Air Quality Monitoring and Analysis Based Predictive System

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Project Proposal Report

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DECLARATION

I declare that this is my own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
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Signature of the Supervisor (Ms. Chathurangika Kahandawaarachchi) | Date

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ABSTRACT

Sri Lanka is grappling with an acute air pollution crisis, stemming primarily from vehicular emissions that affect the daily lives of its citizens. To address this pressing issue, we present a timely research program focusing on real-time air quality monitoring and analysis across the entire extension of Sri Lanka. The proposed system integrates innovative technologies to automatically process extensive data, providing insight into air quality levels within specific areas.

Our methodology involves deploying an air quality monitoring and analytics-based forecasting system. The system not only monitors ambient air quality but also suggests optimal routes with minimum air pollution, generates heat maps for easy identification of current air quality, and predicts future air quality levels in each area. The prototype uses two air sensors, an Arduino Uno board and a Wi-Fi module to operate strategically placed in open spaces between smart buildings. The collected sensor data is transmitted to the information processing center for real-time visualization through IoT technology. The data processing center stores real-time data in a database, enabling the front-end system to draw accurate air quality levels on maps. The system visualizes less polluted routes and predicts air quality levels in specific areas. In addition, an energy harvesting system is introduced to ensure sustainable energy consumption of the device.

The proposed system suggests optimal routes, providing a low-cost, highly portable and easily maintainable solution for users. Our real-time dynamic pollution mapping system not only addresses immediate air quality issues in Sri Lanka, but also provides a forward-looking approach to pollution management. The integration of IoT technology, gas sensors and energy harvesting boost the efficiency and sustainability of the system, making it a valuable tool for citizens looking to navigate the least polluting roads.

Keywords: Air Quality Monitoring, Real-time Dynamic Pollution Mapping, Internet of Things, heat map generating, route suggestion

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LIST OF ABBREVIATIONS

NEA	National Environmental Authority
API	Application Program Interface
DB	Database
IT	Information Technology

1. INTRODUCTION

1.1 Background Literature

Air pollution poses a significant threat to environmental health globally, affecting the well-being of populations and ecosystems alike. With increasing industrialization and urbanization, the need for effective air quality monitoring systems has become prominent. This literature review explores current research and technological advances in the domain of real-time, time-dependent dynamic pollution mapping, focusing on the complex challenges associated with continuous monitoring, data processing, and dynamic visualization.

The adverse effects of air pollution on human health are well documented, ranging from respiratory diseases to cardiovascular diseases [1]. In addition, environmental consequences such as smog formation and acid rain highlight the wider environmental impact [2]. Vehicle emissions, industrial processes and agricultural practices contribute significantly to air pollution levels in the environment [3]. As such, accurate and timely monitoring strategies are needed to mitigate the impact of air pollution.

Conventional air quality monitoring systems mainly rely on fixed monitoring stations that provide periodic data snapshots. However, these systems often lack the spatial resolution needed to capture the dynamic nature of air pollution across different locations [4]. The emergence of real-time monitoring technologies provides an opportunity to overcome these limitations and provide a more comprehensive understanding of pollution dynamics [5].

Recent advances in sensor technologies, especially gas sensors, have facilitated the development of compact and cost-effective devices for real-time air quality monitoring [6]. These sensors can measure various pollutants including particulate matter (PM), nitrogen dioxide (NO2) and sulfur dioxide (SO2), enabling a more detailed assessment of air quality [7]. Integration with Internet of Things (IoT) technology has further improved the capabilities of these devices, allowing continuous data transmission and remote monitoring [8].

One key aspect of addressing air pollution is the ability to dynamically map pollution levels in real time. Dynamic pollution mapping involves continuously collecting data from different locations and visualizing pollution levels on dynamic maps. This can help identify areas of increased pollution, assess the effectiveness of pollution control measures, and guide people to choose less polluting routes [9].

