

**CAPSTONE PROJECT REPORT**

**AI and IoT-based Smart Air Quality Monitoring System with Automated Alerts**

**SOFTWARE ENGINEERING FOR AUTOMATION (CSA1024)**

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Date of Submission

**3.04.2025**

# ABSTRACT

The **AI and IoT-based Smart Air Quality Monitoring System with Automated Alerts** is a sophisticated solution designed to monitor and improve air quality using the power of the Internet of Things (IoT) and Artificial Intelligence (AI). This system utilizes various sensors to measure air pollutants such as PM2.5, PM10, CO2, CO, and other gases, and transmits the data in real-time to a cloud-based platform for storage and analysis. Machine learning algorithms are employed to analyze the data and identify trends or anomalies, triggering automated alerts to notify users when air quality deteriorates beyond safe limits. This system aims to improve public health by providing timely alerts, enhancing environmental awareness, and offering insights for policy-making and personal health decisions. The system is scalable, easy to integrate into urban environments, and has applications in smart homes, industries, and public spaces.

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# ACKNOWLEDGMENTS

ACKNOWLEDGEMENT

I take immense pleasure in expressing my sincere gratitude to the honorable chancellor, Dr. N. M. Veeraiyan for being a source of inspiration. I take this opportunity to express my gratitude to the Vice Chancellor Dr. S. Suresh Kumar for providing all the facilities to complete this capstone project successfully.

I sincerely thank the Director of Academics, Dr. Deepak Nallasamy Sir for his visionary thoughts and support. My special thanks to the Director of SIMATS Engineering Dr. Ramya Deepak Mam for being a constant source of inspiration and for providing excellent capstone project ambience.

I would like to express my sincere gratitude to my research supervisor Dr.fahad , Professor, Department of Computer and Engineering, Saveetha School of Engineering College, for motivating around all obstacles and for being such an outstanding mentor.

My special thanks to my mentor Dr. Narendran,for valuable support and guidance. I would like to thank HOD, all staff members of my Nano technology , who were always there at need of the hour and provided the facilities, which I required for the completion of my capstone project.

I would like to express my profound gratitude to my family members and friends for their encouragement and support. I would like to thank God for not letting me down at the time of crisis and guided me on right direction.

