

Original Article

An AI-Based Ventilation KPI Using Embedded IoT Devices

Shiny Pradheepa¹, Madhumitha.S²

¹Assitant professor, Department of EEE, Francis Xavier Engineering College, Tirunelveli.

²Student, Department of EEE, Francis Xavier Engineering College, Tirunelveli.

Received Date: 25 February 2026

Revised Date: 05 March 2026

Accepted Date: 23 March 2026

Abstract: An AI-based Key Performance Indicator (KPI) framework is developed for monitoring and controlling ventilation quality using embedded devices. The system integrates real-time data from MQ-02 and MQ-135 gas sensors, processed through machine learning algorithms to generate predictive outputs that guide ventilation control decisions. These streamlined models are designed specifically for embedded deployment, continuously monitoring critical KPIs related to air quality index, ventilation efficiency and response time to ensure smart order situational adaptive ventilation. The solution has scalability, low power consumption and stable functioning under various conditions-all because these models are combined with small IoT devices (they don't differ in size and price from ordinary calculators or digital watches). By processing raw sensor data into actionable insights, this helps to improve ventilation performance and contributes toward green, smart infrastructure in the archetype of Smart Cities.

Keywords: AI-Based Ventilation, IOT Devices, KPI, Real Time Monitoring, Gas Sensor, Embedded Device.

I. INTRODUCTION

As health, sustainability, and smart infrastructure become more important topics of conversation, we need to pay even closer attention to how well air can circulate through enclosed public spaces – as institutions of education often have a high density of occupants for extended periods. Conventional ventilation systems are typically static and do not take into account dynamic variables, such as occupancy rates and CO₂ build-up. This can create poorly ventilated environments that promote fatigue, decreased attention span and the spread of airborne diseases.

This project aims to fill the gap and provide robotic, intelligent, low-cost, and scalable solutions for continuous indoor air quality monitoring and automation. Finally, this project introduces a significant need for more intelligent healthier learning environments by utilizing the amalgamation of artificial intelligence powered multi-dimension predictive models and in-built IoT without connectivity solutions, which are valuable to contemporary Smart University eco-systems as well as the wider ambitions for Smart Cities.

A. Problem Statement

Traditional building ventilation systems are inefficient because they operate without real-time monitoring and actionable metrics, leading to poor Indoor Air Quality (IAQ) and high energy use. Current methods are unable to adapt to dynamic occupancy updates, resulting in under- or over-serviced spaces. Lack of objective, real-time performance indicators (KPIs) to evaluate ventilation efficacy. Improperly regulated ventilation in enclosed spaces (e.g., classrooms) can lead to disease transmission, particularly due to high accumulation. Outdated systems waste energy because they do not adjust ventilation rates based on actual occupancy or environmental data. Difficulty in remote, real-time monitoring and integration of IoT sensor data (temperature, humidity,) for automated, data-driven decisions.

B. Objective

Developing a new KPI that highlights a tool for decision making to assess performance of ventilation and keep it within safe healthy limits. Reinforcement neural networks are specifically used to estimate the number of people (using Wi-Fi data) and CO₂ accumulation prediction (based on sensor data). Reconciliation of occupant comfort & safety (disease avoidance) with energy conservation in demand-controlled Ventilation Use low-cost LoRa-based sensors as embedded IoT proto types to monitor IAQ parameters (temperature, humidity etc).

C. Scope and Study

Future scopes of the proposed work / The Embedded Ventilation KPI System is a favourable technology in future along with its possible implementation in practical world. In future, the system can be improved by development of AI & ML algorithms to predict analysis and also give autonomy for air control. This would enable the system to learn from historical data, predict air quality changes, and automatically calibrate airflow for best performance. Advanced versions may also integrate cloud-based solutions for data analytics to allow centralized management of the data collected from systems distributed over many buildings or campuses in smart city infrastructure. For example, focus on renewable energy resources (like solar-powered ventilation units) could enhance sustainability and energy rationality.



