Optimized Traffic Management and Analytics System

Higher National Diploma in Management Information Systems

Final Project Documentation

24.1

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The project is submitted in partial fulfilment of the requirements for the module Innovation Business Solution & Prototype as part of the Higher National Diploma in Information System Management at the National Institute of Business Management.

Declaration

I certify that this proposal does not incorporate without acknowledgement, any material previously submitted for a Higher National Diploma in any institution and to the best of my knowledge and belief ,it does not contain any material previously published or written by another person or myself except where due reference is made in the text. I also hereby give consent for my project proposal, if accepted, to be made available for photocopying and for interlibrary loans, and for the title and summary to be made available to outside organizations.

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Preambles

Kandy, Sri Lanka, is recognized as a city of significant cultural and historical importance, attracting both residents and tourists. However, challenges related to increasing traffic congestion and inefficiencies in the current traffic management system are faced. This proposal outlines the development of an Optimized Traffic Management and Analytics System that is designed to address these challenges. By leveraging modern technologies, automated incident reporting, real-time data collection, and comprehensive traffic analysis will be facilitated by the system. The goal is to enhance traffic flow, improve incident response times, and foster community engagement, ultimately contributing to a more efficient and sustainable urban transport environment.

Abstract

This proposal presents the Optimized Traffic Management and Analytics System for Kandy, Sri Lanka, which is aimed at improving urban traffic management. A user-friendly interface will be featured for reporting traffic incidents, allowing accidents and road closures to be reported by users with real-time acknowledgment. Comprehensive traffic insights will be provided through automated data collection, while advanced analytics will be used to identify congestion patterns and peak traffic hours. Efficient tracking and response to reported issues will be enabled by centralized incident management, supported by automated notifications to relevant authorities. Additionally, mechanisms for user feedback will be implemented to enhance system performance and user experience. It is expected that the successful implementation of this system will reduce traffic congestion, improve incident response times, and provide actionable insights for better decision making, ultimately enhancing the quality of urban mobility in Kandy.

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Chapter 1: Introduction

1.1 Overview

Kandy's historical and cultural city status in Sri Lanka is no insignificant factor; currently, Kandy is also dealing with ever-increasing traffic challenges for anyone who enters the city. Overall congestion coupled with the delays attributed to the hilly landscape, narrow streets, and lack of public transport options means that many people are affected including Kandy residents and visitors. These challenges are hampering residents' day to day commutes and ultimately Kandy's growth potential and tourism demand. Kandy has proposed the creation of an Optimized Traffic Management and Analytics System to address these traffic challenges. An optimized traffic management and analytics system that mitigates the reduction of effective mobility including incident reports, traffic data collection, and analytics. This system will utilize modern technology to facilitate real time traffic management and infrastructure information. This would enable a significant improvement in mobility in Kandy and perhaps create more mobility opportunities to Kandy while entering the city.

1.2 Current Traffic Management Operations in Kandy

Traffic management systems are unreliable and inefficient in Kandy. Now, for some key elements:

• Traffic Control - Major intersections are usually manned by police officers or using traffic lights, who have little or no control of traffic flow.

• Incident Reporting - Members of the public make telephone reports, which can be misreporting or not reporting an incident - enlisted reporting is unreliable data.

• Traffic Monitoring - The manual monitoring process simply does not allow rapid response to changing circumstances, and further exacerbates vehicular congestion and delays.

• Public Transport - A poor performing bus service creates heavy road congestion from poor bus coordination.

• Parking - Heavy congestion is aggravated by inadequate parking and leftover residential parking in the city's central area.

• Data Usage - The lack of a comprehensive view of general traffic levels means traffic is managed reactively instead of proactively, and no attempt can be made to implement a decent traffic management system.

Overall, Kandy is just not capable of sufficient traffic and transport operations that includes the basic modes, infrastructure and technology to address the traffic issues Kandy is currently facing.

1.3 Users and Responsibilities

- Local drives / Private stakeholders/ City or municipal authorities: Traffic operations / Traffic methods. Traffic operation are incrementally sophistication using Traffic Management Systems that led a class traffic intervention to have lower delays, and better mobility overall, better urban planning and infrastructure, and the bonus of having traffic data, from real time data collection.
- Law enforcement agencies: Utilize the traffic analytics to determine where the high violation locations are and how to best use their limited resources at the various locations across their geography.
- Public works department: Look a traffic patterns that uses the highest volume in population, such as reducing vehicle rush hour, or street closures during peak use times.
- Transportation authorities responsibilities: To merge traffic data to develop better bus routes that are coordinated between service providers, allowing for meeting commuter's transportation needs with flow.
- Emergency Services: To determine real time traffic collection and patterns, while utilizing best routes during high density roadway utilization, during emergency response need. Time savings could help with saving lives and property.
- Urban Planners and Developers: Responsibilities: Review of traffic data to analyze how new developments will impact already established traffic patterns. Foster an understanding of informed decision-making for sustainable developments and zoning parameters.

- Environmental Agencies: Responsibilities: Analysis of traffic flow to encourage environmentally friendly methods of transportation. Further development for improved ideas to mitigate air pollution and promote sustainable transport.
- Academic and Research Institutions: Responsibilities: Study traffic patterns and behaviours to develop new theories and models on urban mobility. Further contribute to the knowledge body of transportation engineering and urban studies.
- Private Sector Companies: Responsibilities: Use of traffic analytics to optimize delivery routes and decrease delivery times. Improve efficiency and operational costs.

1.4 Problem definition

Kandy is facing some serious traffic management issues, which are impacting urban mobility, safety, and overall quality of life. The existing situation is largely dependent on manual processes, which limits traffic signal control effectiveness, incident reporting, and traffic data management. The following are some of the actual issues facing traffic management in Kandy;

- Poor Traffic Control: Major intersections within Kandy are being managed manually with little regard to moving actual traffic.
- Incident Reporting Issues: The method of reporting traffic incidents in Kandy is very public reliant. As a result, incident detection is slow and often inaccurate. As such, the ability to respond to incidents is negatively affected.
- Public Transport Coordination Problems: A lack of integrated traffic data is restricting the effective scheduling and routing of public transport vehicles. This further adds delays to commuters.
- Limitations to Data Use: The lack of real-time traffic data prevents timely proactive decision making and allows for lack of foresight, replacing strategy with reaction for traffic management.
- Insufficient Infrastructure Planning and Lack of Access: Urban planners have no access to usable traffic data and are unable to plan for new developments and prioritize infrastructure investment.

These issues lead to longer travelling times and increased accident levels giving rise to overall public safety issues for Kandy. The issues identified here indicate the need for a comprehensive automated traffic management system to be implemented in Kandy.

1.5 Project Objectives

- Traffic Flow Enhancements: We will establish automated traffic management solutions to improve efficiency, mitigate congestion and better direct vehicles at critical intersections.
- Incident Response Enhancement: We will develop a dedicated incident detection and reporting to make (it) easier to detect and respond to traffic incidents as quickly as possible for public safety.
- Traffic Forecasting Support: We will provide a forecasting framework for traffic flows based on historic and current conditions to inform future directions.
- Infrastructure Findings: We will provide insights on existing infrastructure and make recommendations based on traffic flows, etc.
- Road Planning Advice: We will provide city planners with information to support planning for new building developments or increased road building extensions.
- Rout request: We will create a framework for drivers to request information to use alternate routes to mitigate delay during their drive due to incidents or road closures.
- Public Safety Improvement: We will also identify recommendations of traffic , public safety improvements through enforcement and traffic flow mechanisms.
- Sustainable Transportation Promotion: Traffic systems will be analyzed for sustainable transportation options that will help to decrease carbon emissions and air contamination.
- Community Stakeholder Engagement: Local communities and stakeholders will be engaged in the traffic management process to integrate their feedback and concerns.
- Continuous Improvement Facilitation: A system will be developed for continuous monitoring and evaluation of the traffic management system to promote continuous improvements.

- Operational Efficiency Increase: The operational efficiency of traffic management and enforcement agencies will be enhanced through advanced technologies.

1.6 Proposed Solution

1. Live-Traffic Monitoring Dashboard:
    - Displays live traffic conditions (level of congestion) and other traffic conditions while also providing the user with information about accidents and closures of roads.
    - Uses user incidences, historical traffic data, presented in simple descriptive statistics and BI tools.
2. Route Planning Tool:
    - Provides automatic routing suggestions, using the actual traffic condition data, in order to minimize travel time.
3. Incident Reporting:
    - Provides an easy-to-use interface for the user to report traffic incidents, road hazards, and other information.
    - Collects and displays user reports, in real-time, and completes instant viewing of traffic-related issues.
4. Traffic Predicted Insights:
    - Provides predicted traffic conditions based on historical traffic data.
    - Utilizes basic statistical methods for forecasting-predicting traffic flow.
5. User Feedback and Engagement:
    - Provides for user feedback on traffic related conditions and app experience and usefulness through feedback.
    - Uses surveys for feedback or simple feedback forms.
6. Agile Development Framework:
    - Was developed using agile methodology and incorporated feedback from users, to allow for continuous improvement, and ability to respond and correct for changing traffic conditions.
    - Used multiple iterations, with user-testing to incorporate feedback.
7. Automated Alerts and Notifications:

- Provides alerts to users about relevant/incidents, closures of roads, and public transport delays.
- Using simple rules-based systems to automate alerts for dissemination.

1.7 Chapter Summary

In this chapter the traffic management situation in Kandy, Sri Lanka is described, and the proposed Optimized Traffic Management and Analytics System is described. The city's hilly environment, narrow roads, and limited public transportation greatly contribute to unnecessary congestion and delays. Opportunities for greater efficiency in the current system include common procedures for manual traffic management, and shortcomings in accurate incident reporting. From this examination I have identified key challenges to effective traffic management and coordinated infrastructure planning. This proposed system has key features enabling traffic flow and incident reporting and will provide a realtime traffic response dashboard which shows the need for this system.

Chapter 2: Methodology

2.1 Introduction

The overall process of developing and deploying the proposed Optimized Traffic Management and Analytics System for Kandy is based on an organized and collaborative process. This will ensure that the design not only appropriately meets the needs of the primary traffic management issues facing the city, but also addresses stakeholder requirements. A data collection protocol will be established which will gather relevant traffic data and input from users, and what's learned will then influence the design of the traffic management and analytics system. An agile software development process will be employed to take advantage of flexibility in iterative updates based on stakeholder contributions. Also, testing strategies will be used to provide assurance of reliability and performance, and will ultimately benefit urban mobility for all users.

2.2 Data Collection Method(s)

The data collection methodologies utilized allowed for an extensive amount of data to be collected pertaining to all elements of the Optimized Traffic Management and Analytics System for Kandy. The research drew information from a number of locations in order to build a knowledge base to inform the system, taking stock of the current challenges in traffic management and constructing a system that would work better. Hence the method of collecting data by multiple approaches is described below.

- Online Research and Surveys: By examining the processes of already understood traffic management systems or online analytics systems, we were able to extract best practices or innovative ideas. This offered the necessary motivation to design a system that was useful and usable.
- Traffic Volume Counts: Traffic volume counts, both manual and automated were conducted at key locations and intersections to gather information on the movement patterns of different types of vehicles. This information was considered essential to assess peak travel times and the locations of congestion to determine when and where actions were needed.
- Interviews: In person interviews were conducted with local authorities, traffic management specialists, and stakeholders in order to understand their goals and

expectations. With the use of the same questions, commuters and local residents were also interviewed to gather their thoughts on current traffic challenges, thereby designing a system that was more user friendly.

- Study of Past Trends: Historical traffic data from regional transportation agencies was studied to comprehend past traffic behavior, points of congestion, and the frequency of incidents. This study was considered important for recognizing trends in traffic patternology and for informing either an unintentional or intentional predictive model of future traffic behavior.
- Weather Data Review: The weather data research and studies for the past was reviewed to study past and researched impacts of weather conditions and traffic trends. This data was deemed very important to comprehend the weather impacts on traffic and safety behaviors and to develop a method to integrate real-time weather data into the future system.
- Geo-spatial Data Study: Geographic Information System (GIS) data was reviewed to study past spatial trends of traffic data and infrastructure. The review provided critical areas of focus and impediments to improve infrastructure.

2.3 Software Process Model

The Optimized Traffic Management and Analytics System for Kandy will be developed using Agile software development methodology which is known for fostering iterative improvements, collaboration, and flexibility to guarantee that the system is developed in an efficient manner and meets the needs of stakeholders.

2.3.1. Agile Methodology

The Agile methodology will be employed to facilitate a dynamic and responsive development process. Key characteristics include:

Figure 1:Agile Model

- Iterative Development: In this project, the effort will be broken down into iterations or sprints, a manageable timeframe of two to four weeks. After each sprint there will be a potentially shippable product increment, which means that the project will maintain a focus on continuous feedback and improvement.
- Collaboration: The project will allow for the constant engagement with and collaboration with stakeholders, including: local authorities, traffic management stakeholders and end-users of the product. The project will prioritize communication with stakeholders to respond to their needs and expectations on an ongoing basis.
- Flexibility: The project will allow for changes in requirements, even late in the process of development. This approach is recognized as being important because it will allow the team to adjust based on newly acquired knowledge and data and recommendations from users receiving the information.

2.3.2. Phases of the Agile Process

There will be the following phases to the Agile process.

- Planning: There will be a series of planning sessions to outline the goals, scope and deliverables of the project. In this planning session, user stories will be created to communicate a specific and specific collection of requirements in relation to an articulated user's perspective.

- Design: A preliminary design will be created to outline the architecture of the system, user interface, and produce prototype(s) of major and key design components to visualize critical components and get an early response of user expectations input.
- Development: Through an iterative process of cycles, the coding and implementation will be carried out. The team will be working on project detail relative to early adopted user stories that had been prioritized at the beginning of each sprint.
- Testing: Continuous testing will be integrated into the development process. Automated tests will be created to ensure that new features do not introduce bugs, and user acceptance testing will be conducted to validate that the system meets user needs.
- Deployment: Once we have tested the system successfully, we will deploy it in front of a limited number of users and take any guidance through user feedback to eliminate any problems or improvements that may need to be made.
- Review and Retrospective: At the end of every sprint, we will hold a review meeting to show the completed work that we have done as planned to stakeholders. We would then have a retrospective meeting to talk about what went well, what could be better, and what could we improve in the next sprint process.

2.3.3. Tools and Technologies

- Project Management Tools: Trello will be used for task management and tracking progress. The Trello board is located here: Trello Board
- Version Control Systems: Git will be used for version control so that team members can collaborate and manage code changes and development.
- Continuous Integration/Continuous Deployment (CI/CD): CI/CD tools will be used to automate testing and deployment to ensure the new code can be deployed easily and in a repeatable manner.

2.4 Software Development Tools

1. Frontend Development Tools

- HTML
- CSS
- JavaScript

2. Backend Development Tools

- PHP
- Python

3. Database Management Tools

- MySQL
- PL/SQL

4. Data Analysis and Visualization Tools

- R/ SPSS
- Power BI
- Tableau

5. Project Management Tools

- Trello

6. Version Control Systems

- Git.
- GitHub

7. Mapping and Navigation Tools:

- Google Maps API
- OpenStreetMap

8. Communication and Collaboration Tools

- Microsoft Teams

9. Design and Prototyping Tools

- Figma
- Canva

10. Integrated Development Environments (IDEs)

- Visual Studio Code

2.5 Testing Strategies

1) Unit Testing

- Purpose: The individual parts will be checked for correctness.
- Method: The tests will be created for key functions to guarantee that they work as anticipated.

2) Integration Testing

- Purpose: The trouble-free working of different modules will be guaranteed.
- Method: The communications between the frontend and backend will be verified to make sure that the data flow is correct.

3) Functional Testing

- Purpose: The application will be verified to be in accordance with the set requirements.
- Method: Test scenarios arising from the user stories will be performed, and exploratory testing will be carried out.

4) Performance Testing

- Purpose: The application reaction time and the efficieny under the load will be tested.
- Method: The performance criteria will be set, and stress tests will be done.

5) User Acceptance Testing (UAT)

- Purpose: The end-users will be involved in the validation process so that the application is in line with their requirements.
- Approach: Real users will be involved in testing to gather feedback and make necessary adjustments.

6) Regression Testing

- Purpose: Assurance will be provided that new changes do not disrupt existing functionality.

- Approach: Regression tests will be automated to run after code changes.

7) Security Testing

- Purpose: Vulnerabilities will be identified, and application security will be ensured.
- Approach: Regular security assessments will be conducted, and best practices will be followed.

2.6 Project Plan (WBS, Gantt Chart)

2.6.1 Work Breakdown Structure

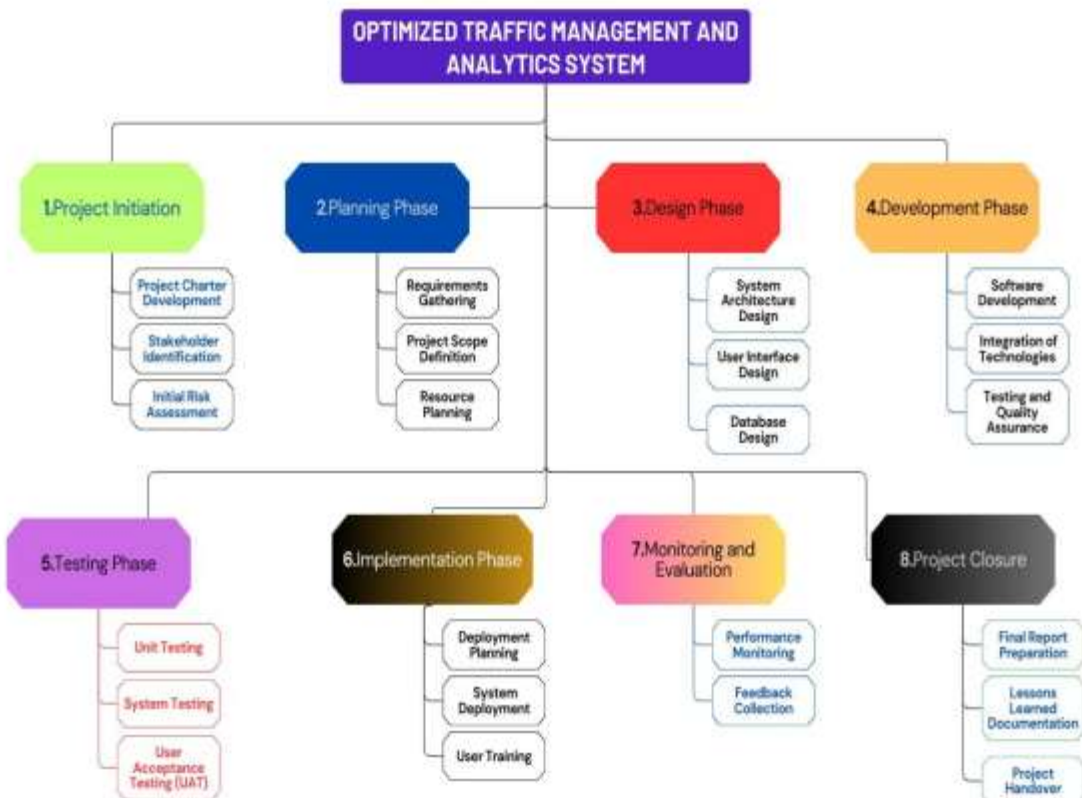


Figure 2: Work Breakdown Structure

2.6.2 Gantt chart

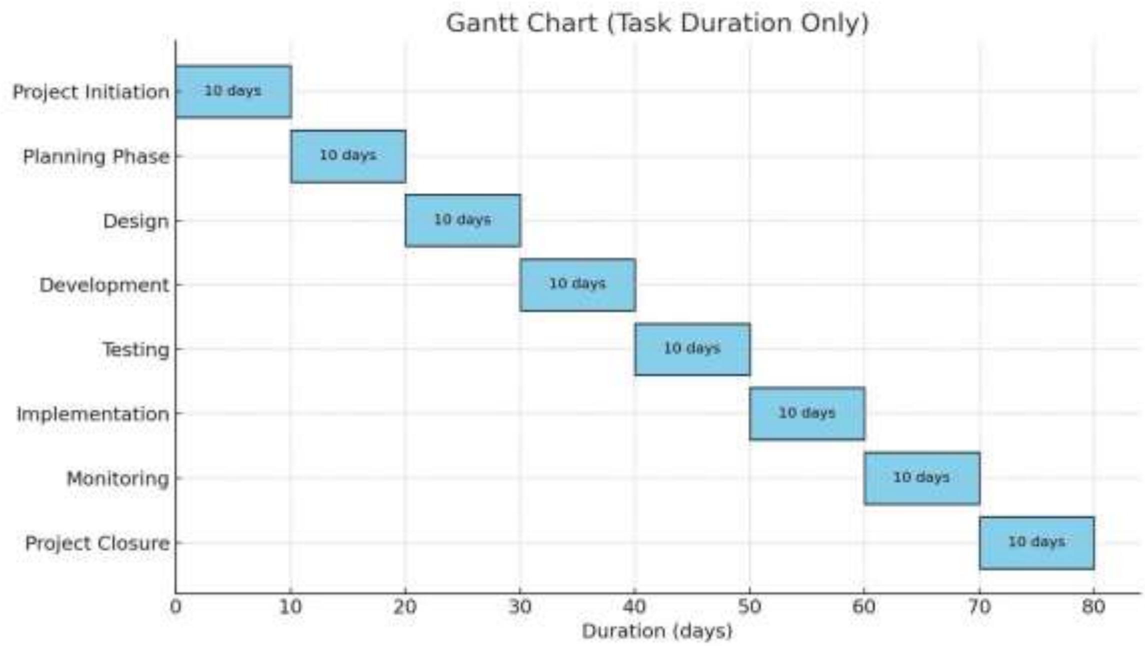


Figure 3:Gantt chart

2.7 Chapter Summary

First and foremost this chapter is about the research done in the final stages of identifying and planning a traffic management system for the city of Kandy. The data collection activities included online research, traffic counts, and interviews with some people in the traffic department and analysis of historical, weather and GIS data.Agile was the development approach used in this project. This approach is known for being very good for stakeholder and team collaboration and iterative incremental progress. The main stage of the project included planning, design, development, testing, deployment and review.A lot of tools and technologies such as HTML, PHP, Python, MySQL, Tableau, Git and Google Maps API was used to develop and analyze.

A full testing regime from unit to security tests was used to ensure the product is of high quality and meets performance and user satisfaction.

Work Breakdown Structure, which is a hierarchical decomposition of the total scope of work to be done by the project team to achieve the project objectives and deliverables, and a Gantt chart, which is a type of bar chart that shows a project schedule, was used to plan and manage the project to ensure timely and organized development.

Chapter 3: System Design

3.1 System Architecture

The system architecture describes the configuration and structure of the optimized traffic management and analytics system as well as where each component fits in the design, how they interact with each other, and the technology to be employed for implementation. A modular, scalable and maintainable design was recommended to meet evolving future needs.

3.1.1 Overview of the Proposed System

The proposed system will consist of the following components:

- Data Collection Module: Collect both historical and real-time traffic data from the sample case and available data sources.
- Data Processing Module: Process and analyze the data to understand traffic patterns and trends.
- User Interface Module: Provide users with an interface to access traffic information and special routing decisions.
- Reporting Module: Provide reporting on the analyzed data in graphic form.
- Feedback Module: Collect user feedback for system improvement purposes.

3.2.1 Use Case Diagram of Proposed System

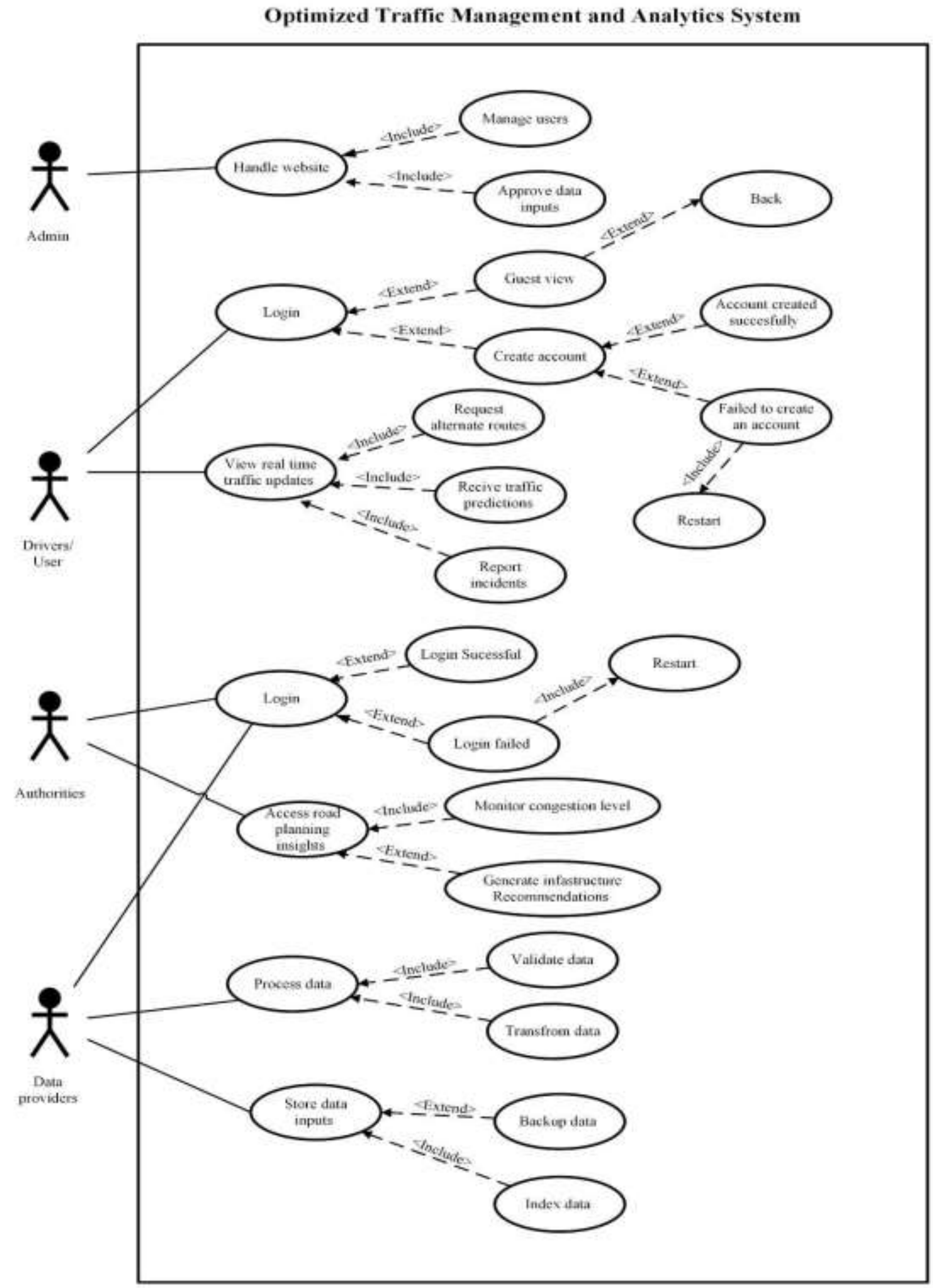


Figure 4: Use case Diagram for the proposed system

Functional Overview of Use Cases

The Optimized Traffic Management and Analytics System consists of four main actors: 1) Admin; 2) Driver/User; 3) Authorities and 4) Data Providers.

- Admin: Responsible for the management of the website, user account administration and validate Data inputs. Main features will be user administration and data validation.
- Driver/User: Will be able to receive traffic updates and submit requests for alternate routes. Users are welcome to log in as a guest or sign up for an account. Having an account will provide users additional features: incident reporting and traffic predictions.
- An authorities - will have a special login to observe congestion information as well as road planning intelligence. Recommendations of infrastructure improvements will come from look at full traffic data.
- Data Providers - will take data inputs and process the data to validate the data, then transform and save it. Data will be validated again. We will regularly back up the data and will index the data for access.

