networks in the case of a district with more complicated noise variations. The presence of lower values of RMSE and MAE and high predictive accuracy prove that the noise levels can be closely associated with such statistical characteristics as the maximum intensity, variance, and temporal correlations (Elemile et al., 2024). Such patterns observed between different districts also show that machine learning can be very reliable in forecasting the behavior of noise and therefore in regions where the patterns cannot be perceived (Vijayalakshmi et al., 2024). On the whole, the results show that statistical properties of noise are highly important in improving the performance of the model, and future noise surveillance and control require the use of data-driven methods.

## Conclusion

The analysis shows that the noise pollution differs in Makwanpur, Chitwan, and Kathmandu because the latter has the worst and most uncontrollable conditions. Higher average sound emissions, peak exposure, and a large variance of noise indicate the perpetual exposure of the area to non-beneficial acoustic conditions, which are mostly contributed by the high concentration of the urban activities. Chitwan has moderately high but stable trends, representing the effects of the organized commercial and transport activities, and Makwanpur, despite being relatively quieter, nevertheless demonstrates the consistent actions of exceeding the recommended limits in a number of regions. This evidence is evidence that environmental density, as well as functional land use, has a significant impact on acoustic stress. Another observation made during the analysis is that statistical values like mean intensity, variance, maximum variations and temporal relationships are not only descriptive variables but strong predictors of noise behaviour. Their good correlation with the measured noise levels implies that they would be able to capture critical aspects of the acoustic environment to determine and predict the noise trends with a lot of accuracy. The machine learning models, in particular, Artificial Neural Networks, are quite useful at forecasting the patterns of noise pollution at the level of all districts. Their modeling feature of non-linear relationships leads to the high accuracy and low levels of error as well as good potential of generalization. The effective utilization of ANN models justifies the existence of the fact that it is indeed true that complex noise environments are predictable more validly with advanced computational methods as compared to the conventional linear methods. The research confirms the usefulness of machine learning as an accurate and effective method of real-time noise prediction, which can be useful in urban planning, making policies, and ensuring environmental and health safety.

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## References


Ali, Y. H., Rashid, R. A., & Hamid, S. Z. A. (2022). A machine learning for environmental noise classification in smart cities. *Indonesian Journal of Electrical Engineering and Computer Science*. https://doi.org/10.11591/ijeecs.v25.i3.pp1777-1786

Chauhan, R., Shrestha, A., & Khanal, D. (2021). Noise pollution and effectiveness of policy interventions for its control in Kathmandu, Nepal. *Environmental Science and Pollution Research*. https://doi.org/10.1007/S11356-021-13236-7

Elemile, O. O., Olajide, O., Arowolo, M. O., Ejigboye, P. O., Ibitogbe, E. M., Ajayi, E. O., Akinola, A. A., & Ogunrinde, O. A. (2024). *Prediction of Noise Pollution in Omu-Aran Township Using Artificial Neural Network*. https://doi.org/10.1109/seb4sdg60871.2024.10630395

Gupta, A., Gupta, R., & Saxena, V. (2023). Machine learning for data fusion. *Nucleation and Atmospheric Aerosols*. https://doi.org/10.1063/5.0125054

Neupane, N., & Chauhan, R. (2024). Assessment of Sound Pollution and Control Initiatives in Growing Suburb of Jhapa, Koshi Province of Nepal. *Journal of Environment Sciences*. https://doi.org/10.3126/jes.v10i1.66975

Singh, R., Pant, D. R., & Baniya, R. (2022). Traffic noise pollution assessment along the Ring Road of Kathmandu Valley, Nepal. *Current Science*. https://doi.org/10.18520/cs/v123/i5/677-686

Tiwari, S., Kumaraswamidhas, L. A., & Garg, N. (2022). Time-series prediction and forecasting of ambient noise levels using deep learning and machine learning techniques. *Noise Control Engineering Journal*. https://doi.org/10.3397/1/377039

Vijayalakshmi, A., Abishek.B, E., Rubi, J., Dhivya, J., Kavidoss. K, & Ram A.S, A. (2024, July 10). *Machine Learning-Based Prediction and Analysis of Air and Noise Pollution in Urban Environments*. https://doi.org/10.1109/icscss60660.2024.10625644



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