II. COMPONENTS

A. Components and Specifications:

- ATMEGA 328
- MQ 2 Smoke Sensor
- MQ-135 Gas Sensor
- LCD-Liquid Crystal Display
- Relay Driver
- Python IDE software
- Embedded C programming

III. BLOCK DIAGRAM

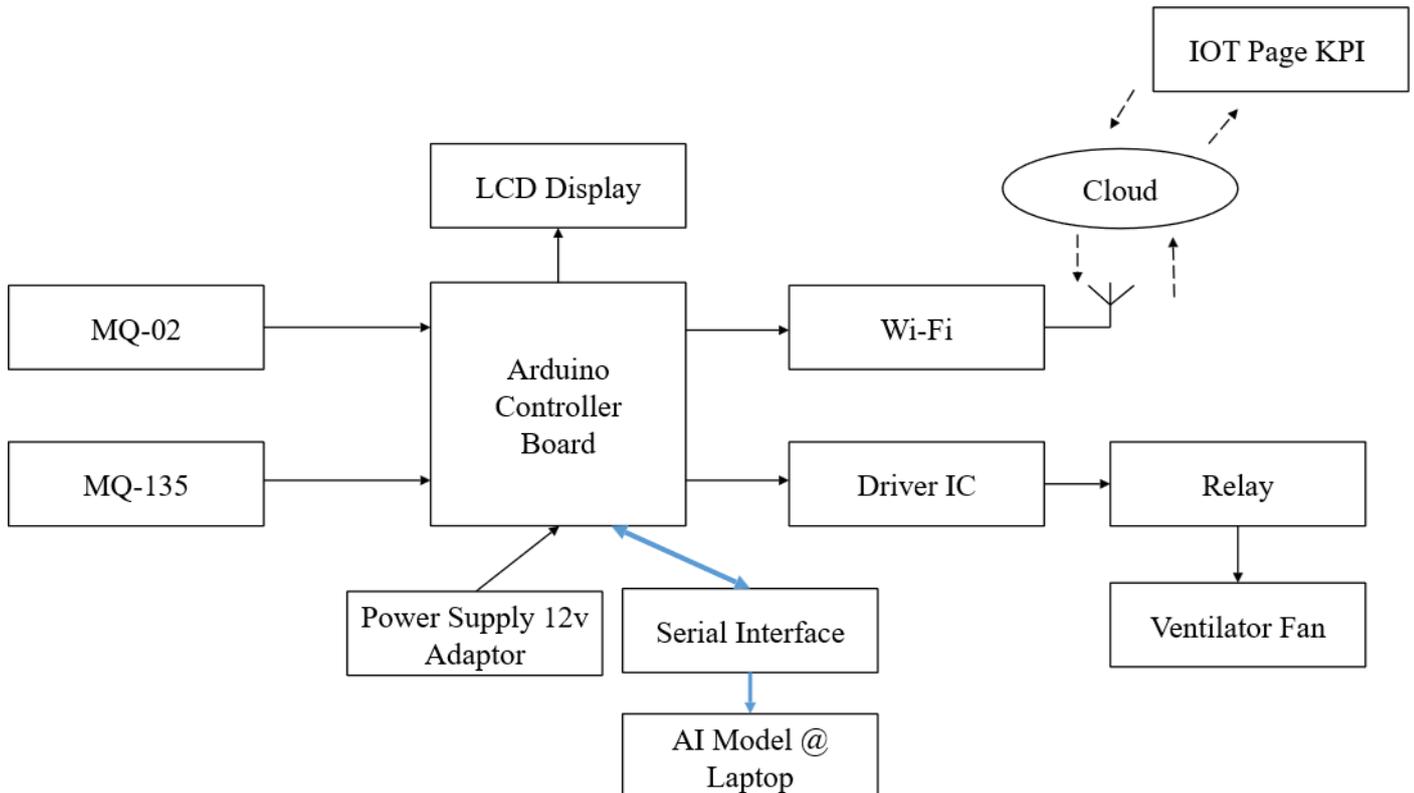


Figure 1 : Block Diagram of System

A. Working

Block diagram of AI based ventilation KPI system with embedded IoT devices The system comprises MQ-02 and MQ-135 attached to a controller board (Arduino shown in here with the possibility of replacing it with Node MCU for Wi-Fi based IoT) to monitor air quality. The controller board receives and processes the sensor inputs, showing real time readouts on an LCD display. The data is sent to the cloud through Wi-Fi where it can be further analysed and displayed on an IoT KPI dashboard. A serial interface allows the system to communicate to an AI model on a laptop, where intelligent decisions enable predictive ventilation control. In this case, a power supply (adapter 12V) is used to supply the whole circuit. The controller actuates a ventilator fan using a driver IC and relay mechanism to keep indoor air quality at the best levels automatically. Cloud-based connected IoT platforms enable real-time monitoring, intelligent decision-making, and remote access.

IV. CIRCUIT DIAGRAM

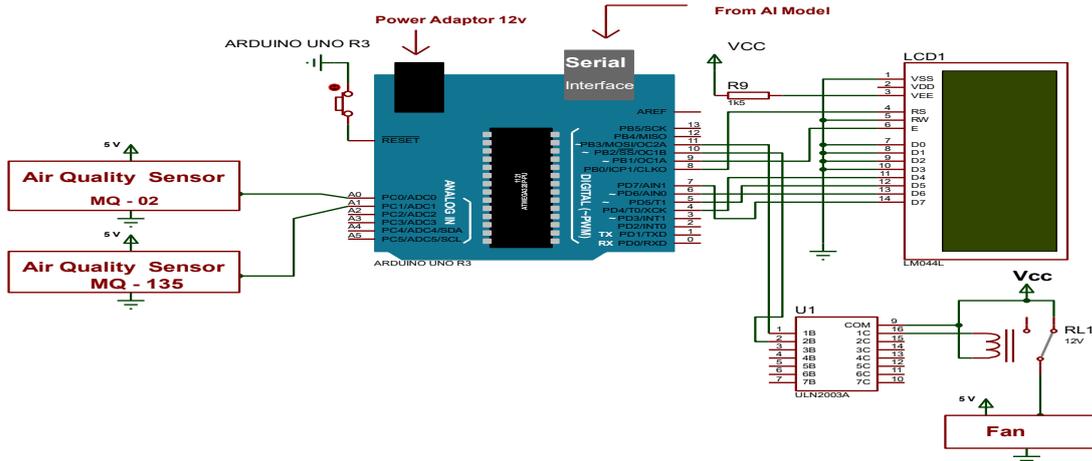


Figure 2 : Circuit Diagram of the System

V. RESULT AND DISCUSSIONS

“An AI-Based Ventilation KPI Using Embedded IoT Devices” describes a system that, leveraging regression neural networks and low-cost sensors, computes a ventilation Key Performance Indicator using levels of Wi-Fi occupancy data. As shown in this study, such a system can help facilitate proactive monitoring of indoor air quality and classroom ventilation effectiveness via the SmartUA platform.

VI. CONCLUSION

The significance of air ventilation to the health, comfort, and productivity of enclosed space dwellers was a key conclusion found in study(ies) such as; In indoor environments, limited ventilation can increase CO₂ levels and accumulate other airborne contaminants, which adversely influence health outcomes and cognitive behavior. In response to this issue, the study proposed a new metric, the Ventilation Key Performance Indicator (KPI_v), tailored for optimized functionality in Smart City and Smart University contexts. The KPI_v is a metric representing quantitative data helpful in making more informed decisions on the management of indoor air quality and ventilation performance. By estimating levels of occupancy and CO₂ build-up, it provides a transparent and dynamic assessment of ventilation performance instantaneously. The Embedded Ventilation KPI_v system proposed herein offers a novel and future-forward approach to air management in academical and urban contexts. This not only enhances insight and management of indoor air quality, but also fits the larger mindset of Smart Cities that use data-driven solutions. This involves machine learning (AI) in predictive controls, cloud-based analytical tools and multi-sensor fusion that would help to improve accuracy, responsiveness and scalability of solutions leading to healthier and energy efficient indoor ecosystems.

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