VISLIGHT: LEVERAGING INTELLIGENT TRAFFIC LIGHT SENSORS TO MITIGATE URBAN CONGESTION DURING RUSH HOURS.

A Thesis Proposal
Submitted to the Faculty of the Department
of Computer Studies
Cavite State University – Imus Campus
City of Imus, Cavite

In partial fulfillment
of the requirements in the subject
COSC 75A – Software Engineering II

JOSE ANGELO B. BITANGA
JOHN ROBERT L. OLAÑO
GWEN MARINIE C. PACIENTE
JANUARY 2024

TABLE OF CONTENTS

INTRODUCTION

Urban Congestion is one of the problems that the world is facing right now especially for daily commuters and riders. One of the nations most affected by this issue is the Philippines, where in 2023, commuters and drivers spend around 240 hours stalled on the road, with urban congestion accounting for nearly 170 of those hours (Inquirer, 2024). The Government also found ways to combat this issue by creating the Unified Vehicular Volume Reduction Program (UVVRP) where it aims to reduce about 20% of vehicles however this doesn't solve the issue where it only reduces by 4.3% (J. R. F. Regidor, 2018).

The world finds solutions through the use of technology that could enhance or mitigate the problems faced by the society. Intersections are one of the reasons for urban congestion which would be solved by traffic lights. However, 19% of urban traffic is caused by waiting at traffic signals (*Congestion Causes*, n.d.). That is why it is important to use smart traffic lights since it significantly decreases delays and stops by 20% to 30% (Wang et al., 2024).

This paper focuses on building the VisLight, a vital system that enhances safety and convenience for both pedestrians and drivers. It assists citizens in safely crossing busy streets by providing timely signals, while also optimizing traffic flow for vehicles, reducing congestion caused by poorly managed crosswalks and intersections. By adapting to real-time traffic conditions, this system minimizes delays and improves overall road safety, creating a smoother commuting experience for everyone involved. VisLight is an Intelligent Traffic Light Sensor which aims to mitigate Urban Congestion during rush hours.

STATEMENT OF THE PROBLEM

The current traffic light system in most cities in the Philippines is neither innovative nor designed to effectively address the traffic congestion that many people experience. Pedestrians primarily rely on signal lights to determine their actions: the red light indicates they must stop, the yellow light signals that the red light is about to appear, and the green light indicates they can go. However, this system does not account for the varying needs of pedestrians or drivers. An updated traffic management system is necessary to reduce delays and provide more responsive adjustments to better serve everyone on the road. **What features can be added to a basic traffic light system to help alleviate urban congestion?**

People with limited awareness of road safety, particularly senior citizens and individuals with disabilities, must be properly guided and supported. Crossing the road remains a challenge for these individuals, even with the construction of overpasses and pedestrian walkways. Pedestrian lanes should always be clearly marked, well-maintained, and safe for use at all times to ensure the safety and accessibility of all road users. **How can a traffic light system be accessible and increase pedestrian safety?**

Persistent issues at intersections, delays in emergency vehicle access, extended wait times for pedestrians, and the frequent occurrence of accidents must be addressed. These problems are common and largely a result of the limited effectiveness of current traffic light systems in ensuring safety and efficient traffic flow. **How can the enhanced traffic light sensors be managed to effectively optimize road efficiency for both pedestrians and drivers?**

The current traffic light system in many cities in the Philippines is outdated and inefficient, contributing to congestion, pedestrian safety concerns, and delays. The development of a system like VisLight will effectively address these issues and provide practical solutions. Tackling these problems is crucial for improving both road safety and the well-being of citizens.

OBJECTIVES OF THE STUDY

Generally, the study aims to develop a system and an application that will provide assistance to users and reduce congestion in selected areas.

Specifically, it aims to:

a. Gather all essential information to optimize traffic flow; reduce congestion and vehicle wait times by dynamically modifying traffic light patterns based on real-time data, resulting in smoother traffic flow across intersections.
b. Develop an effective and well-managed system that will address the utmost needs of road users during travel, prioritizing safety, convenience, and efficiency.
c. Provide enhancements to existing traffic light systems, aiming to improve road efficiency for both pedestrians and drivers by optimizing traffic flow, reducing congestion, and increasing safety.

SIGNIFICANCE OF THE STUDY

This research intends to develop VisLight, a vital system that enhances safety and convenience for both pedestrians and drivers. The study is significant and will benefit the following:

Drivers. The development of a system that provides real-time information on traffic flow and offers assistance will help drivers make informed decisions about their routes, allowing them to determine whether they should continue their drive or take an alternative path. This will help reduce congestion, prevent traffic jams, and minimize the chances of drivers being stuck on the road for hours.

Pedestrians. The development of this system and application will significantly improve pedestrian safety on the road. Pedestrians will be easily tracked and monitored, receiving real-time guidance on whether it is safe to cross and when they can proceed. Additionally, the long-term effectiveness of the system will provide ongoing support, ensuring that pedestrians can navigate the roads with confidence, free from safety concerns.

Future Researchers. Future researchers will recognize the potential benefits of such a system for urban areas and may be inspired to adopt similar approaches, developing even more advanced solutions. These researchers could build upon this study to further enhance its effectiveness, ultimately improving the daily commute for citizens by reducing road-related issues and ensuring safer, more efficient travel for both drivers and pedestrians.

In summary, the significance of this study lies in its focus on citizens who drive and crossroads to reach their destinations. Additionally, researchers play a key role, as their work could lead to further improvements that have a lasting, positive impact on all road users.

TIME AND PLACE OF THE STUDY

The study was carried out at Cavite State University - Imus Campus, under the supervision of Mr. Ricky Tepora, who holds the position of Instructor for the subject of Software Engineering II. The study, which takes place over the first semester of the academic year 2024-2025, focuses on creating the VisLight system to reduce urban congestion at the Emilio Aguinaldo Highway Intersection. To successfully accomplish its goals of enhancing traffic flow and lowering congestion in this crucial area, the research intends to improve the characteristics found in this study.

SCOPE AND LIMITATIONS OF THE STUDY

The scope of the VisLight system encompasses the integration of intelligent features designed to optimize urban traffic management and enhance road safety. This innovative solution aims to streamline traffic flow, reduce congestion, and improve the commuting experience for both drivers and pedestrians. By leveraging real-time data and adaptive technology, the system addresses the diverse needs of road users, fosters efficient traffic management, and promotes safer and more accessible intersections. VisLight is focused on creating a well-managed, sustainable, and user-centered approach to urban mobility, ensuring a smoother and safer journey for all.

Dashboard Module. The Dashboard Module serves as the homepage for the VISLIGHT application, providing a comprehensive overview of relevant information for both mobile and PC users. On the mobile application, the dashboard displays suggested places based on the user's current location, real-time traffic and weather data for the city, and a search function similar to Google Maps for finding specific locations. On the PC application, the dashboard offers real-time traffic data displayed per city, the operational status of traffic lights (indicating whether they are functioning correctly or experiencing issues), and the capability to modify traffic light timings and sequences. This centralized view ensures users have access to essential information and control functionalities depending on the platform they are using.

Login Module. The Login Module prioritizes the security and authenticity of user interactions, requiring valid login credentials, typically usernames and passwords. On the VisLight mobile application, users can create accounts to gain access to the application's features. Conversely, on the PC application, access to the VisLight admin account is restricted to authorized personnel only, ensuring that sensitive administrative functions are controlled and managed by designated individuals. This distinction in access control reflects the different usage contexts and security requirements of the mobile and PC platforms.

Map Module. This module provides a real-time visual representation of the road network and traffic conditions. It displays a dynamic map overlaid with traffic information, including vehicle density, traffic flow directions, and congestion hotspots. The map module integrates data from the sensor module to accurately reflect current traffic conditions. It may also incorporate other data sources, such as GPS data from connected vehicles or traffic cameras, to enhance its accuracy and comprehensiveness. This module is essential for visualizing the real-time traffic situation.

Status Module. This vital functionality is designed to monitor the health and operational status of all components within the VisLight system, including sensors, communication infrastructure, and software applications. It promptly provides alerts and notifications in the event of malfunctions, errors, or connectivity issues, ensuring system reliability and efficiency. This module also tracks key performance indicators to evaluate the system's overall effectiveness, identifying areas for improvement and necessary modifications. In addition to maintaining the system's integrity, the Status Module keeps users informed about the application's status on their devices. It alerts users if there are errors in delivering requested information, issues caused by low or no internet connection, or if the phone's location cannot be determined. By ensuring smooth operations and clear communication, the Status Module enhances both system reliability and user experience.

Sensor Module. This serves as the cornerstone of the VisLight system's intelligent traffic management capabilities by collecting real-time traffic data from strategically placed sensors at intersections. Leveraging advanced technologies such as inductive loops, video cameras, and radar, this module detects critical parameters, including vehicle presence, speed, and volume. The collected data is transmitted to a central system for processing and analysis, forming the foundation for dynamic traffic optimization. By providing accurate and timely information, this module ensures the system can respond effectively to changing traffic conditions, improving overall road efficiency and reducing congestion.

Notification Module. This functionality keeps users informed about real-time traffic conditions and help them make well-informed travel decisions. It notifies users about the current state of the roads, including whether their area is experiencing congestion, if a specific route is recommended for driving, or if the roads are deemed safe for travel. It also provides insights into whether a particular day or time is optimal for traveling, accommodating user preferences for timely and relevant updates. Short user-friendly updates are sent each time a user activates the application depending on their preferred settings. By delivering accurate and personalized notifications, this feature ensures users can plan their journeys efficiently and with confidence.

Emergency Notification. Aligned with the Notification Module, this functionality enhances the application by providing timely alerts to users when an accident occurs nearby or within the Emilio Aguinaldo Highway. This feature ensures that users are immediately informed of the situation through a prominent alert, accompanied by a "Be safe, drive safely" message displayed in all users' applications. In addition to accident notifications, this module includes the capability to suggest alternative routes to help users avoid affected areas, minimizing delays and ensuring smoother travel. Furthermore, it provides real-time updates on the status of the incident, such as clearance progress or emergency response activities, allowing users to stay informed and adapt their plans accordingly. The capabilities of this feature collectively promote safer and more efficient road usage.