Although technological advances have enabled real-time monitoring, several challenges remain. Data accuracy, sensor calibration, and the need for a robust information processing infrastructure are critical considerations [10]. In addition, the dynamic nature of pollution requires algorithms that can predict future air quality levels based on historical data [11]. These challenges underscore the importance of a comprehensive and well-integrated approach to real-time dynamic pollution mapping.

1.2 Research Gap

The current state of research in real-time dynamic pollution mapping has made significant progress in understanding and addressing the various dimensions of this complex problem. However, several critical research gaps remain, and further investigation is needed to improve the efficacy of these systems. A significant gap emerges in the standardization of color coding schemes to identify different levels of air pollution. Prior studies have acknowledged the importance of visual representation in dynamic pollution mapping [12], and more extensive exploration is necessary to design and implement universally understood color schemes, ensuring consistency and clarity across different dynamic pollution mapping applications.

Moreover, a research gap exists in optimizing the integration of sensor data into dynamic heat maps. Research "B" Despite some studies exploring the use of gas sensors to monitor specific pollutants [13], further research is needed to address challenges related to data fusion, calibration, and developing algorithms that can transform sensor data into meaningful visual representations. Bridging this gap is critical to creating more reliable and informative dynamic pollution maps.

The proposed mobile applications have users options to select specific periods when pollution levels are generally low. Although the temporal variability of pollution levels is acknowledged, additional exploration is needed to develop user-friendly interfaces that empower individuals to customize their dynamic pollution maps based on specific time intervals. This feature is essential for users trying to plan activities during periods of low pollution, contributing to more informed decision-making and improved public health outcomes.

The proposed mobile applications that play a key role in providing real-time pollution data to end users. While some studies have touched on the role of mobile applications [14], more in-depth investigation is needed to explore user preferences, and ensure the interface is intuitive and user-friendly. Optimization of mobile applications represents a critical aspect of improving user engagement and facilitating effective use of real-time pollution data.

Addressing these research gaps is essential to advancing the field of real-time dynamic pollution mapping. Standardization of color-coding schemes, optimization of sensor data integration, customization options for specific periods and improvements in mobile application design collectively contribute to the development of robust and user-friendly systems for monitoring and mitigating the impact of air pollution. As technology continues to evolve, addressing these gaps will lead to more comprehensive understanding and standardization, leading to effective solutions to address the global challenge of air pollution.

The below table 1.1 illustrates a tabularized format for the above-mentioned facts with regard to Realtime dynamic pollution heatmap.

Table 1.1 Comparison with existing applications

Product Reference	Research A	Research B	Research C	Proposed System
Color coding schemes to identify different levels of air pollution.	✓	✓	✓	✓
Integration of sensor data into dynamic heat maps.	✕	✓	✕	✓
Users options to select specific periods when pollution levels are generally low	✕	✕	✕	✓
Mobile Application	✕	✕	✓	✓

1.3 Research Problem

Research in real-time dynamic pollution mapping faces several critical issues that require in-depth investigation to improve the effectiveness of these systems. The challenge is to optimize the spatial resolution of real-time pollution maps to ensure accuracy. While there has been significant progress in deploying sensor technologies for real-time monitoring [15], there is a research gap in refining the spatial resolution to capture fine-scale changes in air pollution levels. Solving this problem requires a fine-grained exploration of sensor deployment strategies, calibration techniques, and data processing methods to achieve a level of granularity that accurately reflects the dynamic nature of pollution across different locations [16].

Improving user engagement in real-time pollution heatmaps at different times of the day represents a significant challenge. Although the importance of user-friendly interfaces in mobile applications has been recognized [17], extensive research is needed on the development of engagement strategies for various seasonal environmental pollution. This includes understanding user behavior at different times of the day and developing interface designs for different user preferences. Optimizing user activity is critical to ensuring that individuals are able to effectively interpret and use real-time pollution information, contributing to informed decision-making and public health outcomes.

