Predictive Machine Learning Modeling of Urban Traffic Air Pollution: A Case Study of the Entebbe–Kampala Road, Uganda

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Abstract

Air pollution in Africa is a growing yet often overlooked threat, worsened by increased industrial activity, urban development, air travel, and road traffic. This study examines the impact of traffic flow and meteorological conditions on urban air quality along the Entebbe–Kampala corridor in Uganda. Traffic monitoring was conducted on three road sections and air quality was measured using AirQo mobile sensors. Traffic surveys showed motorcycles, saloon cars, and light goods vehicles dominate, while heavy trucks contribute minimally. Pearson correlation, regression analysis and extreme gradient boost models were used in analysis with Shapley Additive Explanation quantifying marginal contributions of traffic and meteorological variables to emission levels. Air quality monitoring revealed temporal variation, with $PM_{2.5}$ peaking at night due to stable atmospheric conditions limiting dispersion. Correlations confirmed pollutant co-occurrence during evening and night, emphasizing risk of accumulation under low atmospheric mixing. Regression analyses demonstrated strong positive relationships between Average Daily Traffic and $PM_{2.5}$, CO_2, and TVOC concentrations with R^2 values ranging from 0.89 to 0.986. Wind speed explained 45 to 71% of pollutant variances, reflecting its role in pollutant dispersion and resuspension. Traffic volume emerged as a primary driver of emissions using SHAP explanations. This study considered a small sample size and limited data collection which may affect applicability and fail to reflect seasonal or long-term variations in patterns of emissions and traffic. It underscores the need for urban air quality policies in Uganda integrating pollutant-specific measures like traffic control to reduce $PM_{2.5}$, stricter speed regulation for TVOCs, and enhanced fuel efficiency for heavy vehicles to lower CO_2. The study provides validated, locally calibrated models and evidence-based insights to guide targeted traffic and emission management in rapidly urbanizing African cities.