Control Module. The main feature of VisLight is this module, which gives authorized users the ability to manage traffic lights in the event of emergencies or unexpected malfunctions. It enables real-time adjustments to minimize interruptions, guaranteeing a more seamless traffic flow and cutting down on delays brought on by technical problems. The module's seamless integration with the optimization and monitoring systems guarantees that all modifications are data-driven and sensitive to the traffic situation at hand. It enables operators to promptly handle unforeseen situations, like accidents, road closures, or high-priority vehicles like fire trucks and ambulances, by permitting instantaneous manual overrides. Additionally, the Control Module has an easy-to-use interface that streamlines intricate processes, lowering the possibility of human error and guaranteeing prompt and effective decision-making. It also records every action taken, giving future analysis and accountability a record.

Pedestrian Safety Module. This module serves as a dynamic guide to help people cross crowded streets safely. It offers visual indicators and real-time signals to make sure pedestrians know when it's safest to cross. In order to reduce dangers, integrated sensors automatically modify the crossing signals based on current conditions while monitoring traffic flow and pedestrian movement. In order to accommodate those with impairments or restricted movement, the module also includes auditory cues and unambiguous visual prompts, guaranteeing accessibility and inclusivity. Moreover, countdown timers and warnings let pedestrians know how long it is left to cross, enabling them to make wise choices and cross intersections with assurance. The Pedestrian Safety Module promotes pedestrian safety while ensuring efficient traffic movement by serving as an intelligent crossing guide.

The study acknowledges certain limitations that may affect the system's effectiveness and adaptability. The VisLight system is specifically designed for urban environments in the Imus City and may not be seamlessly applicable to other cities with different traffic systems, policies, and infrastructures. Technological constraints are also essential to highlight, such as the reliance on internet connectivity for communication between servers, sensors, and traffic lights to enable real-time traffic monitoring and management. Limited or unstable internet connectivity could hinder the system's ability to provide accurate and timely traffic updates, potentially increasing congestion.

The system's software users are restricted to individuals with high knowledge of traffic flow and management to ensure proper maintenance and handling of sudden errors in the traffic algorithm. This limitation minimizes the risk of misuse or mismanagement, but it also excludes the possibility of broader user involvement. Driver and pedestrian guides regarding traffic conditions will be available exclusively on the Android OS(Android 8.0 and up), while traffic monitoring and other related controls will be limited to Windows OS (Windows 7 and up) devices and only the admin can access this feature. This separation of functionalities may pose accessibility challenges for users who rely on a single platform.

Additionally, failure to maintain real-time data awareness, whether due to device malfunction or system downtime, could worsen urban congestion rather than alleviate it. The system's success is also dependent on user adoption and proper implementation, which could face challenges such as resistance to new technology or limited understanding of the system's operation.

Lastly, external factors such as changes in urban infrastructure, government policies, and unforeseen financial constraints may impact the system's implementation and long-term sustainability, which are beyond the scope of this study.

DEFINITION OF TERMS

Algorithms. A set of rules or instructions designed to solve a specific problem or perform a computation.

Arduino. A programmable electronic board used to control sensors and devices.

Congestion. A state where traffic flow is heavily hindered due to an excessive number of vehicles on the road, leading to delays and inefficiencies.

Intelligent. The ability of a system or device to process information and make decisions autonomously.

Management System. A structured framework used to control and monitor operations.

Pedestrian. A person traveling on foot who are crossing the road.

Real-Time. The ability to process and respond to information instantly.

Rush Hours. Peak times during the day when traffic volume is highest, typically during morning and evening commutes.

Sensor-Based. Technology that uses sensors to gather data, such as traffic density or vehicle speed, for analysis and decision-making.

Simulation. The use of computer models to mimic real-world scenarios for testing and improving management strategies.

Traffic Jam. A situation where vehicle movement comes to a halt or slows significantly due to congestion or other disruptions.

Traffic Light. A signaling device positioned at intersections to control vehicle and pedestrian flow, using red, yellow, and green signals.

Urban Traffic. The movement of vehicles and pedestrians within city areas, often characterized by high density and complex interactions.

VisLight. A proposed intelligent traffic management system designed to enhance safety, optimize traffic flow, and improve convenience for both pedestrians and drivers in urban areas.

CONCEPTUAL FRAMEWORK

The schematic diagram below shows the conceptual framework of the approach (Input-Process-Output-Feedback) that researchers used to describe the framework below.

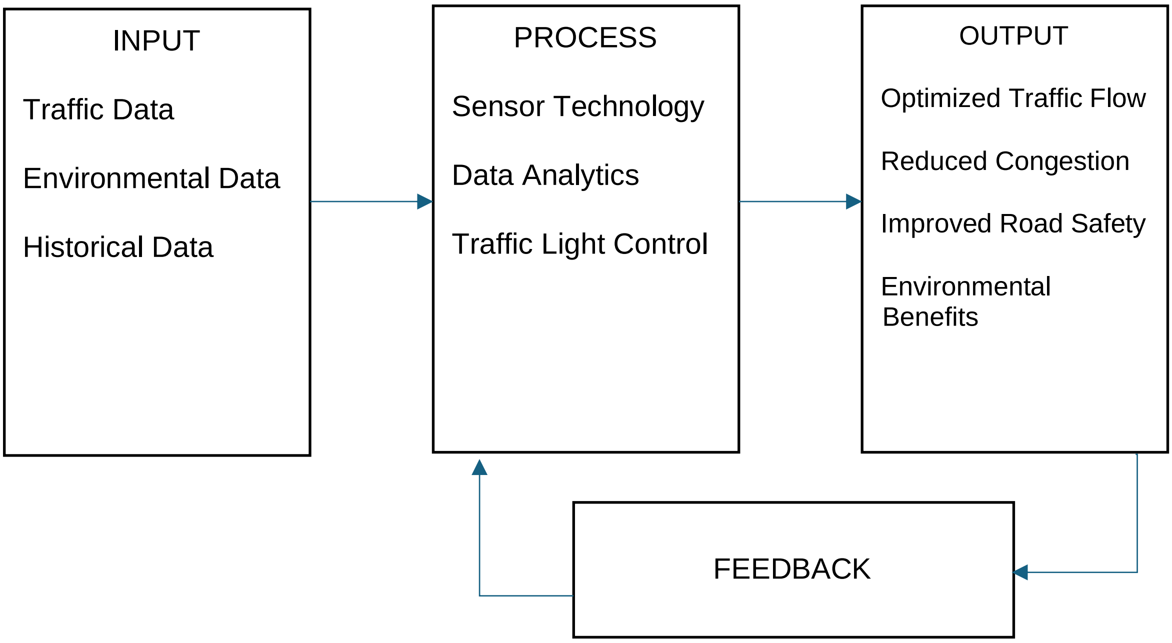


Figure 1. Framework for VisLight: Leveraging Intelligent Traffic Light Sensors to Mitigate Urban Congestion during rush hours.

The study's conceptual framework comprises input, traffic, environmental, and historical data. The process involves sensor technology, data analytics, and traffic light control. The output involves the optimized traffic flow, reduced congestion, improved road safety, and environmental benefits. And it also includes feedback for continuous monitoring and real-time updates refine traffic light operations and improve system performance over time.

REVIEW OF RELATED LITERATURE

FOREIGN LITERATURE

Intelligent Transportation Systems (ITS)

Ravish and Swamy (2021) in their study, indicated that roads could be safer and greener with enhanced efficiency through the application of emerging Intelligent Transportation Systems (ITS) technologies. Their paper conducts a literature survey to identify the effectiveness of key existing Intelligent Transportation Systems (ITS) for managing traffic and examines their performance based on functional efficiencies. The findings indicate that ITS options are diverse, involve a range of technologies, and have the potential to address most traffic-related issues. However, the application of ITS should be tailored to the specific characteristics of the location or area where traffic management is needed. When the appropriate ITS is selected based on the nature of the location, travel time and congestion can be reduced, leading to improved safety and increased productivity.

Artificial Intelligence

Artificial intelligence (AI) is the simulation of human intelligence processes by technology, particularly computers. Akhtar and Moridpour (2021) discussed the traffic congestion prediction problem as something that can be defined through the estimation of parameters related to traffic congestion into the short-term future. Akhtar and Moridpour (2021) highlighted in their study the capability of Artificial Intelligence to provide necessary models that can be used to further mitigate urban congestion.

Traffic Light Synchronization

Tomar et al. (2022) studied different traffic light control technologies and found that traffic light synchronization techniques are capable of solving urban congestion. Traffic light synchronization is a method wherein a car moving at a certain speed down one side of the road may keep going to the other end of the road indefinitely by getting as many green lights as possible at junctions (Tomar et al., 2022). The study enables adaptation of Traffic light synchronization for the desired Smart traffic light for it discusses the benefit, development, and application of the technique.

Traffic simulation

In this study conducted by Dorokhin et al. (2020), motion modeling was used for traffic studies, modeling, planning and development of transport networks and systems. It represents the construction of a working model that reflects the similarity of properties or relations with the real problem under consideration. Modeling makes it possible to study the complex tasks of traffic not in real conditions, but in the laboratory. In the three simulation models conducted in transport infrastructure, there is no ideal model to solve the whole complex of problems associated with traffic flows. Each simulation model allows one to solve a certain range of transport problems, and therefore the use of a particular model depends on the purpose of the study. Summing up the analysis, it can be assumed that the selection of the right model in accordance with the objectives of the study is an important step towards solving transport problems.

Arduino

Arduino is an open-source physical computing platform that may be used to create interactive things that can be connected to the Internet or stand alone. Arduino was first created for designers, artists, and other creatives who do not have to be electrical engineers to integrate physical computing into their work (Banzi & Shiloh, 2022). Later on, it emerged as the preferred venue for literally millions of people looking to use digital technology for innovation. The Arduino project is a widely used educational tool that was created in an educational setting. Teaching strategies, curriculum, and other material are shared by the same open-source mindset that gave rise to the community that freely exchanges knowledge, solutions, and projects.

Google Maps

Google Maps is a web-mapping service that is an invaluable tool for many users for interactively navigating areas of the Earth especially in metropolitan areas. It regularly serves vast quantities of travel time queries from users and enterprises alike (Derrow-Pinion et al., 2021). Google Maps shall be utilized to track traffic flow by providing real-time information about the current traffic situation in multiple areas. It will provide visual input to the users and managers of the software application.

LOCAL LITERATURE

Driver Education

Bugabuga and Puyo (2024) stated that by prioritizing quality education, competent instructors, hands-on experience, and the strategic use of technology, the country can lay the foundation for a more effective driver education system and safer roads. However, according to them, further research and the implementation of appropriate regulatory measures are essential in order for these efforts to help reduce road accidents and foster responsible driving behaviors across the nation.