# CHAPTER 1: INTRODUCTION

## Background Information

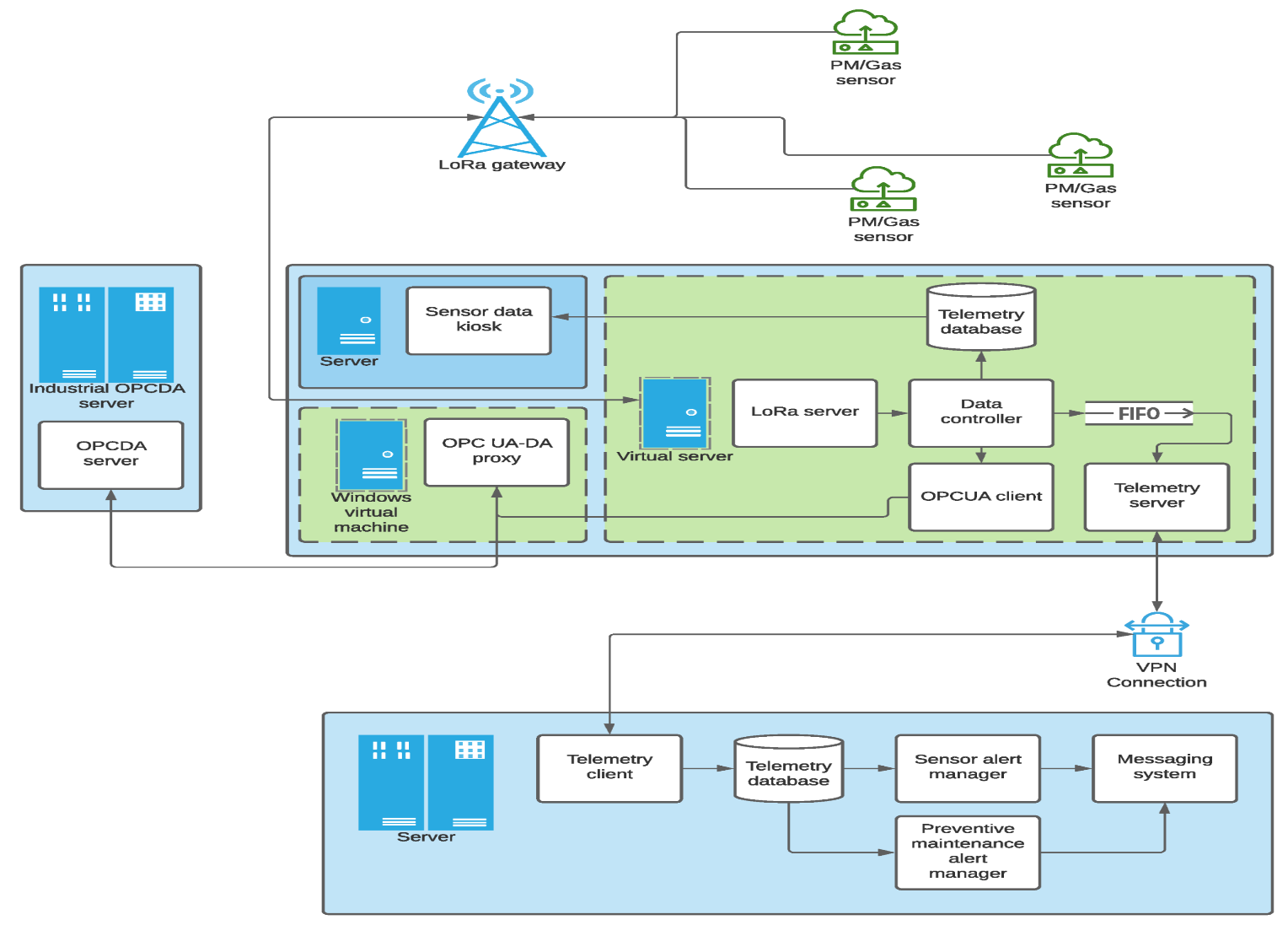
Air quality has become a major global concern due to the increasing levels of pollutants in the atmosphere, primarily from industrial activities, vehicular emissions, and other human-induced factors. Poor air quality contributes to a range of health problems such as respiratory diseases, heart conditions, and premature deaths. Real-time monitoring of air quality can help mitigate these issues by providing timely data for decision-makers and individuals to take preventive actions. 

Fig 1- AI and IoT-based Smart Air Quality Monitoring System with Automated Alerts

## Project Objectives

Despite the advancements in air quality monitoring, existing solutions are often limited in terms of real-time capabilities, accuracy, and accessibility. There is a need for an affordable, scalable, and automated system that provides real-time air quality monitoring with predictive capabilities.

## Significance

* To design a smart air quality monitoring system using IoT devices to collect data on various air pollutants.
* To integrate AI algorithms to analyze the collected data and predict air quality trends.
* To implement an automated alert system that notifies users when the air quality surpasses predefined thresholds.
* To develop a user-friendly dashboard for real-time monitoring and historical data analysis.

## Scope

* **Real-time Air Quality Monitoring:** The system continuously collects data on air pollutants such as CO₂, CO, NO₂, PM2.5, PM10, humidity, and temperature.
* **IoT Integration:** Sensors transmit real-time data to cloud-based platforms for analysis and remote access.
* **AI-Based Data Analysis:** Machine learning algorithms predict air quality trends and detect anomalies.
* **Automated Alerts:** Sends notifications via SMS, email, or mobile applications when pollution levels exceed safe thresholds.
* **User Accessibility:** Web and mobile interfaces for real-time monitoring and historical data visualization.
* **Smart City Integration:** Can be integrated with smart city infrastructure for urban planning and environmental management.
* **Scalability:** Deployable in various environments such as industrial zones, urban areas, and residential spaces.
* **Energy Efficiency:** Utilizes low-power IoT devices to ensure long-term sustainability.

## Methodology Overview

* Install IoT-based air quality sensors.
* Measure pollutants (CO₂, CO, NO₂, PM2.5, PM10, humidity, temperature).
* Position sensors in strategic locations for accurate readings.
* Continuously collect air quality data.
* Transmit data via Wi-Fi, LoRa, or GSM to cloud storage.
* Use machine learning algorithms to analyze data.
* Detect anomalies and predict air pollution trends.
* Set predefined thresholds for air quality parameters.
* Send alerts via SMS, email, or mobile notifications when pollution levels are high.
* Provide real-time monitoring via web and mobile applications.
* Display air quality indices, historical trends, and graphical representations.
* Regular calibration of sensors for accuracy.
* Continuous AI model updates for improved predictions and alerts.