Developing algorithms that can enable real-time pollution maps to respond dynamically to sudden environmental events and provide timely and accurate information poses a significant research problem. Current research has touched on predictive algorithms for future pollution levels [18], but there is a gap in creating algorithms that can dynamically adapt to unexpected events such as industrial accidents or natural disasters. The challenge is not only to predict pollution trends, but also to develop algorithms that respond in real-time to sudden changes, ensuring that relevant users receive accurate and timely information to facilitate prompt decision-making and response.

These research issues emphasize the complexity of real-time dynamic pollution mapping and highlight key areas that require focused investigation. Optimizing spatial resolution, enhancing user activity at different times of the day, and developing responsive algorithms for sudden environmental events represent critical challenges that, once addressed, can significantly contribute to the progress of real-time pollution mapping systems.

2. OBJECTIVES

2.1 Main Objectives

The main objective is to pioneer an accurate time-dependent heat map system leveraging real-time sensor data collection. Users can dynamically select different time periods, visualize pollution-free zones, and visualize optimal route proposals from origin to destination. This cutting-edge approach empowers user with accurate and real-time information, revolutionizing navigation in urban environments while reducing exposure to air pollution.

2.2 Specific Objectives

- Development of an Interactive Heatmap for Data Visualization:
    - Highlight and display pollution-affected areas and their severity in a dynamic heatmap.

- Dynamic Time-Period Selection Feature:
    - Integrate a user-friendly interface allowing dynamic selection of time periods for personalized pollution visualization.

- Notifying users in different pollution levels:
    - Personalized notifications based on user routines, offering timely alerts during periods of high or low pollution levels.

3. METHODOLOGY

System Architecture Diagram

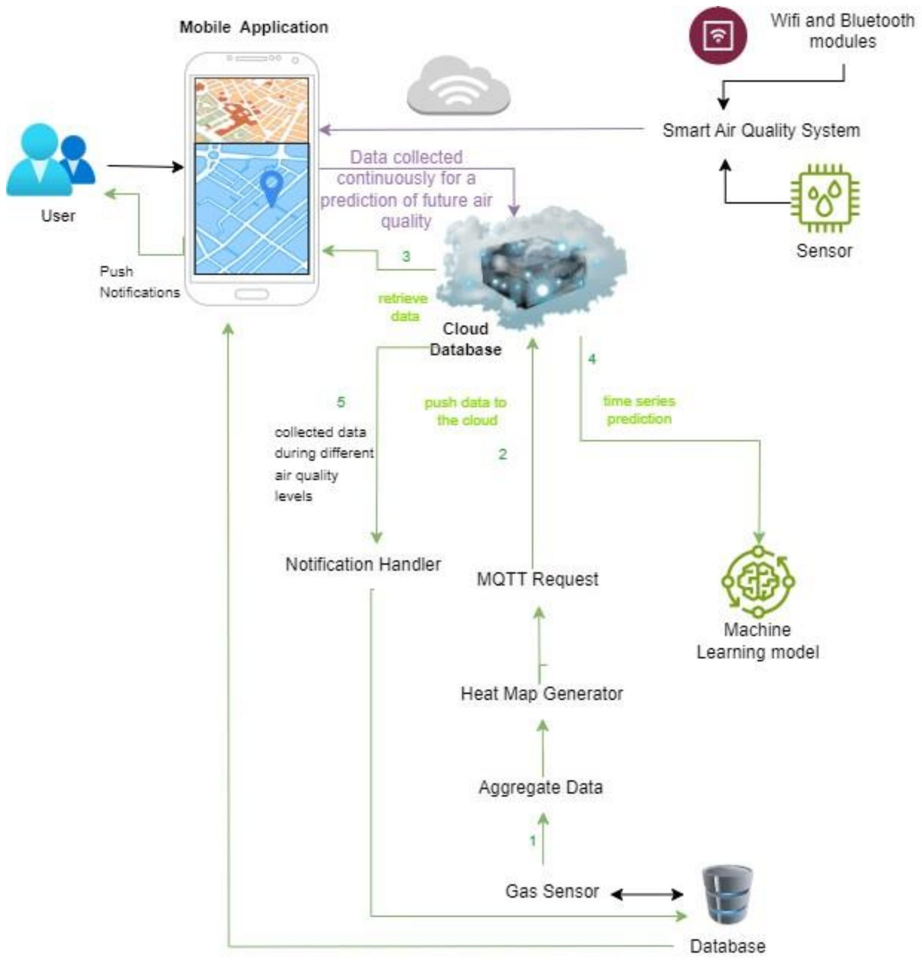

Figure 3. 1 System Architecture Diagram

Identify the types of sensors to be used, the data structure and frequency of data collection.