Naïve Bayes Algorithm

Naive Bayes comes from a family of algorithms based on Bayes' Theorem. It is widely utilized for its simplicity and efficiency in machine learning, and for classification problems. Libnao et al. (2023) presents a Traffic Incident Prediction and Classification System (TIPCS) that uses the Naïve Bayes Algorithm to proactively forecast and categorize traffic incidents, ultimately enhancing incident management and optimizing traffic flow. Libnao et al. (2023) suggests that with it, an incident can be predicted specifically on how it is likely to occur and and it would be classified appropriately. It was also mentioned that as it is trained on historical incident data, the system is continuously updated with new information, allowing its accuracy to improve over time.

Traffic Congestion

The study conducted by Aydinan (2020) aims to assess the main reasons or possible causes of traffic congestion in the city and to identify potential courses of action to alleviate congested traffic across Cabanatuan. Data analysis revealed that poor maintenance is one of the four key reasons of traffic congestion, poor control measures come next, then physical inadequacy, and last human error. According to the study, the most significant result of traffic congestion is vehicle interposition. One of the recommendations was that road users follow traffic laws and regulations, particularly by keeping in their proper lane, avoiding counterflow, and invading in any way feasible when traffic congestion occurs. Moreno (2023) discussed the perspective of the daily commuter in Zamboanga City, showing that traffic congestion could lead to longer journey times, elevated stress levels, and decreased productivity. The article also shed light to factors of traffic congestion which are inadequate road infrastructure, unregulated street parking, and inefficient traffic flow management. The study recommends improving road infrastructure, creating stricter parking regulations and improving policies.

Ergonomic Risk Factors of Traffic Enforcers

Traffic enforcers are one of the most dangerous occupations to have; they are prone to workplace accidents, injuries, and illnesses since they are frequently exposed to ergonomic risk factors while executing their duties. According to Gumasing et al. (2023), traffic enforcers are vulnerable in such settings since they are exposed to fluctuating environmental elements such as ambient temperature, air pollution, and UV radiation, all of which contribute to the development of various health diseases. The study found that traffic enforcers in Manila City are more likely to suffer from musculoskeletal disorders (MSDs) due to poor posture and exposure to environmental risks like heat, noise, and air pollution. Therefore, it is advised to implement administrative measures, like job rotation or shifting, and regular rest periods in order to reduce the risk of MSDs. Additionally, it emphasizes how smart traffic sensors can reduce the number of traffic enforcers who may be exposed to danger factors.

Internet of things (IoT)

The Internet of Things, or IoT, is a network of sensors and software designed to communicate and share information via the internet (Paradina & Noroña, 2021). The Internet of things (Iot) is always described as linked to gadgets and smart devices. However, this past few years, it expands to smart cities where traffic patterns and sensors are now connected to each other. This enables traffic lights to be connected to each other using Internet of things (IoT) plus studies show that it can also use agriculture for part tracking of the plants. Also, for real-time monitoring of the traffic which could help researchers to analyze the traffic patterns and mitigate the traffic congestion in urban areas.

REVIEW OF RELATED STUDIES

FOREIGN STUDIES

Automated Real-Time Intelligent Traffic Control System for Smart Cities Using Wireless Sensor Networks

Hilmani et al. (2020) presented an intelligent and connected system based on the deployment and implementation of wireless sensor networks (WSNs) at road intersections and also in car parks in order to make roads and cities smarter. This system was put together through the combined use of several innovative IoT technologies, such as WSN, RFID, and mobile application. As per Hilmani et al. (2020), this system is different from existing systems, due to the fact that it regroups two intelligent systems namely the traffic light control system and the intelligent parking system.

Leveraging Large Language Models (LLMs) for Traffic Management at Urban Intersections: The Case of Mixed Traffic Scenarios

Masri et al. (2024) highlight that effective traffic management systems can alleviate congestion, reduce emissions, and enhance safety for all road users. They propose that incorporating Large Language Models (LLMs) into traffic control systems could improve their flexibility and responsiveness to fluctuating traffic conditions, offering a powerful solution to the challenges faced by contemporary urban areas. This paper adds to the expanding body of knowledge on AI-driven traffic management, providing valuable insights into the practical application of LLMs in urban settings.

Traffic light optimization with low penetration rate vehicle trajectory data

Wang et al. (2024) enable to create a traffic light optimization recognized as an economical technique for lowering energy use and traffic in cities without affecting the physical infrastructure for roads. Using vehicle trajectory data, the researcher found a re-timing system could be done without the use of any sensor or detector. The study proclaimed that it can be used at any fixed-time signalized intersection worldwide (Wang et al., 2024).

Sensors in Traffic Management System

One effective way to lessen traffic congestion is to integrate sensors into traffic light systems, a practice that has been extensively researched. The Smart Traffic Management System (STMS) aims to improve accessibility to emergency services, reduce traffic, and minimize wait times in order to revolutionize urban mobility (Jangeed et al., 2024). Innovative solutions are more important than ever as cities throughout the world struggle with growing issues including transportation congestion, safety risks, and environmental degradation. To capture vital traffic data including vehicle counts and speeds, the STLCS strategically deploys sensors at crucial locations utilizing a variety of technologies, including infrared, radar-based, and inductive loop sensors.

STLS: Smart Traffic Lights System for Emergency Response Vehicles

Because emergencies can be anything from a fire to an accident to a natural disaster, emergency response vehicles are on call around-the-clock in case someone requests for help. However, given that they will be traversing numerous traffic lights and heavy traffic in the future, are their replies as prompt as we anticipated? This issue was resolved by a system developed by Almuraykhi and Akhlaq (2019); it connects micro-controlled traffic lights, Google maps, an Android app, the MQTT (Message Queuing Telemetry Transport) protocol, and the Internet. Google Maps determines the shortest route to the destination and the locations of all traffic signals along the route, and the Android app lets the user choose the destination. The mobile app also provides the arrival time for each traffic signal controller. When the car eventually reaches the traffic lights, it will discover that they are open and do not interfere with the other signals. Following a number of tests and assessments, it was determined that the system is 100% dependable and performs exceptionally well.

LOCAL STUDIES

Effective Utilization of Traffic Lights in Common Congested Areas in Urban Settings through Crowdsourcing

Villaluz (2023) addressed the objectives of minimizing traffic congestion in urban areas, by coming up with the idea of producing an adaptive traffic light scheduling system, developing a mobile application for user engagement, and creating an Arduino-compatible microcontroller simulation for traffic lights. Villaluz (2023) believes that adopting innovative approaches and leveraging technology, will result in the creation of a smarter and more efficient transportation infrastructure.

SURATSA: Implementation of Surigao Real-Time Adaptive Traffic Signal Algorithm (RATSA) For Traffic Management in Barangay Luna, Surigao City Philippines

Buniel and Tantoy (2024) demonstrated an adaptive traffic light system based on real-time vehicle detection that can significantly improve traffic management in urban areas. This research presents the implementation and evaluation of an adaptive traffic light system prototype in Barangay Luna, Surigao City, Philippines. Buniel and Tantoy (2024) utilized Arduino Mega boards and ultrasonic sensors to detect vehicle presence in three lanes, dynamically adjusting traffic light sequences to optimize traffic flow. It is specifically aimed to optimize traffic flow, enhance pedestrian safety, and adapt to diverse traffic conditions.

Development of a CNN-based Intelligent Traffic Control System for Emergency Vehicle Detection and Intersectional Traffic Flow

Cirsostomo et al. (2024) describe the use of (convolutional neural network) CNN-based where able to estimate traffic density and detect and classify vehicles. This technology enables traffic lights to go and stop based on the level of the traffic in a particular area. Since the system will accept footage and the server analyzes the given data to produce a traffic analysis. The study focuses on improving the road infrastructure by adding sensors and other technologies to create an effective and efficient traffic system for the local.

Web Camera and Fuzzy Logic System Controlled Traffic Light System

In the Philippines, traffic is heavy, particularly in urban regions that are trading centers and central business districts. Pre-timed traffic light systems are no longer effective at reducing traffic congestion because they only focused on vehicle factors. However, most intersections have pedestrian lanes, which must also be taken into account when intelligent traffic signals are making decisions. In order to control traffic congestion, Sequera (2019) developed a study that uses a fuzzy logic system and a web camera (computer vision). Timing controls based on the camera's acquired images may enhance the traffic systems. The algorithm for calculating the duration of congestion using camera vision is good after testing. With counted pixels, it can roughly determine the equivalent centimeters. Testing the fuzzy logic system yielded satisfactory results. As anticipated and specified by the rule base, it can produce the given time.

Design and Development of Cross Capture Cam (3C): A Disaster and Traffic Management and Monitoring System using Image Detection

The application of image-based processing algorithms using well placed CCTV cameras on city streets is covered in the study by Niño et al. (2024). It focuses on planning and creating a traffic and disaster monitoring system that employs image processing to keep an eye on events in Urdaneta City's Public and Safety Office. The researchers emphasize quick deliverable production and a cooperative atmosphere between developers and clients by using Extreme Programming (XP) as the software development technique. User acceptance was evaluated using ISO 9126, which provides a systematic method for analyzing software quality. The researchers advise more technical testing on the CCTV equipment for future improvement, despite the testing findings showing a high acceptance level (GWM of 4.5).

