

DhuliX: Real-Time Air Quality Monitoring and Visualization System

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Abstract

Rapid urbanization, increasing vehicular emissions, industrial activities, and uncontrolled urban expansion have significantly degraded air quality in Dhaka, Bangladesh, creating severe environmental and public-health challenges for urban residents. Exposure to high concentrations of particulate matter (PM), particularly PM_{2.5}, is associated with respiratory diseases, cardiovascular complications, and long-term health risks, while existing fixed air-quality monitoring stations often fail to capture dynamic street-level pollution variations and localized exposure hotspots across different urban regions. To address these limitations, we developed DhuliX, an AI-assisted real-time mobile air-quality monitoring and visualization system designed for smart urban environments. The proposed system integrates the high-precision Sensirion SPS30 particulate matter sensor with ESP32-based edge processing and wireless communication technologies to enable continuous mobile environmental sensing from moving public transportation vehicles operating across multiple urban corridors of Dhaka, including Ashulia, Uttara, Motijheel, Mirpur, Dhanmondi, and Gulshan/Banani. The platform continuously measures PM_{1.0}, PM_{2.5}, PM_{4.0}, and PM₁₀ concentrations at regular intervals, generating high-resolution pollution data from diverse traffic-intensive regions throughout the city. To improve measurement reliability and system efficiency, collected sensor data are preprocessed using onboard filtering and calibration techniques before being transmitted through MQTT over WiFi/4G networks to a cloud-based time-series database for real-time visualization through interactive dashboards and map-based interfaces. Additionally, the system incorporates AI-assisted analytical techniques including spatial hotspot analysis, anomaly detection, and short-term pollution trend forecasting to identify high-risk exposure zones and better understand urban air-quality dynamics. By integrating mobile sensing, edge computing, cloud visualization, and intelligent environmental analysis, DhuliX provides a scalable, cost-effective, and real-time framework for future smart-city air-quality monitoring, prediction, and environmental management initiatives.

Problem Statement and Objectives

Problem:

- Existing fixed monitoring stations cannot capture real-time street-level pollution variations across different urban regions. [1]
- Lack of mobile air-quality monitoring limits the identification of pollution hotspots and commuter exposure in traffic-intensive areas. [2]