3.2.2 Entity-Relationship Diagram (ERD) of Proposed System

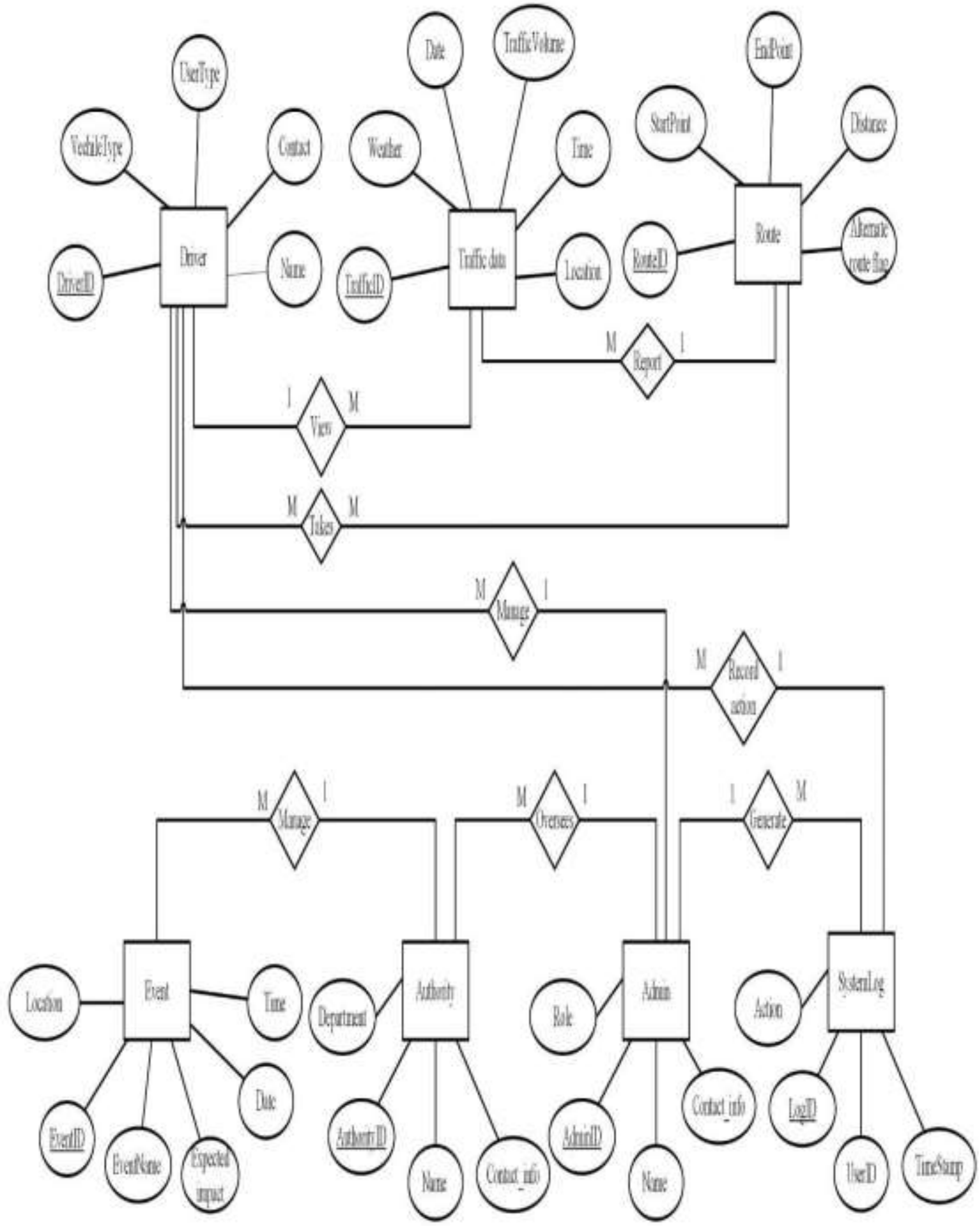


Figure 5: ERD

Functional Overview of the Entity-Relationship Diagram (ERD)

- Driver: Drivers will have access to register and manage their profiles which will include their vehicle information and contact details. All drivers will have access to real-time traffic data. This data will allow them to see where the traffic conditions are at any specific time and notify them of any incidents or traffic congestion. Each driver will have access to multiple traffic data reports (1 to M).
- Traffic data: Traffic data will be used to hold traffic data components such as traffic volume, weather, date, and time. The traffic data components will be observed and statistically calculated to create traffic patterns that will provide information to drivers about current traffic reports. Each traffic data report is associated with a specific route (M to 1).
- Route: Routes will have specific starting and stopping locations along with distance, and indicate alternate routes available. Drivers will be able to select routes based on traffic data, and routes will have many drivers and many reports (M to M). Drivers will receive recommendations for the best paths based on traffic conditions.
- Event: Events including accidents, road closures, and construction activities are managed in the system. Each event has information related to the expected impact and location of the event, which is communicated to drivers and authorities with details included. The system can also manage multiple events for each authority (1 to M).
- Authority: The authorities are responsible for managing the traffic and can evaluate the traffic feed to process events and create reports for their plans to improve infrastructure. Each authority can have one or more admins that will be managed in the system (1 to M).
- Admin: Admins have a role to manage the system as a whole- user accounts for drivers and authorities, data inputs, and system logs. Admins will have role and manage the system to keep the data reliable. Each admin can have multiple drivers, and authorities in the system (1 to M).

- System Log: The system log is for logging actions taken by users on the system. This gives a history of what interactions occurred, which can be referenced by an auditor or analyst to view a traffic event. The system log can reference multiple actions taken by multiple users (1 to M).

3.2.3 Context Diagram of Proposed System

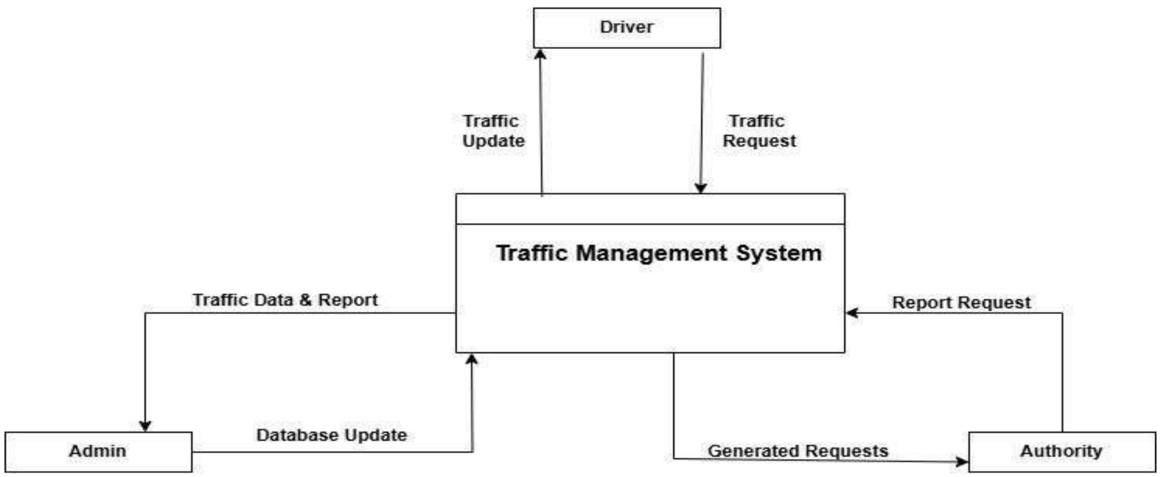


Figure 6:context diagram of Proposed System

Functional Overview for the Context Diagram

- Driver: Drivers have received real-time traffic updates to keep them aware of the current traffic conditions. Drivers can request specific traffic information which is processed by the system.
- Authority: Authorities submitted a request for traffic reports to understand the traffic conditions and incidents. Authority collected traffic data produced the reports, and authority can also submit additional requests for insight as required.
- Admin: Admins have received incoming traffic data from a collection of various inputs ready to be processed. Admins also have received updates on traffic report and overall system performance from the traffic reports and a new traffic data and report has been uploaded into the central database.
- Central Database: The central database is used to store all traffic data, users' data, and reports. All actors have access to information that is relevant and current.

3.2.4 Level 1 DFD of Proposed System

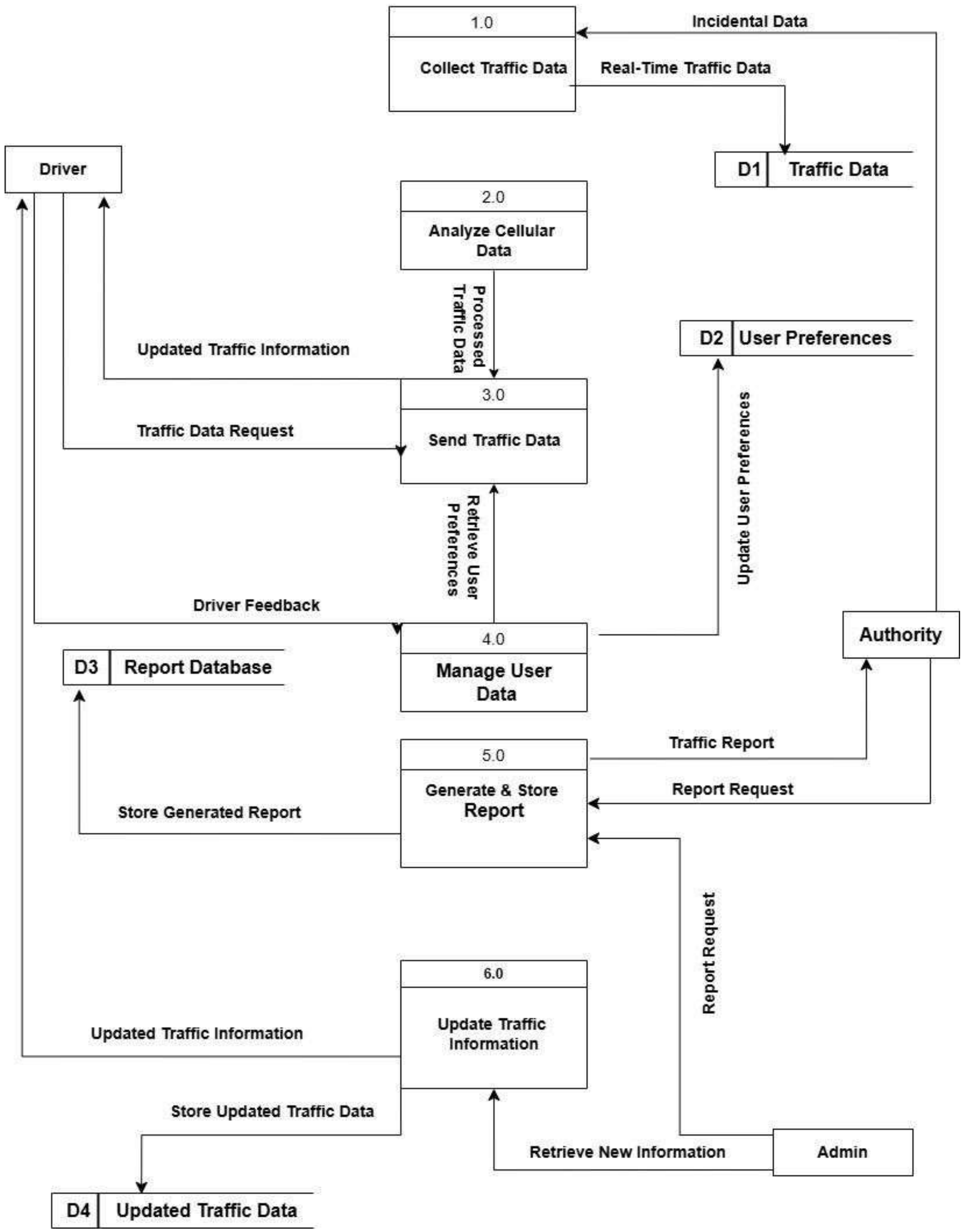


Figure 7: Level 1 DFD of Proposed System

Functional Overview for the Level 1 DFD of the Traffic Management System

- Collect Traffic Data: The D1 Traffic Data store collects real-time traffic data, and incident data from authorities to improve accuracy.
- Analyse Cellular Data: Cellular data is used to obtain processed traffic data to hand off to other processes.
- Send Traffic Data: Traffic Data is sent to drivers. The D2 Updated Traffic Information store stores updates regarding traffic data, as well as handles driver requests for traffic data.
- Manage User Data: It retrieves user preferences and sends these to the traffic data process. Driver feedback needs to be collected and sent to enhance system performance.
- Generate and Store Report: Traffic reports that are generated, are stored in the D4 Report Database. Reports are sent to the authorities and also handles reports requested from authorities and admin staff.
- Update Traffic Information: Updates to traffic information is sent to drivers, and is stored in the D5 Updated Traffic Database, new incoming information is sent from admin to ensure data is accurate.

3.2.5 Sequence Diagram of Proposed System

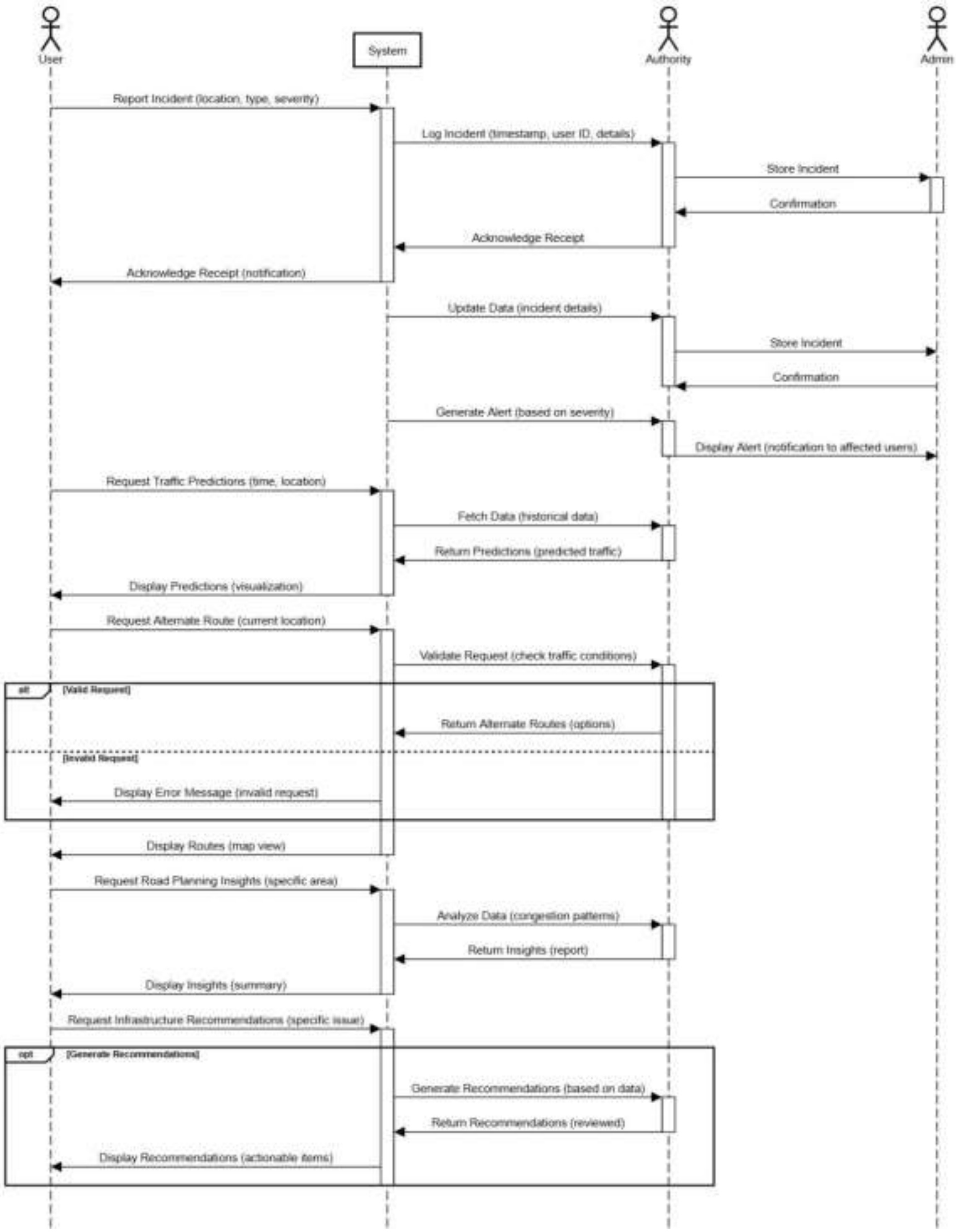


Figure 7: Sequence Diagram of Proposed System

Functional Overview for Sequence Diagram

- User Actions:

  User submits an incident report to System. System confirms receipt of the incident. User requests Traffic Predictions, and System would retrieve historical information including traffic collisions and return traffic predictions.

- User requests for Alternative Routes:

  User requests alternative routes from User's location. System would process the request, querying its database for possible alternative routes and return a number of alternative routes popping up in a map view.

- User requests for Insights:

  User requests road planning Insights. The System will generate insights based on the relevant data investigated. User requests Infrastructure recommendations, and the System would make recommendations regarding conclusions for the User.

- Alternative Paths (Error Handling):

  If the User submits an invalid request, there will be an error message displayed followed by a process as appropriate. User would be promted to correct and resubmit the original request.

- Optional Actions (Generate Recommendations):

  System generates recommendations based on the insights generated and returns for User feedback.

- System sends and updates anything regarding Authority:

  System sends details of the incident to Authority indicating receipt of incident report. Relevant data would be updated and alerts sent to Authority.

- Authority to Admin Communication:

  Confirmation of the incident is sent by the Authority to the Admin. Alerts and notifications regarding the incident are received by the Admin.

- Authority to Admin Communication:

  Confirmation of the incident is sent by the Authority to the Admin. Alerts and notifications regarding the incident are received by the Admin

3.2.6 Class Diagram of Proposed System

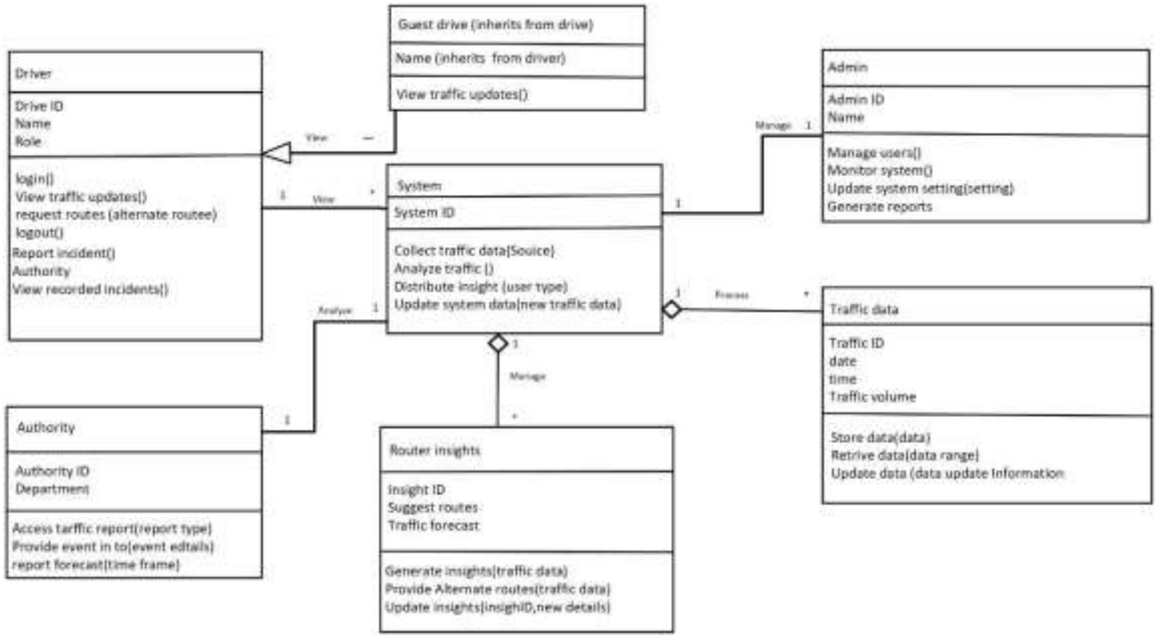


Figure 8: Class Diagram of Proposed System

Functional Overview for Class Diagram.

- Guest Driver: The Guest Driver is a user role that is limited in terms of features that they are able to access. They can access traffic updates.
- Driver: The Driver is a registered user, and the Driver can do all the previous actions plus they can log in, view traffic updates, request a route, report incidents, and view records.
- System: The System controls the flow of data and interaction between users, traffic data, and authorities. Traffic data is collected, insights are distributed, and information is refreshed.
- Admin: The Admin is responsible for all system operation. Admins manage users' accounts, monitor system performance, update settings, and generate reports.
- Traffic Data: The traffic data is stored, managed, and can be accessed for storage, retrieval and update along with aggregation with Route Insights.

- Route Insights: The traffic data is analyzed, develop insights and recommendations. The recommendations provided to drivers are suggestions for routes and traffic forecasts.
- Authority: The authority that manages traffic and data. This authority has access to traffic data, event information and forecasts.

3.2.7 Swimlane Diagram of Proposed System

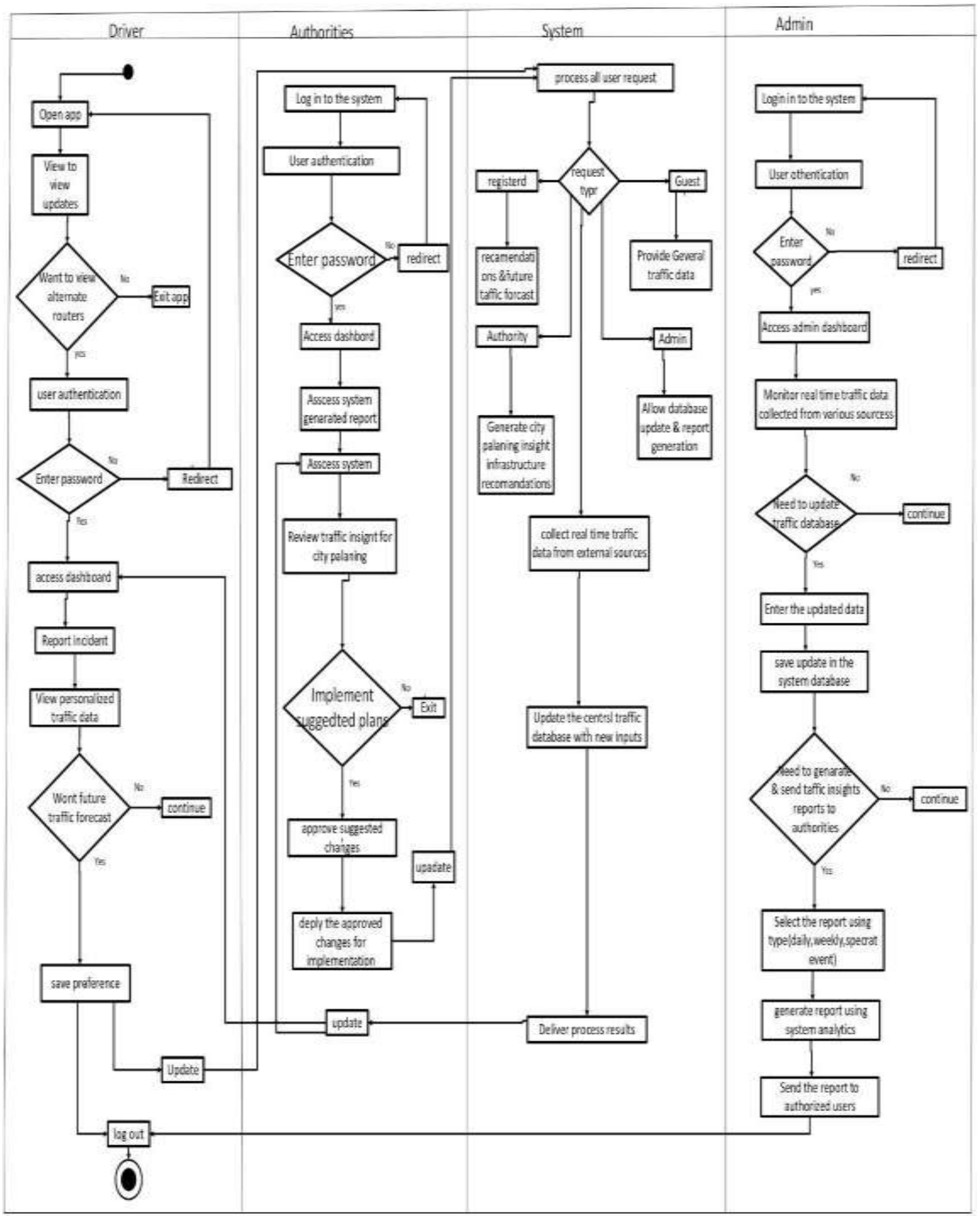


Figure 9: Swimlane Diagram of Proposed System

Functional overview for the Swimlane Diagram

- Driver: The Driver opens the application to look at general traffic updates. The Driver is then authenticated when logging in to the dashboard by entering a password. The Driver accesses personalized traffic data when authentication is successful and the Driver also logs reported incidents. A traffic forecast request is offered, along with preferences for updates in the future.
- System: The system processes all Driver requests, everything offered by the system is considered general traffic data offered to guest users, while registered users get personalized recommendations. The system utilizes real-time traffic data supplied from external sources and updates the central traffic database. Then, once processed the results are found in the dashboards for users.
- Authority: The Authority logs into the system and does user authentication, when they have access, they have access to their dashboard where they would review traffic insights for city planning purposes. The Authority always received suggested traffic plans for approval or outright dismissal, any approved changes would be enacted, and would then update the system.
- Admin: An Admin user will log into the system and authenticate when required. The Admin will monitor the real-time traffic data and make updates to the traffic database as required. The Admin will generate reports and send those reports to authorized user, which has the option for type of report (daily, weekly, etc.) Once the Admin have completed their tasks, the Admin will log out from the system.

3.2.8 Activity Diagram of Proposed System

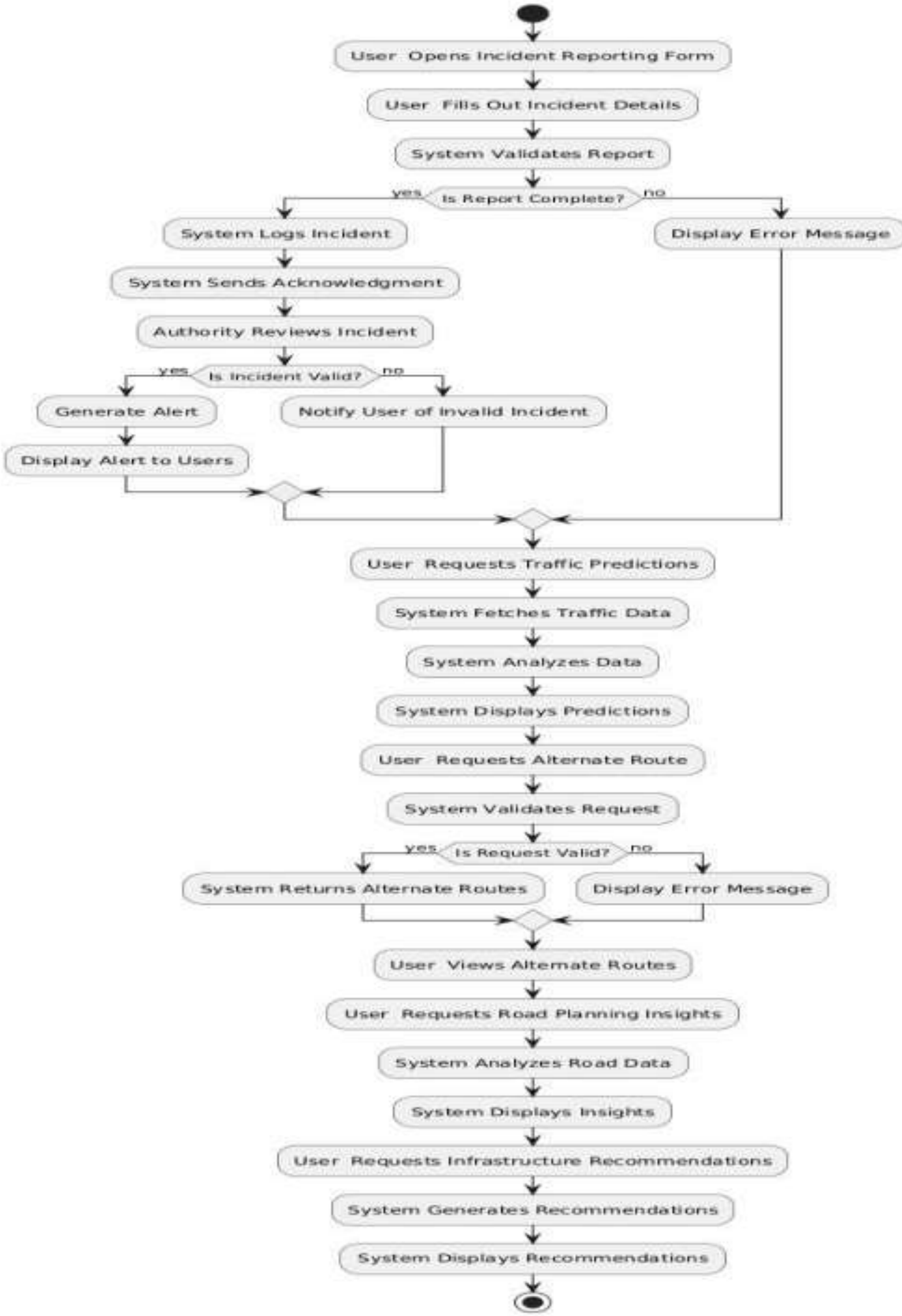


Figure 10: Activity Diagram of Proposed System

Functional overview for the Activity Diagram

- Incident Reporting: A reporting form is launched by the user and the required incident information is entered by the user. The system checks if the report is complete; if it is not, it will give the user an error message. Once the report is complete, the incident is logged, and an acknowledgment is issued to the user.
- Incident Review: The incident is reviewed by the system to determine whether or not it is valid. If the incident is determined to be invalid, the user is informed. If the incident was validated, alerts are generated and shown to the user.
- Traffic Prediction Requests: A user requests a traffic prediction, and the system retrieves and examines the relevant traffic data; the traffic predictions are shown to the user.
- Alternate Routes: The system validates requests for alternate routes as they are received. If the alternate route request is valid, the system returns the alternate routes to the user; it the alternate route request is not a valid request, it will provide the user with an error.
- Road Planning Insights: The user requests road planning insights, and the system examines the relevant data, then displays the insights.
- Infrastructure Recommendations: Infrastructure recommendations are generated by the system upon user request and are displayed for the user’s review and consideration.