TABLE OF COMPARISON

Table 1. Table of Comparison

Projects	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Year	**2019**	**2019**	**2020**	**2023**	**2024**	**2024**	**2024**	**2024**	**2024**	**2024**	**2024**
Real-Time Data Collection	✓	✓	✓	✓	✕	✓	✓	✓	✓	✓	✓
Traffic Signal Control	✓	✓	✓	✓	✓	✕	✓	✓	✓	✓	✓
Software Application	✓	✓	✓	✓	✕	✓	✓	✕	✕	✓	✓
Emergency Vehicle Alert	✓	✕	✕	✓	✕	✕	✕	✕	✕	✕	✓
Sensors	✓	✓	✓	✓	✕	✓	✓	✓	✓	✓	✓
Traffic Algorithm	✓	✓	✓	✓	✓	✓	✓	✕	✓	✓	✓
Feedback system	✕	✓	✓	✕	✕	✓	✓	✓	✓	✕	✓
Video Capture	✕	✕	✓	✓	✕	✓	✓	✓	✕	✕	✓

Google Map Analysis	✓	✕	✓	✓	✕	✕	✕	✕	✕	✕	✓
Arduino Based	✓	✕	✕	✓	✕	✕	✓	✕	✕	✓	✓
Traffic Light Synchronization	✕	✕	✕	✕	✕	✕	✕	✕	✕	✕	✓

Legend:

A- STLS: Smart Traffic Lights System for Emergency Response Vehicles

B- Web Camera and Fuzzy Logic System Controlled Traffic Light System

C- Automated Real-Time Intelligent Traffic Control System for Smart Cities Using Wireless Sensor Networks

D- Efficient Utilization of Traffic Lights in Common Congested Areas in Urban Settings through Crowdsourcing

E- Traffic light optimization with low penetration rate vehicle trajectory data

F- Design and Development of Cross Capture Cam (3C): A Disaster and Traffic Management and Monitoring System using Image Detection

G- Sensors in Traffic Management System

H- Development of a CNN-based Intelligent Traffic Control System for Emergency Vehicle Detection and Intersectional Traffic Flow

I- Leveraging Large Language Models (LLMs) for Traffic Management at Urban Intersections: The Case of Mixed Traffic Scenarios

J- SURATSA: Implementation of Surigao Real-Time Adaptive Traffic Signal Algorithm (RATSA) For Traffic Management in Barangay Luna, Surigao City Philippines

K- VisLight: Leveraging Intelligent Traffic Light Sensors to Mitigate Urban Congestion during rush hours.

SYNTHESIS

Urban traffic congestion poses a significant challenge worldwide, impacting economies, the environment, and quality of life. Addressing this issue requires innovative and effective traffic management strategies that can adapt to ever-changing traffic patterns. Different studies collectively highlight a clear shift towards dynamic, adaptive systems capable of responding in real-time to fluctuating traffic conditions, marking a significant advancement in urban mobility. It explores diverse approaches to intelligent traffic management, ranging from sensor-based systems to advanced artificial intelligence applications. This evolution promises to optimize traffic flow, reduce emissions, and enhance overall safety for all road users.

Early advancements in intelligent traffic management focused on integrating sensor networks into existing traffic infrastructure. Hilmani et al. (2020) proposed an intelligent and connected system utilizing wireless sensor networks (WSNs), RFID, and mobile applications to create a combined traffic light control and intelligent parking system. This integrated approach aimed to optimize both traffic flow at intersections and parking availability within urban areas. This interconnectedness of traffic management components represented a significant step towards more holistic urban planning. Similarly, Jangeed et al. (2024) emphasized the crucial role of various sensors—including infrared, radar-based, and inductive loops—in capturing essential traffic data, such as vehicle counts and speeds. This data collection enabled more responsive and data-driven traffic light control within a Smart Traffic Management System (STMS).

Further research explored the potential of optimizing existing infrastructure without requiring extensive and costly physical modifications. Wang et al. (2024) demonstrated that effective traffic light optimization could be achieved using readily available vehicle trajectory data. This approach enabled a re-timing system for traffic signals without the need for deploying additional sensors or detectors. This method offered a significantly more cost-effective solution for improving traffic flow at existing signalized intersections worldwide. Furthermore, Villaluz (2023) focused on developing an adaptive traffic light scheduling system, coupled with a user-friendly mobile application for crowdsourced data and an Arduino-compatible microcontroller simulation. This approach emphasized the importance of user interaction and the use of accessible, open-source technology in traffic management solutions.

It is widely understood that, not only ordinary vehicles are using the road to go to one place to another but also different types of emergency response vehicles which helps them respond to the scene quickly. The critical need for rapid response during emergencies has also driven significant innovation in traffic management strategies. Almuraykhi and Akhlaq (2019) seamlessly integrates micro-controlled traffic lights, Google Maps, a dedicated Android application, and the MQTT protocol to prioritize emergency vehicle movement. By dynamically adjusting traffic signals based on the emergency vehicle's calculated route, this system aimed to minimize delays and ensure timely responses to critical situations. This integration of real-time navigation and traffic control represents a vital advancement in public safety infrastructure. This system allows for preemption of traffic signals, giving emergency vehicles right of way.

More recent studies have explored the application of advanced technologies like computer vision and artificial intelligence in traffic management. Sequera (2019) developed a system using a web camera and fuzzy logic to control traffic lights, effectively taking into account both vehicle and pedestrian traffic. This approach demonstrated the potential of computer vision to capture real-time traffic data, including pedestrian presence, and the effectiveness of fuzzy logic in handling the inherent uncertainties and complexities of real-world traffic scenarios. On the other hand, Niño et al. (2024) focused on designing a comprehensive disaster and traffic management system using image processing from strategically placed CCTV cameras, emphasizing rapid software development and rigorous user acceptance testing. Cirsostomo et al. (2024) further advanced this approach by developing a sophisticated CNN-based intelligent traffic control system specifically designed for emergency vehicle detection and efficient intersectional traffic flow, demonstrating the power of deep learning in analyzing complex video data for enhanced traffic management.

Some studies explore the exciting potential of integrating Language Models into traffic management systems. Masri et al. (2024) convincingly argue that LLMs can significantly enhance the flexibility and responsiveness of traffic control systems to rapidly changing traffic conditions and unexpected events. This integration represents a significant step towards creating truly adaptive and intelligent systems capable of understanding and responding to highly complex and dynamic traffic patterns in real-time. Furthermore, Buniel and Tantoy (2024) implemented a practical real-time adaptive traffic signal algorithm (RATSA) using readily available Arduino Mega boards and ultrasonic sensors, demonstrating the practical application of adaptive control strategies in a specific urban setting. These advancements point towards a future of highly intelligent and responsive traffic management systems.

Overall, the development of intelligent traffic management has progressed remarkably from basic sensor-based systems to sophisticated AI-driven solutions. The seamless integration of WSNs, computer vision, fuzzy logic, CNNs, and language models has enabled the development of increasingly dynamic, responsive, and intelligent systems. While foundational sensor-based systems provide the essential data collection infrastructure, advanced AI and machine learning techniques offer the potential for far more intelligent and adaptive control strategies. Future research should prioritize further refining these cutting-edge technologies, seamlessly integrating them into existing infrastructure, and addressing the remaining challenges of real-world implementation to create truly smart, efficient, and sustainable urban transportation systems for the future.

METHODOLOGY

The study design and methods used in the creation of the suggested system are the main topics of this chapter. It describes the researchers' methodical procedures, starting with the development of the study plan, then moving on to the techniques for gathering data, and concluding with the use of these discoveries in building the system.

A thorough explanation of the supplies, instruments, and machinery needed to complete the job effectively is also included in this section. It also gives a summary of the methodical process used to guarantee that the collected data is efficiently examined and used to accomplish the project's goals.

Research Design

The goal of the research project, VisLight: Leveraging Intelligent Traffic Light Sensors to Mitigate Urban Congestion During Rush Hours, is to create an application and system that will help users and reduce traffic in specific locations. By providing precise, real-time indications to guarantee a safe crossing, the system specifically aims to improve pedestrian safety at crosswalks. Additionally, by dynamically modifying traffic signal patterns in response to real-time data, it seeks to improve traffic flow, hence increasing overall road efficiency and offering all users a more seamless, well-coordinated traffic experience.

By using a descriptive research approach, the researchers will be able to gather, examine, and interpret pertinent data from the study's target audience. The VisLight system will be developed using the input and answers received, guaranteeing precise, real-time traffic solutions that improve pedestrian safety and streamline traffic flow. The system seeks to give all road users a safer and more effective traffic experience by attending to user demands and real-time data.

The research will make use of the Software Development Life Cycle (SDLC) Prototyping Model to direct the development process. software development process that entails building a preliminary software product prototype before producing the finished version (GeeksforGeeks, 2023).

Usually, the procedure consists of repeated cycles in which prototypes are constructed, examined, and refined in response to user input. By emphasizing flexibility and adaptability, prototyping helps to minimize expensive adjustments during later phases of development while guaranteeing that the finished product meets user demands and expectations. By addressing basic needs and integrating input at every level of development, this technique promotes continual improvement, making it especially helpful for projects with complicated requirements or where user engagement is important.

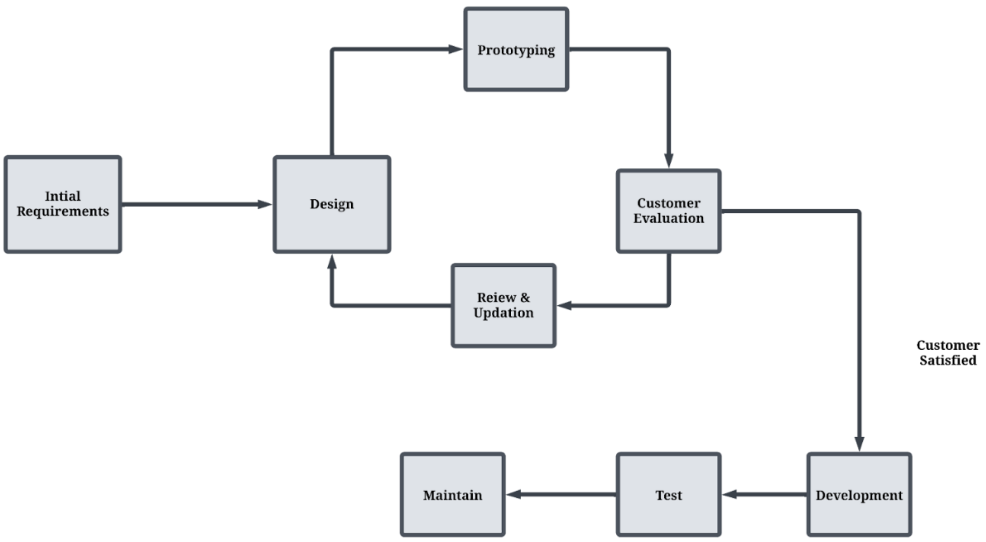


Figure 2. Prototyping Model

Initial Requirements. The researchers gather and define the system's basic demands during the VISLIGHT project's first requirements stage. This entails using data collection methods to gather information on the expectations and concerns of different users in urban traffic management as well as those impacted by traffic congestion. Critical features are handled first by prioritizing requirements based on participant input once the feedback is reviewed. The expectations for each project contributor are then made clear through the creation of a formal requirements specification document. In order to adjust to changing needs and make sure the system efficiently reduces urban congestion during rush hours, it is imperative that participants be continuously engaged throughout the project lifecycle.

