SMART TRAFFIC CONTROL SYSTEM

A Mini Project Report Submitted in the partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

In

DEPARTMENT OF COMPUTER SCIENCE ENGINNERING

By

Bala Aditya– 2320030043

Deepika Ketavarapu – 2320030328

Hansi Challagulla – 2320030331

Vivek Uppalapati– 2320030332

Akshara Budha - 2320030377

Under the Esteemed Guidance of

Dr. K. Swapnika

Koneru Lakshmaiah Education Foundation

(Deemed to be University estd. u/s. 3 of the UGC Act, 1956)

Off-Campus: Bachupally-Gandimaisamma Road, Bowrampet, Hyderabad, Telangana - 500 043.

Phone No: 7815926816, www.klh.edu.in

K L (Deemed to be) University

DEPARTMENT OF COMPUTER SCIENCE ENGINEERING

<u>Declaration</u>

The Mini Project Report entitled "**Smart Traffic Control System"** is a record of Bonafide work of **Bala Aditya – 2320030043, Deepika Ketavarapu – 2320030328, Hansi Challagulla – 2320030331,Vivek Uppalapati – 2320030332, Akshara Budha – 2320030377,** submitted in partial fulfillment for the award of B. Tech in Computer Science and Engineering to the K L University. The results embodied in this report have not been copied from any other departments/University/Institute.

Bala Aditya – 2320030043

Deepika Ketavarapu – 2320030328

Hansi Challagulla – 2320030331

Vivek Uppalapati – 2320030332

Akshara Budha – 2320030377

K L (Deemed to be) University

DEPARTMENT OF COMPUTER SCIENCE ENGINEERING

CERTIFICATE

This is certify that the mini project based report entitled "**Smart Traffic Control System"** is a bonafide work done and submitted by **Bala Aditya – 2320030043, Deepika Ketavarapu – 2320030328, Hansi Challagulla – 2320030331, Vivek Uppalapati – 2320030332, Akshara Budha – 2320030377** in partial fulfillment of the requirements for the award of the degree of **BACHELOR OF TECHNOLOGY** in Department of Computer Science Engineering, K L (Deemed to be University), during the academic year **2024-2025.**

Signature of the Supervisor

Signature of the HOD

Signature of the External Examiner

ACKNOWLEDGEMENT

The success in this project would not have been possible but for the timely help and guidance rendered by many people. Our wish to express my sincere thanks to all those who has assisted us in one way or the other for the completion of my project.

Our greatest appreciation to my guide, **Name of the AOOP faculty of respective section**, Department of Computer Science which cannot be expressed in words for his/her tremendous support, encouragement and guidance for this project.

We express our gratitude to **Dr. Ramesh Babu Sir (CSE)/Dr. Kaja Shareef Sir (CSIT)**, Head of the *Department for Computer Science Engineering/ Department for Computer Science and Information Technology* for providing us with adequate facilities, ways and means by which we are able to complete this project-based Lab.

We thank all the members of teaching and non-teaching staff members, and also who have assisted me directly or indirectly for successful completion of this project. Finally, I sincerely thank my parents, friends and classmates for their kind help and cooperation during my work.

Bala Aditya – 2320030043

Deepika Ketavarapu – 2320030328

Hansi Challagulla – 2320030331

Vivek Uppalapati – 2320030332

Akshara Budha – 2320030377

TABLE OF CONTENTS

1.ABSTRACT

The development of an intelligent traffic light control system based on real-time vehicle density aims to optimize traffic flow and reduce congestion at intersections. This system utilizes sensor-based or computer vision techniques to detect and analyze the density of vehicles on multiple roads converging at a junction. The road with the highest vehicle density is dynamically allocated the green light, while the other roads receive red or orange signals accordingly. In cases where two or more roads have equal density, the system follows a predefined cyclic pattern based on time intervals to ensure fair and systematic traffic management. The system integrates microcontrollers, IoT sensors, and AI-driven algorithms to make real-time decisions, improving efficiency and minimizing unnecessary waiting times. By prioritizing roads with higher density and adapting to dynamic traffic conditions, this smart traffic light system enhances urban mobility, reduces fuel consumption, and mitigates environmental impact.

Team Name:

Team IntelliTraffic

Team Members:

1. 2320030043 Bala Aditya
2. 2320030328 Deepika Ketavarapu
3. 2320030331 Hansi Challagulla
4. 2320030332 Vivek Uppalapati
5. 2320030377 Akshara Budha

2.INTRODUCTION

Traffic congestion is a critical issue faced by cities worldwide, resulting in economic losses, environmental degradation, and safety hazards. As urban populations continue to grow, the demand for efficient transportation systems becomes increasingly urgent. Traditional traffic management systems, which often rely on fixed signal timings, are ill-equipped to handle the dynamic nature of modern traffic. These systems fail to account for variations in traffic volume throughout the day, leading to inefficient traffic flow and increased waiting times at intersections. The introduction of smart technologies, particularly artificial intelligence, offers a promising solution to these challenges. AI can analyze vast amounts of data in real-time, enabling traffic signals to adapt to current conditions rather than relying on predetermined schedules. This project aims to develop a Smart Traffic Light Controlling System that utilizes AI to optimize traffic signal timings based on real-time traffic data. By implementing this system, we seek to reduce congestion, improve travel times, and enhance road safety. The project will explore various AI algorithms and their effectiveness in managing traffic signals, as well as the integration of hardware components such as sensors and cameras. Additionally, the project will engage with stakeholders, including city planners and traffic management authorities, to ensure that the system meets the needs of the community. The goal is to create a flexible and efficient traffic management solution that can be implemented in urban areas to improve the overall transportation experience for all road users.