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# CHAPTER 2: Problem Identification and Analysis

## Description of the Problem

* Air pollution is a major environmental and health concern, leading to respiratory diseases, cardiovascular issues, and environmental degradation.
* Traditional air quality monitoring systems are expensive and lack real-time data accessibility.
* Lack of public awareness and timely alerts results in prolonged exposure to harmful pollutants.
* Urbanization and industrial activities contribute significantly to deteriorating air quality.

## Evidence of the Problem

 Reports from the **World Health Organization (WHO)** indicate that millions of premature deaths are linked to air pollution annually.

 Studies show increasing levels of pollutants such as **PM2.5, CO₂, and NO₂** in urban and industrial areas.

 Government air quality index (AQI) reports highlight frequent exceedance of safe pollution levels.

 Real-world incidents, such as smog in major cities, demonstrate the urgent need for air quality monitoring.

## Stakeholders

 **General Public:** Individuals affected by air pollution seeking healthier living conditions.

 **Government & Environmental Agencies:** Regulatory bodies responsible for implementing pollution control measures.

 **Industries & Businesses:** Organizations needing compliance with environmental regulations.

 **Healthcare Sector:** Doctors and researchers studying air pollution-related health impacts.

 **Smart City Developers:** Urban planners integrating technology for sustainable city management.

 **Academia & Researchers:** Scientists utilizing air quality data for studies and policy recommendations.

## Supporting Data/Research

* + - **WHO & Environmental Protection Agency (EPA) reports** provide global and regional air quality data.
    - **Satellite and ground-based monitoring studies** confirm the rising levels of air pollutants.
    - **Research articles on AI & IoT in air quality monitoring** highlight advancements in real-time data collection and prediction.
    - **Case studies from smart cities** show successful implementation of AI-driven air monitoring systems.

**Medical research papers** link air pollution exposure to respiratory, cardiovascular, and neurologica disea

# CHAPTER 3: SOLUTION DESIGN AND IMPLEMENTATION

## Development and Design Process

 Identify project requirements and objectives.

 Design system architecture, including hardware and software components.

 Select appropriate IoT sensors for air quality monitoring.

 Develop AI algorithms for data analysis and anomaly detection.

 Implement real-time data transmission and cloud storage.

 Test and refine the system for accuracy and efficiency.

## Tools and Technologies Used

* + - IoT sensors (CO₂, CO, NO₂, PM2.5, PM10, humidity, temperature).
    - Microcontrollers (Arduino, Raspberry Pi, ESP8266/ESP32).
    - Communication protocols (Wi-Fi, LoRa, GSM, MQTT).
    - Cloud platforms (AWS, Firebase, Google Cloud).
    - AI & Machine Learning frameworks (TensorFlow, Scikit-learn).
    - Data visualization tools (Power BI, Matplotlib, Tableau).

## Solution Overview

 IoT-based system for real-time air quality monitoring.

 AI-powered data analysis for trend prediction and anomaly detection.

 Cloud storage and web/mobile interface for user accessibility.

 Automated alerts for unsafe air quality levels.

## Engineering Standards Applied

 IEEE 802.11 for wireless communication.

 ISO 14000 for environmental management and sustainability.

 IEEE 11073 for health-related data transmission.

## Ethical Standards Applied

 Ensuring data privacy and security.

 Providing accurate and unbiased environmental information.

##  Promoting environmental sustainability and public health.

## Solution Justification

* Real-time monitoring improves response time to air quality issues.
* AI-driven insights enhance predictive analysis and decision-making.
* Scalable and cost-effective solution for urban and industrial areas.

# CHAPTER 4: RESULTS AND RECOMMENDATIONS

## Evaluation of Results

 Discuss the performance of your AI and IoT-based air quality monitoring system.

 Present key metrics such as accuracy, real-time responsiveness, sensor precision, and effectiveness of automated alerts.

 Compare results with existing air quality monitoring solutions.