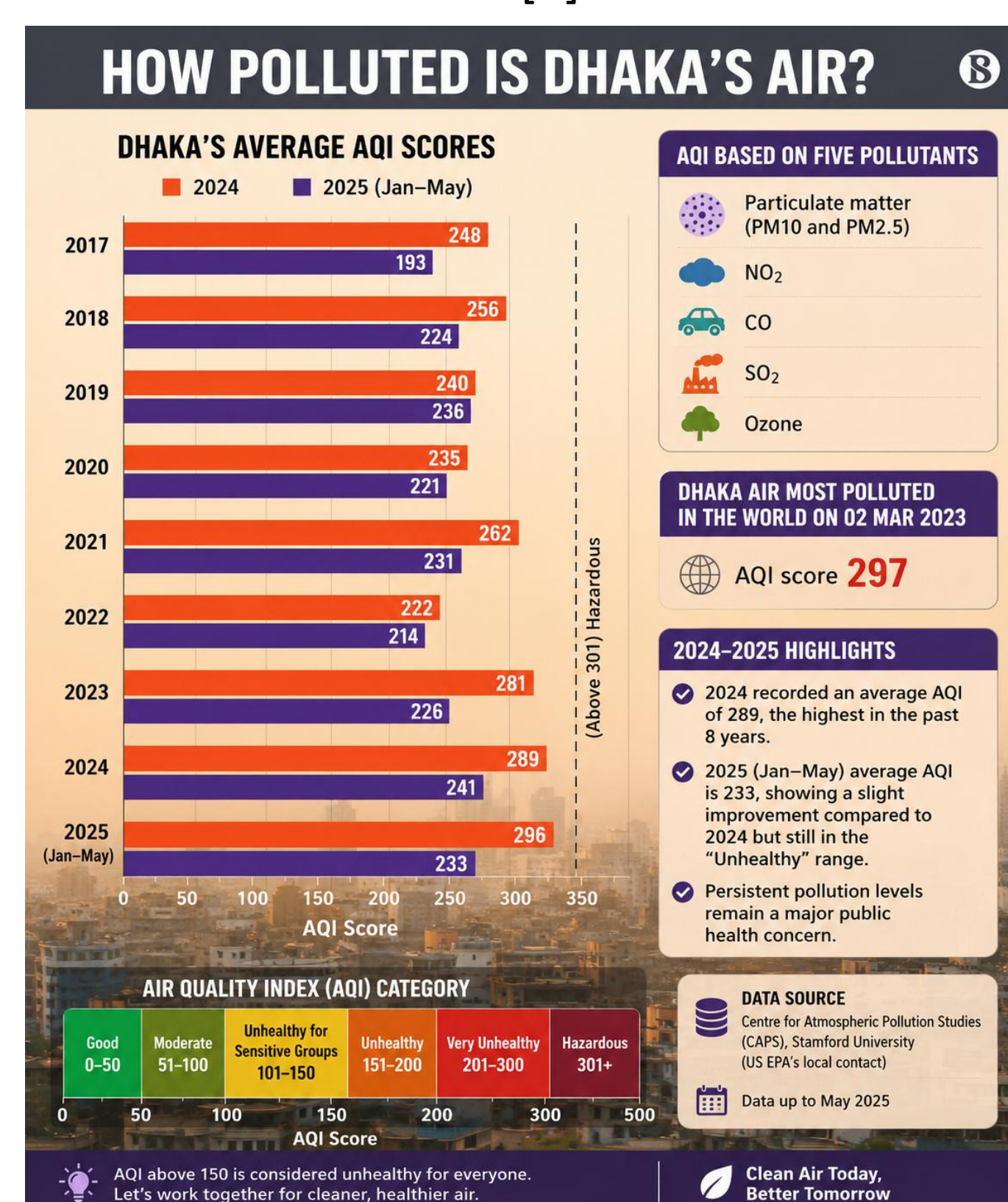


Figure: Infographic of Dhaka's air pollution.(The Business Standard)

Objectives:

- To develop a real-time mobile air-quality monitoring system capable of collecting environmental data from different urban regions of Dhaka city.
- To integrate the Sensirion SPS30 particulate matter sensor with the LILYGO T-SIM7670G-S3 LTE ESP32-S3 development board for continuous monitoring of PM_{1.0}, PM_{2.5}, PM_{4.0}, and PM₁₀ concentrations.
- To establish a cloud-based data transmission and storage framework using HTTP over 4G LTE/WiFi networks for real-time monitoring and analysis.
- To visualize pollution data through interactive dashboards and map-based monitoring systems for researchers, citizens, and policymakers.
- To identify pollution hotspots, abnormal exposure zones, and traffic-related pollution patterns using AI-assisted data analysis techniques.
- To develop a scalable and cost-effective smart-city air-quality monitoring solution for future environmental management and policy support.

Reference

- [1] Guan, Y., Johnson, M. C., Katzfuss, M., Mannhardt, E., Messier, K. P., Reich, B. J., & Song, J. J. (2019). Fine-Scale spatiotemporal air pollution analysis using mobile monitors on Google Street View vehicles. *Journal of the American Statistical Association*, 113(531), 1111–1124. <https://doi.org/10.1080/01621459.2019.1665576>
- [2] Rahman, R., & Kabir, A. (2023). Spatiotemporal analysis and forecasting of air quality in the greater Dhaka region and assessment of a novel particulate matter filtration unit. *Environmental Monitoring and Assessment*, 195(7). <https://doi.org/10.1007/s10661-023-11731-y>
- [3] Rahman, M. A., Kalam, A., & Al-Mamun, M. (2023). Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health. *Frontiers in Public Health*, 11. <https://doi.org/10.3389/fpubh.2023.1269362>
- [4] Azkar, M. a. M. B. L., Chatani, S., & Sudo, K. (2012). Simulation of urban and regional air pollution in Bangladesh. *Journal of Geophysical Research Atmospheres*, 117(D7). <https://doi.org/10.1029/2011jd016509>