3.2.9 Database Schema of Proposed System

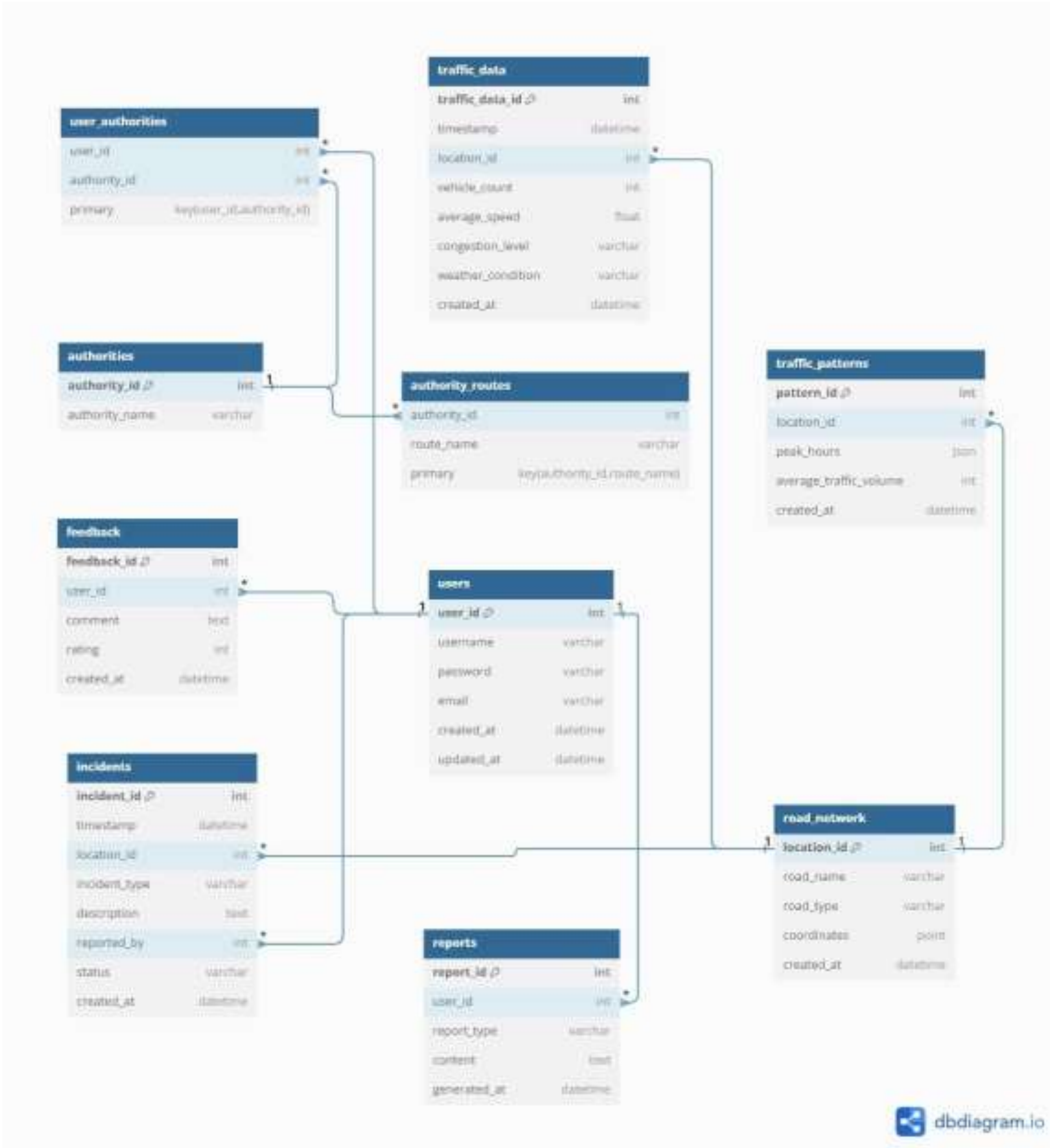


Figure 11: Database Schema of Proposed System

Functional Overview of Database Schema

- Users: Users are recorded in the users table, including user ID, username, password, email, account created datetime, and account updated datetime.

- Traffic Data: Traffic information in real time is logged in the traffic_data table, which holds traffic data ID, timestamp, location ID, vehicle count, average speed, congestion, and weather.
- Reports: Reports submitted by users are captured in the reports table, which includes report ID, user ID, report type, report, and timestamp of report generation.
- Authorities: Authorities that manage traffic are stored in the authorities table, with authority ID, and authority name.
- Incidents: Incidents that have been reported are contained and fully described in the incidents table, this table contains incident ID, timestamp, the location ID, incident type, incident description, reported by, status of incident, and the created timestamp.
- Road Networks: Road infrastructure is stored in the road_networks table, this table includes location ID, and the road name, type of road, the coordinates of the road, and the created timestamp.
- Traffic Patterns: Traffic flows are evaluated in the traffic_patterns table, this table includes pattern ID, location ID, peak hours, average count of traffic-flow, and created timestamp.
- Authority Routes: Managed routes are available from the authority_routes table, and includes authority ID, and the route name.

3.3 Summary

This chapter presented the System Design for the Optimized Traffic Management and Analytics System, which described the modular architecture, scalable architecture, and connections between each main component (data collection, processing, reporting, and user interfaces). It presented diagrams (use case diagrams, entity relational diagram, context diagram, data flow diagrams, sequence diagrams, class diagrams, swimlane diagrams, activity diagrams, and database schema) to illustrate the different ways users (Drivers, Admins, Authorities, and Data Providers) will interact with the system. The design will allow traffic updates in real-time (to drivers), incident reporting (for muchas), as well as predictive analytics and infrastructure planning support, representing the basis of a data-driven traffic management system.

Chapter 4: Analysis

4.1 SWOT Analysis

Strengths:

- Increased Data Analysis: Business Intelligence (BI) and Robotic Process Automation (RPA) can enhance data analysis.
- Real-time Traffic Monitoring: The ability to monitor real-time traffic situations can provide for prompt decision making.
- User Feedback: User feedback systems can be used to gain user insights that can be used to continuously improve the process.

Weaknesses:

- Residual Methodological Decisions: Alternatives to ML and DSA may make it hard for the system to analyze complex data patterns.
- Technology Issues: Apart from technology infrastructure issues, this system relies on information that may be lost due to power outages and/or cyber-attacks.
- Operational Complexity: The introduction of BI and RPA into a legacy system may present operational and budgetary constraints.

Opportunities:

- IoT Devices: There are opportunities to use Internet of Things (IoT) devices for enhanced data collection and monitoring.
- Additional Services: there are opportunities to develop indirect products like automated reporting and traffic optimization directed towards user experience.
- Smart City: Smart City initiatives provide opportunities for the application of targeted initiatives in traffic management and urban planning as both evolve into strategically based competitive filters.

Threats:

- Cyber security Threats: All new technology can be subject to being targeted by cyber-attacks that may deny data integrity and trust by customers focused on immediate personal activity.
    - ❖ Regulatory Changes: Changes in regulations regarding data privacy and traffic management could impact system operations.
- Competition: Increased competition may arise from other traffic management solutions, potentially leading to market share loss.

4.2 GAP Analysis

Traffic Control

- Current State: Traffic lights are partially automated, an officer can exercise manual control during peak hours.
- Desired Future State: A fully automated traffic management system is desired.
- GAP: Inefficiency in traffic flow management comes from the partial automation of traffic lights and manual control traffic management.
- Action Plan: An automated traffic management system will be deployed from existing technologies and person training.

Incident Reporting

- Current State: public reporting produces inaccuracies and delays.
- Desired Future State: Real time incident reporting is desired.
- GAP: Timely and accurate incident data is not provided by existing reporting methods.
- Action Plan: Real time incident reporting will be deployed by developing a smartphone app that is easy to use and connects with existing reporting systems.

Public Transportation

- Current State: Poor coordination of public transport and schedules.
- Desired Future State: A public transportation system that uses real time data and is integrated.

- GAP: There are delays and inefficiencies because the public transport is not integrated.
- Action Plan: An integrated public transport system will result through working with operators and using GPS to track public transportation.

Data Use

- Current State: Use of historical data and reactive management is limited.
- Desired Future State: A proactive approach, tapping into real-time data and analytics, is desired.
- GAP: Current systems lack the potential for proactive decision-making.
- Action Plan: A data analytics framework will be put in place, by acquiring a good real-time processing tool for data and training personnel.

Infrastructure Planning

- Current State: Serious lack of adequate traffic data for comprehensive urban planning.
- Desired Future State: Good access to detailed traffic data for good infrastructure development is desired.
- GAP: Urban planners lack the necessary data to make good decisions.
- Action Plan: Good access to traffic data will be created by building a centralized traffic data base and good updates.

User Engagement

- Current State: Very limited user feedback mechanisms.
- Desired Future State: A comprehensive user feedback and engagement system is wanted.
- GAP: The systems ability to adapt is limited due to lack of user engagement.
- Action Plan: A user feedback and engagement system will be established by creating user feedback mechanisms and regularly surveying.

Performance Monitoring

- Current State: There is no systematic performance monitoring of traffic management.
- Desired Future Site: There is a desire to have a continuous performance monitoring and performance reporting system.

- GAP: The current system is not supplying performance metrics.
- Action Plan: A continuous performance monitoring system will developed, by identifying required key performance indicators, and implementing automated reporting.

Integrating Technology

- Current State: There is currently an over-reliance on outdated technology and manual work processes.
- Desired Future State: There are hopes to be using modern technologies (BI, RPA etc...) for optimised data collection in the future.
- GAP: Current technology infrastructure is not appropriate for advanced analytics and automation.
- Action Plan: Upgrade technology infrastructure by scrutinising current systems, and engaging in investment in modern technology, and continue training staff.

4.3 Risk Assessment

Technological Risks

- Cybersecurity Weaknesses: The unauthorized access to sensitive traffic data may be compromised.
- Capacity Problems: There will likely be potential bottlenecks with performance during peak traffic.
- System Reliability: Old infrastructure could cause increased system failures or downtime.
- Integration limitations: The challenges of integrating new technology and the existing system, particularly at identified point, may cause disruptions to operations.

Operational Risks

- Data Quality: Errors with real-time reporting or user inputs may jeopardize reliability and effectiveness.
- Stakeholder Coordination: Engagement across a number of stakeholders may be challenging.

- Complexity of Implementation: Maintaining collaboration and resource allocation is difficult under an Agile framework and may provide challenges.
- Change Management: Resistance from staff and users will impede the implementation.
- Training & Support: Poor usage of the system may occur due to inadequate training and support.

Technical Risks

- Unauthorized access to sensitive traffic data may be Knowledge Gaps
- Lack of Expertise in DSA, ML, and IoT: Familiarity with Data Science Analytics, Machine Learning, and the Internet of Things may be lacking.
- Alternatives:
- Robotic Process Automation (RPA): Efficiency in data handling may be improved through RPA.
- Business Intelligence (BI): Better decision-making may be enabled by BI tools for data analysis and reporting.
- Data Warehouse Management (DWM): Effective organization and management of data may be ensured through DWM.
- Opportunity for Implementation: Enhanced capabilities in data management and analysis may be achieved by leveraging RPA, BI, and DWM, with future integration of DSA, ML, and IoT features for optimized traffic flow and safety.

Project Risks

- Schedule Delays: The project may delay due to technical problems not foresee Register Track UpdateCancelseen. Overbudget: Work may cost more than estimated due to unforeseen challenges
- Scope Change: If the project scope unexpectedly changes, resources will be overtaxed and delays will occur. Environmental Risks
- Regulatory Changes: If new data privacy laws are enacted, we may need to modify our processes for handling data to stay in compliance.

Public Use:

- Hesitancy with digital systems and users can hinder user use and data collection. Environmental impact: The infrastructure and systems will be effective only if their design considers the environmental impact, including the effect of earthquakes or urbanisation.
- Political/Economic Considerations: Political and economic factors could affect the funding and sponsorship possible for the project.

4.4 Risk Mitigation Techniques

1. Technical Safeguards
    - Modular and Scalable Structure: We will create a modular and scalable structure for the architecture to support continued development and flexibility.
    - Strong Security Protocols: Strong security protocols will be instituted to secure sensitive data, such as multifactor authentication and secured user logins.
    - Stress Testing: The system will be stress tested to verify stability and to look for potential blocking points to performance.

2. Operational Measures
    - Data Validation: Data validation will be used to enhance the accuracy of user-generated content and used to ensure data integrity.
    - Training Stakeholders: Stakeholders and users will be trained so they can effectively mobilize the system.
    - Collaboration: Understanding and established clear communication lines to enable all project participants to jointly collaborate together and share information.

3. Project Controls
    - Project Management Program: A project management program, such as Trello, will be used for better sprint planning, task tracking, and overall organization of the project.
    - Regular Risk Review: The identified risks will be monitored by means of periodic reviews to their status, and if necessary to change the resources for mitigation of the emerging issues.
    - Roles and Responsibilities: Roles and responsibilities will be created within the project team to improve accountability and efficiency in decision making.
4. Environmental Safeguarding
    - Compliance with Regulation: Local and global data laws will be adhered to in protecting end-user privacy and in complying with legal requirements.
    - Environmental Impact Assessments: Assessments will be created to determine environmental impacts and the best mitigation strategies employed.
    - Public Consultation: Outreach will be conducted to educate users about the system and its benefits to build public support and acceptance.

4.4 Chapter Summary

In chapter 4 we reviewed the proposed traffic management system through the different lands SWOT, GAP, and risk assessments. The key strengths that we found within the system were the real-time monitoring of traffic and the processing of data. The key weaknesses we found relative to system processing were reliance on media force methods In GAP analysis, we found gaps in traffic control, incident reporting, data utilization, and proposed a course of action for each. We addressed risks in the system, which included technical, operational, and environmental factors, and proposed mitigations for those risks. Overall, the chapter emphasized the potential to improve efficiency and resilient through automation, integration, and proactive planning.

Chapter 5: Data Analysis

5.1 Introduction

In this chapter, we examined traffic behaviors and patterns in the Kandy area, as well as major causes of traffic congestion during both peak and non-peak times. We had to mix simulation (and real-time data, such as Google Maps traffic features) with our lack of digitized traffic history logs (which were not available from the Road Development Authority [RDA] of Sri Lanka) - we tried to make as much meaning as possible regarding this analysis of traffic.

The purpose of the analysis is to identify traffic patterns and anomalies, understand peak congestion times, and to understand how vehicles interact with the bottlenecks or major congestion areas of the urban environment. The information learned in this analysis section is aimed at informing the design of a rule-based, intelligent traffic management and incident response system focused on the Kandy metropolitan area.

Beginning with the study of the most significant traffic bottlenecks in Kandy, we then document our data generation process prior to describing the exploratory data analysis (EDA) and other methods we used, which includes anomaly detection, cluster analysis, and time series trends in order to obtain usable information to inform the design of a useful system.

5.2 Identification of Key Bottlenecks

We identified the major entry bottlenecks into the Kandy city area before simulating and analyzing traffic flows. The Kandy city region has several routes which lead into the Kandy city area from several bridges and highway designations. We note that, added with many conflicts associated with the roads used during peak hours, these roadways are subject to vehicular congestion.

Key Bottlenecks Identified:

1. Peradeniya (Peradeniya Junction) via Colombo–Kandy Road (A1)
    - A crucial entry from Colombo.

- Heavy amounts of vehicles along the route and constant traffic congestion during peak hours.

2. Katugastota Bridge via Kurunegala–Kandy Road (A10)
    - Primary major northern entry into Kandy.
    - Heavy flow of vehicles from the direction of Kurunegala and Matale.
3. Tennekumbura Bridge via Mahiyanganaya–Digana–Ampitiya Road (A26)
    - Secondary northeast direction entry into Kandy from agricultural regions.
    - Heavy use of bus routes and school zone traffic in that area.
4. Southern access via Watapuluwa–Kundasale route
    - Largely undefined and is a newer access to Kandy but a growing corridor.
    - Growing suburbia housing and school traffic bundles travel.

During our preliminary site visits as part of site logging, we observed that Katugastota Bridge and Peradeniya Junction were the most photographed along with evidence of most traffic congestion. Based upon these combinations of characteristics we narrowed our focus for detailed traffic flow simulation and traffic performance analysis to Katugastota Bridge, which is evidence of complex merging and strategic bottlenecks location.

Figure 12: Satellite view of the Katugasthota region highlighting the key traffic bottleneck

Figure 13: Normal view of the Katugasthota region highlighting the key traffic bottleneck

5.3 Bottleneck Overview

5.3.1 Bottleneck 1: Katugastota Entry (North-East Confluence)

- Main Entry Point A
- Routes:
    - ❖ Kandy–Matale–Jaffna Road (two-way, high volume)
    - ❖ Katugastota–Madawela–Bambarella–Digana Road (two-way, high volume)
- Sub-entry Routes:
    - ❖ Katugastota–Madawala Road (low traffic except peak hours)
    - ❖ Katugastota–Market Road
- Junction Type: Four-lane merge (2 entry, 2 exit)
- Complexity: Sub-road vehicles must navigate exit lanes to reach the main entry route

5.3.2 Bottleneck 2: Southern Merge Zone

- Routes:
    - ❖ Kurunegala–Kandy Main Road (two-way, high volume)
    - ❖ Peradeniya–Haloluwa Road (two-way, high volume)
- Junction Type: Four-lane structure (2 entry, 2 exit)
- Complexity: Vehicles from different directions merge into narrow central lanes near the town center

5.3.3 Main Bottleneck: Katugastota Junction

- Function: Central merging point of both Bottlenecks 1 and 2
- Features:
    - ❖ High-volume vehicle interaction zone
    - ❖ Complex merging and exit pattern
    - ❖ Exit vehicles from Katugastota combine with outbound traffic from both bottlenecks
- Impact: Primary source of congestion, especially during peak hours

5.4 Sample of Simulated Traffic Dataset

The traffic analysis for this study is based on a comprehensive simulated dataset generated for three years, from January 1, 2022, to December 30, 2024. This dataset forms the foundation for identifying and analyzing traffic bottlenecks around the Katugasthota region.

Dataset Overview:

- Total Records: 338,400
- Features (Columns): 21
- Date Range: 2022-01-01 to 2024-12-30
- Interval: Hourly data for selected days (2–3 days per week)
- Granularity: Captures route-level data, vehicle types, speeds, multipliers, and contextual flags (e.g., holidays, school days)
- Detected Anomalies (Z-score method): 5,814

Key Attributes:

The dataset includes the following critical fields:

- Timestamp: Date and time of the entry
- Bottleneck: Identifier of the bottleneck area (e.g., Bottleneck 1, Bottleneck 2)
- Route: Road segment or approach name
- Vehicle Type: Car, bus, lorry, motorcycle, etc.
- Volume: Number of vehicles recorded in that segment and time
- Traffic Intensity: Categorized as Low, Moderate, or High
- Average Speed: Calculated in km/h
- Speed Status: Slow, Normal, Fast
- Modifiers: Flags for school days, holidays, Sundays, and working days

Timestamp	Bottleneck	Entry Point	Route	Vehicle Type	Traffic Multiplier
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Kandy-Matale-Jaffna Road	Car	1.6
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Kandy-Matale-Jaffna Road	Truck	1.6
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Katugastota-Madawela-Bambarella	Car	1.6
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Katugastota-Madawela-Bambarella	Bus	1.6
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Katugastota-Madawela-Bambarella	Truck	1.6
2022-01-01 07:00:00	Bottleneck 1	Main Entry A	Katugastota-Madawela-Bambarella	Three-wheeler	1.6
2022-01-01 07:00:00	Bottleneck 2	Main Entry B	Kurunegala-Kandy Main Road	Motorcycle	1.6
2022-01-01 08:00:00	Bottleneck 1	Main Entry A	Kandy-Matale-Jaffna Road	Three-wheeler	1.5
2022-01-01 08:00:00	Bottleneck 1	Main Entry A	Katugastota-Madawela-Bambarella	Truck	1.5
2022-01-01 08:00:00	Bottleneck 1	Sub Entry A	Katugastota-Madawala Road	Three-wheeler	1.5
2022-01-01 08:00:00	Bottleneck 1	Sub Entry B	Katugastota-Market Road	Three-wheeler	1.5
2022-01-01 08:00:00	Bottleneck 2	Main Entry B	Kurunegala-Kandy Main Road	Motorcycle	1.5

Figure 14:Sample of Simulated Traffic Dataset 1

Traffic Multiplier	Vehicle Volume	Traffic Intensity	Avg Speed (km/h)	Speed Status	Is School Day
1.6	182	Moderate	27.2	Sluggish	TRUE
1.6	176	Moderate	12.2	Heavy Congestion	TRUE
1.6	180	Moderate	34.6	Smooth	TRUE
1.6	176	Moderate	15.4	Heavy Congestion	TRUE
1.6	176	Moderate	12.2	Heavy Congestion	TRUE
1.6	174	Moderate	28.3	Sluggish	TRUE
1.6	190	Moderate	43.6	Smooth	TRUE
1.5	177	Moderate	23.3	Sluggish	TRUE
1.5	174	Moderate	14	Heavy Congestion	TRUE
1.5	177	Moderate	23.6	Sluggish	TRUE
1.5	180	Moderate	22.5	Sluggish	TRUE
1.5	171	Moderate	44.2	Smooth	TRUE

Figure 15:Sample of Simulated Traffic Dataset (2)

Route	Vehicle Type	Traffic Multiplier	Vehicle Volume	Traffic Intensity	Avg Speed (km/h)	Speed Status
Kandy-Matale-Jaffna Road	Car	1.6	182	Moderate	27.2	Sluggish
Kandy-Matale-Jaffna Road	Truck	1.6	176	Moderate	12.2	Heavy Congestion
Katugastota-Madawela-Bambarella	Car	1.6	180	Moderate	34.6	Smooth
Katugastota-Madawela-Bambarella	Bus	1.6	176	Moderate	15.4	Heavy Congestion
Katugastota-Madawela-Bambarella	Truck	1.6	176	Moderate	12.2	Heavy Congestion
Katugastota-Madawela-Bambarella	Three-wheeler	1.6	174	Moderate	28.3	Sluggish
Kurunegala-Kandy Main Road	Motorcycle	1.6	190	Moderate	43.6	Smooth
Kandy-Matale-Jaffna Road	Three-wheeler	1.5	177	Moderate	23.3	Sluggish
Katugastota-Madawela-Bambarella	Truck	1.5	174	Moderate	14	Heavy Congestion
Katugastota-Madawala Road	Three-wheeler	1.5	177	Moderate	23.6	Sluggish
Katugastota-Market Road	Three-wheeler	1.5	180	Moderate	22.5	Sluggish
Kurunegala-Kandy Main Road	Motorcycle	1.5	171	Moderate	44.2	Smooth
Kandy-Matale-Jaffna Road	Motorcycle	1.4	168	Moderate	41.7	Smooth
Kandy-Matale-Jaffna Road	Motorcycle	1.5	178	Moderate	32.5	Smooth
Katugastota-Madawala Road	Three-wheeler	1.5	175	Moderate	31.1	Smooth
Katugastota-Market Road	Bus	1.5	169	Moderate	15.8	Heavy Congestion
Katugastota-Market Road	Truck	1.5	178	Moderate	19.9	Heavy Congestion
Katugastota-Market Road	Three-wheeler	1.5	169	Moderate	20.4	Sluggish

Figure 16:Sample of Simulated Traffic Dataset (3)

h)	Speed Status	Is School Day	Is Holiday	Is Sunday	Is Working Day	Hour	Day	Month	Year	Volume Z-Score
27.2	Sluggish	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.466494771
12.2	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.284148679
34.6	Smooth	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.40571274
15.4	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.284148679
12.2	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.284148679
28.3	Sluggish	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.223366648
43.6	Smooth	TRUE	FALSE	FALSE	TRUE	7	Saturday	January	2022	3.709622894
23.3	Sluggish	TRUE	FALSE	FALSE	TRUE	8	Saturday	January	2022	3.314539694
14	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	8	Saturday	January	2022	3.223366648
23.6	Sluggish	TRUE	FALSE	FALSE	TRUE	8	Saturday	January	2022	3.314539694
22.5	Sluggish	TRUE	FALSE	FALSE	TRUE	8	Saturday	January	2022	3.40571274
44.2	Smooth	TRUE	FALSE	FALSE	TRUE	8	Saturday	January	2022	3.132193602
41.7	Smooth	TRUE	FALSE	FALSE	TRUE	13	Saturday	January	2022	3.041020556
32.5	Smooth	TRUE	FALSE	FALSE	TRUE	16	Saturday	January	2022	3.34493071
31.1	Smooth	TRUE	FALSE	FALSE	TRUE	16	Saturday	January	2022	3.253757663
15.8	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	16	Saturday	January	2022	3.071411571
19.9	Heavy Congestion	TRUE	FALSE	FALSE	TRUE	16	Saturday	January	2022	3.34493071
20.4	Sluggish	TRUE	FALSE	FALSE	TRUE	16	Saturday	January	2022	3.071411571

Figure 17:Sample of Simulated Traffic Dataset (4)

5.5 Traffic Pattern Visualization

5.5.1 Heatmaps and Calendar Heatmaps

To better understand temporal traffic patterns, a calendar heatmap was generated to visualize total vehicle volume across days of the week and weeks of the year. This visualization helps identify recurring congestion trends and seasonal traffic fluctuations.

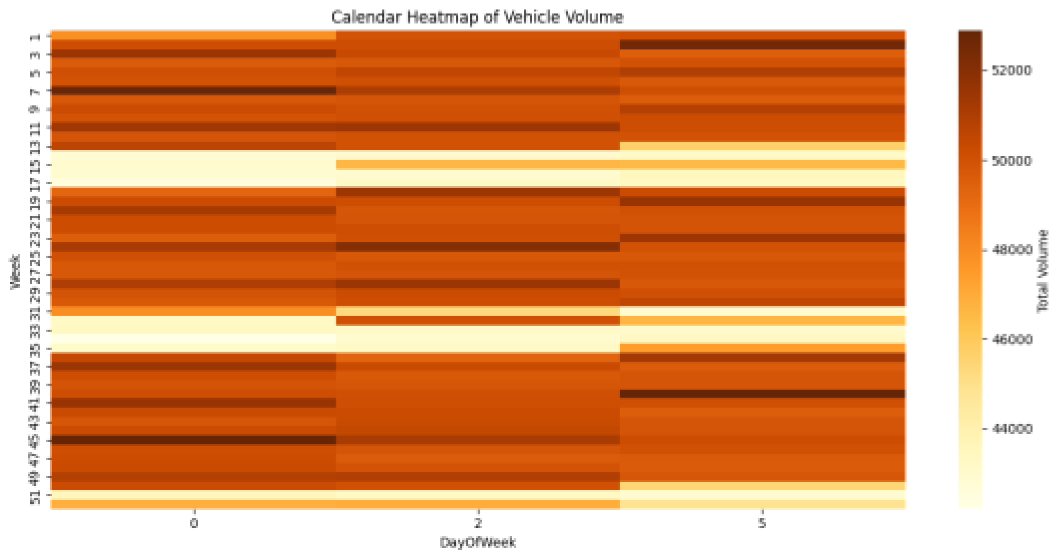


Figure 18: Calendar Heatmap of Vehicle Volume

- X-axis: Days of the week (0 = Monday, 6 = Sunday)
- Y-axis: Week numbers (1 to 52)
- Color Gradient: Represents total vehicle volume, ranging from light yellow (lower volume) to dark brown (higher volume)

This heatmap reveals:

- Consistent high traffic volumes during weekdays, especially mid-week.
- Noticeable dips in volume during weekends and public holidays.
- Seasonal peaks, likely corresponding to school terms or festive periods.

Such insights are crucial for planning dynamic traffic signal timings and scheduling road maintenance during low-traffic periods.

5.5.2 Monthly Calendar Heatmap

To also investigate intra-month traffic behaviors, a monthly calendar heatmap was developed. This heatmap presents vehicle volumes daily over the first 12 weeks of the year (see Figure below). It provides a detailed visualization of how traffic volume varies intra-monthly across the testing period.

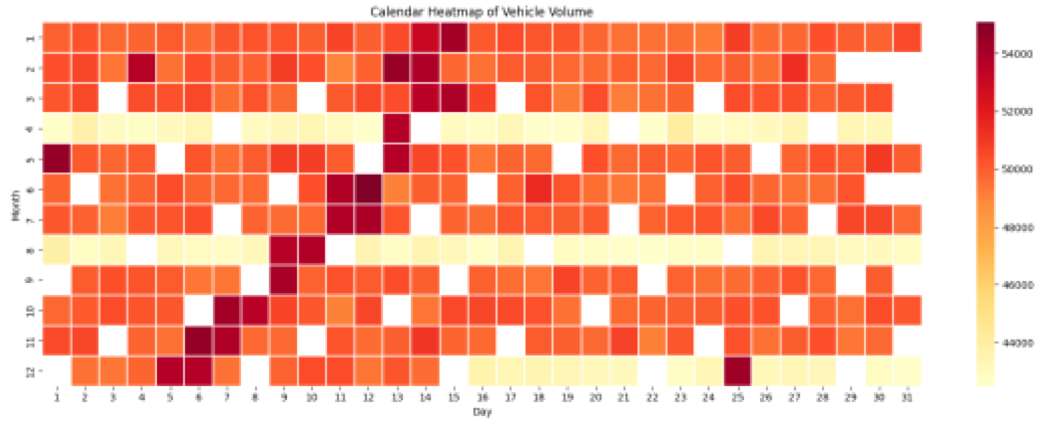


Figure 19:Monthly Calendar Heatmap of Vehicle Volume

- X-axis: Days of the month (1 to 31)
- Y-axis: Week numbers (1 to 12)
- Color Gradient: Ranges from light yellow (low volume) to dark red (high volume)

Insights:

- Traffic volumes appear to peak around the middle of the month. This may be connected to salary cycles, school timetables or market days.
- The amount of traffic appears less at the beginning and the end of the month. This corresponds to public holiday periods and also to periods with lower levels of activity.
- These visualizations can help in identifying suitable opportunities for road maintenance or traffic rerouting.

5.5.3 Correlation Heatmap of Contextual Features

In order to visualize the relationships between important traffic variables and contextual features a correlation heatmap was generated. The correlation heatmap visualizes the strength and direction of linear relationships between traffic variables like vehicle volume, average speed, traffic multipliers and contextual flags i.e. holidays or school days.