Design. The researchers transform user requirements and expectations into a structured framework for the VisLight system, creating a design based on the gathered requirements. Making intricate flowcharts and diagrams that describe the system architecture, user interfaces, and interaction procedures is part of this design. The researchers made sure the design successfully satisfies the defined needs and important elements are included, such as real-time data integration from sensors and adaptive traffic light algorithms. In order to handle future system expansions, scalability and future improvement concerns are also included. This early design is a vital starting point for the prototype, helping researchers to create a working model that can be tested and improved in response to user input.

Prototyping. The researchers create a preliminary working model of the VisLight program using the design. Users may see how the system works thanks to this interactive prototype, which depicts the main features and user interactions specified in the design. In order to verify their integration and usability, developers concentrate on putting together different features and components while requesting early user input. The team can save development time and improve communication by using rapid prototyping methodologies to move from concept to functioning model in a short amount of time. In the end, this first working model establishes the framework for additional testing and verification, guaranteeing that VisLight successfully satisfies user requirements prior to extensive deployment.

Customer Evaluation. The researchers gather input on the prototype's usability and usefulness by presenting it to users for evaluation. Users engage with the prototype during this session, giving them the opportunity to test out its features and offer feedback based on their experiences. It is crucial to create targeted questions that help consumers express their ideas, such as pointing out any problems or making suggestions for enhancements, in order to provide productive feedback. Promoting open communication with researchers and users helps identify design flaws and strengths while guaranteeing that their needs are met. The researchers gather input, examine it to find trends, rank the changes that need to be made, and then refine the prototype to better meet user expectations before moving on to the next phase of development.

Review and Updation. The researchers follow the customer evaluation, the prototype is thoroughly reviewed and updated based on the necessary adjustments identified during the evaluation process. Specific methods, such as user feedback analysis, performance testing, and scenario-based simulations, are considered to determine the system's requirements. These insights are used to refine the prototype, ensuring it effectively meets the needs of the users and improves overall functionality.

Development. The researchers have completed numerous iterations of prototyping, evaluation, reviewing, and updating, leading to the development of the final and actual system of VisLight. Its development has now reached an advanced stage. The system integrated real-time data processing and decision-making algorithms to adjust traffic signals dynamically based on situational factors, such as emergencies, pedestrian safety, and traffic congestion levels. Reliable and efficient materials, specifically durable polycarbonate housings for lights, infrared and radar sensors for vehicle detection, and wireless communication modules for data exchange were utilized. The core algorithm employed machine learning to analyze traffic patterns and prioritize emergency vehicles while simultaneously informing pedestrians when it is safe to cross and notifying drivers of reduced congestion. The holistic approach of the final system enhanced traffic flow, safety, and responsiveness, marking a significant improvement over traditional traffic control methods.

Test. The researchers evaluated the prototype in a simulated urban traffic environment to assess its functionality, accuracy, ability to reduce congestion during rush hours, and capability to detect emergency vehicles. Key performance, such as response time to detect vehicles and traffic time will be analyzed. This process included iterative refinements based on performance, ensuring the system’s reliability and adaptability for real-world application.

Maintain. The researchers ensure the system's components remain functional until the deployment of the system. Hardware elements like sensors and Arduino boards are inspected regularly for durability, while software algorithms are updated and debugged as needed.In order to detect and fix any possible problems before they impair the system's functionality in an actual setting, this continuous maintenance is essential. During this stage, the researchers also get user feedback so that any required modifications and enhancements may be made. The researchers can improve the system's efficacy and dependability by regularly assessing its performance, which will eventually facilitate a more seamless transition to full deployment. Frequent maintenance increases user trust in the system's capabilities while also extending its lifespan.

Participants of the Study

The researchers opted to collect data using a survey form since it is the most appropriate method for descriptive investigations. The primary source of data to be gathered were the Bachelor of Science in Computer Science students from different years. In gathering the respondents, it will be based on what type of road user they are (drivers, pedestrians, or cyclists). The survey was conducted through Google Forms and sent through the official Computer Science organization of CvSU – Imus Campus to easily disseminate it.

Table 2. Respondent's Classification Table

CLASSIFICATION	FREQUENCY	PERCENTAGE
DRIVERS	10	40%
PEDESTRIANS	10	40%
CYCLISTS	5	20%
TOTAL	**25**	**100%**

Sampling Technique

For the survey on improving the traffic light system, stratified random sampling is used to make sure different groups of people are well-represented. The population is divided into different categories, such as location, type of commuter (drivers, pedestrians, cyclists), demographics (age, occupation), and traffic levels (high or low traffic areas). People are randomly selected from each category to take part in the survey. This method ensures that the feedback comes from a broad range of people, giving a clearer picture of how the traffic light system can be improved for everyone. This technique ensured the survey results are reliable and better reflect the needs of all users.

Data to be Gathered

The researchers utilized questionnaires as the primary data collection tool. The questionnaires are designed to be clear, concise, and relevant to each category of participants. Questions for drivers and cyclists focused on wait times and traffic flow, while questions for pedestrians address safety concerns and crossing times. These questionnaires were distributed to the randomly selected individuals within each stratum, ensuring that responses are gathered from a diverse group. Using this method allowed us to collect consistent and comparable data across all participant groups, helping to identify common issues and specific needs related to the traffic light system. The insights gained from the questionnaires served as a guide towards the improvements of the system based on the actual experiences and preferences of the users.

Statistical Treatment of Data

The researchers collected the data by encoding, tallying, and tabulating for clarity and better interpretation of the findings. The following statistical tools were used to analyze the data gathered in the researcher's study, calculate the total scores on the Likert scale. While the weighted mean score is calculated by dividing the total scores by the total number of respondents. See the solutions below.

1. **Frequency Count and Percentage** was used to analyze respondent's profile. Frequency and percentage are suitable tools since it will cater the data needed by the researcher.

The formula is $P = \left(\frac{f}{t}\right) * 100$

Where:

P = Percentage

f = Frequency

t = Total number of population

2. **Mean-** The mean also known as the “average” is the calculated “central” value of a set of numbers by adding all the values and dividing the total by the total number of respondents.

The formula is $X = (\sum x)/t$

Where:

X = Mean

x = Weight of each value

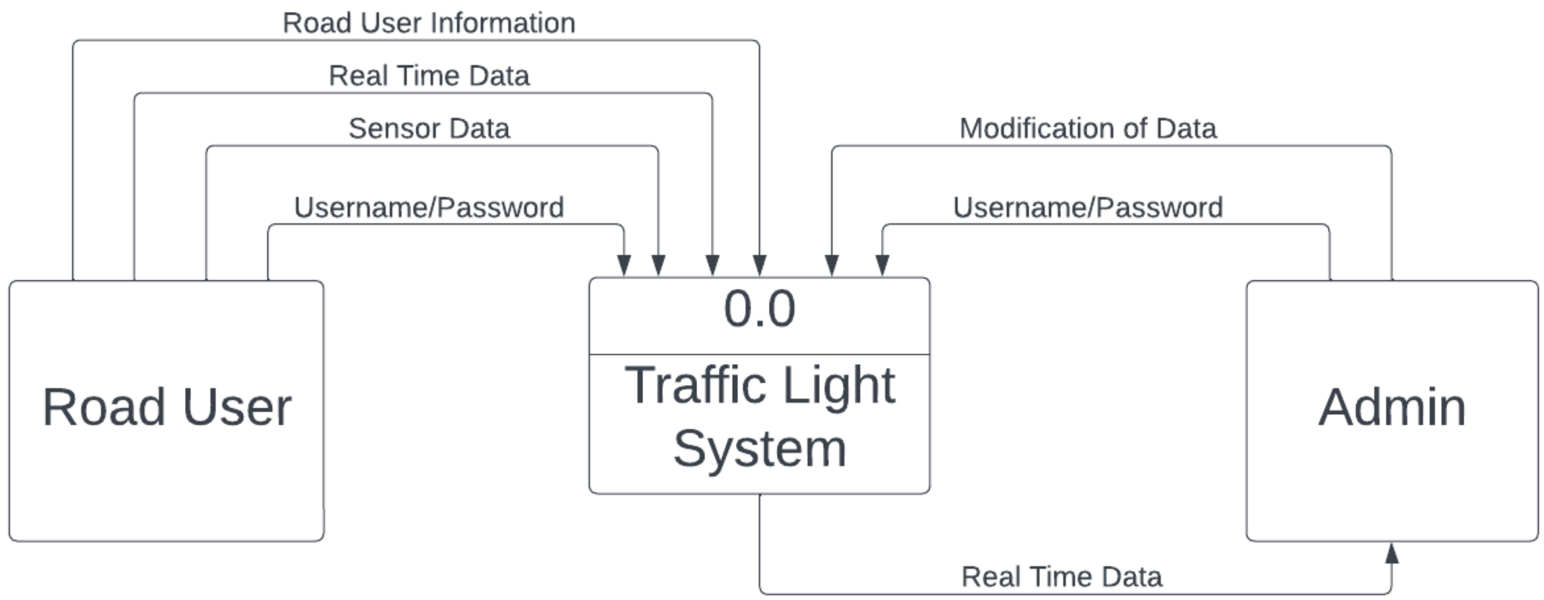
$\sum =$ Summation

T = Total number of population

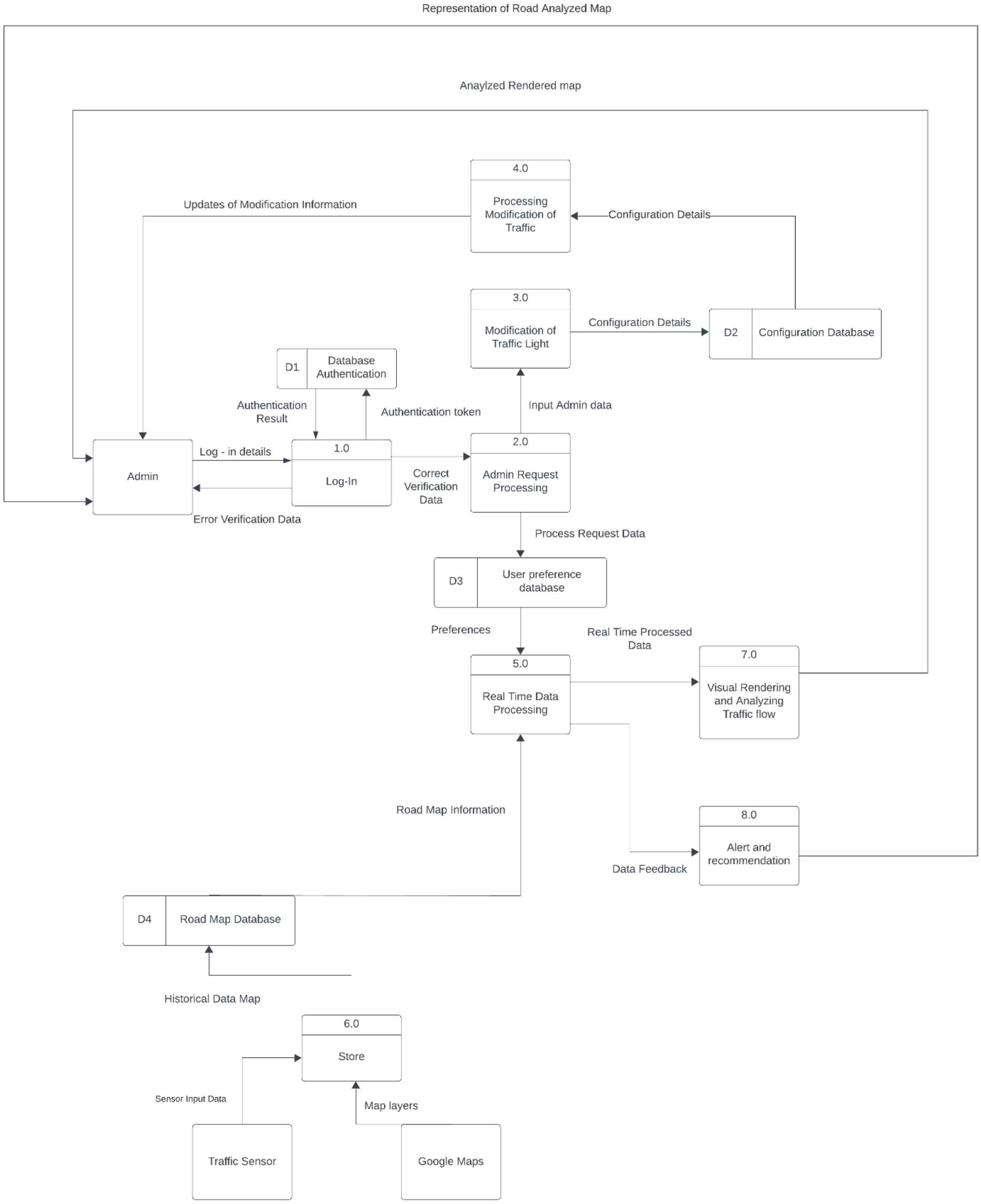
APPENDICES

Appendix A. Prototype (Admin).

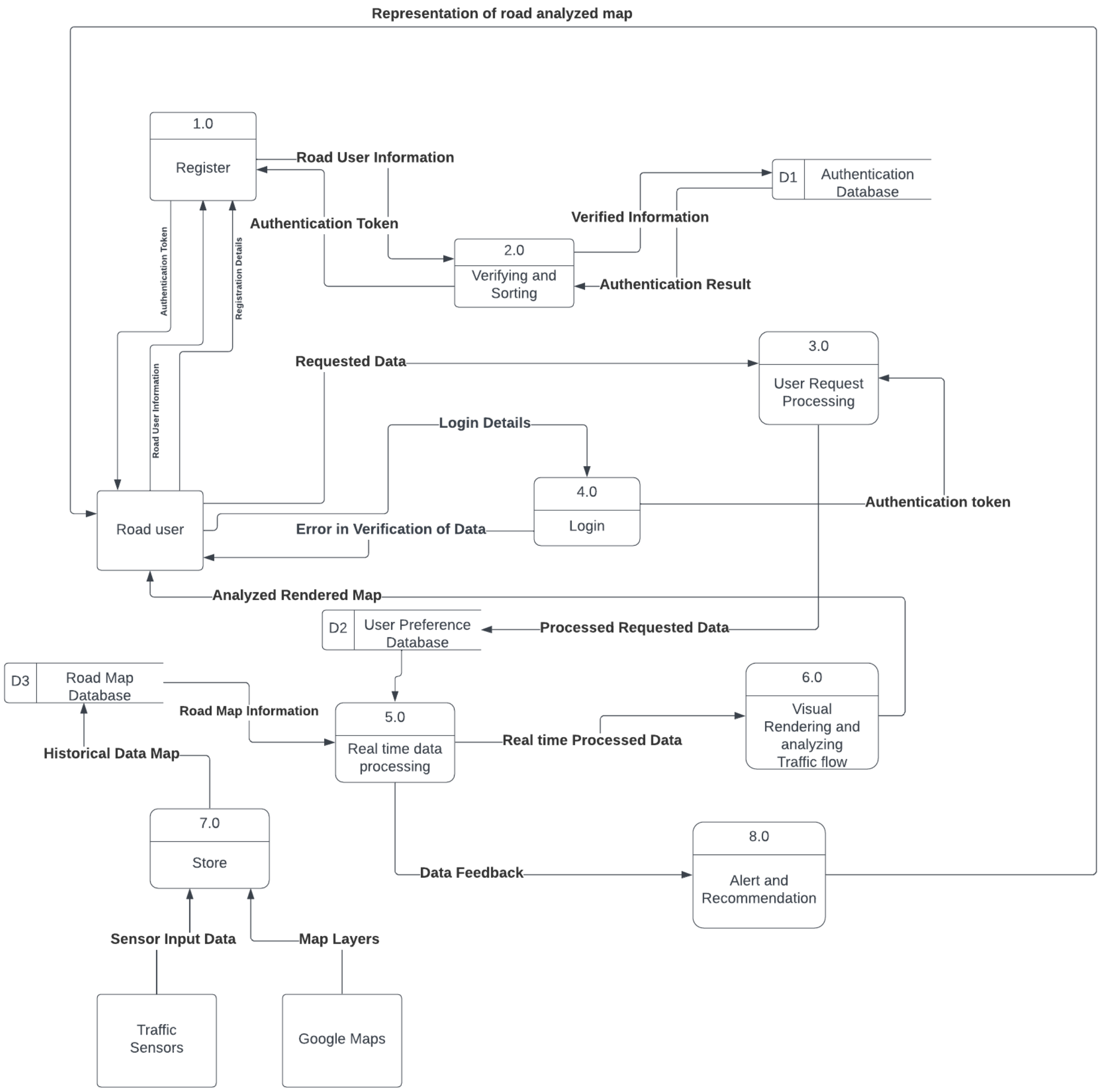
Appendix B. Prototype (User).



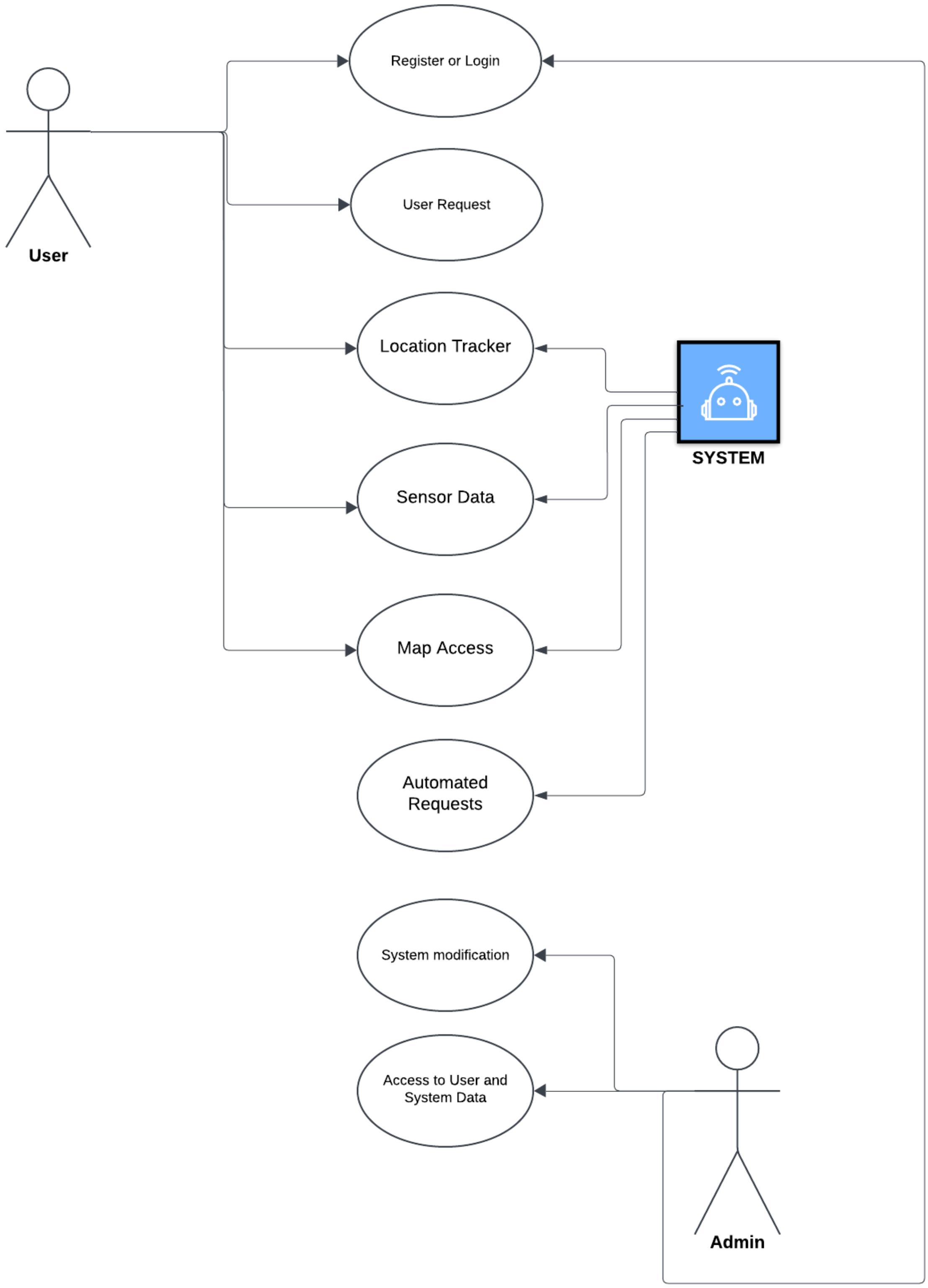
Appendix C. Context Flow Diagram.