Methodology

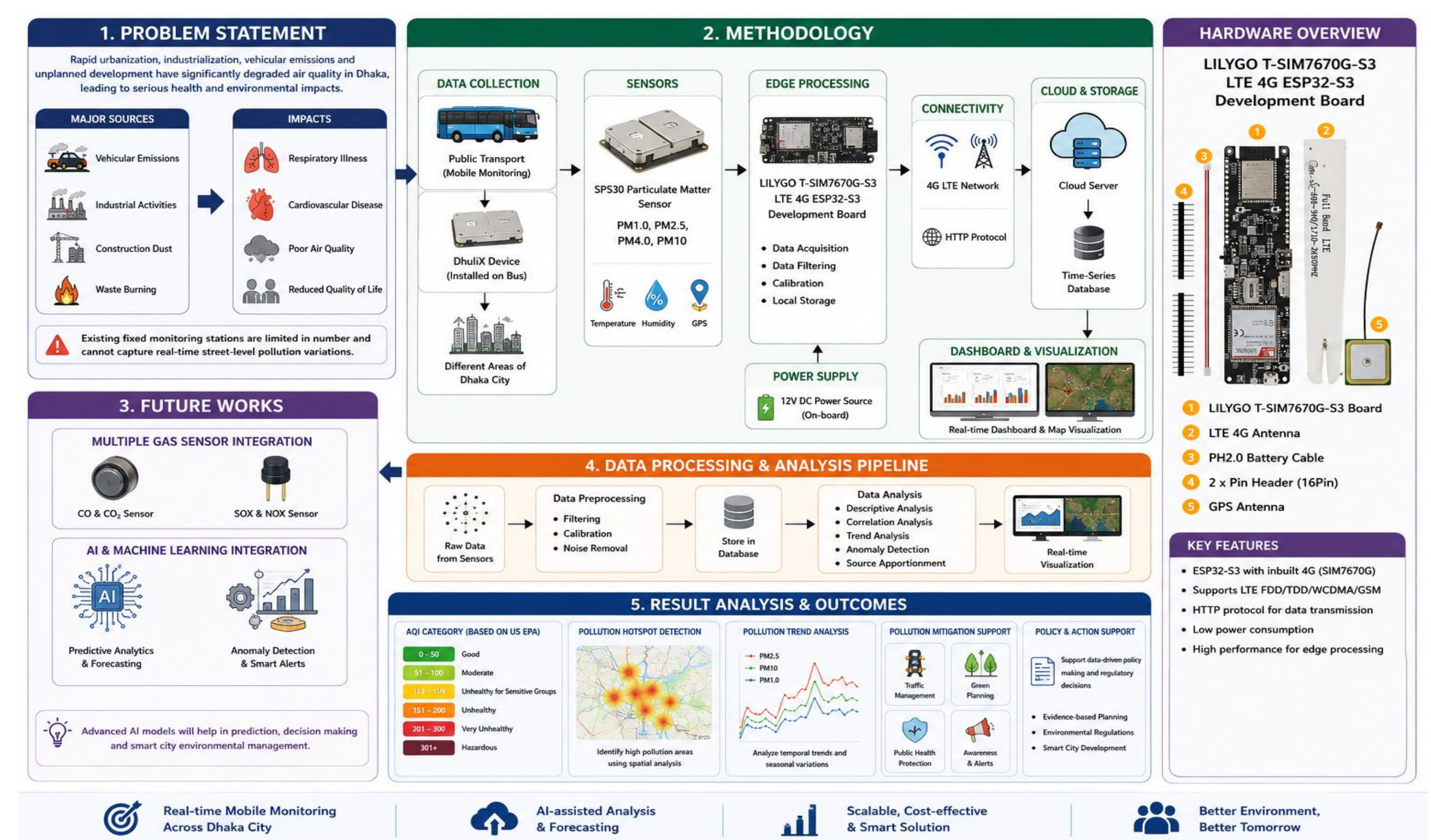


Figure: Methodology Workflow of the DhuliX Mobile Monitoring System

1. Sensor Integration:

High-precision SPS30 PM sensor and environmental sensors integrated with the LILYGO T-SIM7670G-S3 LTE ESP32-S3 development board. Installed inside weather-protected enclosures on public transportation vehicles for real-time outdoor monitoring.

2. Data Pipeline:

Air-quality data are collected every 1 minute and transmitted through HTTP over 4G LTE/WiFi networks to a cloud database for storage and processing.

3. Hotspot Analysis:

Collected data are analyzed to identify highly polluted areas, abnormal pollution spikes, and traffic-related exposure zones across different regions of Dhaka city.

4. Visualization & Reporting:

Real-time air-quality data are displayed through live dashboards and map-based visualization platforms for monitoring and environmental analysis. Automated alerts are generated for high-pollution areas and unhealthy exposure conditions.