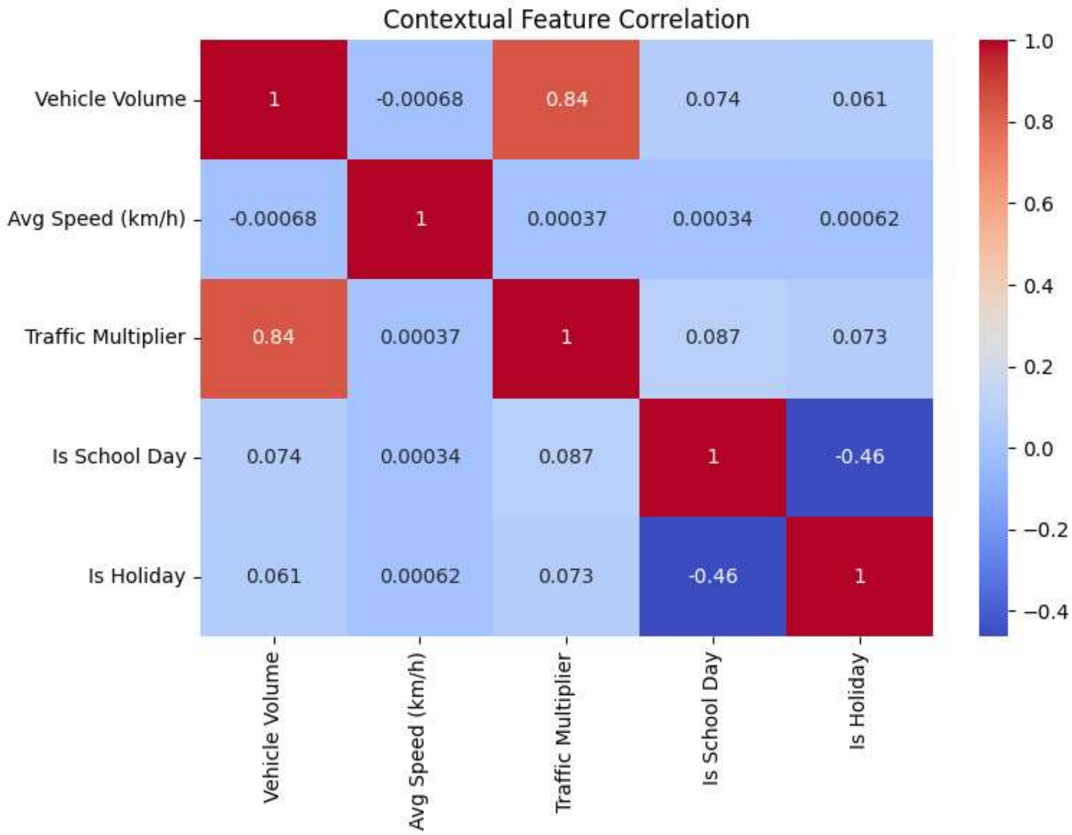


Figure 20:Contextual Feature Correlation Heatmap

- Color gradient: blue indicates a negative correlation, red indicates a positive correlation, and the intensity of the color indicates the amount of correlation from -1 to +1.
- Key findings:
    - ❖ Vehicle Volume has a strong positive correlation with Traffic Multiplier (0.84), meaning that as vehicle volume increases, volume will scale correctly and as expected based on contextual multipliers.
    - ❖ There are weak or negligible correlations between Vehicle Volume and Avg Speed as a whole (overall), suggesting that vehicle volume alone does not dictate speed.

- ❖ School Days and Holidays each had small, positive correlations with Vehicle Volume and Traffic Multiplier, indicating possible shifts of human patterns during only school or holidays.

This heat map provides valuable information to improve traffic behaviour prediction models by demonstrating which contextual variables most strongly affect traffic behaviour.

5.5.4 Correlation Matrix of Core Traffic Variables

To investigate the potential relationships between core traffic metrics for the traffic patterned examined, a correlation matrix heatmap was created. A correlation matrix is a great first step to determine how variable such vehicle volume vs. average speed, traffic multipliers, and time of day/hour are linearly correlated and how strongly they are related.

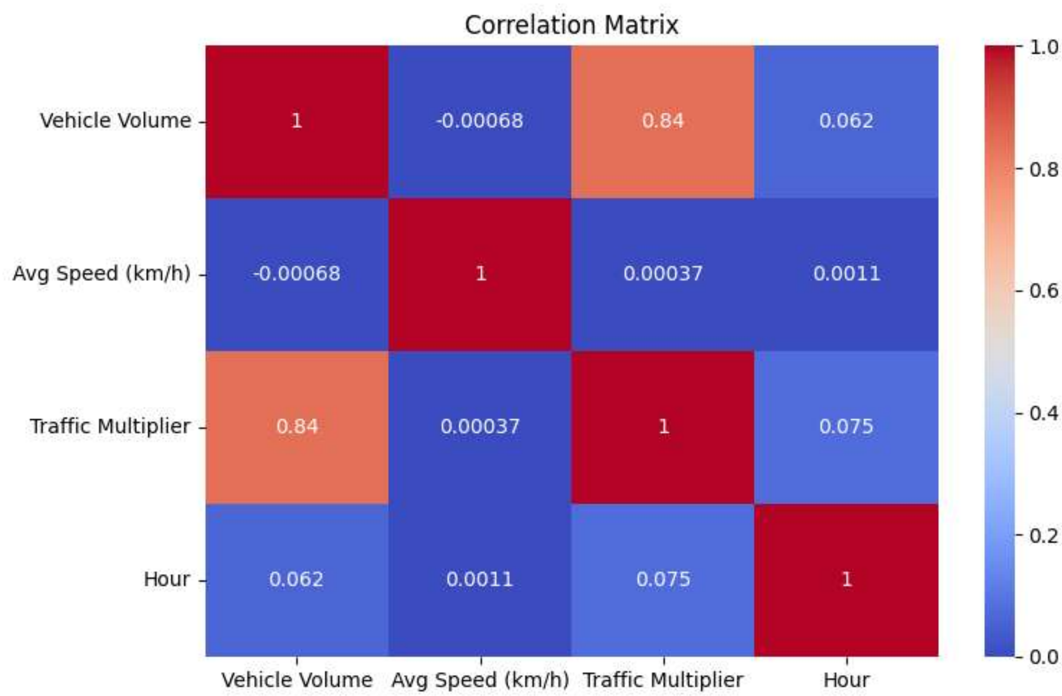


Figure 21:Correlation Matrix of Core Traffic Variables

- Colour Gradient: Ranging from blue (negative correlation) to red (positive correlation), with values from -1 to +1.
- Key Findings:
    - ❖ Vehicle Volume and Traffic Multiplier demonstrate a strong positive correlation (0.84), meaning that contextual multipliers (i.e. school days, holidays) greatly affect traffic volume.

❖ A weak positive correlation (0.062) was revealed between Volume and Hour, indicating that hour does have a small effect on volume.

❖ Average Speed has very little correlation with the other attributes. This suggests that average speed may be impacted by other more complex or external influences that are not included in this matrix.

5.5.5 Box Plot: Vehicle Volume on Holidays vs. Working Days

To assess the role of context in calendar policy around vehicle volume and traffic behaviour, a box plot was produced that identified comparatives between vehicle volumes on holidays and working days. This visualization provides a quantified difference in flow for amount of vehicular traffic for holidays and working days.

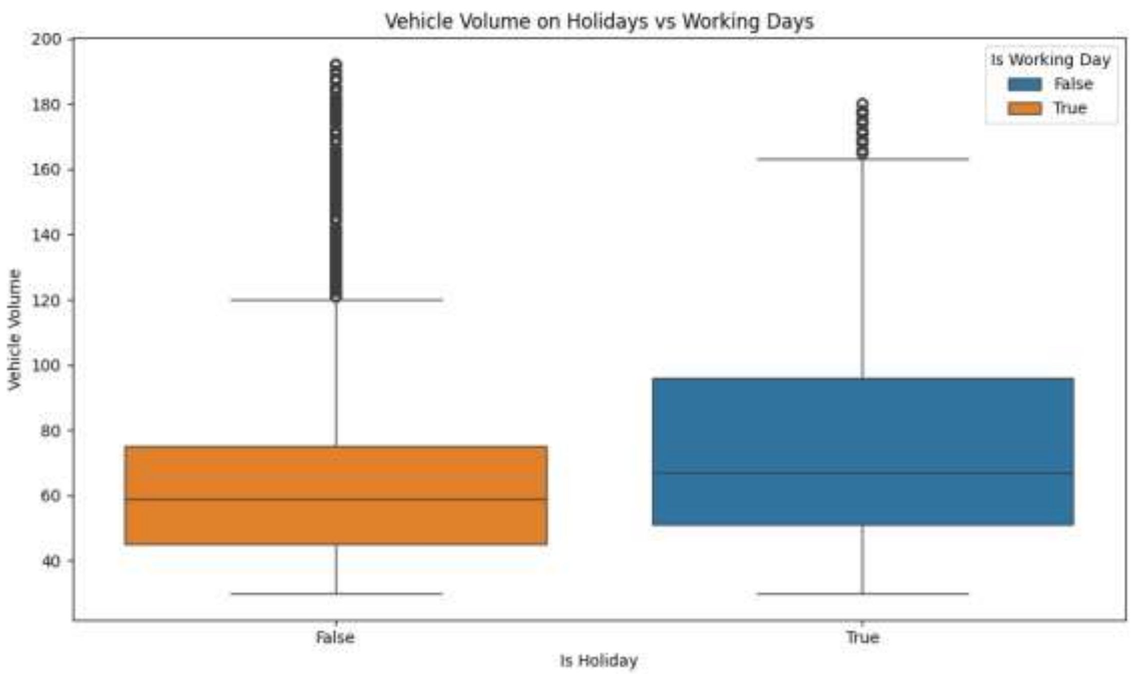


Figure 22:Box Plot of Vehicle Volume by Holiday Status

- X-axis: holiday status (True = Holiday, False = Non-Holiday)
- Y-axis: Vehicle Volume
- Color Legend: Working day status
  - ❖ Orange: Non-working days
  - ❖ Blue: Working days

Insights as follows:

- Working days have a higher median vehicle volume, a greater interquartile range, or more variation - meaning more consistent and heavier volumes.
- Holidays have lower median volumes, and less extreme values - thus suggests less travel activity.
- This comparison gives credit to the contextual flags/historical stats (holidays) as a potential factor for predictive modeling of traffic, as well as for the real-time traffic management logic.

5.5.6 K-Means Clustering: Volume vs. Speed

K-means clustering was used to discover natural clusters or groups within traffic behaviour, using vehicle volume and average speed as input features. K-means is an unsupervised learning technique and can help separate traffic conditions into differing congestion indicators which may help in determining whether these traffic patterns need to be handled differently.

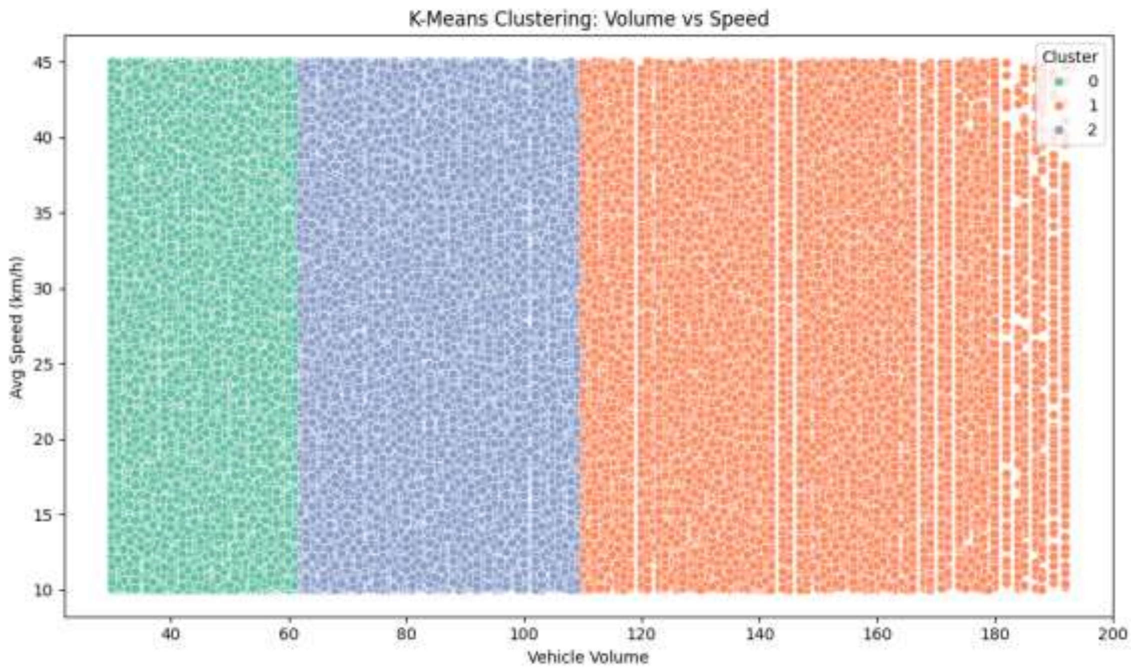


Figure 23:K-Means Clustering of Vehicle Volume vs. Average Speed

- X-axis: Vehicle Volume (0 to 200)
- Y-axis: Speed (km/h) (0 to 50)
- Cluster Labels:

- ❖ Cluster 0 (Green): low-volume, high-speed; a freely flowing route or an off-peak period of driving.
- ❖ Cluster 1 (Blue): moderate volume and speed; a likely transitional traffic condition.
- ❖ Cluster 2 (Orange): indicative of high-volume, low-speed; may indicate congestion or peak-hour conditions.

Insights:

- The clustering provides a clear means of assessing behaviour in traffic flow that can support signal timings, route diversion, or delay estimation related to congestion.
- The cluster variables may also be used as tags for supervised model training or real-time traffic state classification.

5.5.7 Pair Plot: Multivariate Relationship Exploration

To further explore the pairwise relationships of key traffic variables, a pair plot (i.e. scatterplot matrix) was created. This format is useful as it provides a small sample of possible relationships between these variables while also looking for possible correlations or clusters.

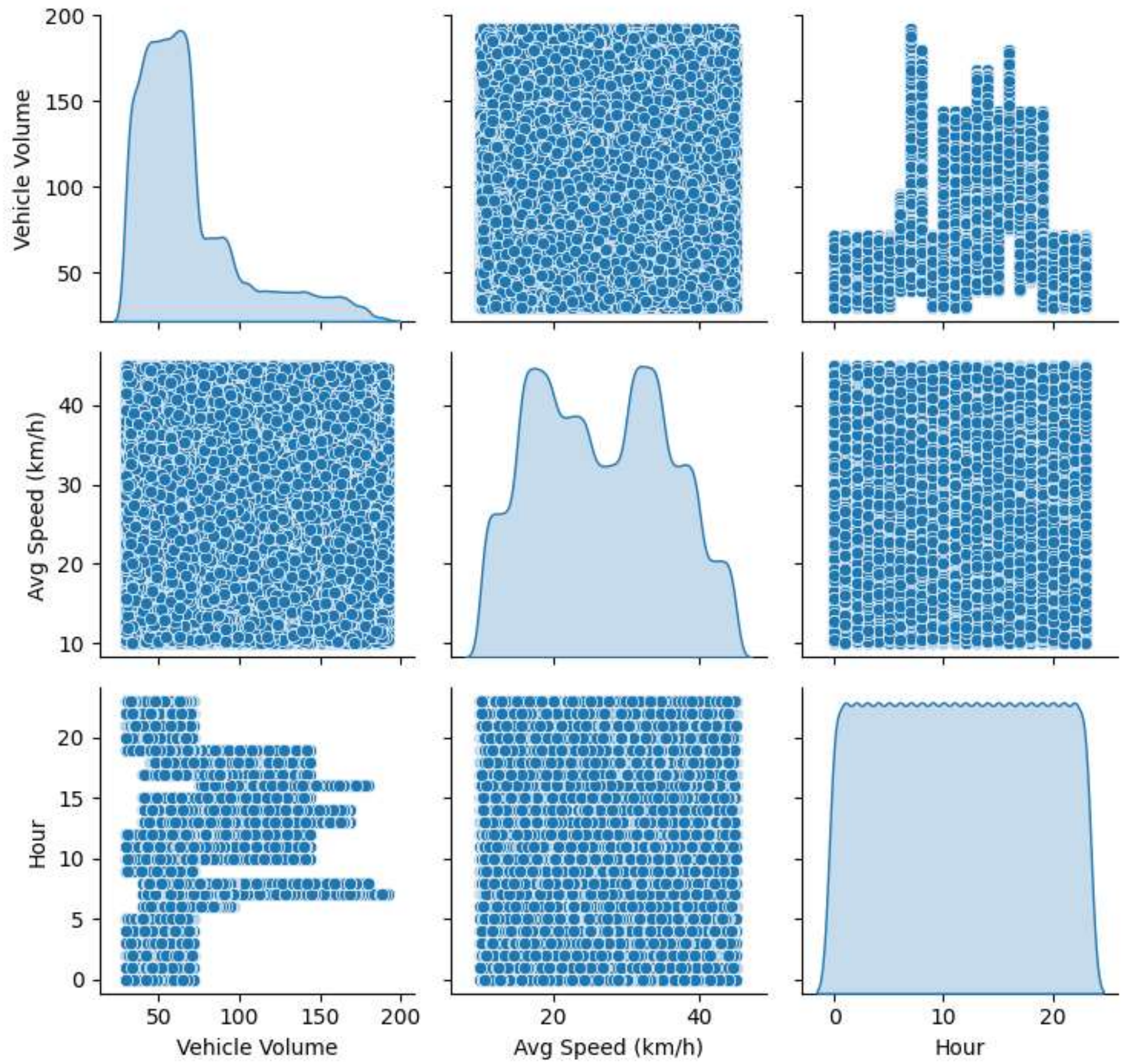


Figure 24:Pair Plot of Vehicle Volume, Average Speed, and Hour

- Diagonal Cells: Histograms showing the distribution of every variable.
- Off-Diagonal Cells: Scatter plots showing each of the pairwise relationships between:
    - ❖ Vehicle Volume and Avg Speed
    - ❖ Vehicle Volume and Hour
    - ❖ Avg Speed and Hour

Contrary to this, we gather the following insights:

- The Vehicle Volume vs Hour plot is shown that there is a slight level of concentration of traffic volume during distinctly specified hours showing peak periods.
- The Vehicle Volume vs Avg Speed plot shows a scattered distribution suggesting that speed is not linearly dependent on volume.
- The histograms illustrate that while both vehicle volume and hour have noticeable peaks, average speed is relatively uniform distributed.

Overall, this plot is useful for identifying trends, clusters, and maybe outliers in multivariate traffic data to support more advance statistical modeling.

5.5.8 Heatmap: Average Speed by Hour and Day

Heatmap: Average Speed by Hour by Day-A heatmap representing the average speed within each hour of every day was generated in order to evaluate any time based patterns in traffic speed. Heatmaps can help provide insights into the optimal times when traffic volume flowed quickly or slowly - which is important for optimizing signal timing and evaluating route planning.

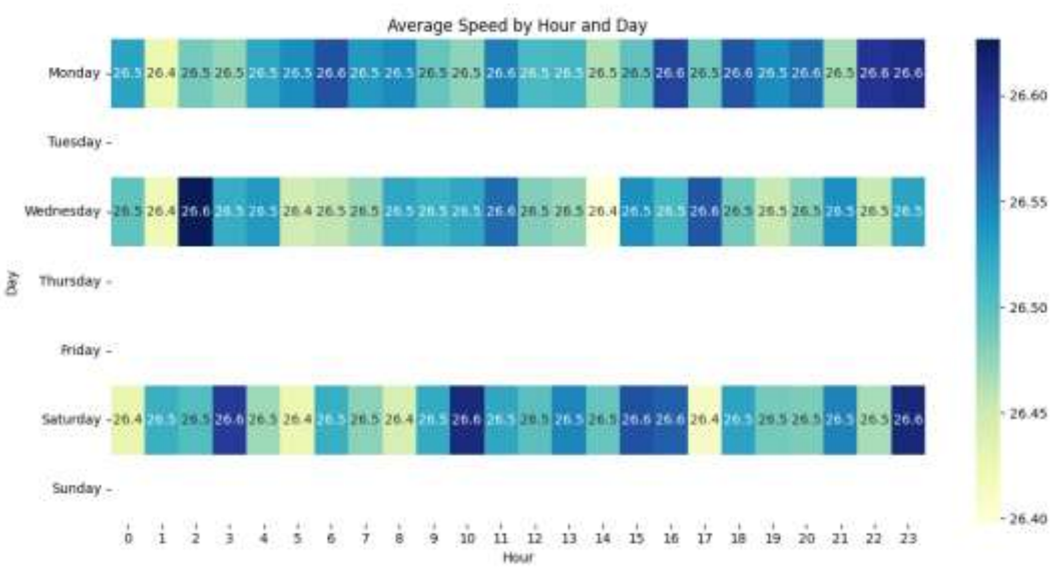


Figure 25:Heatmap of Average Speed by Hour and Day

This heatmap focused on:

- X-axis: Hours of the day (0-23)
- Y-axis: Weekday days (Monday-Sunday)
- Color Gradient

- ❖ Light Yellow: Lower Average Speeds (~ 26.40 km/h)
- ❖ Dark Blue: Higher Average Speeds (~ 26.60 km/h)

Conclusions:

- There are small differences in speed but they are consistent. Average speeds are slightly lower during morning and evening peak times of the weekday periods.
- Midday and late night hour have slightly higher average speed where traffic volume does not have a significant effect.
- Weekend days have a more uniform speed distribution, indicating lower amounts of congestion and traffic disruptions.

This heat map complements other congestion information, allowing one to identify higher periods of congestion, and manipulating change based on speed limits or traffic signal coordination.

5.5.9 Scatter Plot: Speed vs. Volume by Traffic Intensity

To identify how traffic volume impacted average speed, based on varying traffic conditions, a scatter plot is provided. The scatter plot contains traffic intensity information identified by category. The scatter plot provides insight into how congestion can impact traffic movement and average speeds.

Figure 26:Scatter Plot of Speed vs. Volume by Traffic Intensity

- X-axis: Vehicle Volume (0–200)
- Y-axis: Average Speed (km/h) (0–50)
- Color Coding:
    - ❖ Blue: Low traffic intensity
    - ❖ Orange: Moderate traffic intensity

Insights:

- Under low traffic intensity, vehicles maintain a wide range of speeds, indicating free-flowing conditions.
- As volume increases, especially under moderate intensity, average speeds tend to cluster in the lower range, suggesting congestion effects.
- The inverse relationship between volume and speed becomes more apparent in moderate traffic, supporting the need for dynamic traffic control measures during peak periods.

This plot is instrumental in validating the system's logic for congestion detection and route optimization.

5.5.10 Time Series Decomposition: Vehicle Volume

To uncover underlying patterns in traffic volume over time, a time series decomposition was performed. This technique separates the original signal into three components—trend, seasonality, and residuals providing a clearer understanding of long-term behavior and short-term fluctuations.

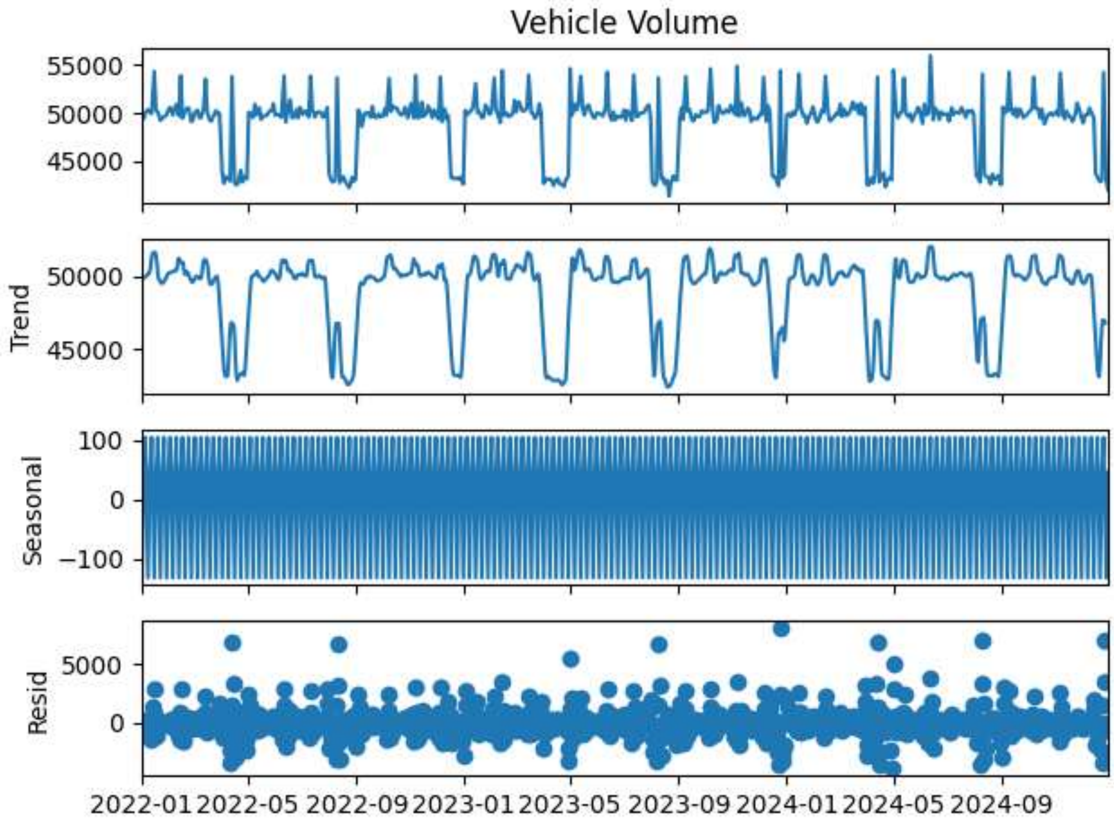


Figure 27: Time Series Decomposition of Vehicle Volume (2022–2024)

- Top Plot (Vehicle Volume): The original time series showing daily or weekly vehicle volume.
- Trend Component: A smoothed version of the data revealing the long-term direction of traffic volume. It shows a gradual increase over the years, indicating growing traffic demand.
- Seasonal Component: Captures repeating patterns within the data, such as weekly or monthly cycles. The seasonal variation is relatively small (±100), suggesting consistent but subtle periodic fluctuations.
- Residual Component: Represents irregularities or noise not explained by the trend or seasonality. These spikes may correspond to anomalies like road closures, events, or weather disruptions.

Insights:

- The upward trend supports the need for scalable traffic infrastructure.

- Seasonal patterns can inform scheduling of maintenance or public transport adjustments.
- Residuals highlight the importance of real-time monitoring for unexpected traffic surges.

5.5.11 Time Series Residual Analysis

To further investigate irregularities in traffic volume data, a residual plot was generated as part of the time series decomposition. Residuals represent the portion of the data not explained by the trend or seasonal components, highlighting anomalies and unpredictable fluctuations.

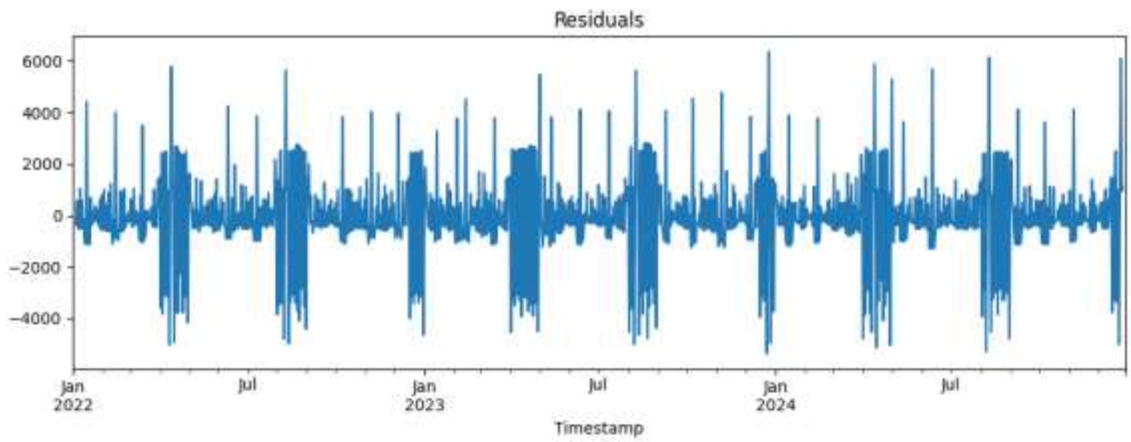


Figure 28:Time Series Plot of Residuals (2022–2025)

- X-axis: Timestamp (January 2022 to January 2025)
- Y-axis: Residual values (ranging from -6000 to +6000)
- Title: "Residuals"

Insights:

- The residuals fluctuate around zero, as expected, but several spikes indicate significant deviations from expected traffic patterns.
- These deviations may correspond to unplanned events such as road closures, accidents, weather disruptions, or public gatherings.
- Monitoring residuals in real time can enhance anomaly detection and support dynamic traffic response strategies.

This analysis reinforces the importance of integrating real-time data feeds and anomaly detection mechanisms into the traffic management system.

5.5.12 Seasonal Component Analysis

As part of the time series decomposition, the seasonal component was extracted to isolate recurring patterns in traffic volume across the observed period. This component helps identify periodic fluctuations that repeat over consistent intervals, such as weekly or monthly cycles.