Appendix D. Data Flow Diagram (Admin).



Appendix E. Data Flow Diagram (Road User).



Appendix F. Use Case Diagram.

USE CASE DESCRIPTION

REGISTRATION/LOGIN

ACTORS
User (Drivers, Pedestrians/Road Users)
Admin

PRE-CONDITION
The system will first ask if the user wants to register or login.
The customer will encounter the register and login button, which they can choose from
according to their needs. Both the register and login button will require the user to input
their personal information to serve as their identity for their account.
The admin will encounter a login form.

POST-CONDITION
The system will save the entered account information for registration.
The system will verify the logged in information.

NON-FUNCTIONAL REQUIREMENTS
1. Security
2. Safety

EXCEPTION, ERROR SITUATION
USER
Email is already registered.
Password does not meet the requirement.
Incorrect email / password.
Account does not exist.

ADMIN
Incorrect email / password.
Account does not exist.

DIALOGS / SCENARIO
USER
1. Interact as Customer or Admin?
2. Login/Register?
3. Register with the given account information?
4. Enter registered email and password.
5. Enter account email and password.

ADMIN
1. Interact as Customer or Admin?
2. SYSTEM: Enter Admin account email and password.

SPECIFIC USER INTERFACE REQUIREMENTS
1. User Control and Freedom

2. System Accessibility
3. Error Management
4. Security and Verification

USER REQUEST

ACTORS
User (Drivers, Pedestrians/Road Users)
System

PRE-CONDITION
The system will provide options for the user’s needs.
The customer will encounter the system's interface for all user requests.

POST-CONDITION
The system will process the user’s request.
The customer will attain his/her requested action or information.

NON-FUNCTIONAL REQUIREMENTS
1. Performance
2. Reliability
3. Maintainability

EXCEPTION, ERROR SITUATION
1. Request cannot be made.
2. Too many requests.
3. You are not eligible for this request.

DIALOGS / SCENARIO
1. What would you like to do?
2. Allow system to access specific information?
3. Select Yes to Continue.
4. Is there anything else you would like to do?

SPECIFIC USER INTERFACE REQUIREMENTS
1. Access to System’s Dashboard
2. Request Forms/Entry Forms
3. System Search

LOCATION TRACKER

ACTORS
User (Drivers, Pedestrians/Road Users)
System

PRE-CONDITION
System will ask for User’s approval to access his/her location.
User will open the phone's location.

POST-CONDITION
System will read user’s location information.
User will be updated with location related information.

NON-FUNCTIONAL REQUIREMENTS
1. Performance
2. Reliability
3. Scalability
4. Security

EXCEPTION, ERROR SITUATION
1. Location cannot be found.
2. Phone's location is not turned on.
3. System cannot read the user's location data.

DIALOGS / SCENARIO
1. Turn on phone's location?
2. Allow application to access your location?

SPECIFIC USER INTERFACE REQUIREMENTS
1. Real-Time Location Display
2. Map Interaction
3. Location History/Tracking
4. Location Permission
5. Alerts and Notifications

SENSOR DATA

ACTORS

System
User (Drivers, Pedestrians/Road Users)

PRE-CONDITION

System will detect people and vehicles from the road through built sensors and its cameras.

POST-CONDITION

System will update users with sensor gained data.
Users will be able to see the current road situation.

NON-FUNCTIONAL REQUIREMENTS
1. Performance
2. Latency
3. Reliability
4. Scalability

EXCEPTION, ERROR SITUATION
1. Miscalculation of data obtained from sensor.
2. Inability to detect additional vehicles and pedestrians.
3. Inaccurate relay of data.

DIALOGS / SCENARIO
1. User will ask for current traffic flow in specific location.

2. System will read current location's condition through activation of sensors.
3. System will share data gathered by sensor.
4. User will be informed.

SPECIFIC USER INTERFACE REQUIREMENTS

1. Real-Time Data Visualization
2. Data Filtering and Customization
3. Sensor Status Indication
4. Historical data Access
5. Alert Management and Notifications

MAP ACCESS

ACTORS

User (Drivers, Pedestrians/Road Users)
System

PRE-CONDITION

System will ask permission to access device's location.
System will ask the user to turn on location services.

POST-CONDITION

User will turn on location.
System's Map will be accessed.

NON-FUNCTIONAL REQUIREMENTS

1. Performance
2. Accuracy
3. Scalability
4. Usability

EXCEPTION, ERROR SITUATION

1. Location cannot be found.
2. Map cannot be loaded.
3. You are not eligible to access map.

DIALOGS / SCENARIO

1. Allow application to access device's location?
2. Turn on device location
3. Would you like to view map?
4. View Map Options.

SPECIFIC USER INTERFACE REQUIREMENTS

1. Responsive Map Controls
2. Current Location Indicator
3. Search and Location Lookup

AUTOMATED REQUESTS

ACTORS

System

PRE-CONDITION
System will read user-allowed fetched data from previous operations.

POST-CONDITION
System will perform required operations for expected user requests.

NON-FUNCTIONAL REQUIREMENTS
1. Reliability
2. Scalability
3. Performance
4. Logging and Traceability

EXCEPTION, ERROR SITUATION
1. Service Unavailable
2. Data not found
3. Too many requests being made at a time

DIALOGS / SCENARIO
System: Initiating automated requests to assess traffic flow in a specific area.
System: Requesting information in a specific area.
Traffic data successfully retrieved.
System: Processing and saving traffic data for future analysis.
System: Data saved successfully. Next request scheduled in 15 minutes.

SPECIFIC USER INTERFACE REQUIREMENTS
1. Real-Time Status
2. Error and Entry Mechanism
3. Scheduled Request Overview
4. System Alerts

SYSTEM MODIFICATION

ACTORS
System
Admin

PRE-CONDITION
System will authorize the admin's request to modify.
System will provide the panel for modification.

POST-CONDITION
The admin will run through the system’s current condition.
Admin will configure the system.

NON-FUNCTIONAL REQUIREMENTS
1. Security
2. Performance
3. Usability
4. Scalability
5. Fast Updation

EXCEPTION, ERROR SITUATION
1. Admin unauthorized
2. System timed out
3. System settings could not be updated

DIALOGS / SCENARIO
1. Enter admin account information.
2. Admin request accepted.
3. What would you like to do?

Admin: Request to update system's sensor reading.
Admin: Install new devices added.
System: Accepts and reads new device data.
System: System Updated.

Admin: Request to change system's dashboard
System: Accepts and Updates Admin according to admin's request
System: System Updated

SPECIFIC USER INTERFACE REQUIREMENTS
1. Clear Navigation and Menu Structure
2. Confirmation and Validation
3. Real-Time Feedback
4. System Change History
5. Error Handling

ACCESS TO USER AND SYSTEM DATA

ACTORS
Admin
System

PRE-CONDITION
System will first ask for the admin's email and password.
System will authorize the admin's request for access.

POST-CONDITION
The admin will gain access to the system.
The system will provide user data to the admin.

NON-FUNCTIONAL REQUIREMENTS
1. Security
2. Data Integrity
3. Performance
4. Compliance
5. Auditability

EXCEPTION, ERROR SITUATION
1. Admin account not found.
2. Request for access denied.
3. Requested user not found.
4. System updates cannot be loaded.
5. Error in loading user and system information.

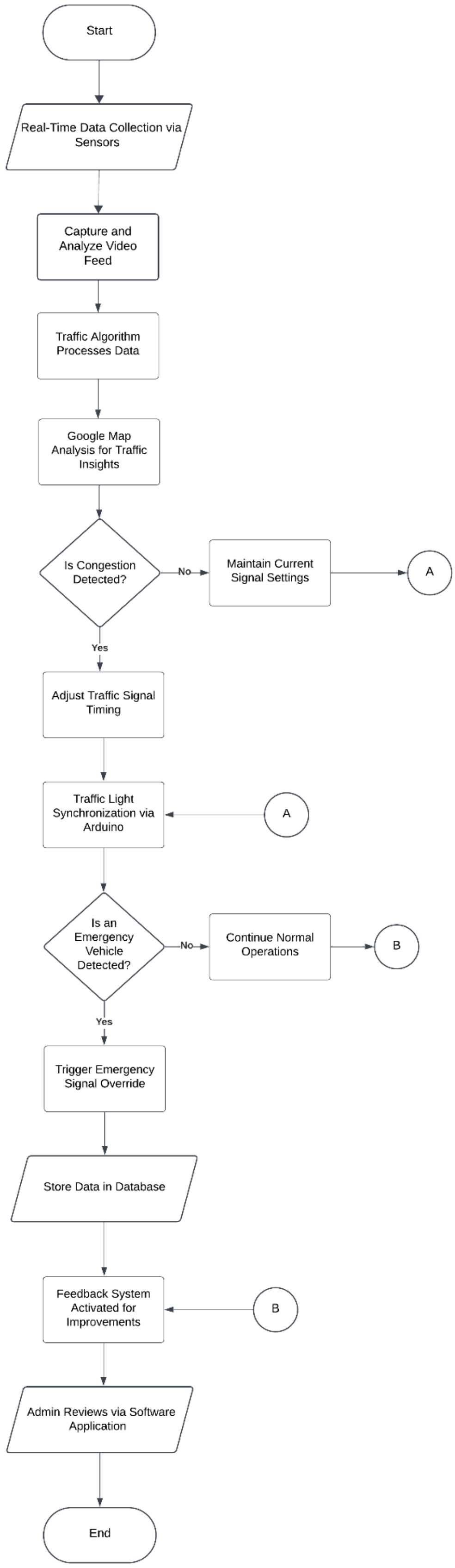
DIALOGS / SCENARIO

1. Enter admin account information.
2. Admin request accepted.
3. What would you like to do?
4. Admin: initiate modification request
5. System: Modification request accepted and added
6. System: System Updated
7. Admin: Request user’s data
8. System: Provide user data
9. Admin: Modify user data
10. System: Update user’s data in system