 Include data visualizations like graphs, charts, or tables.

## Challenges Encountered

 Hardware-related issues (e.g., sensor calibration, durability, power consumption).

 Software and algorithmic challenges (e.g., AI model accuracy, data processing delays).

 Connectivity and data transmission problems in IoT networks.

 Environmental factors affecting sensor readings (e.g., humidity, temperature interference).

 Ethical and privacy concerns related to data collection.

## Possible Improvements

 Enhancing AI model accuracy using more training data.

 Upgrading sensor technology for better precision.

 Implementing edge computing to process data locally and reduce latency.

 Improving energy efficiency for continuous operation in remote areas.

 Adding predictive analytics for proactive air quality management.

## Recommendations

* Policy recommendations for smart city integration.
* Proposals for further AI enhancements in real-time monitoring.

# Chapter 5: Reflection on Learning and Personal Development

## Key Learning Outcomes

* + 1. **Academic Knowledge**

 Application of machine learning in environmental monitoring.

 Understanding IoT architectures and sensor networks.

 Data analysis and visualization techniques.

## Technical Skills

 Programming skills in Python, Node.js, or Arduino for IoT applications.

 AI model training and deployment for real-time data analysis.

 Cloud computing and database management for IoT applications.

## Problem-Solving and Critical Thinking

* + - * Addressing sensor inaccuracies and AI model limitations.
      * Optimizing network communication in IoT systems.
      * Managing large-scale environmental data efficiently.

## Challenges Encountered and Overcome

 Technical limitations of hardware and software.

 Real-world deployment difficulties and environmental constraints.

 Troubleshooting AI model biases and incorrect predictions.

## Application of Engineering Standards

* + - * Compliance with IEEE and ISO standards for IoT and AI technologies.
      * Adhering to air quality monitoring regulations.
      * Industry-standard best practices for system security and data integrity.

## Application of Ethical Standards

 Ensuring responsible data collection and privacy protection.

 Avoiding AI bias in air quality predictions.

 Ethical considerations in using air quality data for decision-making.

## Insights into the Industry

* + - * Growing role of AI in environmental monitoring.
      * The impact of IoT on smart cities and public health.
      * Market demand for automated air quality monitoring solutions.

## Conclusion of Personal Development

* + - * Summary of skills gained and knowledge applied.
      * Reflection on future applications of AI and IoT in environmental science.

# CHAPTER 6: CONCLUSION

## Summary of Key Findings

 Overview of system performance and efficiency.

 AI’s role in improving air quality monitoring.

 Effectiveness of IoT-based alerts in real-time decision-making.

## Impact and Significance

 Benefits for public health and environmental monitoring.

 Contribution to smart city infrastructure.

 Cost-effectiveness compared to traditional air quality monitoring.

## Future Prospects

* + - Expansion to larger-scale deployments.
    - Integration with government environmental agencies.
    - Use of AI for predictive analytics and early warnings.

## REFERENCES

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2. "Implementation of IoT-Based Air Quality Monitoring System for Subway Tunnels": This study focuses on deploying an IoT-based air quality monitoring system in subway tunnels, employing sensors to measure particulate matter and utilizing cloud computing for real-time data analysis and automated alerts. ​[PMC](https://pmc.ncbi.nlm.nih.gov/articles/PMC7432224/?utm_source=chatgpt.com)
3. "AirSPEC: An IoT-empowered Air Quality Monitoring System integrated with a Machine Learning Framework to Detect and Predict defined Air Quality parameters": This research presents an IoT framework integrated with machine learning models to monitor and predict air quality parameters, providing real-time data visualization and alerts through a NodeRED dashboard. ​[arXiv](https://arxiv.org/abs/2111.14125?utm_source=chatgpt.com" \t "_blank)
4. "Smart Air Quality Monitoring for Automotive Workshop Environments": This study discusses the development of an environmental monitoring system based on IoT and AI technologies, using sensors to measure temperature, humidity, and toxic gas concentrations, with real-time data transmission and automatic alerts to improve worker health and safety. ​[arXiv](https://arxiv.org/abs/2410.03986?utm_source=chatgpt.com" \t "_blank)

These references provide insights into the integration of AI and IoT technologies for real-time air quality monitoring and the implementation of automated alert systems in various environments.