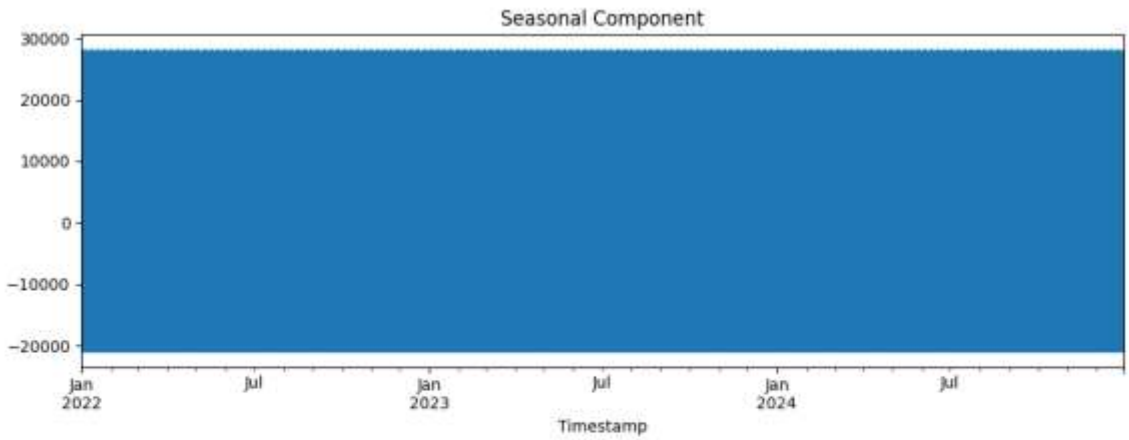


Figure 29:Seasonal Component of Vehicle Volume (2022–2025)

- X-axis: Timestamp (January 2022 to January 2025)
- Y-axis: Seasonal variation in vehicle volume (ranging from -20,000 to +30,000)
- Graph Style: Solid blue fill indicating dense, overlapping data points

Insights:

- The seasonal component reveals consistent cyclical behavior in traffic volume, likely corresponding to weekly work schedules, school terms, or monthly economic activity.
- Peaks and troughs repeat at regular intervals, validating the presence of predictable traffic surges and lulls.
- Understanding these patterns enables proactive traffic management, such as adjusting signal timings or deploying resources during expected high-volume periods.

This analysis supports the integration of seasonality-aware forecasting models into the traffic analytics system.

5.5.13 Trend Component Analysis

As part of the time series decomposition, the trend component was isolated to reveal the long-term progression of traffic volume over the three-year period. This component smooths out short-term fluctuations to highlight the underlying direction of change.

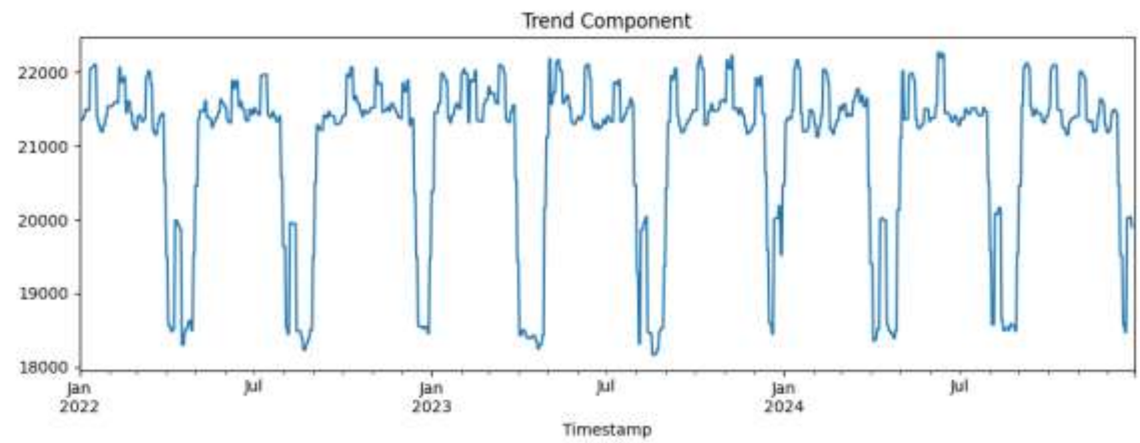


Figure 30:Trend Component of Vehicle Volume (2022–2025)

- X-axis: Timestamp (January 2022 to January 2025)
- Y-axis: Smoothed vehicle volume (ranging from 18,000 to 22,000)
- Graph Type: Line plot showing gradual changes over time

Insights:

- The trend line exhibits a cyclical rise and fall, with periodic peaks and troughs suggesting seasonal or policy-driven influences.
- A general upward trajectory is observed, indicating increasing traffic volume over the years—likely due to urban expansion, population growth, or increased vehicle ownership.
- These insights support the need for scalable infrastructure and adaptive traffic control systems that can accommodate long-term growth.

This trend analysis is essential for forecasting future traffic loads and planning sustainable urban mobility strategies.

5.5.14 Anomaly Detection in Vehicle Volume

To identify unusual traffic patterns, a time series anomaly detection analysis was conducted using statistical thresholds. This visualization highlights deviations in vehicle volume that fall significantly outside the expected range.

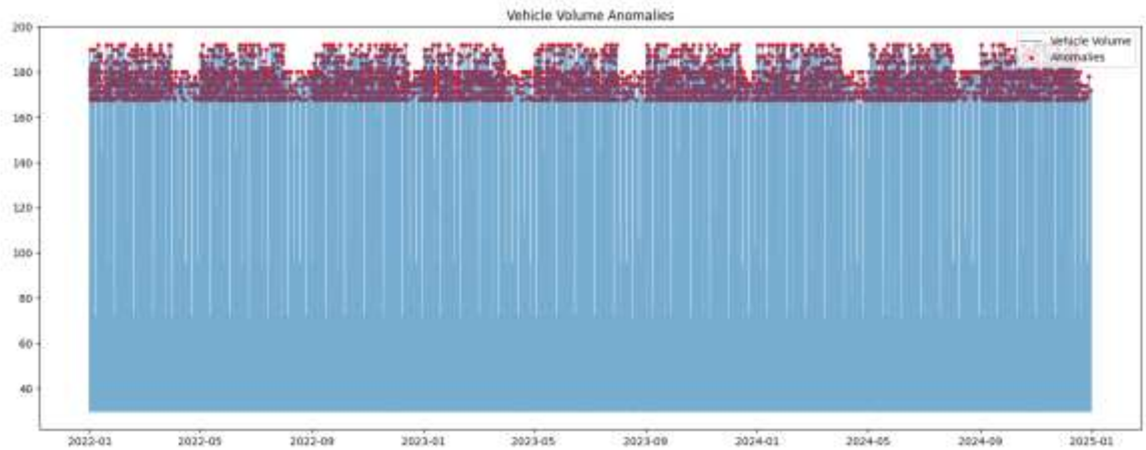


Figure 31:Vehicle Volume Anomalies (2022–2024)

- X-axis: Date range from January 2022 to January 2024
- Y-axis: Vehicle Volume (0–200)
- Data Series:
    - ❖ Blue Line: Normal vehicle volume over time
    - ❖ Red Dots: Detected anomalies based on Z-score thresholds

Insights:

- Anomalies are scattered across the timeline, with clusters appearing during certain months—possibly due to events, roadworks, or weather disruptions.
- These spikes represent instances where traffic volume was significantly higher or lower than the norm.
- Detecting such anomalies is crucial for real-time alert systems and for refining predictive models to account for exceptional conditions.

This analysis supports the development of a responsive traffic management system capable of adapting to unexpected changes in traffic flow.

5.5.15 Box Plot: Volume Distribution per Route per Hour

To understand how traffic volume varies across different routes and times of day, a multi-category box plot was generated. This visualization compares hourly vehicle volume distributions for each major route entering or exiting the Katugastota region.

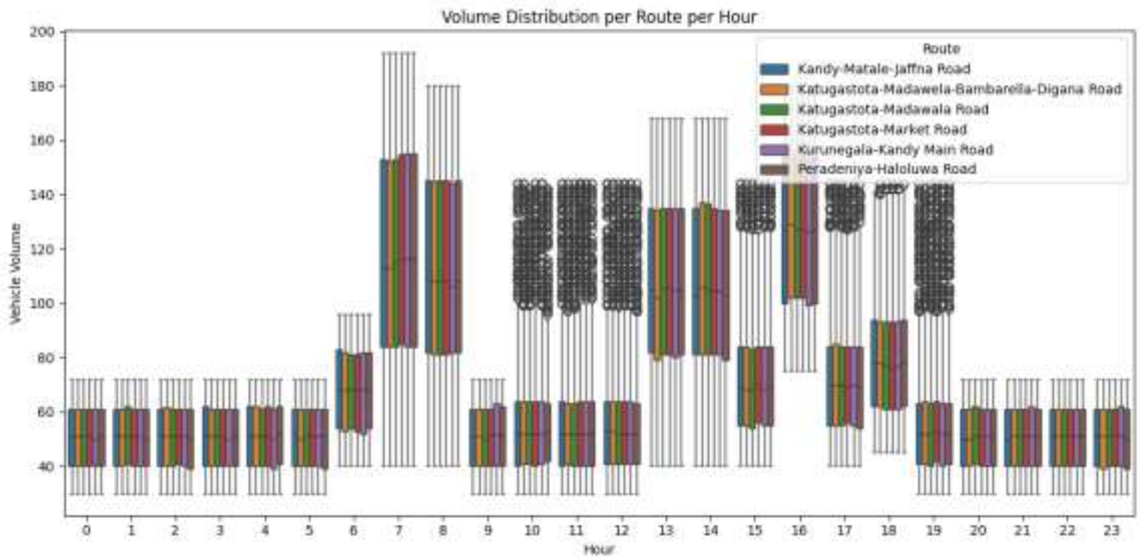


Figure 32:Volume Distribution per Route per Hour

- X-axis: Hour of the day (0 to 23)
- Y-axis: Vehicle Volume
- Color Legend: Represents seven key routes:
    - ❖ Matale–Jaffna Road
    - ❖ Katugastota–Madawala–Bambaralla–Digana Road
    - ❖ Katugastota–Madawala Road
    - ❖ Katugastota–Market Road
    - ❖ Kandy Man Road
    - ❖ Kurunegala–Kandy Main Road
    - ❖ Peradeniya–Halloluwa Road

Insights:

- Certain routes, such as Kurunegala–Kandy Main Road and Matale–Jaffna Road, show consistently higher volumes during morning and evening peak hours.
- Routes like Katugastota–Market Road exhibit more sporadic volume spikes, possibly due to localized commercial activity.
- The spread of the box plots indicates variability in traffic flow, with some routes experiencing wide fluctuations in volume throughout the day.

This analysis is essential for route-specific traffic signal optimization and for prioritizing infrastructure upgrades on high-volume corridors.

5.5.16 Trendline Visualization of Vehicle Volume

To observe the overall direction and consistency of traffic volume over time, a trendline visualization was created. This plot overlays a regression line on top of the raw vehicle volume data to highlight long-term movement and variability.

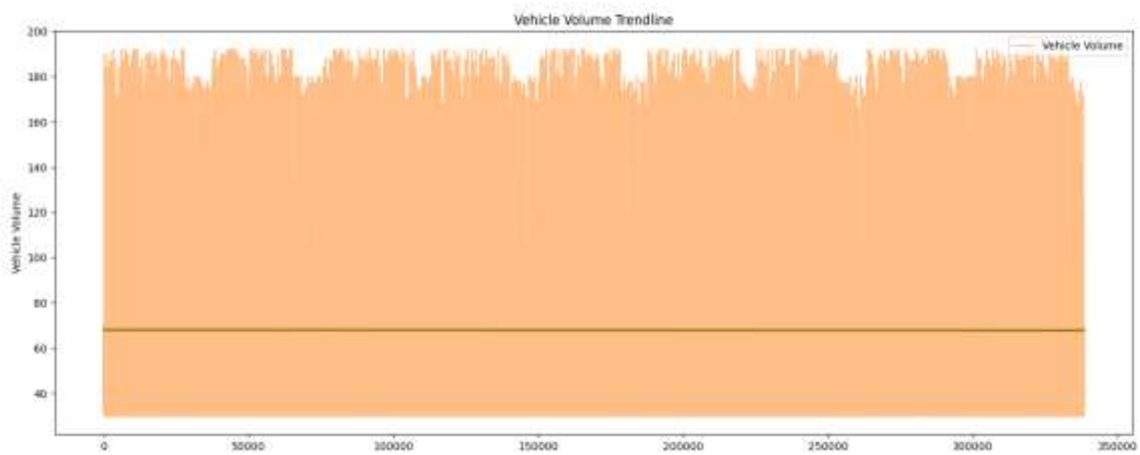


Figure 33:Vehicle Volume Trendline

- X-axis: Represents the timeline or data index (0 to ~3,000,000)
- Y-axis: Vehicle Volume (0 to 180)
- Visual Elements:
    - ❖ Orange Shaded Area: Raw vehicle volume data
    - ❖ Green Line: Fitted trendline indicating the general direction of volume changes

Insights:

- The trendline remains relatively flat, suggesting that while there are fluctuations in traffic volume, the overall average remains stable over the observed period.
- The orange area shows significant short-term variability, indicating the presence of daily or hourly traffic surges.
- This visualization is useful for confirming the stability of traffic flow and identifying whether interventions are needed to manage long-term growth.

This trendline supports the use of smoothing techniques in traffic forecasting and helps validate the consistency of the simulated dataset.

5.5.17 Z-Score Anomaly Detection in Vehicle Volume

To identify statistically significant deviations in traffic volume, a Z-score-based anomaly detection method was applied. This technique flags data points that deviate substantially from the mean, helping to isolate unusual traffic events.

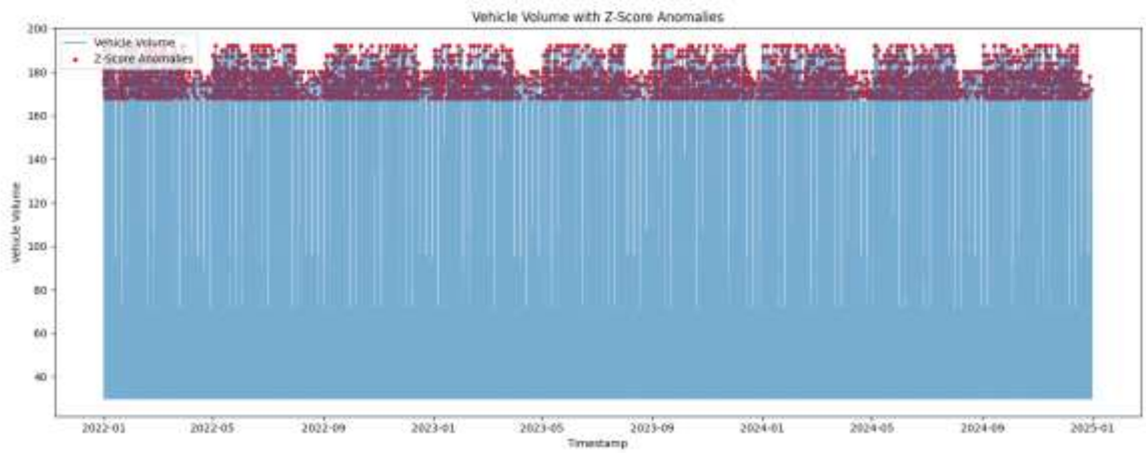


Figure 34:Vehicle Volume with Z-Score Anomalies (2021)

- X-axis: Timestamp (January 2021 to September 2021)
- Y-axis: Vehicle Volume (0 to 200)
- Data Points:
    - ❖ Blue: Normal vehicle volume
    - ❖ Red: Anomalies detected using Z-score thresholds

Insights:

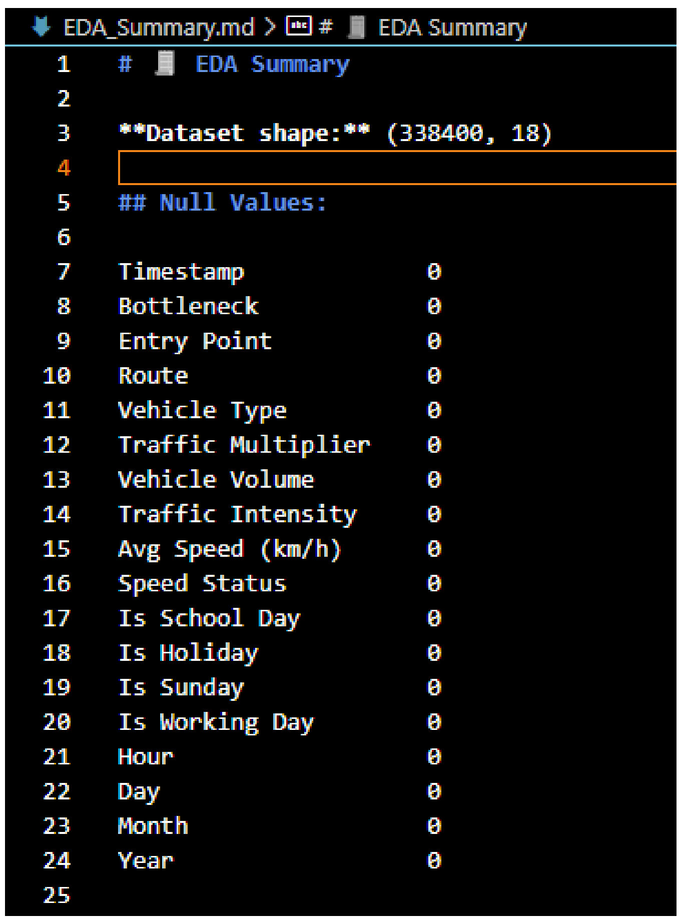
- Several red points indicate traffic volumes that are significantly higher or lower than the norm, suggesting potential incidents, events, or data irregularities.
- The Z-score method is effective for real-time anomaly detection, enabling the system to trigger alerts or reroute traffic dynamically.
- This approach enhances the robustness of the traffic management system by accounting for unpredictable fluctuations.

This analysis supports the integration of statistical anomaly detection into the system's incident response module.

5.6 Exploratory Data Summary

This section presents a statistical overview of the simulated traffic dataset used for identifying congestion and incident-prone areas.

5.6.1 Null Value Inspection



```
EDA_Summary.md > # EDA Summary
# EDA Summary

**Dataset shape:** (338400, 18)

## Null Values:

Timestamp            0
Bottleneck           0
Entry Point          0
Route                0
Vehicle Type         0
Traffic Multiplier   0
Vehicle Volume       0
Traffic Intensity    0
Avg Speed (km/h)     0
Speed Status         0
Is School Day        0
Is Holiday           0
Is Sunday            0
Is Working Day       0
Hour                 0
Day                  0
Month                0
Year                 0
```

Figure 35:Null Value Inspection

5.6.2 Descriptive Statistics (Sample)

Metric	Traffic Multiplier	Vehicle Volume	Avg Speed (km/h)	Hour	Year
Count	338,400	338,400	338,400	338,400	338,400
Mean	0.80	67.94	26.51	11.5	2023
Min	0.60	30	10.0	0	2022
25%	0.60	45	18.8	5.75	2022
50%	0.60	60	26.3	11.5	2023

Table 1: Descriptive Statistics (Sample)

5.6.3 Anomaly & Clustering Highlights

- Volume Anomalies (Z-score > 3): 5,814 records
- Clustering Applied: K-Means (k=3)

5.7 Rule-Based Traffic Condition Detection

To derive actionable insights from the dataset, domain-specific rule logic was applied for detecting congestion conditions and potential incidents.

5.7.1 Rule Logic and Purpose

Rule Name	Condition Description
High Volume	Vehicle Volume > 1200 – identifies unusually high congestion load.
Low Speed	Avg Speed < 15 km/h – flags speed reductions or obstructions.
Potential Congestion	Combination of High Volume **and** Low Speed.
Incident Detection	Sudden variation in volume and speed across time intervals:

Table 2: Rule Logic and Purpose

5.7.2 Rule-Based Function

```
def apply_rules(df):
    df['Is High Volume'] = df['Vehicle Volume'] > 1200
    df['Is Low Speed'] = df['Avg Speed (km/h)'] < 15
    df['Potential Congestion'] = df['Is High Volume'] & df['Is Low Speed']

    df['Is Incident'] = (
        (df['Vehicle Volume'].diff().abs() > 500) &
        (df['Avg Speed (km/h)'].diff().abs() > 10)
    )

    summary = {
        "High Volume Records": df['Is High Volume'].sum(),
        "Low Speed Records": df['Is Low Speed'].sum(),
        "Detected Congestion": df['Potential Congestion'].sum(),
        "Potential Incidents": df['Is Incident'].sum(),
    }

    return df, summary
```

5.8 Chapter Summary

This chapter provided a structured analysis of traffic in Kandy, from bottleneck identification to detailed simulation and data-driven insights. Simulated data effectively captured real-world bottleneck behavior using structured rules, anomaly detection, and clustering. EDA revealed consistent trends, congestion triggers, and outliers. A rule-based model identified congestion zones and possible incidents, offering a foundation for building an intelligent traffic management and incident response framework tailored to Kandy’s unique urban flow.

Chapter 6: Project Management

6.1 Introduction

The development of the Optimized Traffic Management and analytics System required effective project management. Due to the complexity of the system and the number of stakeholders involved in the system's implementation, we adopted the Agile project management methodology. The Agile methodology allows for flexibility, continual improvement, and broad stakeholder involvement through the life of the project. This chapter will highlight the project management strategies, tools, and processes we used, including task tracking through Trello, scope management through the Work Breakdown Structure (WBS), and timelines through the Gantt chart.

6.2 Project Management Approach

6.2.1 Agile Methodology

We chose the Agile methodology because of its iterative characteristics, focus on collaboration and flexibility. The project work was divided into multiple sprints, two or three weeks in length. After the end of each sprint, we held sprint reviews and retrospectives to track progress,

6.3 Project Planning and Execution

6.3.1 Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) was created in order to consider breaking down the project into manageable pieces:

- Initiation: Create Project Charter, Identify Stakeholders, Complete Initial Risk Assessment
- Planning: Gather Requirements, Complete Feasibility Study, Identify Resource Requirements
- Design: Architectural Design, User Interface Design, Database Design
- Development: Software Development, Technologies Integration
- Testing: Unit Testing, System Testing, User Acceptance Testing (UAT)
- Implementation: Deployment Plan, Data Migration, User Training
- Monitoring: Performance Monitoring, Collect Feedback

- Closure: Final Report, Document Lessons Learned, Document Acceptance

As a hierarchical WBS, this ensured that it clear on task assignment, ways we track and updates on our work.

6.3.2 Gantt Chart

The Gantt chart provided a visual timeline of project activities, milestones, and dependencies. It was instrumental in:

- Monitoring task durations and deadlines
- Identifying critical paths
- Managing resource allocation
- Adjusting timelines based on sprint outcomes

6.4 Project Management Tools

6.4.1 Trello

Trello was used as the primary tool for task management and sprint planning. Each sprint had its own Trello board, organized into columns such as:

- Product Backlog
- Sprint 1
- Sprint 2
- To Do
- In Progress
- In Review
- Completed
- Accepted
- Planning
- Project Management and Team Setup
- Sprint Reviews and Repositories

Team members were assigned to tasks with due dates, checklists, and attachments. Trello facilitated transparency, accountability, and real-time collaboration.

6.4.2 Trello Board Structure

The Trello board was organized into the following columns:

- Product Backlog: All user stories and features
- Sprint 1 / Sprint 2: Time-boxed development cycles
- To Do: Tasks ready for development
- In Progress: Tasks currently being worked on
- In Review: Tasks under peer or supervisor review
- Completed: Functionally complete tasks
- Accepted: Approved by stakeholders
- Planning: Brainstorming and backlog grooming
- Project Management and Team Setup: Admin tasks and documentation
- Sprint Reviews and Repositories: Sprint outcomes and GitHub links.

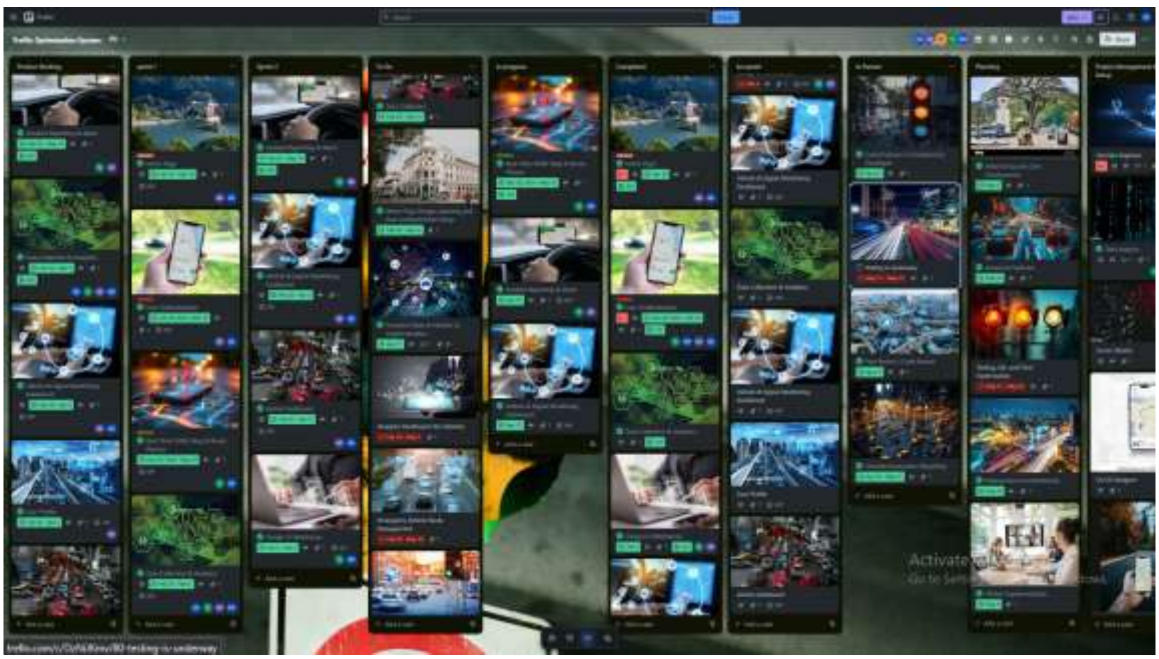


Figure 36: Trello Board

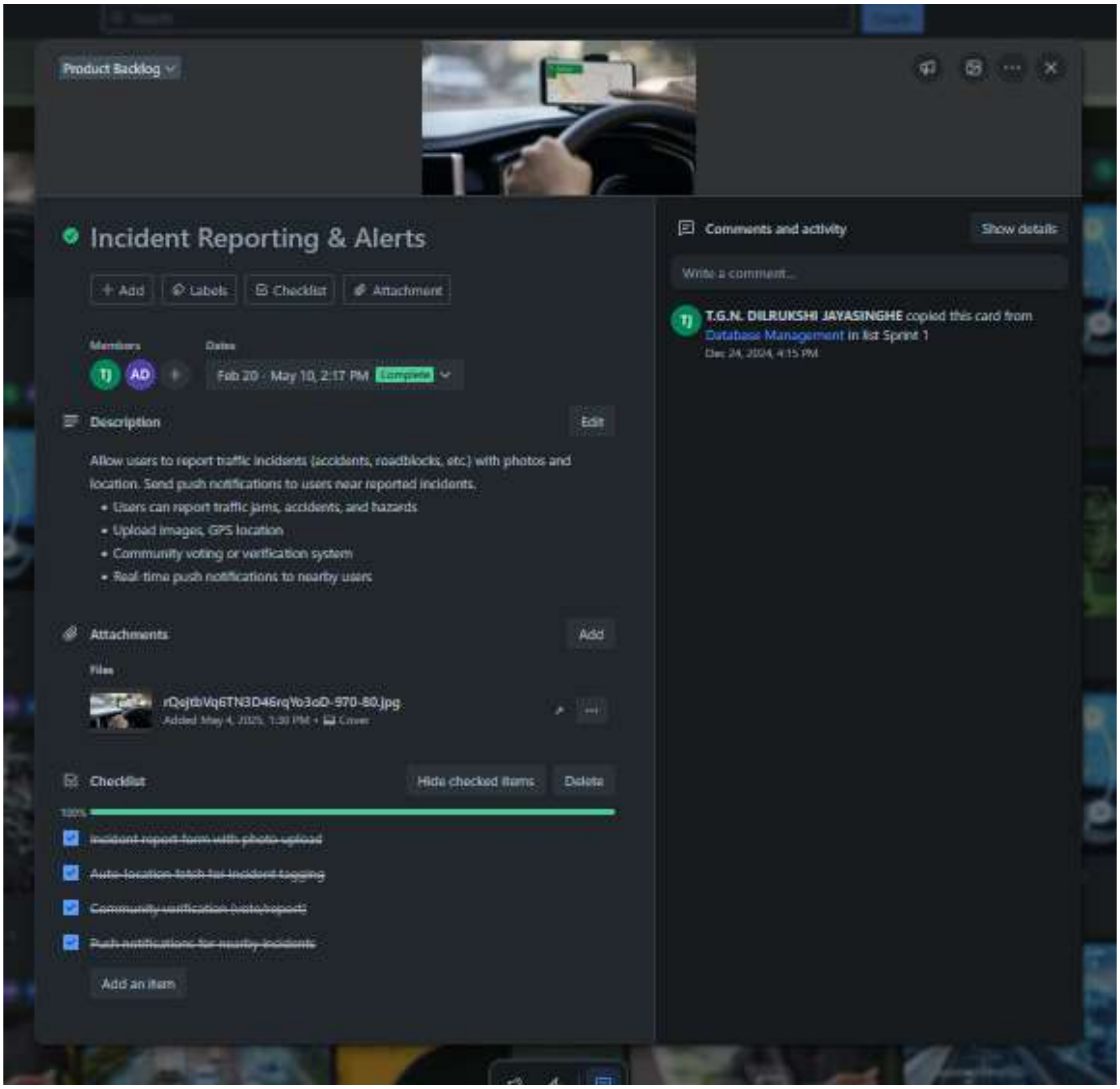


Figure 37: Trello card

6.5 Agile Practices Implemented

- Sprint Planning: We selected tasks from the backlog to complete during the sprint and assigned tasks to the team based on capacity.
- Daily Stand-ups: Each day the team met for a short daily meeting to outline what we've completed, what we are currently working on, what is blocking us from progress.
- Scrum Meetings: Conducted weekly scrum meetings to get the team on the same page, review the sprint goals, and check-in on continuous delivery.