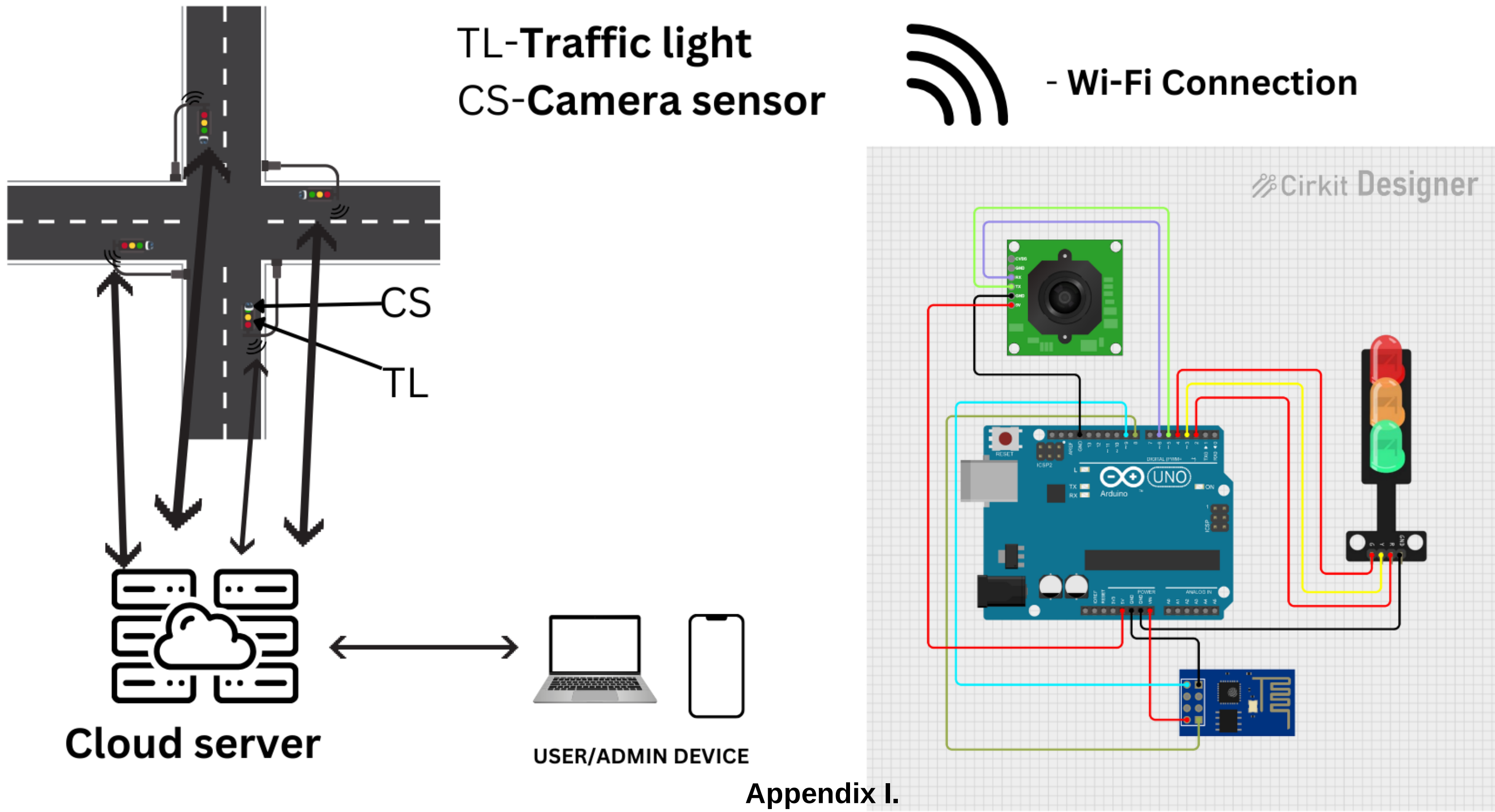
SPECIFIC USER INTERFACE REQUIREMENTS

1. Data Filtering and Sorting
2. Data Integrity
3. Audit and Compliance
4. Security
5. Performance Metrics
6. Backup and Recovery
7. Data Anonymization or Redaction

Appendix G. Used Case Description.



Appendix H. Flowchart.



Appendix I. Architectural Design.

REFERENCES

Akhtar, M., & Moridpour, S. (2021). A review of traffic congestion prediction using Artificial Intelligence. Journal of Advanced Transportation, 2021, 1–18. https://doi.org/10.1155/2021/8878011

Almuraykhi, K. M., & Akhlaq, M. (2019). STLS: Smart Traffic Lights System for Emergency Response Vehicles. *2019 International Conference on Computer and Information Sciences (ICCIS)*, 1–6. https://doi.org/10.1109/iccisci.2019.8716429

Aydinan, J. J. B. (2020). TRAFFIC CONGESTION SITUATION IN THE TRICYCLE CAPITAL OF THE PHILIPPINES: ITS CAUSES AND EFFECTS. *International Journal in Management and Social Science*, *08*(12).

Banzi, M., & Shiloh, M. (2022). *Getting Started With Arduino: The Open Source Electronics Prototyping Platform* (4th ed.). Dale Dougherty.

Bugabuga, H., & Puyo, J. (2024). Exploring the Potential of Artificial Intelligence in enhancing Driver Education and Road Safety in the Philippines. International Journal for Multidisciplinary Research (IJFMR), E-ISSN: 2582-2160.

Buniel, G. G., & Tantoy, C. P. (2024). SURATSA: Implementation of Surigao Real-Time Adaptive Traffic Signal Algorithm (RATSA) for traffic management in Barangay Luna, Surigao City, Philippines. International Journal of Research and Scientific Innovation, XI(VIII), 342–357. https://doi.org/10.51244/ijrsi.2024.1108029

Cirsostomo, A. B. C., Fidelino, J. I. R., Landicho, D. K. D., Pareja, J. E. E., del Rosario, J. R. B., & Bandala, A. A. (2023, November). Development of a CNN-based Intelligent Traffic Control System for Emergency Vehicle Detection and Intersectional Traffic Flow. In 2023 IEEE 15th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1-5). IEEE.

Derrow-Pinion, A., She, J., Wong, D., Lange, O., Hester, T., Perez, L., ... & Velickovic, P. (2021, October). *Eta prediction with graph neural networks in google maps*. In Proceedings of the 30th ACM international conference on information & knowledge management (pp. 3767-3776).

Dorokhin, S., Artemov, A., Likhachev, D., Novikov, A., & Starkov, E. (2020). Traffic simulation: an analytical review. *IOP Conference Series Materials Science and Engineering*, *918*(1), 012058. https://doi.org/10.1088/1757-899x/918/1/012058

GeeksforGeeks. (2023, March 30). *Software prototyping model and phases*. GeeksforGeeks. https://www.geeksforgeeks.org/software-prototyping-model-and-phases/

Gumasing, M. J. J., Prasetyo, Y. T., Cardoso, M. M., Freitas, J. S., Nadlifatin, R., & Chuenyindee, T. (2023). Determining the ergonomic risk factors affecting the musculoskeletal disorders of traffic enforcers in Manila City, Philippines. *Work*, *75*(2), 603–614. https://doi.org/10.3233/wor-220011

Hilmani, A., Maizate, A., & Hassouni, L. (2020). Automated Real-Time Intelligent Traffic Control System for smart cities using wireless sensor networks. *Wireless*

Communications and Mobile Computing, *2020*, 1–28. https://doi.org/10.1155/2020/8841893

Inquirer, P. D. (2024, January 18). Manila currently holds the 'world's worst traffic in metro area' title. Asia News Network. https://asianews.network/manila-currently-holds-the-worlds-worst-traffic-in-metro-area-title/

Jangeed, D., Mohammad, I., & Patel, J. (2024). SENSOR BASED SMART TRAFFIC LIGHT CONTROL SYSTEM. *International Journal of Technical Research & Science*, *9*(Spl), 27–35. https://doi.org/10.30780/specialissue-iset-2024/022

Libnao, M., Misula, M., Andres, C., Mariñas, J., & Fabregas, A. (2023). Traffic incident prediction and classification system using naïve bayes algorithm. Procedia Computer Science, 227, 316–325. https://doi.org/10.1016/j.procs.2023.10.530

Masri, S., Ashqar, H., I., & Elhenawy, M. (2024, August 1). Leveraging Large Language models (LLMs) for traffic management at urban intersections: the case of mixed traffic scenarios. arXiv.org. https://arxiv.org/abs/2408.00948

Moreno, F. (2023). Traffic congestion and management in Zamboanga City, Philippines: The public transport commuters' point of view. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4519271

Niño, H., Mariñas, I.,Mariñas, A., & Ocay, A. (2024). Design and Development of Cross Capture Cam (3C): A Disaster and Traffic Management and Monitoring System using Image Detection of Urdaneta City*. International Journal of Computing Sciences Research*, *8*, 2781-2795. https://doi.org/10.25147/ijcsr.2017.001.1.183

Paradina, R. M., & Noroña, M. I. (2021, September). Applications and challenges of adopting Internet of Things (IoT) in reducing road traffic accidents. In *Second Asia Pacific International Conference on Industrial Engineering and Operations Management* (pp. 1210-1230).

Ravish, R., & Swamy, S. R. (2021). Intelligent Traffic Management: A review of challenges, solutions, and future perspectives. Transport and Telecommunication Journal, 22(2), 163–182. https://doi.org/10.2478/ttj-2021-0013

Regidor, J. R. F. (2013). Traffic congestion in Metro Manila: Is the UVVRP still effective? Philippine Engineering Journal, 34(1). http://journals.upd.edu.ph/index.php/pej/article/view/3799/3486

Sequera, M. S. (2019). Web Camera and Fuzzy Logic System Controlled Traffic Light System. *International Journal of Engineering and Techniques*, *5*(3). https://www.ijetjournal.org

Tomar, I., Sreedevi, I., & Pandey, N. (2022). State-of-Art Review of Traffic Light Synchronization for Intelligent Vehicles: Current status, challenges, and Emerging Trends. *Electronics*, *11*(3), 465. https://doi.org/10.3390/electronics11030465

Wang, X., Jerome, Z., Wang, Z., Zhang, C., Shen, S., Kumar, V. V., Bai, F., Krajewski, P., Deneau, D., Jawad, A., Jones, R., Piotrowicz, G., & Liu, H. X. (2024). Traffic light optimization with low penetration rate vehicle trajectory data. *Nature Communications*, *15*(1). https://doi.org/10.1038/s41467-024-45427-4