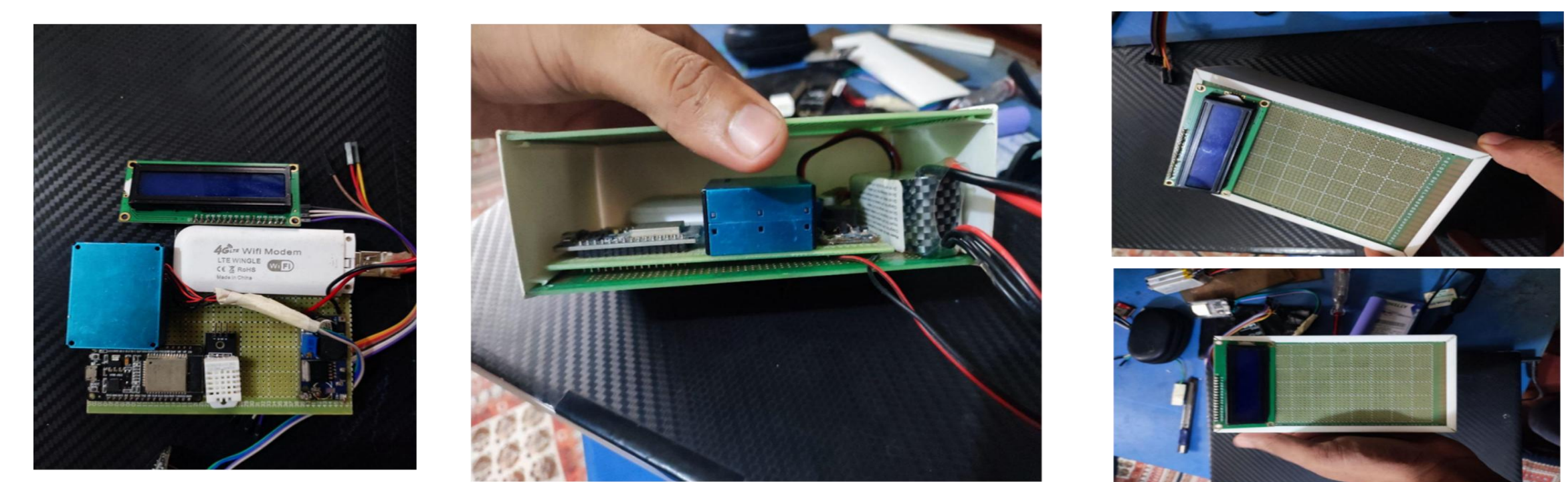
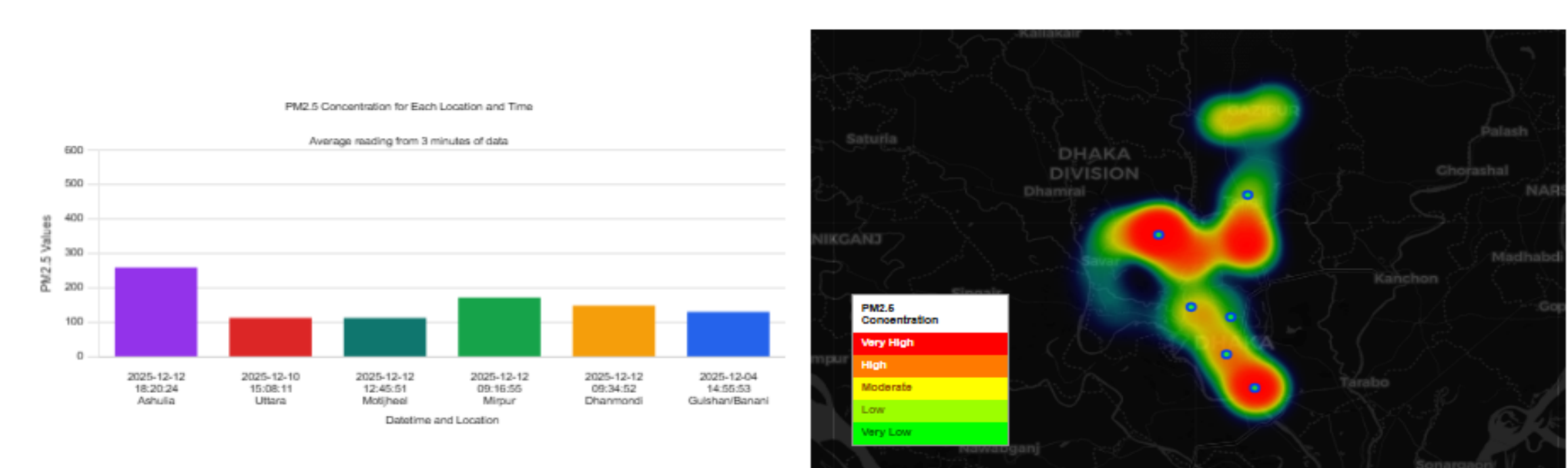


Figure: prototype of our product DhuliX.