- Sprint Reviews: The team demonstrated the completed features and received feedback.
- Retrospectives: Reflected on how the team operated in the sprint process and determined improvements for the next cycle.

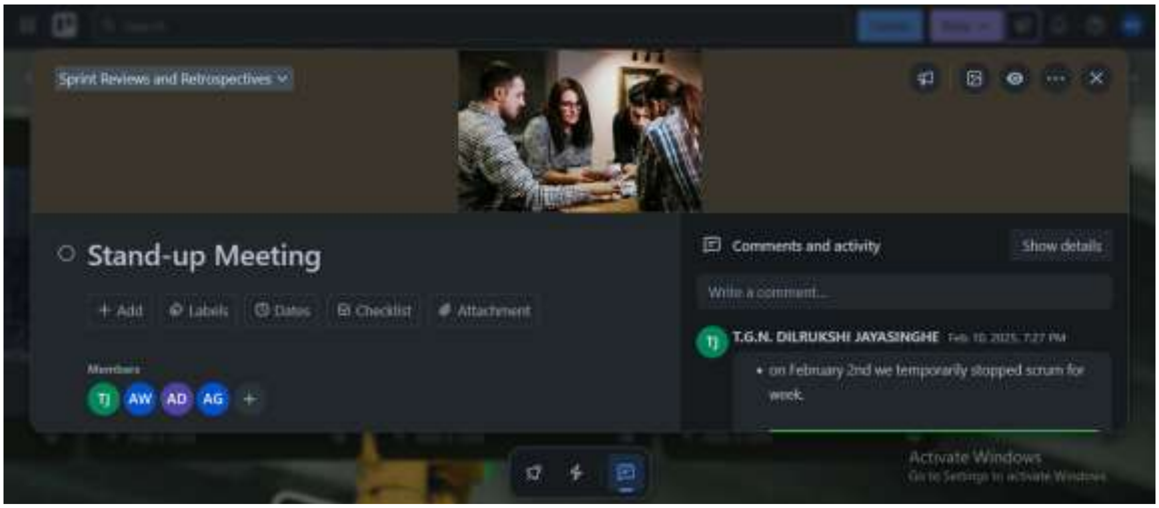


Figure 38: Scrum Meetings

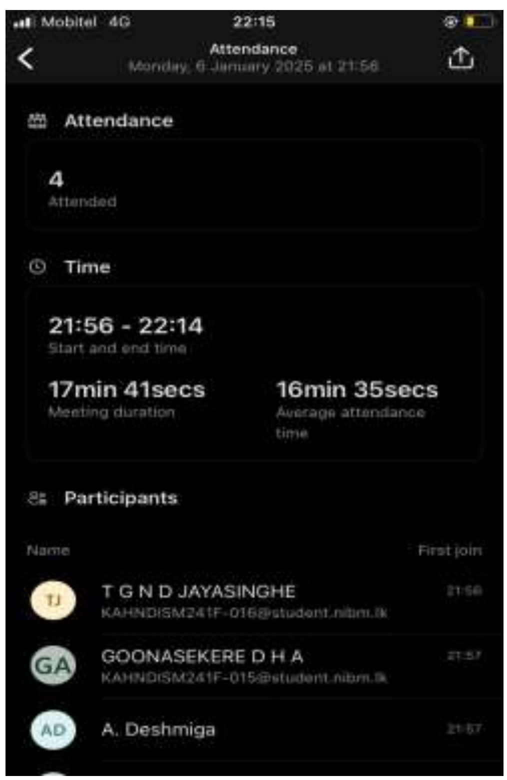


Figure 39: Daily Scrum

6.6 Risk and Change Management

The iterative nature of Agile allowed us to effectively manage risk and change. Specifically:

- Sprints retrospectives with the team to review and identify risks early for mitigation
- Change requests cleared up in a backlog grooming session
- Integration and testing for continuous quality for early identification of issues

6.7 Lessons Learnt

- Agile's flexibility supported changing requirements, user feedback and discussion
- Use of Trello allowed for visual task tracking and caused team coordination and accountability to be improved
- Regular handoffs to stakeholders ensured project teams were well versed in the needs and expectations of the users
- Timeboxing and sprint planning kept the project and team focused and then able to deliver on time

6.8 Chapter Summary

This chapter provided an overview of the project management practices that supported the development of the Optimized Traffic Management and Analytics System.The team successfully coordinated the project, demonstrating flexibility and responsiveness to stakeholder requests and real-world constraints with clear project coordination. They successfully provided deliverables on time to keep the project on track to achieving objectives, by applying agile project management concepts with Trello, and project planning techniques with WBS and Gantt charts.

Chapter 7: Solution Design

7.1 Introduction

In this chapter, we provide a comprehensive design of the Kandy Traffic Management System (Kandy TMS), a web-based solution intended to tackle the immediate traffic congestion issues in the region. It takes the conceptual framework for the system along with established requirements and presents them as a functional and actionable solution. Kandy TMS is structured as a web application using an API model to facilitate real-time surveillance of traffic conditions in Kandy, allow reporting of incidents, including accidents, and facilitate predicting future traffic based on Kandy's traffic conditions. This chapter will illustrate the major system components, data flow architecture, technology stack, means of integration including Maps API, and design principles for user interface to collectively establish a scalable and responsive avenue for traffic management.

7.2 System Overview

The Kandy TMS is a modular, extensible, API-led web application that provides a recommendation engine that utilizes real-time traffic data, user-reported incidents, and predictive analytics to improve traffic flow and mobility in Kandy and the surrounding area. The system is structured around four key functional components:

- Frontend Interface: A responsive web-based interface for normal users and traffic authorities that provides real-time maps, user-created incidents, and thus traffic status.
- Backend Services: REST APIs, and core logic modules that process incoming data, user requests, and offer traffic functionality.
- Database Layer: A centralized and secure data store for traffic logs, user profiles, reported incidents, historic trends, and system appreciation.
- Notification System: Real-time alerts to the users and the authority on incidents, traffic jams, and suggested alternate route options.

7.3 Component Design

7.3.1 Frontend Design

- **Technologies**: HTML, CSS, JavaScript, React (optional)

- **Features**:
    - Live traffic map with congestion indicators
    - Incident reporting form
    - Route suggestion
    - Feedback submission

7.3.2 Backend Design

- **Technologies**: Python (Flask/Django), PHP
- **Responsibilities**:
    - ❖ Handle API requests from frontend
    - ❖ Process and validate user reports
    - ❖ Interface with analytics engine
    - ❖ Manage user authentication and roles

7.3.3 Database Design

- **Technologies**: MySQL, PL/SQL
- **Tables**: Users, Traffic_Data, Incidents, Reports, Feedback, Routes, Authorities
- **Design Principles**:
    - ❖ Normalized schema
    - ❖ Indexing for performance
    - ❖ Backup and recovery mechanisms

7.3.4 Analytics Engine

(Note: This module has been developed and tested independently but is not yet integrated into the deployed Kandy TMS web application.)

- **Technologies**: R, Python (Pandas, Scikit-learn), Power BI
- **Functions**:
    - ❖ Time series forecasting (traffic volume)
    - ❖ Anomaly detection (Z-score)
    - ❖ Clustering (K-Means for traffic states)
    - ❖ Rule-based congestion detection

7.4 User Interface Design and Implementation

7.4.1 Design Goals

- Allow intuitive navigation for both user roles (traffic authorities, public users)
- Represent the real time visibility of traffic conditions including traffic jams
- Progressively disclose reporting requirements to provide ease in the capturing of incidents
- Responsive design to support access from desktop or mobile devices

7.4.2 Proposed UI Designs

The user interface designs for the Kandy Traffic Management System (Kandy TMS) prioritize usability, responsiveness, and clarity on the same devices. The wireframe and high-fidelity mockups were prepared using Canva, delivering an efficient and uncomplicated user experience.

Proposed UI Interface 01: Home Page

Figure 40: Proposed UI Interface 01: Home Page

Proposed UI Interface 02: Contact Us page

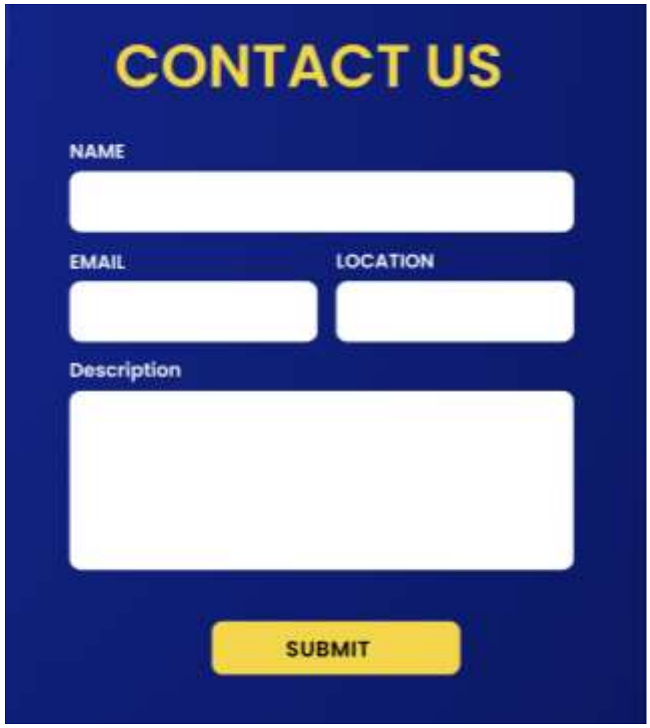


Figure 41:Proposed UI Interface 02: Contact Us page

Proposed UI Interface 03: Incident Reporting Page

Figure 42:Proposed UI Interface 03: Incident Reporting Page

Proposed UI Interface 04: Sign-in Page

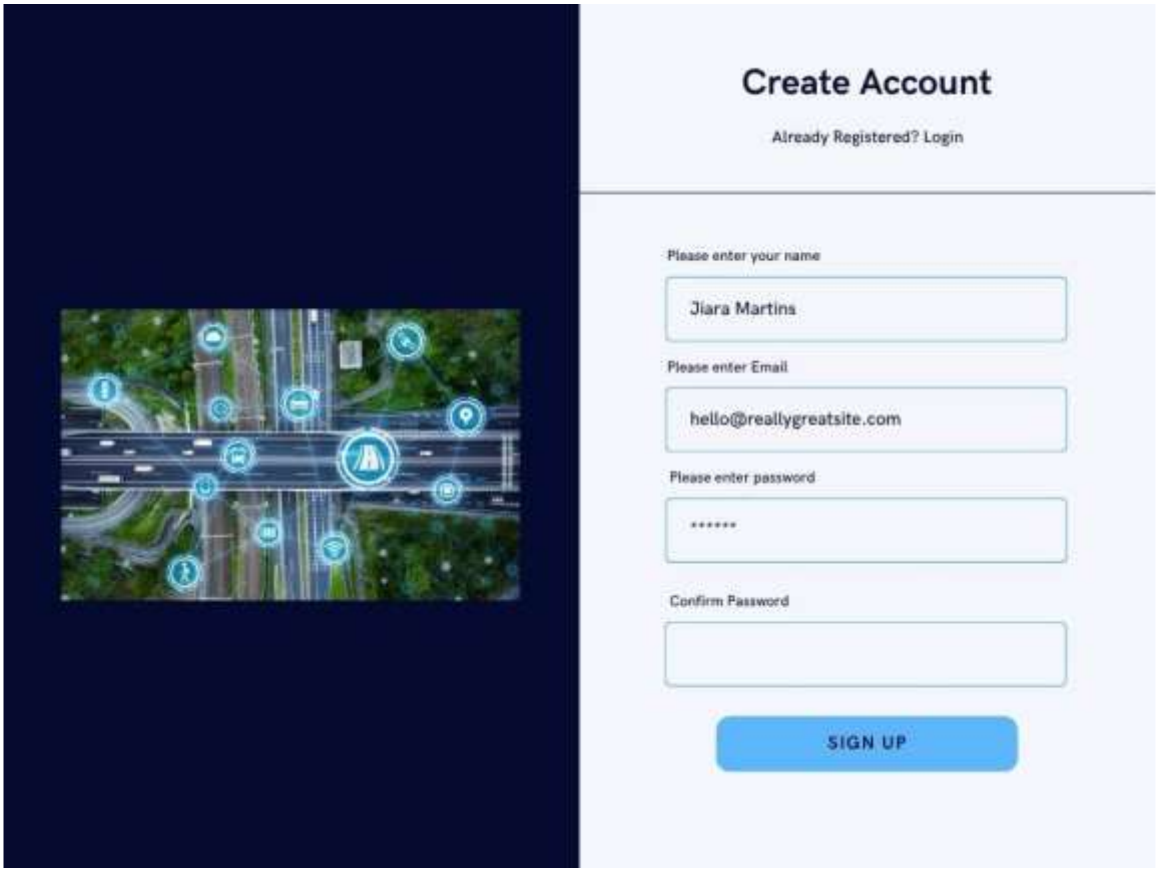


Figure 43:Proposed UI Interface 04: Sign-in Page

Proposed UI Interface 05: Sign-up Page

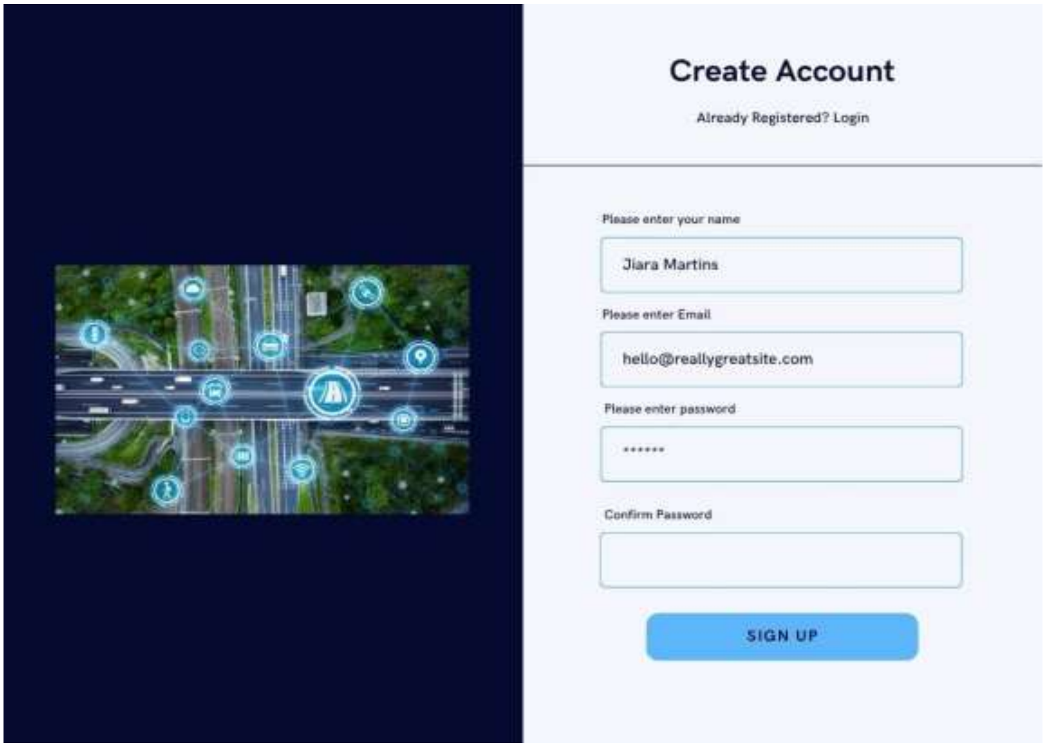


Figure 44:Proposed UI Interface 05: Sign-up Page

Proposed UI Interface 06: Forget Password Page

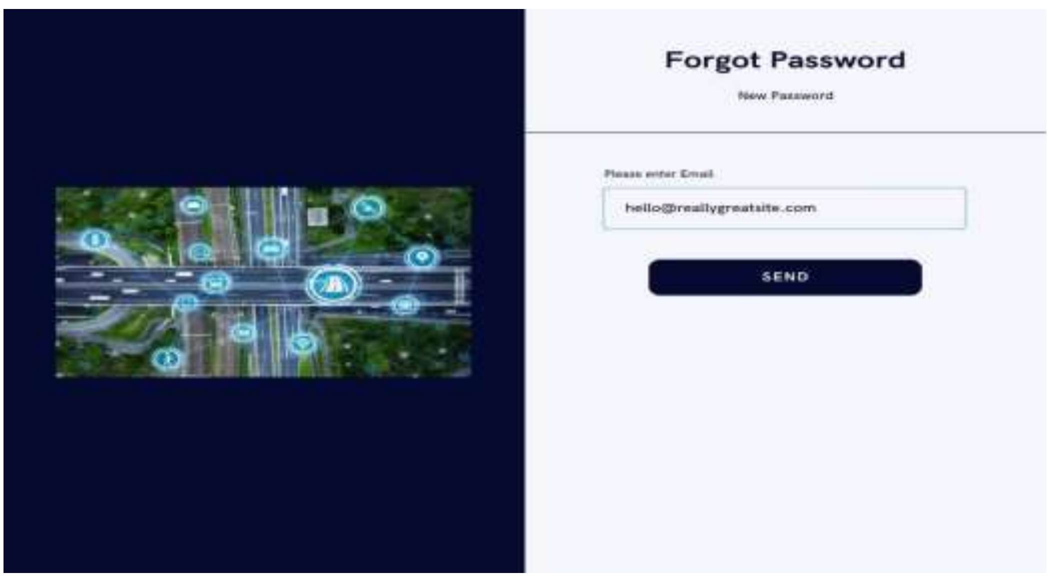


Figure 45:Proposed UI Interface 07: Forget Password Page

Proposed UI Interface 07: Footer page

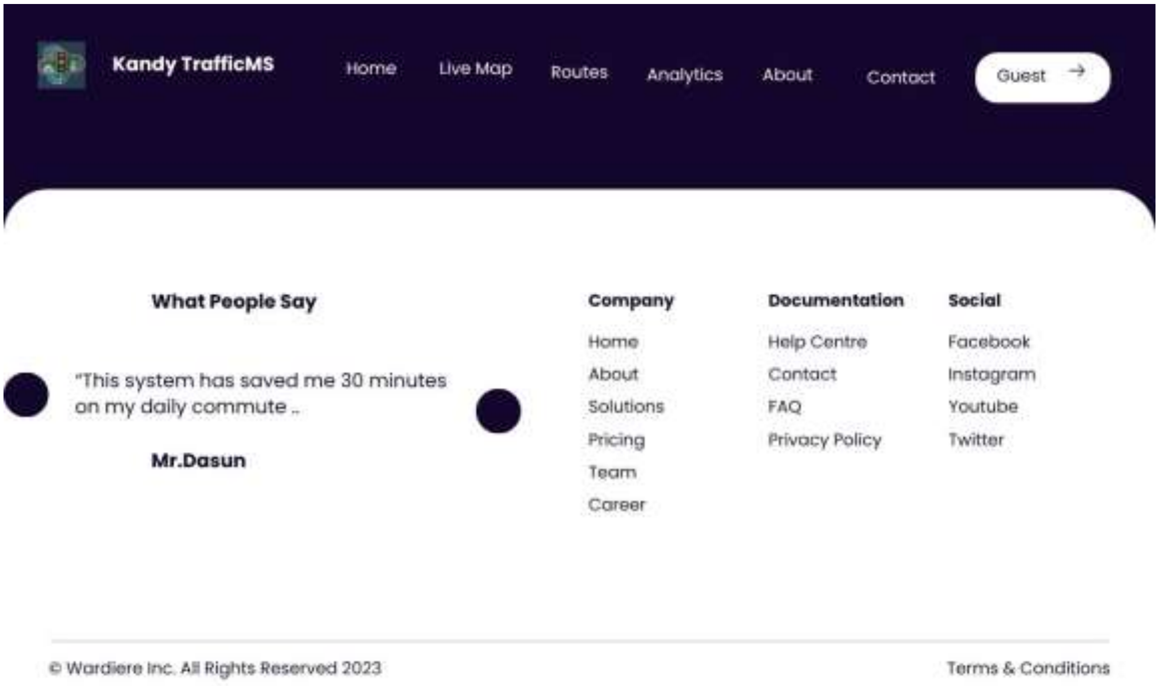


Figure 46:Proposed UI Interface 07: Fotter page

Proposed UI Interface 08: Live map view page

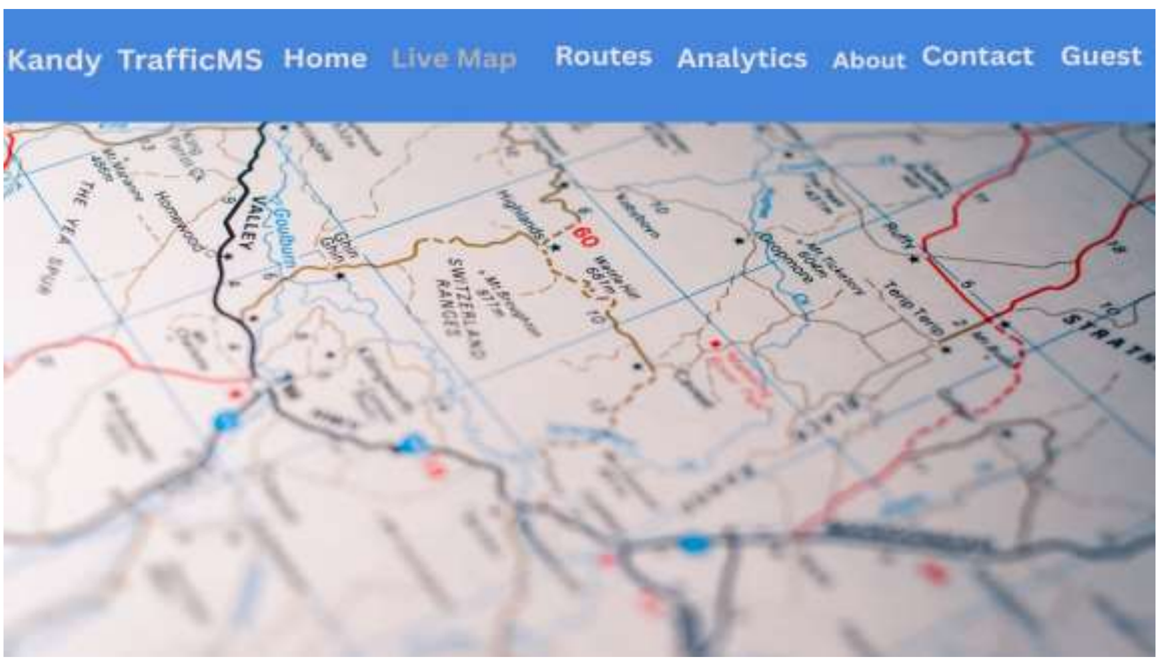


Figure 47:Proposed UI Interface 08: Live map view page

7.4.3 Developed UI Screens

- Technologies Used: HTML, CSS, JavaScript, Bootstrap, Google Maps API
- Implemented Features:

Interface number 01: Home page

Figure 48: Home page

The home page is where the user interface takes shape, consisting of a navigation bar where the user can find Home, Routes, Live maps, Analytics, About, Contacts, and guest drop down for login. The primary actions that users can take are to view the live map of incidents, plan their routes, report on incidents. Users will also be notified of alerts through a notification button.

Interface number 02: Profile Page

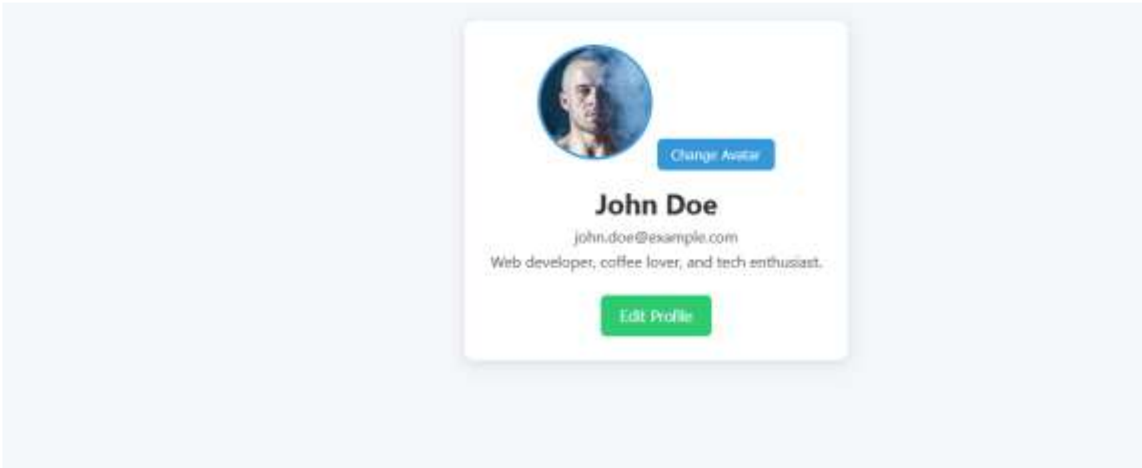


Figure 49: profile page

On the profile page, we present the user's fundamentals as far as the user's name and bio and give the ability to edit their profile.

Interface number 03: Registered user view admin panel

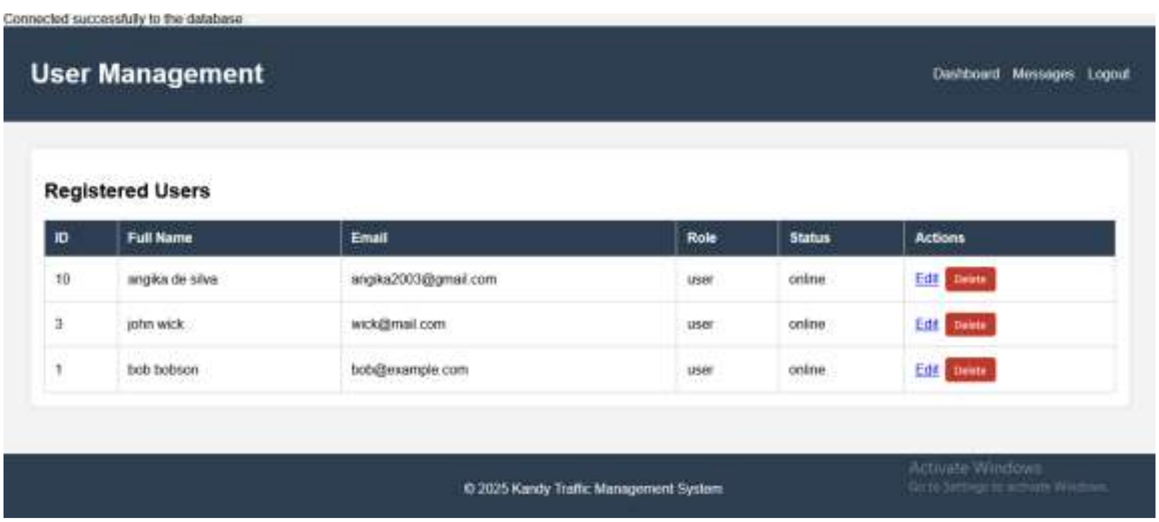


Figure 50:Registered user view admin panel

The registered user view admin portal is where registered user with admin privileges will have the ability to manage users. Admin are able to see user information such as: user id, full name, email, a role, online/offline and delete user if necessary.

Interface number 04: Admin Contact messages page

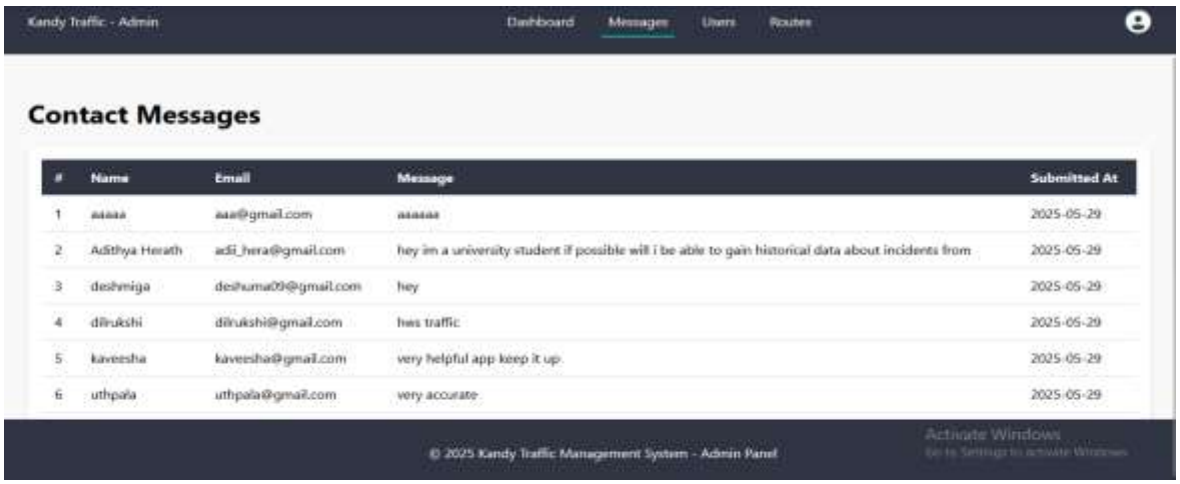


Figure 51:Admin Contact messages page

This page lists all messages submitted to us through the contact us page. This can be essential when we need to review and respond to a message. The information included is; the senders name, email, message content and each timestamp.