Set up a robust data acquisition system to collect sensor data and securely store it in a database. Implementing proper data validation and cleaning processes to ensure the integrity of collected information.

Develop an aggregation mechanism to integrate and process the collected data. Calculate aggregated values based on predefined parameters for each geographic region. Use algorithms to clean outliers and ensure data accuracy.

Implement a heatmap generation module that uses aggregated data to visualize pollution levels across different geographic regions. Apply mapping techniques to represent pollution intensity using a color gradient.

Define color coding schemes based on pollution levels, classifying them into different ranges (low, moderate, high). Assign different colors to each range for clear visualization of the heatmap.

Integrate time series forecasting models to predict pollution trends. Use machine learning algorithms to analyze historical data and provide future predictions. Update these forecasts regularly to improve accuracy.

Develop a notification system that monitors real-time pollution data. Activate triggers to notify users when pollution levels exceed predefined thresholds. Use push notifications or other communication channels for timely alerts.

Create a user-friendly interface to access real-time pollution map, heat map and forecast information. Ensuring ease of navigation and providing users with relevant tools to interact with data.

3.2 Project requirements

3.2.1 Functional Requirements and Non-Functional Requirements

Table 3. 1 Functional and Non-Functional Requirements

Functional Requirements	Non-Functional Requirements
1. Application should be a robust system for the collection of air pollution data from sensors or external sources, ensuring accuracy and reliability in data acquisition.	1.Application should respond Realtime.
2. Application can able to navigate on specific locations for detailed pollution information	2. Application should be accurate.
3. System should be able to real-time mobile push notification system capable of sending timely alerts to users during different pollution levels, ensuring proactive communication and awareness.	3. Heatmap should be user friendly.

3.2.2 Software Requirements

Software requirements are React native, Python, MongoDB, Visual studio code, Postman API.

3.2.3 Personnel Requirements

To enhance the quality, knowledge, continuation and integrity of the research the following are the required personnel.

- Air Quality Scientist
- National Environmental Authority (NEA)

3.3 Software Solution

Agile Scrum Methodology:

The software development life cycle proposed is Agile Scrum methodology. Scrum is an iterative framework for software development that is based on the Agile Manifesto's agile concepts. Scrum is also defined as a lightweight development method that provides full transparency and rapid adaptability. Since, due the above□mentioned behaviors agile supports frequent changes of the component during the phase of implementation with the varying requirements. The modifications will be supported in an efficient manner using agile scrum methodology. Thus, the solution proposed will be implemented according to the framework by supporting the constant changes and rapid adaptabilities.

User-friendly Interface:

Design an intuitive and user-friendly interface for the web and mobile applications. Prioritize ease of use to cater to a diverse user base, including environmental agencies, policymakers, and the general public.

Real-time Data Collection:

Implement a robust data collection system utilizing advanced air quality sensors. Ensure seamless integration with IoT devices for continuous and real-time monitoring of pollutants.

Dynamic Mapping:

Develop dynamic mapping features that visualize pollution levels across different locations. Utilize color-coded heatmaps for easy identification of pollution hotspots, allowing users to make informed decisions about their surroundings.

Mobile Application:

Create a mobile application with features such as real-time notifications, route suggestions based on air quality, and the ability to visualize pollution trends. Support multiple languages for broader accessibility.

Notification System:

Implement a notification system that sends real-time alerts to users based on their preferences and daily routines. Provide alerts for high pollution levels or suggest alternative routes with lower pollution.

Secure Data Transmission:

Ensure the security of data transmission from sensors to the central processing unit. Implement encryption protocols to safeguard sensitive air quality information and maintain data integrity.