# APPENDICES

## Appendix A: Code Snippets

import time

import random

import requests

try:

import paho.mqtt.client as mqtt

except ModuleNotFoundError:

!pip install paho-mqtt

import paho.mqtt.client as mqtt

# MQTT setup

MQTT\_BROKER = "broker.hivemq.com"

MQTT\_TOPIC = "smart\_air\_quality"

# Alert threshold

AIR\_QUALITY\_THRESHOLD = 200

def read\_mq135():

"""Simulated air quality reading (Replace with actual ADC reading logic on Raspberry Pi)"""

return random.randint(50, 300)

def read\_dht22():

"""Simulated temperature and humidity reading (Replace with real sensor on Raspberry Pi)"""

return random.uniform(20, 30), random.uniform(40, 60)

def send\_alert(message):

"""Function to send alerts via email or push notification"""

api\_url = "https://api.pushover.net/1/messages.json"

data = {

"token": "your\_pushover\_api\_token",

"user": "your\_pushover\_user\_key",

"message": message

}

requests.post(api\_url, data=data)

def on\_connect(client, userdata, flags, rc):

print(f"Connected to MQTT Broker with status: {rc}")

client = mqtt.Client()

client.on\_connect = on\_connect

client.connect(MQTT\_BROKER, 1883, 60)

client.loop\_start()

while True:

temperature, humidity = read\_dht22()

air\_quality = read\_mq135()

data = {

"temperature": round(temperature, 2),

"humidity": round(humidity, 2),

"air\_quality": air\_quality

}

client.publish(MQTT\_TOPIC, str(data))

print(f"Data Sent: {data}")

if air\_quality > AIR\_QUALITY\_THRESHOLD:

send\_alert(f"Warning! Poor air quality detected: {air\_quality}")

time.sleep(10)

OUTPUT:

Data Sent: {'temperature': 29.09, 'humidity': 48.87, 'air\_quality': 193}

Data Sent: {'temperature': 29.89, 'humidity': 44.23, 'air\_quality': 215}

Data Sent: {'temperature': 25.07, 'humidity': 52.17, 'air\_quality': 193}

Data Sent: {'temperature': 21.47, 'humidity': 54.04, 'air\_quality': 98}

Connected to MQTT Broker with status: 0

Data Sent: {'temperature': 27.03, 'humidity': 44.02, 'air\_quality': 114}

Data Sent: {'temperature': 24.43, 'humidity': 43.13, 'air\_quality': 274}

Data Sent: {'temperature': 23.11, 'humidity': 46.9, 'air\_quality': 196}

Data Sent: {'temperature': 23.11, 'humidity': 42.03, 'air\_quality': 259}

Data Sent: {'temperature': 20.43, 'humidity': 58.26, 'air\_quality': 52}

Data Sent: {'temperature': 25.66, 'humidity': 55.52, 'air\_quality': 297}

Data Sent: {'temperature': 29.76, 'humidity': 48.41, 'air\_quality': 163}

Data Sent: {'temperature': 28.75, 'humidity': 57.43, 'air\_quality': 95}

Data Sent: {'temperature': 25.35, 'humidity': 55.37, 'air\_quality': 68}

Data Sent: {'temperature': 22.43, 'humidity': 54.0, 'air\_quality': 126}

Data Sent: {'temperature': 26.51, 'humidity': 55.17, 'air\_quality': 94}

Data Sent: {'temperature': 20.84, 'humidity': 46.67, 'air\_quality': 86}

Data Sent: {'temperature': 22.36, 'humidity': 45.28, 'air\_quality': 271}

Data Sent: {'temperature': 29.76, 'humidity': 55.49, 'air\_quality': 173}

## Appendix B: Block Diagram

Data Transactions via Smart Contracts

🌐 Blockchain Ledger (Distributed)

- Stores Air Quality Data

- Immutable & Tamper-proof

- Accessible by Authorities

Secure Data Acess

Government / Environmental Org

Real-time Sensor Data

🤖 AI Model for Predictive Analysis

- Analyzes Historical Data

- Predicts Pollution Trends

📡 IoT Devices (Sensors + Edge)

- DHT22 (Temperature, Humidity)

- MQ135 (CO2, Air Quality)

- Edge Computing Device (Raspberry Pi)

Fig