Interface number 05: Incident reporting admin view

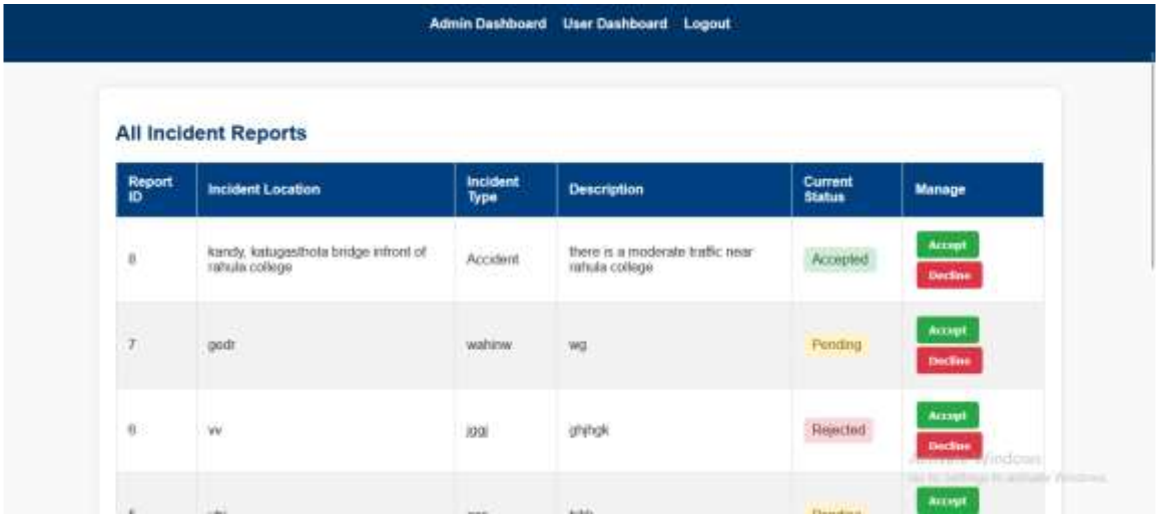


Figure 52: Incident Reporting Admin view

This interface depict the incidence reports. Administrators review actual reports, including report ID, location, report type, report description, and current status. The actions an admin has at their disposal are to either accept, or reject. If accepted, then an alert will notify the user through a popups notification.

Interface number 06: Admin Dashboard traffic status view

Figure 53:Admin trafffic status view 1

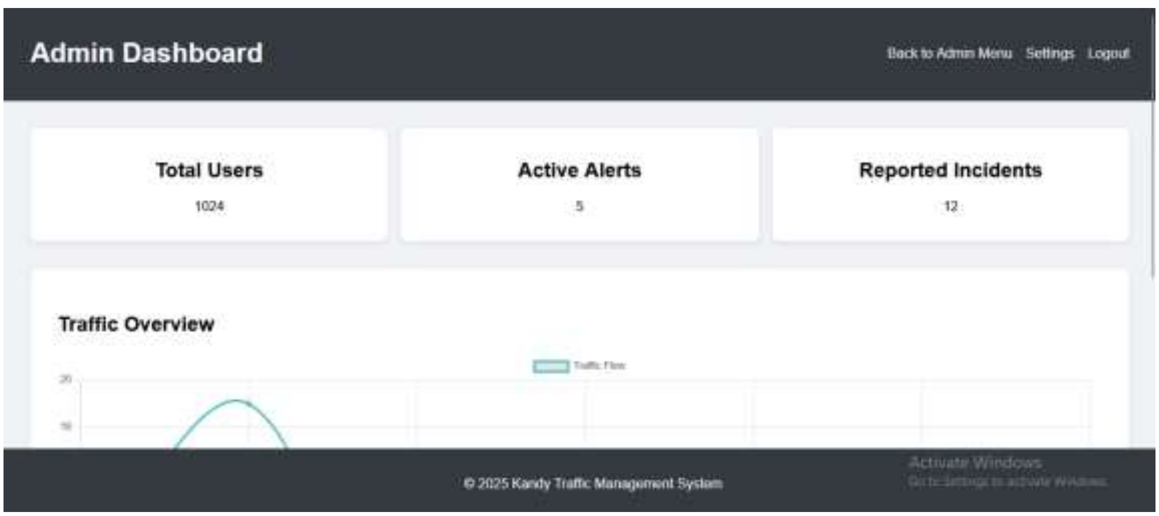


Figure 54: Admin traffic status view 2

Allows administrators to monitor traffic in real-time, providing alerts and live updates on congestion, volume, and reported incidents that may affect the management decisions.

Interface 07: User log-in and Create account page

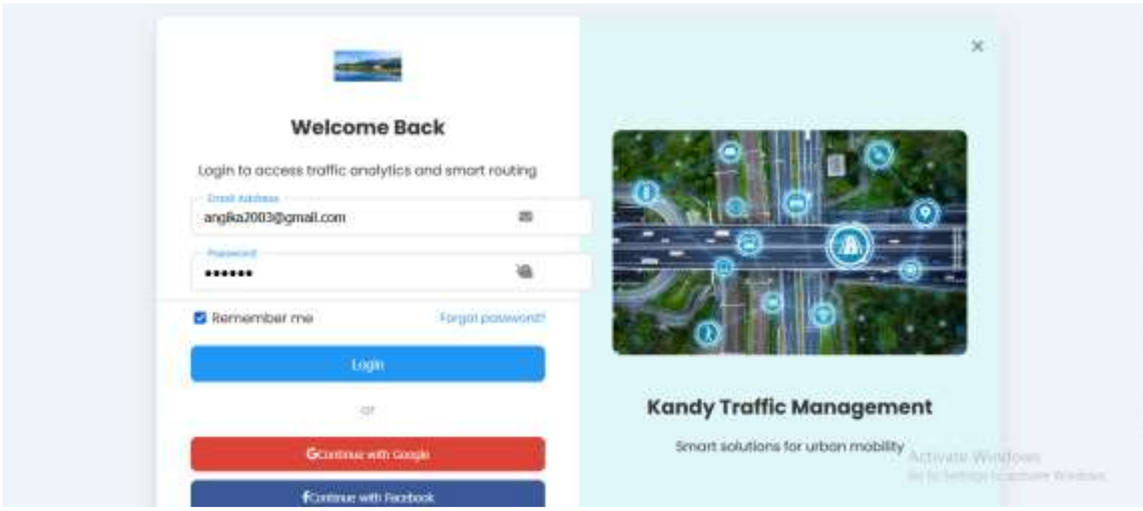


Figure 55:Log-in page

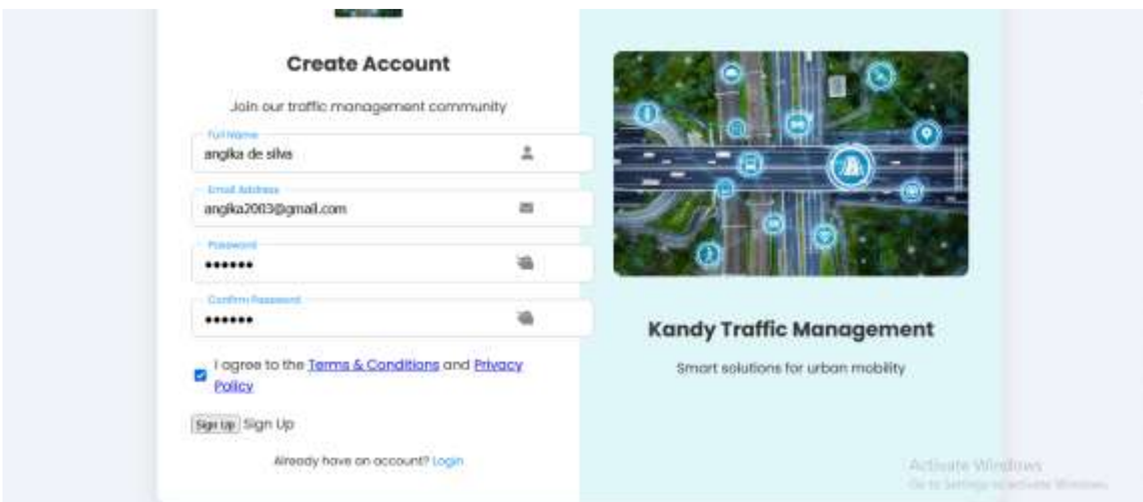


Figure 56:Create account page

Allows users to log in via username/email and password, or create a new account id by providing the full name, email and a password.

Interface number 08: Drop-down list

Figure 57:: Drop-down list

Available through the navigation bar, the drop-down list provides a means to access quick options for the user such as Login, Profile and Settings.

Interface number 09: Footer page

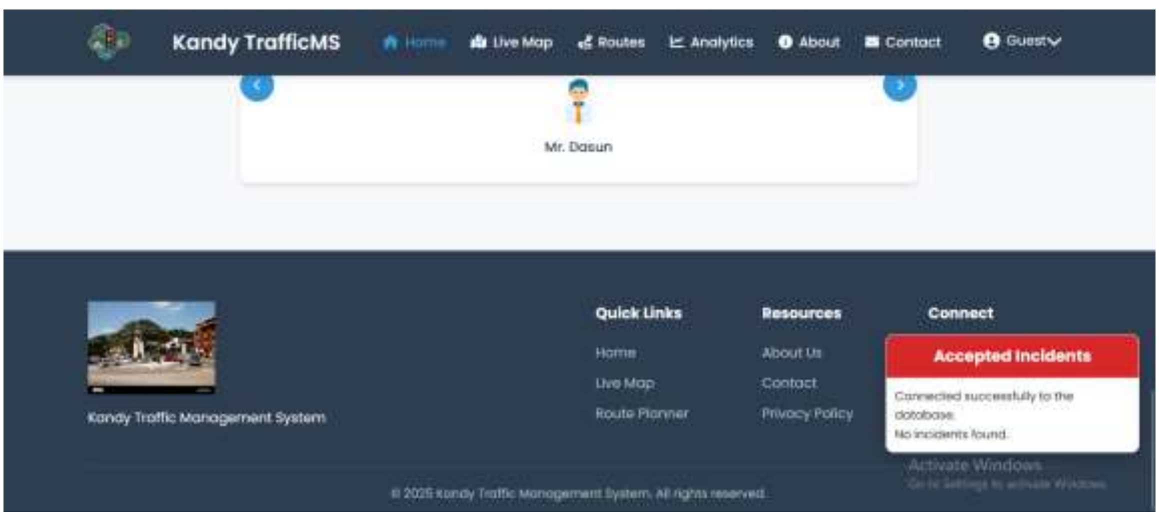


Figure 58: Footer page

Provides quick linking access to important pages and important resources located throughout the site to enhance navigation.

Interface number 10: Feedback Page

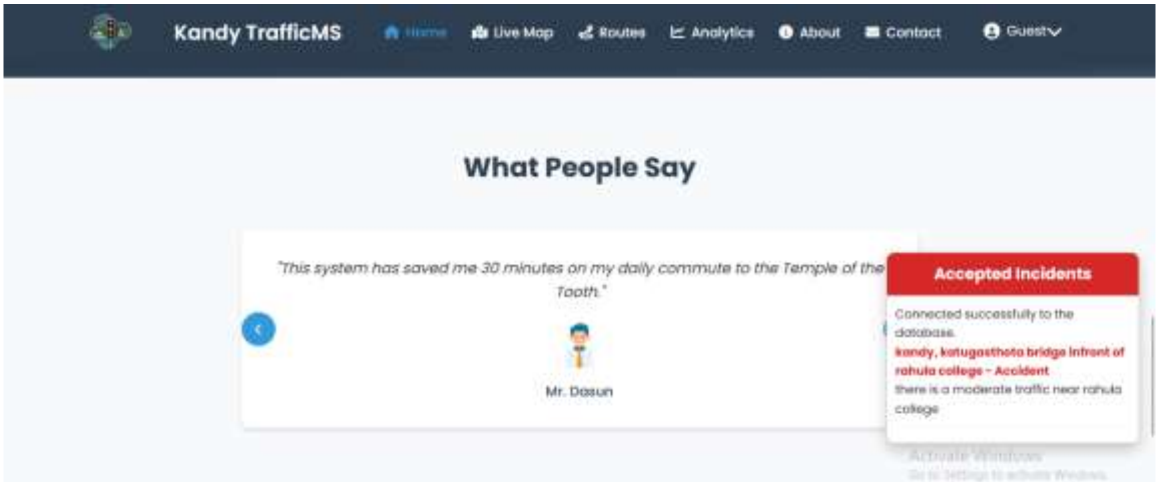


Figure 59: User Feedback page

Displays user inputted feedback submitted to the administrators for review. These user inputs will assist in improving the system.

Interface number 11: Key features and traffic at a glance

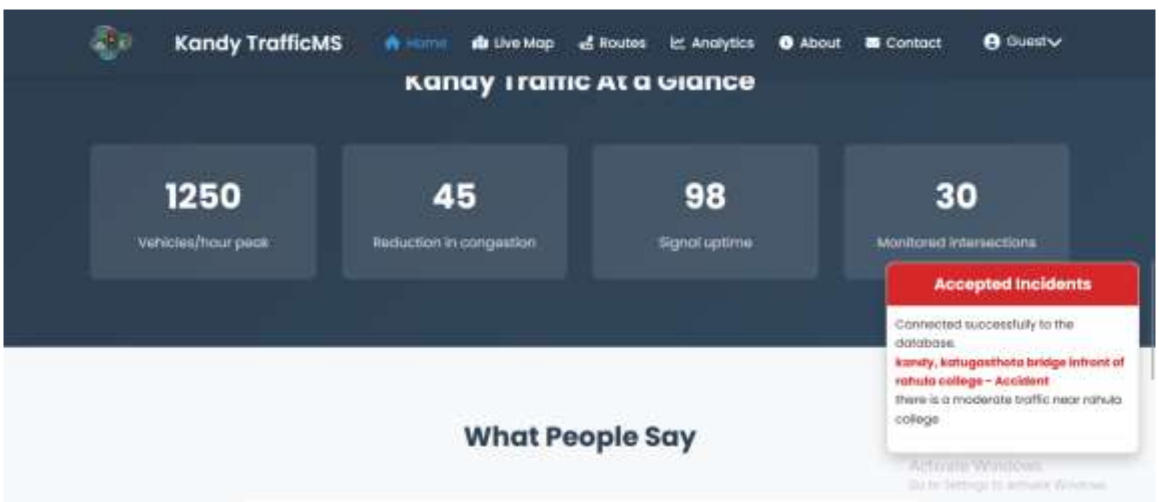


Figure 60: Traffic at a glance page

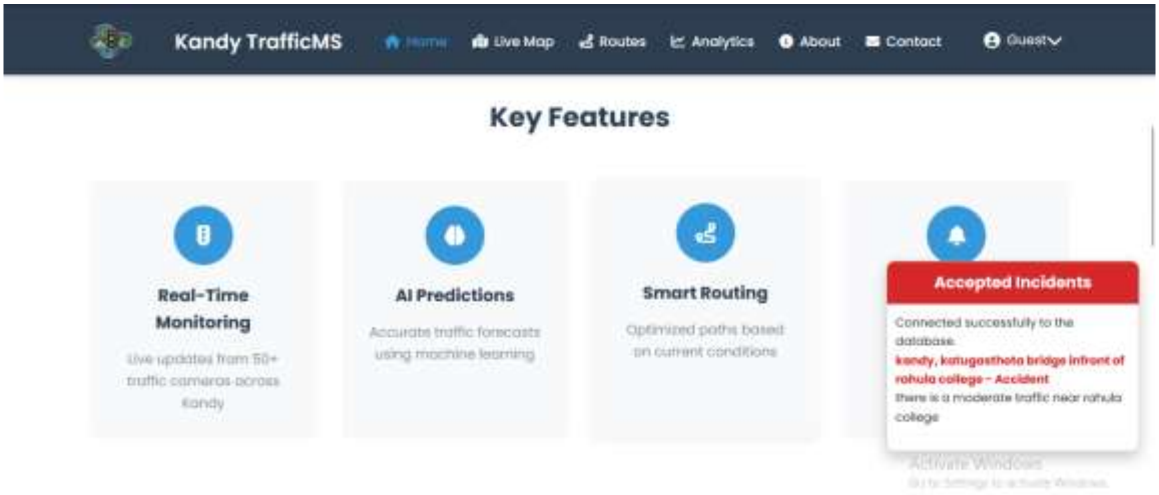


Figure 61: Key features page

Provides a list of important features of the website with current traffic statistics and data as well as a summary of traffic conditions and system functions.

Interface number 12: Contact us page

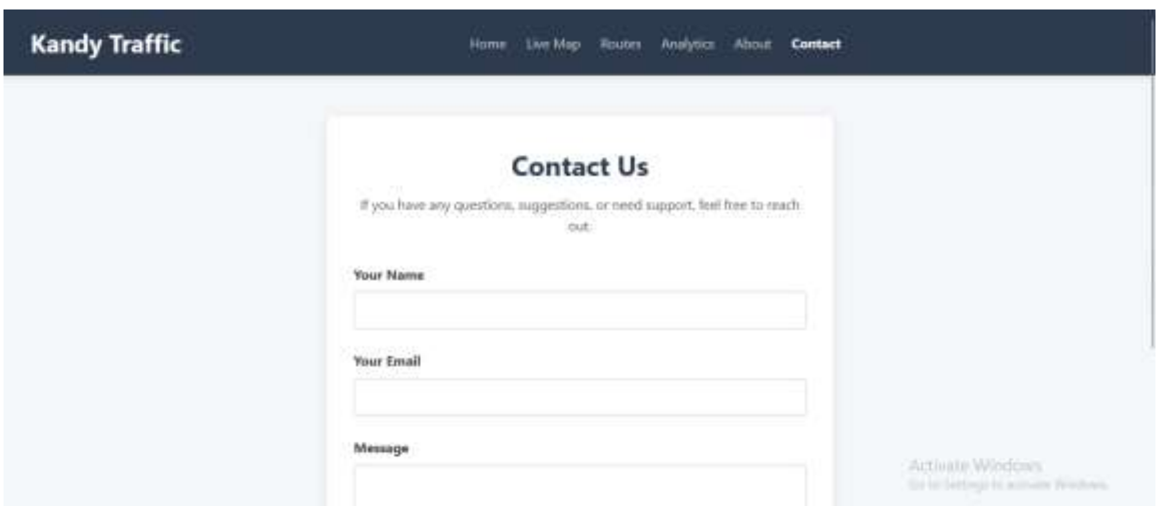


Figure 62: Contact us page

Users can send messages or inquiries through the application by submitting their name, email, and message content

Interface number 13: About us page

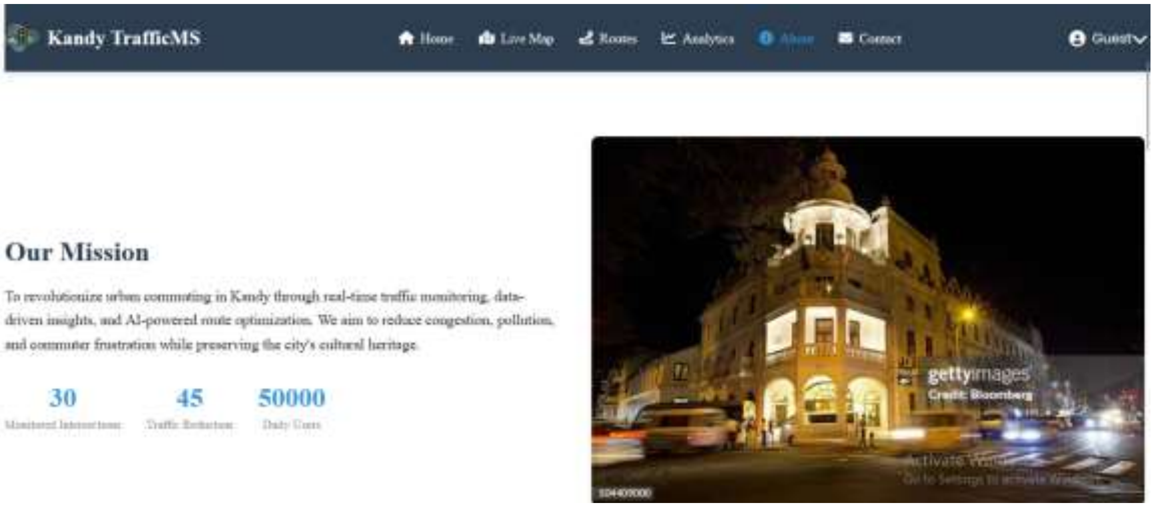


Figure 63:About us page

Includes background information about web application, the project goals, and team members.

Interface number 14: Analytics page

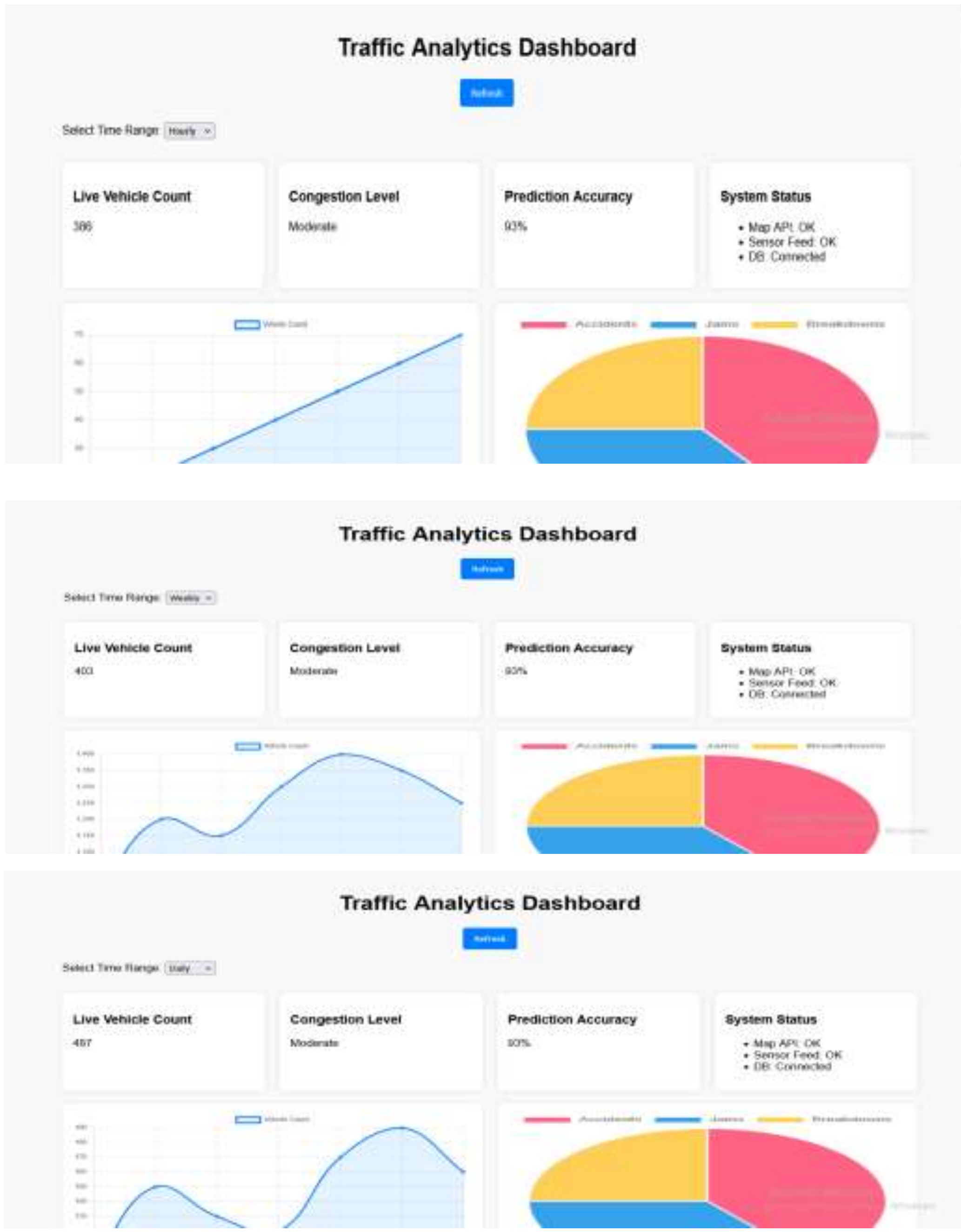


Figure 64:Analytics dashboard

Shows live vehicle counts, congestion predictions, accuracy metrics, and system status with options to view data daily, weekly, or monthly.

Interface number 13: Traffic Optimization Pages

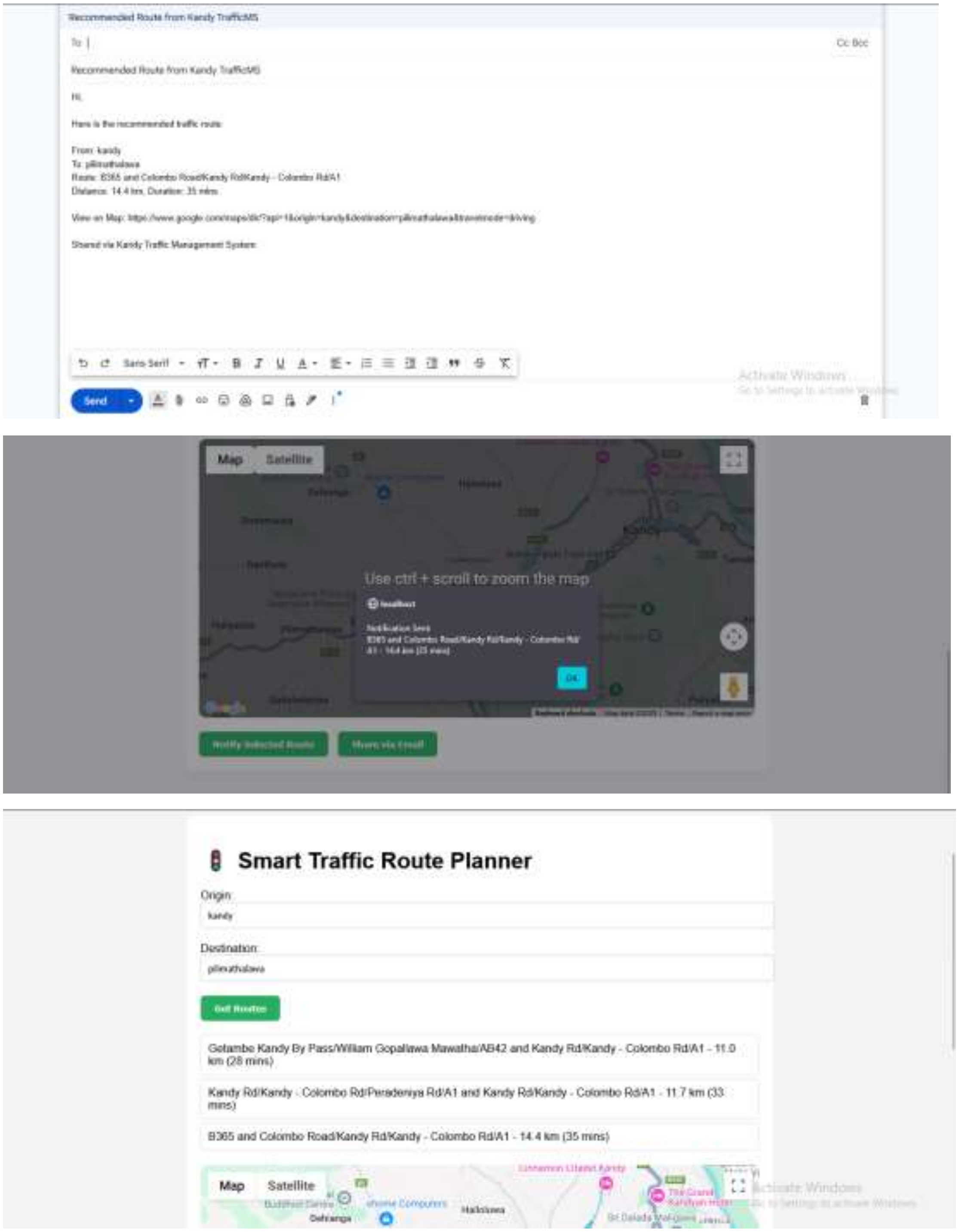


Figure 65: Traffic optimization page

Users can find alternate routes to their destinations and share route information through Gmail integration.