3.3.1 Requirement Gathering and Analysis

- **Stakeholder Meetings**

  Conduct meetings with stakeholders, including environmental agencies, local authorities, and potential end-users, to understand their expectations and specific requirements for real-time pollution monitoring.

- **Environmental Data Requirements**

  Collaborate with environmental experts to identify the essential pollutants and parameters that need monitoring. This involves determining the types of sensors required and the level of accuracy needed for reliable data.

- **Timeframe and Budget Analysis**

  Establish a realistic project timeframe considering the urgency of pollution monitoring needs. Conduct a budget analysis to allocate resources effectively and determine the financial scope of the project.

3.3.2 Feasibility Study

Feasibility Analysis is the process of determination of whether or not a project is worth doing.

- **Technical Feasibility**

To successfully complete the project the advanced knowledge in react native, python, MongoDB, Utilizing external libraries and efficiently fetching data from external APIs will be essential for dynamic mapping.

- **Economic Feasibility**

The project is feasible, emphasizing affordability and reliability in resource utilization. The financial constraints dictate a careful selection of resources and components to ensure cost-effectiveness without compromising the quality and functionality of the real-time pollution heatmap system.

- **Schedule Feasibility**

The project schedule feasibility is paramount, necessitating implementation within the estimated time frame while meeting defined functional and non-functional requirements. A carefully planned project timeline, aligned with the development phases, ensures timely delivery without compromising the quality of the real-time pollution mapping system.

- **Operation Feasibility**

the proposed system addresses existing barriers by effectively reaching stakeholders and providing timely information on pollution levels. Leveraging opportunities identified during scope definition, the system ensures efficient communication and meets the requirements outlined during the system development requirements analysis phase. This operational feasibility underscores the system's potential to contribute significantly to environmental awareness and public health.

3.3.3.2 Dataset

Acquiring a relevant dataset for a real-time time-dependent pollution map is crucial for accurate and dynamic mapping. The dataset should include real-time air quality measurements, meteorological data, and geographical information. Incorporating diverse sources such as government monitoring stations, satellite observations, and IoT sensor data ensures comprehensive coverage. The dataset needs to capture variations over time, considering daily and seasonal fluctuations, allowing the pollution map to provide timely and context-aware information for effective decision-making and public awareness.