Results and Findings

Data Received from 6 different locations of Dhaka Region and Visualize on map



Locations: Ashulia, Uttara, Motijheel, Mirpur, Dhanmondi, Gulshan/Banani

Figure: Map and Bar chart visualization of pm2.5 in 6 different locations.

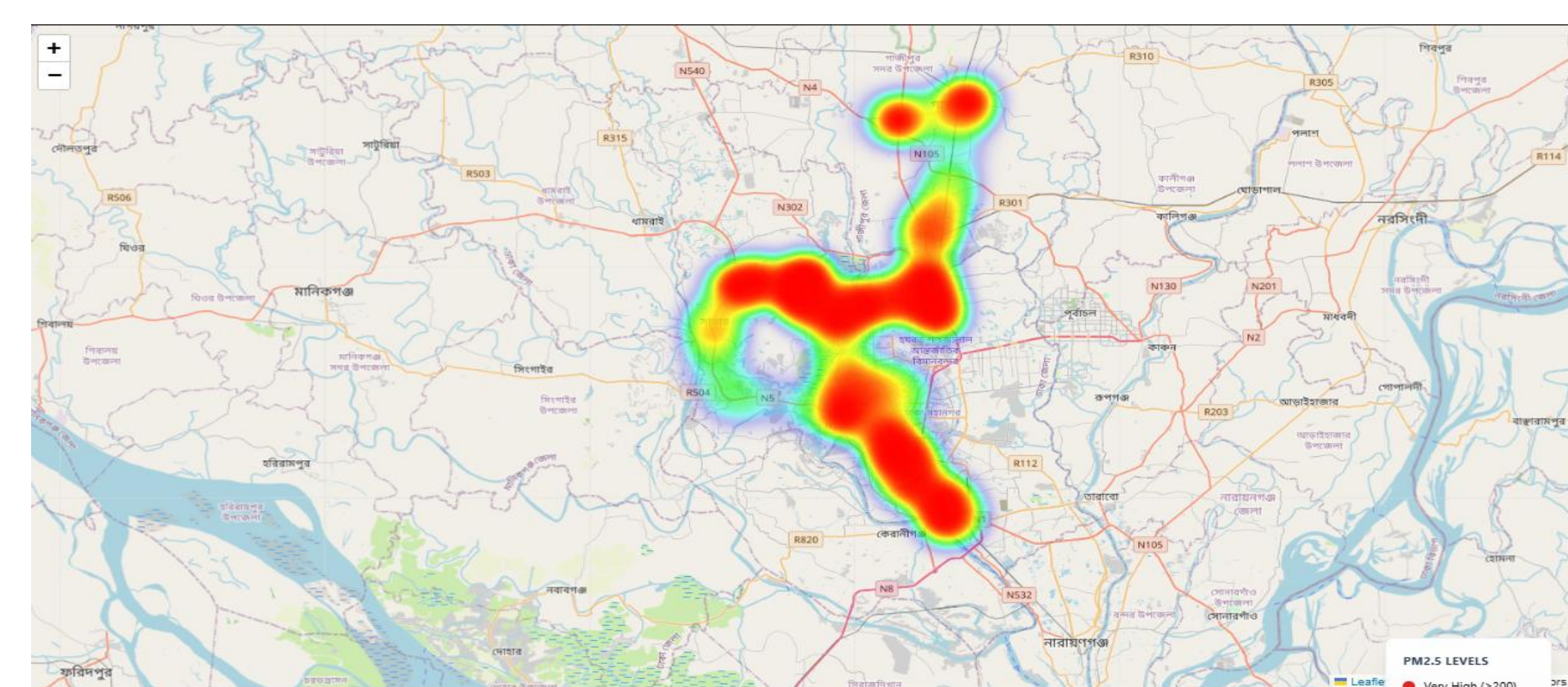


Figure: Real time visualization for the pm2.5 on particular region.

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