Interface number 14: Live-map and live traffic view page

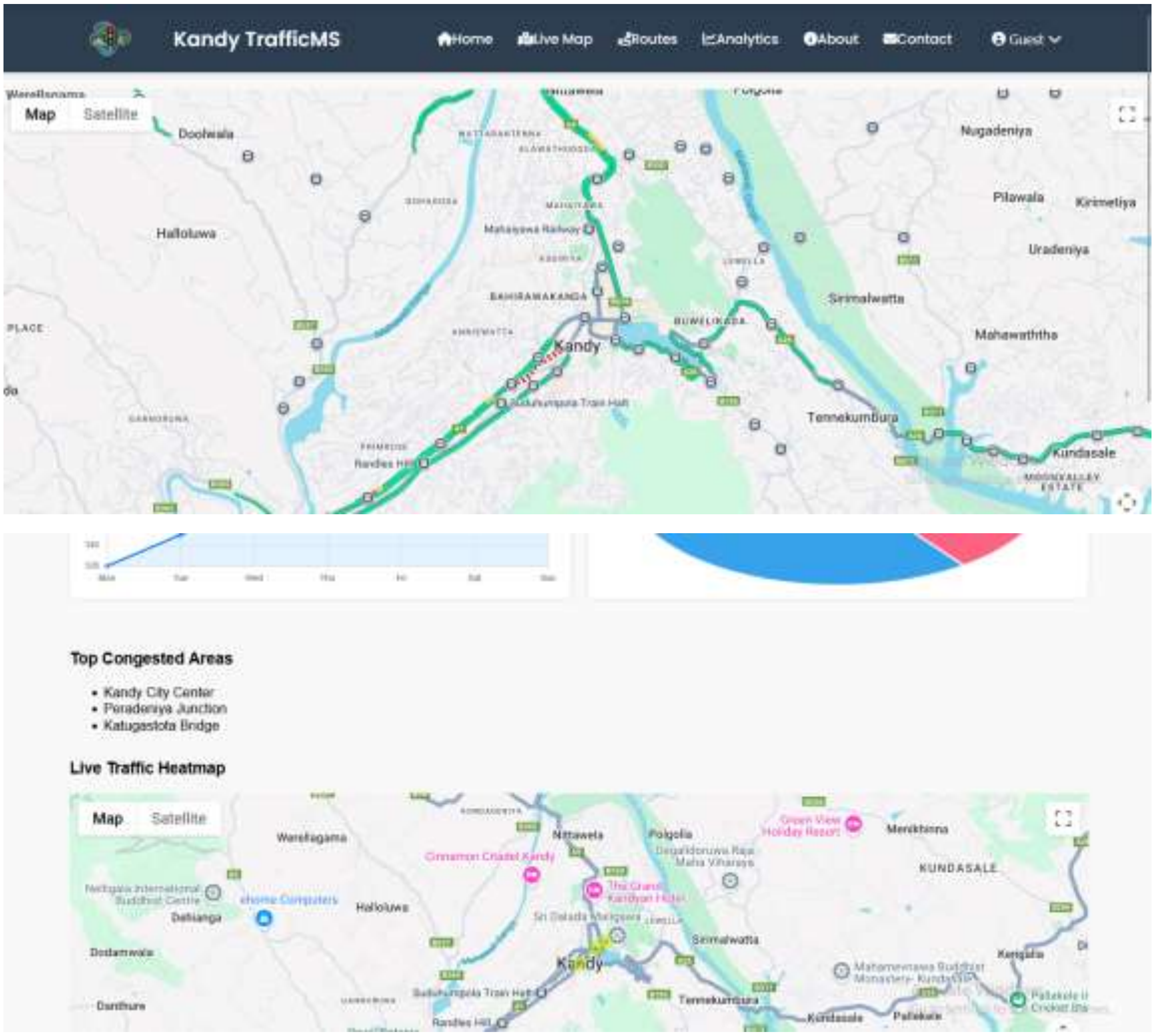


Figure 66: Live map and live traffic view page

Users will view an interactive map with live traffic flows and congestion in real-time.

Interface number 15: Incident Reporting Page

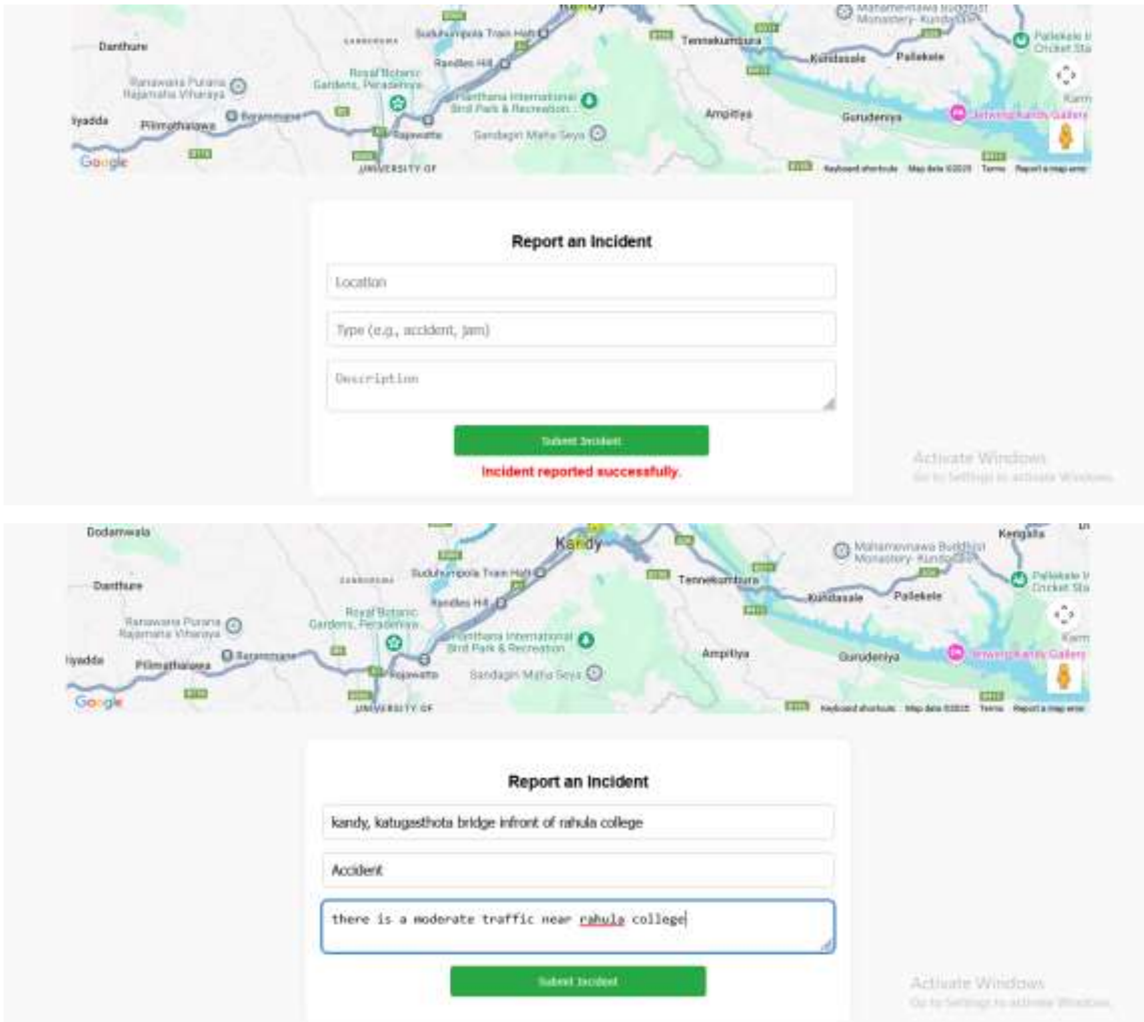


Figure 67: Incident reporting page

Users will be able to report incidents by entering the location, type of incident, and a description.

Interface number 16: Edit Profile page

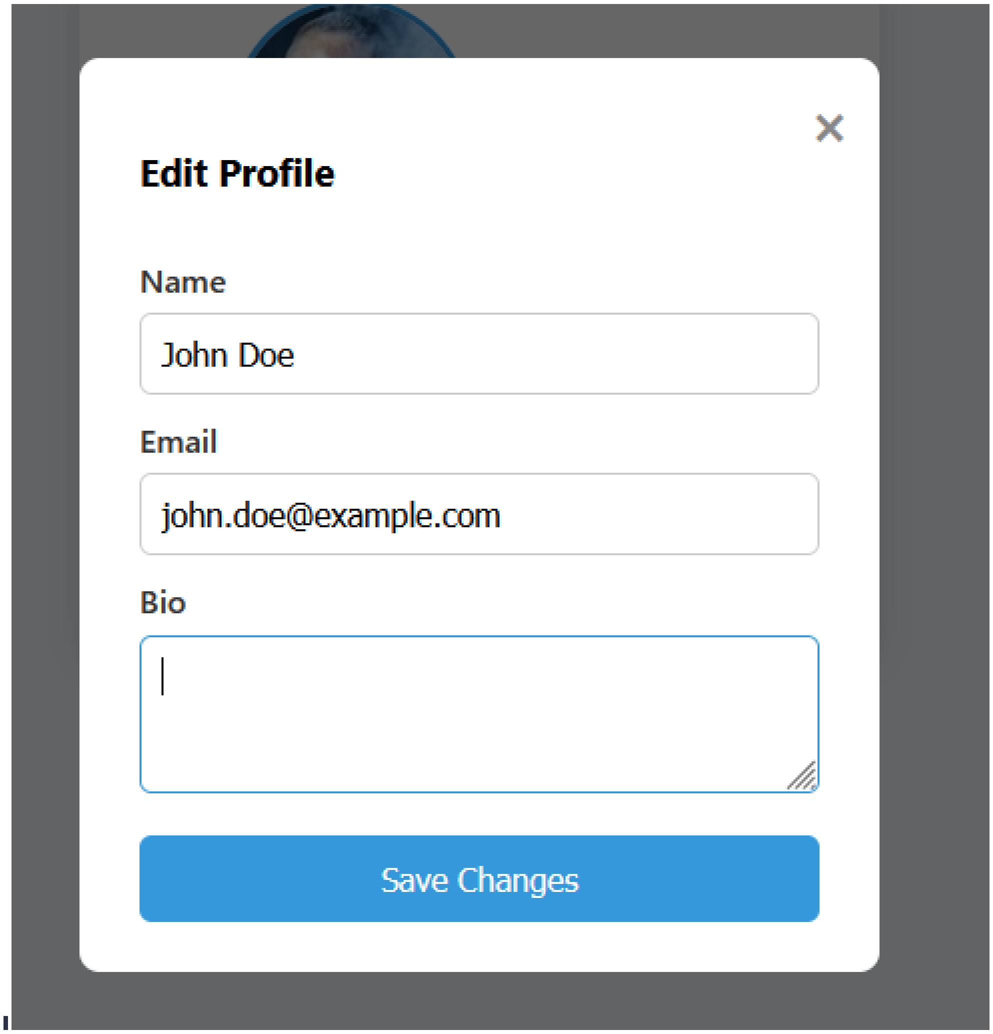


Figure 68: Edit profile page

Provides user the capability to change their personal information, including their name, email, and bio information.

7.5 Database Design Overview

The Optimized Traffic Management and Analysis system has a MySQL relational database, called traffic_system_db, for its backend. This relational database stores and manages data for user accounts, traffic system incidents, and system logs. The database is created and managed using phpMyAdmin. The database was designed with normalization rules to provide data integrity and efficiency. The major tables include users, which stores and manages user credentials and roles; incident_import, which stores real time reports of traffic incidents; and others. The database uses InnoDB as the storage engine (the table type) to provide transaction support and uses utf8mb4 as the character set for use in multilingual environments (e.g. support for Chinese characters, emojis, etc.), the database represents a comprehensive and robust foundation for data driven operations within the system.

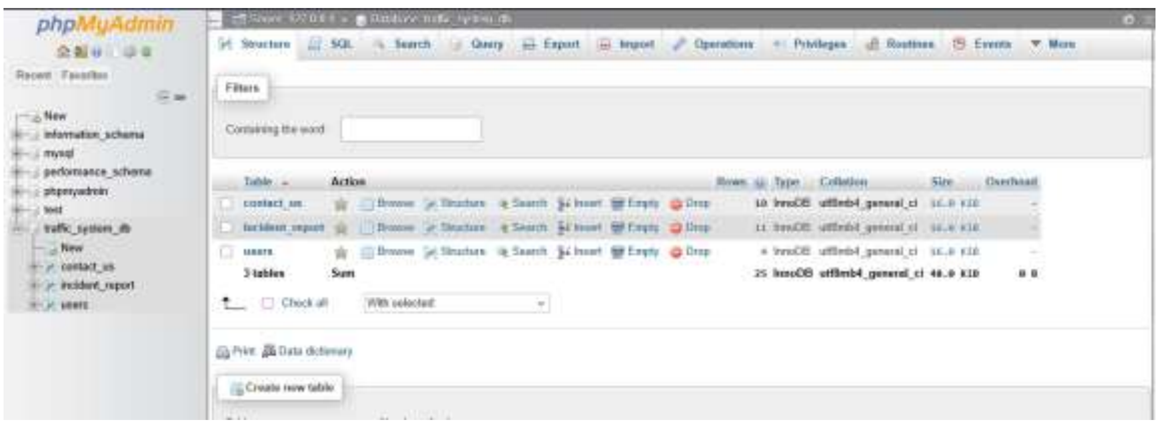


Figure 69: Database

Chapter 8: Quality Assurance and Testing

In order to qualify for reliability and correct operation of the Optimized Traffic Management and Analytics System (OTMAS) a structured quality assurance (QA) and testing method was implemented. Testing on the system was carried out during the development lifecycle using manual and automated testing.

The main tests that were executed included:

- Unit Testing: Ensured that each of the units were valid including such things as the incident reporting form and user login process.
- Integration Testing: Ensured correct communication between the front-end interfaces and any APIs provided by the backend.
- Functional Testing: Ensure that the OTMAS functioned with real-time traffic updates and route suggestions etc. pertaining to all requirements for the system.
- User Acceptance Testing (UAT): conducted a test with a group of users based on sampling, at the end of the project to incorporate their feedback into the system and check usability.
- Security Testing: in this case, you perform the basic components to check for secure login, keep the reports data safe, and role based access.

All of these tests allowed for bugs to be corrected early in the process of code development so that the OTMAS would be stable and have functionality once deployed for the users.

Chapter 9: Conclusion and Future Enhancements

Conclusion

The Optimized Traffic Management and Analytics System (OTMAS) was developed with the intent of addressing the issues of increasing traffic congestion and inefficiencies in Kandy. OTMAS will provide a scalable and intelligent urban mobility solution to a growing issue through real-time monitoring, incident management by users, and predictive analytics. In the terms of successfully addressing stakeholder needs, the project was able to combine modern web technologies, a responsive UI, and a robust backend architecture to develop a fully functional prototype.

Future improvements

For the future advancement and improvement of OTMAS, some of the ideas below should be considered for project expansion and development:

- Mobile Application Development: Expand access to the OTMAS system by developing an android/iOS application
- Machine Learning Development: Build machine learning models of OTMAS in order to predict traffic patterns and detect anomalies
- Internet of Things Integration: Use the real-time data from road sensors and cameras to automate traffic analysis rather than wait for incident reports from users
- Multilingual Development: Include an additional language support of Sinhala and Tamil to broaden accessibility
- Data Analytics Dashboard: Provide authorities with an analytics dashboard which provides additional insights through the use of interactive data visualizations and key performance indicators
- Multi Modal Routing: Include and aggregate bus and train schedules for public transport systems to allow for multi modal routing with real time traffic information.

Together these improvements would take OTMAS from a working prototype to a full functioning smart city traffic management system.

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Appendices

1. The project schedule

Gantt chart	2024-2025				
Task	Start	End	Dec	Jan	May
System design	21-Dec-2024	7-Jan-2025			
Development	09-Jan-2025	22-May-2025			
Testing and debugging	22-May-2025	26-May-2025			
Project documentation	27-May-2025	29-May-2025			
Final project VIVA	30-**No table of figures entries found.**May-2025	30-May-2025			

Table 3: Gantt chart

2. Log sheet

Meeting Date	**Students Indices (participated)**	**Supervisor Comments**	**Signature of the supervisor**
	KAHNDISM24-002 KAHNDISM24-015 KAHNDISM24-016 KAHNDISM24-018		
	KAHNDISM24-002 KAHNDISM24-015 KAHNDISM24-016 KAHNDISM24-018		
	KAHNDISM24-002 KAHNDISM24-015 KAHNDISM24-016 KAHNDISM24-018		
	KAHNDISM24-002 KAHNDISM24-015 KAHNDISM24-016 KAHNDISM24-018		

Table 4: Log sheet

3. GitHub Repository Information

Relative to our use of a version control habit we utilized two GitHub repositories to help facilitate our collaborative development process:

- Structured Repository - This repository contains a final and organized version of the project. This included structure and organization of the code, documentation, and files that can be deployed. All notes were recorded with appropriate messages and version numbers.
- Repository Link: https://github.com/AroojGoonasekere/WEB-TMS.git

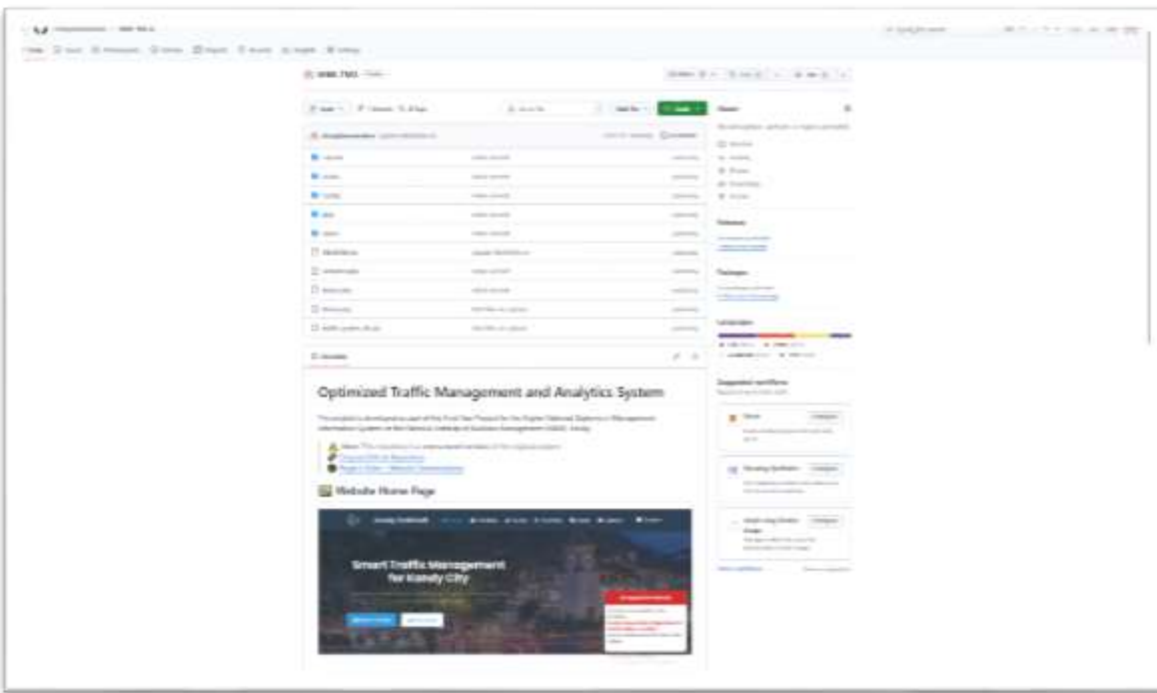


Figure 70: Structured Repository

- Unstructured Repository - This repository is indicative of our development process where during the early stages we were simply uploading the code, experimental features, and early drafts. All files were uploaded without a structured method of committing.
- Repository Link: https://github.com/Deshmiga21/Traffic-Management-System.git

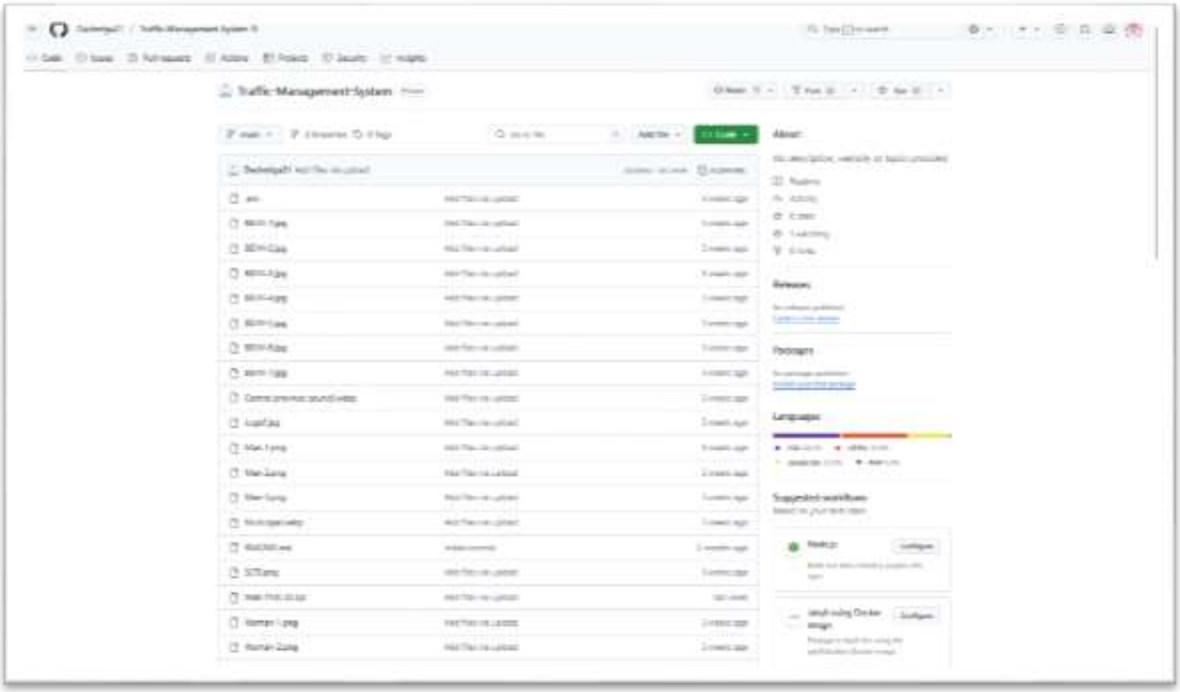


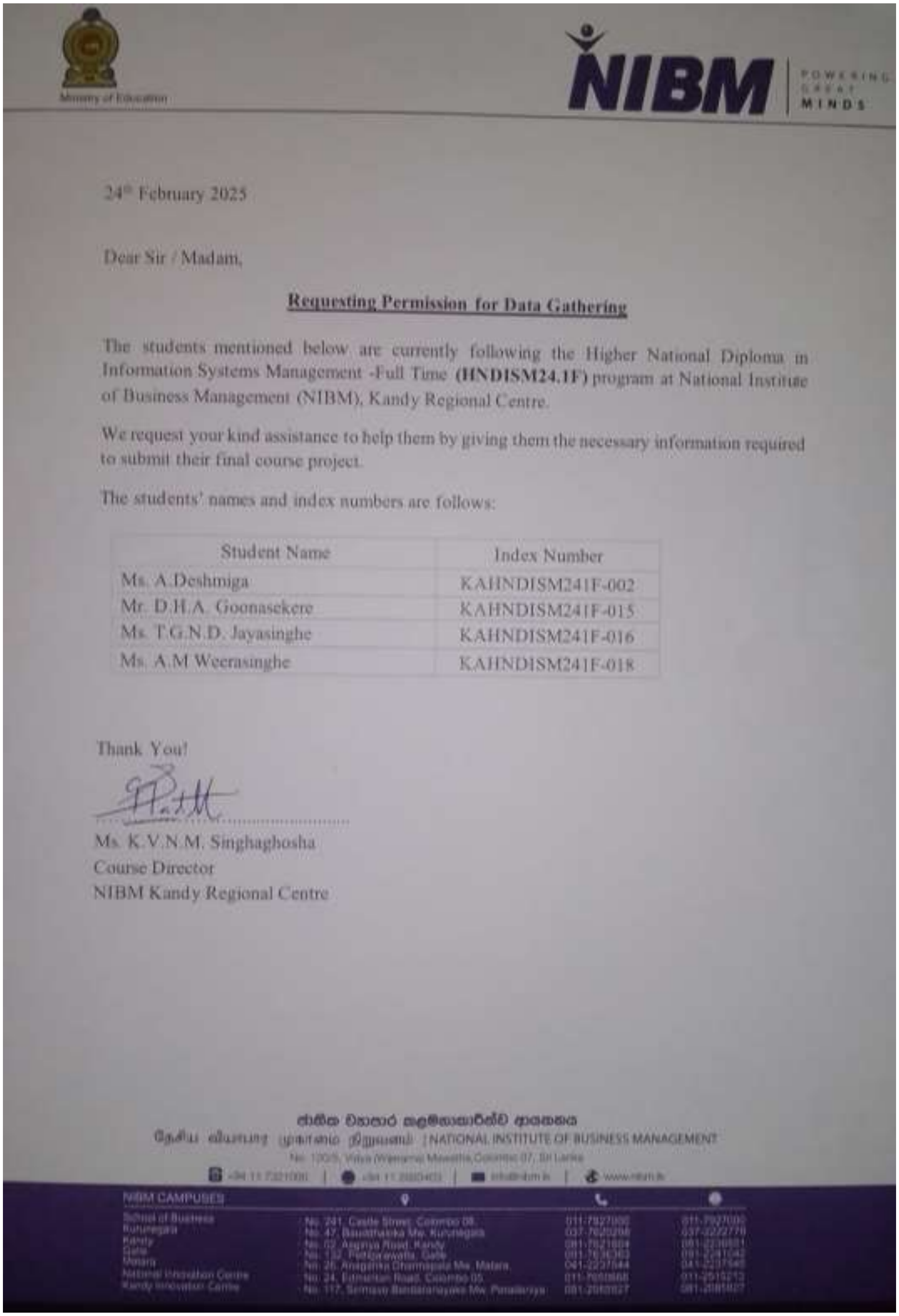
Figure 71: Unstructured Repository

We have not linked our repositories directly to this document for privacy and institutional reasons, however, the repositories are available upon request or through the project's GitHub organization.

4. Functional video demonstration link

- https://drive.google.com/file/d/1LAJKkGejyDM668U6iPMAInNG942ildTa/view?usp=sharing

5. A picture of the data gathering request letter issued by the institute.



Ministry of Education

NIBM POWERING GREAT MINDS

24th February 2025

Dear Sir / Madam,

Requesting Permission for Data Gathering

The students mentioned below are currently following the Higher National Diploma in Information Systems Management -Full Time **(HNDISM24.1F)** program at National Institute of Business Management (NIBM), Kandy Regional Centre.

We request your kind assistance to help them by giving them the necessary information required to submit their final course project.

The students' names and index numbers are follows:

Student Name	Index Number
Ms. A.Deshmiga	KAHNDISM241F-002
Mr. D.H.A. Goonasekere	KAHNDISM241F-015
Ms. T.G.N.D. Jayasinghe	KAHNDISM241F-016
Ms. A.M Weerasinghe	KAHNDISM241F-018

Thank You!

Ms. K.V.N.M. Singhaghosha
Course Director
NIBM Kandy Regional Centre

NATIONAL INSTITUTE OF BUSINESS MANAGEMENT

NIBM CAMPUSES

Figure 72:A picture of the data gathering request letter issued by the institute.

6. User Manual

User Manual

User Manual for Kandy Traffic Management System (TMS) Web Application

Welcome to the **Kandy Traffic Management System (TMS)** web application!
This user manual is designed to guide you through each page and feature of the site, helping you understand how to navigate and make the best use of everything we offer. Whether you're a general user, a commuter, or a system administrator, this manual has you covered.

Table of Contents

Home Page

Overview

The homepage serves as the access point for the TMS platform. It provides a brief introduction to initialize the system, along with a route to access all the key TMS features.
Significant Elements:

- Business Logo: The TMS logo is clickable, allowing users to return to the homepage from any page in the system.
- Navigation Bar: Navigation bar contains links for Home, Live Map, Routes, Analytics, About, and Profile.
- Hero Section: The hero section of the website describes the purpose of the system, and the features of the system.
- Features Section: Quick overview of live traffic, route planning, and alerts.
- Testimonials Section: Read testimonials on the experiences of other users.

- Login/Sign-up Section: Popup forms for users that wish to register or login.
- Footer: Contact information and links to social media, as well as quick links.

Navigation

1. The TMS system can be navigated by clicking links in the navigation bar from any page.
2. If you're on your homepage, you can scroll down to see highlights and benefits of the system shown there.

About Page

Overview

This page describes the background, mission, and goals of the TMS Project.
Includes:

- Project Vision & Mission
- The Problem We are Solving
- Key Stakeholders and System Goals

Navigation

1. Simply scroll down to read the entire section. Return to other pages via the top navbar.

Contact Page

Overview

Do you have feedback or questions? This is where the users would reach out to the TMS team.

Main Elements:

- Contact Form: Name, your email, subject, and message.
- Send button: Submits the message to the admin
- Confirmation: A message to confirm that the form was submitted.
- Social Media Icons: Links to Facebook, Twitter, or other pages if any.

Steps to Use

1. Fill in the form with your message.
2. Click Send.
3. A confirmation will be displayed.
4. Click Get Connected if you would like to check out the social media pages.

Live Map Page

Overview

The Live Map page is for showing current live traffic through the Google Maps API.

Features Includes:

- Live traffic flow color-coded lines.
- Clickable roads to display how much the road is congested.
- Location Detection (if allowed).

Navigation

1. Access the Live map through the navigation bar.
2. Zoom or pan to reveal roads.
3. Click a road to view related public traffic data.
4. View the relevant legend for traffic conditions.

Routes Page

Overview

Intelligently plan your trip using recommended routes based on real-time information.

Features Includes:

- Starting Point and End Point Input
- Multiple Suggested Routes
- Distance, Time, and Traffic Levels for each route
- Route Selection and Email Sharing Option

Steps to Use

1. Enter your Start and End points.
2. View suggested routes.

3. Select one to bookmark.
4. Click Send via Email to send the route via email.

Analytics Page

Overview

The page provides visual traffic insights and data reports.

Includes:

- Real-time traffic statistics
- Historical traffic patterns
- Traffic incident heatmaps
- Peak hour analysis (charts/graphs)

Steps to Use

1. Access Analytics via the navbar.
2. Browse through charts and graphs.
3. Apply filters (if present) for data constriction.

Profile Page

Overview

Each user is provided with a profile page to manage their own settings.

Features :

- View & update profile details
- Update password
- Notification preferences
- Logout button

Steps to Use

1. Click Profile in the navbar.
2. Update your details.
3. Click Save to apply changes.

Admin Dashboard (For Admins alone)

Overview

A powerful panel whereby the administrator can manage the entire system.

Admin Features Are:

- Dashboard Overview
- Manage Users
- Traffic Prediction Tools
- Incident Management
- System Logs and Reports

Steps to Use

1. Log in as Admin.
2. Navigate to the Admin Panel via the Profile dropdown.
3. Select the appropriate section (Users, Routes, Incidents, etc.).
4. Perform actions like add/delete users or view reports.

Thank You

We are glad you can use the Kandy TMS platform. Our platform is built for the community — to make travel safer, faster, smarter. If you have questions, please refer to this guide or contact us through the Contact P