3.3.3 Design

3.3.3.5 Work Breakdown Structure

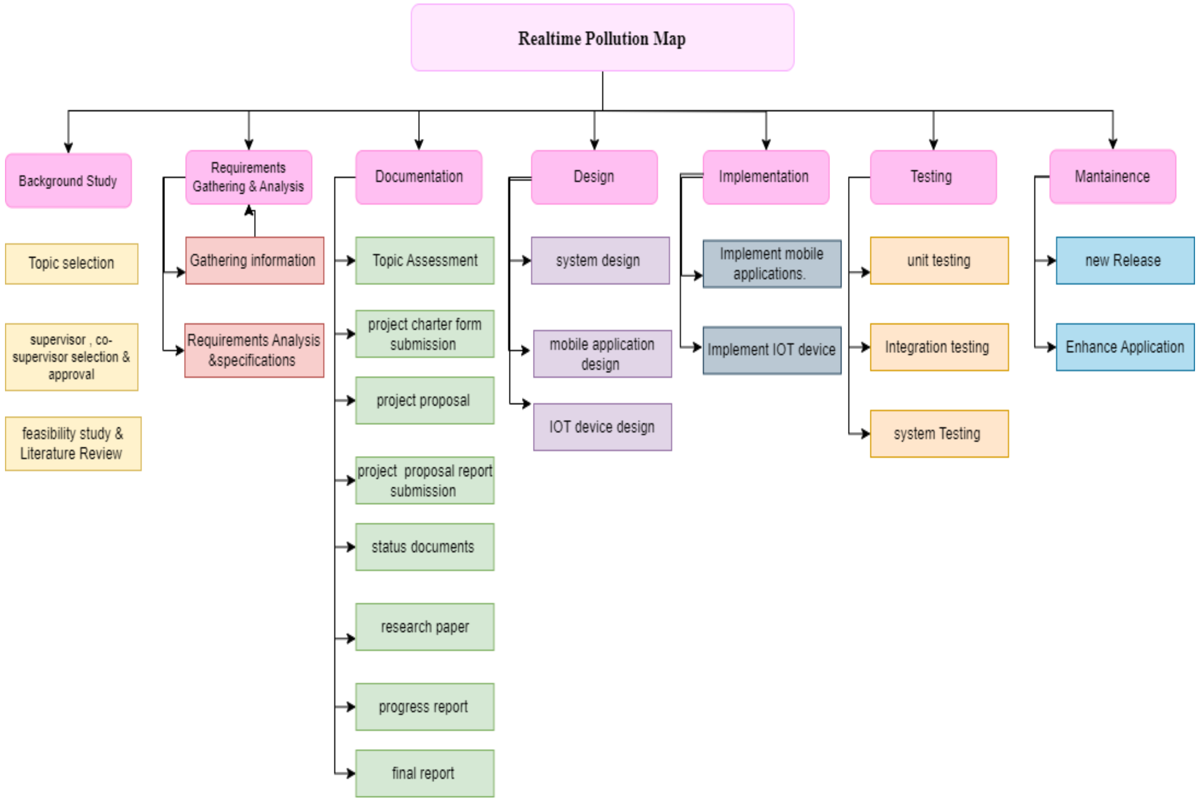

Figure 3. 2 Work Breakdown Structure

3.3.4 Implementation

The proposed system should comply with development of the gathered requirements as given below,

- **Collecting sensor data**

The system creates a seamless connection to the database to obtain real-time sensor data. Using a reliable database management system such as MongoDB ensures efficient data retrieval for accurate and up-to-date pollution information.

- **Visualization of Pollution Levels**

Different color-coding schemes are implemented to visually represent different pollution levels in the dynamic heat map. This ensures that users can quickly interpret and understand air quality in specific areas, improving the usability of the map.

- **Time dependent heat map with selected option**

The heat map features a user-friendly interface and allows users to select specific time periods. This feature enables users to monitor pollution levels at different times, identify non-polluted areas and identify optimal routes based on historical data.

- **Real-time alerts and notifications**

The system will incorporate a robust notification mechanism to inform users of changes in pollution levels in real-time. By continuously monitoring the database for fluctuations in pollution data, the heatmap will alert users instantly, allowing them to make informed decisions.

Implementation steps:

- **Database Integration**

Establish a secure connection to the database to receive sensor data. Implement encryption to ensure data integrity and secure transmission.

- **Color Coding Scheme**

Define a standardized color-coding scheme to represent different pollution levels on the heat map. Implement algorithms to dynamically assign colors based on pollutant concentration.

- **Time dependent heat map**

Integrate a time selection feature into the heatmap interface. Develop algorithms to filter and display pollution data specific to a selected time period.

- **Alerts and Notifications**

Implement a real-time monitoring system that continuously checks changes in pollution levels. When a significant change occurs, trigger notifications to notify users of the updated terms.

- **User Interface Design**

Design an intuitive and user-friendly interface for both web and mobile applications. Ensure seamless navigation and accessibility for users with varying technical expertise.

3.3.5 Testing

The application testing will be done as unit testing, integration testing, system testing and user acceptance testing in the respective phases.

4. GANTT CHART

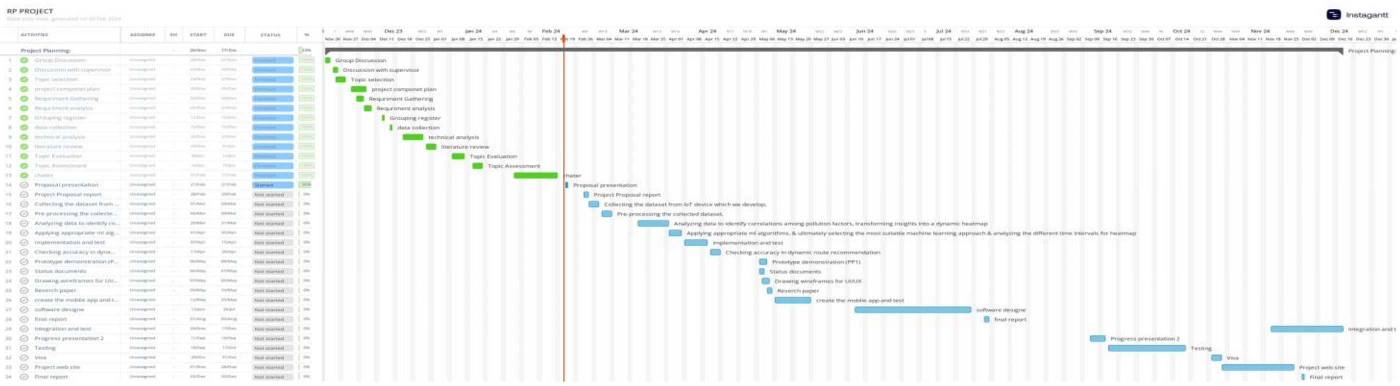

Figure 3. 3 Gantt Chart

5. DESCRIPTION OF PERSONAL AND FACILITIES

Facilitators:

- Ms. Chathurangika Kahandawaarachchi - Sri Lanka Institute of Information Technology (SLIIT)

- Ms. Pipuni Wijesiri - Sri Lanka Institute of Information Technology (SLIIT)

Facilities:

- Central Environmental Authority (CEA)

6. BUDGET AND BUDGET JUSTIFICATION

The estimated budget contains deployment costs, database costs and hosting costs.

Table 5. 1 Budget of the real-time pollution map component

Feature	**Price**
MongoDB Database	Free
Deployment Cost	Rs. 6073 / month
Mobile App -Hosting on Play Store	Rs. 4898
Mobile App -Hosting on App Store	Rs. 19394 /annual

6. COMERCIALIZATION

6.1 Target Audience and Market Space

- **Target Audience**
  - Researchers
  - Vehicle Drivers
  - Stakeholders

- **Market Space**
  - No need of advanced knowledge
    in technology.
  - No age limitation for users.
  - No need of prior knowledge regarding pollution levels.

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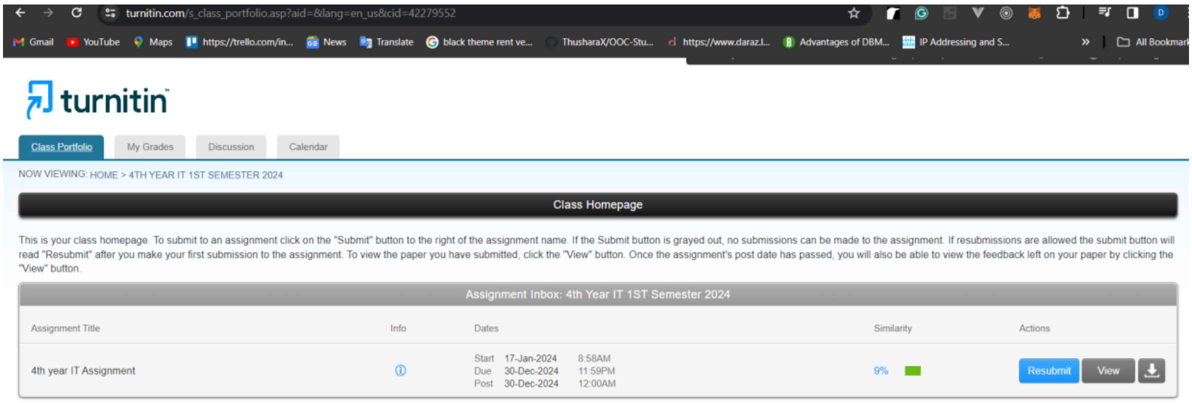
APPENDICES



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