3. LITERATURE SURVEY

The literature on traffic management systems reveals a diverse array of approaches aimed at alleviating congestion and improving road safety. Traditional traffic control methods, such as fixed-time and actuated signal systems, have been widely used but fall short in adapting to real-time traffic fluctuations.

Recent projects have moved toward adaptive signal systems, which use cameras or pressure sensors to adjust green/red timings based on vehicle presence. However, many such systems lack the intelligence or prediction capability offered by AI.

Indian Smart City Mission – Bhopal & Pune

Implemented smart traffic lights integrated with surveillance cameras.

Uses sensor-based signals but lacks true AI adaptability.

SMART-SIGNAL (University of Minnesota)

Monitors real-time traffic data using roadside sensors.

Focuses on performance evaluation and signal optimization.

Not AI-driven, but data-centric.

4. Problem/Opportunity Domain

Domain of Interest: Intelligent Transportation Systems (ITS)

Description of the Domain: The domain selected is **Intelligent Transportation Systems (ITS)**, specifically focused on **Smart Traffic Management using AI**. ITS involves integrating advanced technology, including artificial intelligence and real-time data analytics, to optimize traffic signal timings, reduce congestion, and enhance road safety. It addresses urban mobility challenges by dynamically managing traffic flow based on living conditions rather than relying on static, predetermined signal schedules.

Why did you choose this domain?

We chose this domain driven by our passion for solving traffic congestion problems, our keen interest in artificial intelligence applications, and our commitment to addressing real-world transportation challenges. Specifically, personal experiences heavily influenced our choice—for instance, commuting home typically takes around 30 minutes, but severe congestion at the **Allwyn Signal** intersection can alone cause delays exceeding 20 minutes. During peak hours, vehicle queues extend up to a kilometer, highlighting the urgent need for intelligent, adaptive traffic management solutions.

Problem/Opportunity Statement

Problem Statement: Traditional traffic light systems follow fixed timers, causing unnecessary delays, congestion, and emergency response setbacks. This leads to increased fuel consumption, pollution, and commuter frustration. The proposed Smart Traffic Light System uses AI and IoT sensors to dynamically adjust signals based on real-time vehicle density. This ensures smoother traffic flow, prioritizes emergency vehicles, and reduces environmental impact, creating a more efficient and safer urban transport system.

Problem Description: Severe traffic congestion at busy urban intersections, particularly at junctions like the Allwyn Signal, results in prolonged waiting times, substantial fuel wastage, and heightened risks of accidents. Traditional traffic lights with fixed timings cannot adapt to the fluctuating traffic density during peak hours, leading to vehicle queues extending over a kilometer, thereby significantly disrupting daily commutes. Unnecessary green signal for roads that have no vehicles at all, and the other vehicles would have to wai for 2-3 minutes straight.

Context: This problem primarily occurs during peak commuting hours, such as morning and evening rush periods, when traffic density is significantly higher. For example, at intersections like the Allwyn Signal, traffic often lines up for over a kilometer, causing regular delays exceeding 20 minutes at the signal alone. These situations highlight the inability of traditional, fixed-timing traffic signals to adapt effectively to real-time traffic conditions.

Alternatives: Currently, commuters and city authorities use traditional solutions like fixed-time traffic signals, manual traffic police intervention, and mobile navigation apps (e.g., Google Maps) to manage congestion. Some cities invest in expanding road infrastructure or optimizing fixed signal timings based on historical traffic patterns. However, these approaches often fail to address real-time fluctuations effectively and provide limited relief during peak congestion periods.

Customers: Citizens of Hyderabad or anyone who has the same problem as ours.

Emotional Impact: The customers will have to wait for a bit until it is their time to move. A little patience would save a lot of time and help everyone around. It would also help everything around them develop faster for a happy and free future.

Quantifiable Impact:

- **Time Savings** – Reduces average parking search time by up to **60%**, allowing users to find slots quickly and efficiently.
- **Fuel Efficiency** – Lowers unnecessary fuel consumption by minimizing aimless driving, potentially saving **0.5–1 liter** of fuel per user daily.
- **Increased Slot Utilization** – Improves usage of available parking spaces by up to **30%** through real-time updates and smart allocation.

Alternative Shortcomings:

- **Manual Systems Are Time-Consuming** – Traditional methods rely on human attendants, causing delays and inefficiencies during peak hours.
- **No Real-Time Availability** – Existing alternatives often don't update in real time, leading to users arriving at already-occupied spots.
- **Poor Resource Management** – Without automation, parking spaces are often underutilized or misallocated, resulting in congestion and user frustration.

Any Video or Images to showcase the problem:

Addressing SDGs

Relevant Sustainable Development Goals (SDGs): 9

How does your problem/opportunity address these SDGs?

The development of an **intelligent traffic light control system** based on real-time vehicle density significantly contributes to multiple **Sustainable Development Goals (SDGs)** by improving urban mobility, reducing environmental impact, and enhancing public well-being.

1. SDG 9 – Industry, Innovation, and Infrastructure

By integrating **IoT sensors, AI-driven algorithms, and real-time traffic data**, this system modernizes **urban infrastructure** and enhances **transport efficiency**. The use of **automated traffic management** reduces congestion and improves road capacity, contributing to **smart city development**.

5. STAKEHOLDERS’ MEETINGS

1. **Who are the key stakeholders involved in or affected by this project?**

- Government & Traffic Authorities – Approve and fund the project.
- Traffic Management Departments – Oversee deployment and maintenance.
- Engineers & Tech Developers – Build and implement the system.
- Drivers & Commuters – Benefit from improved traffic flow.
- Law Enforcement & Emergency Services – Ensure safety and priority access.
- Local Businesses & Residents – Affected by traffic changes.
- Environmental Agencies – Monitor the impact on emissions.

2. **What roles do the stakeholders play in the success of the innovation?**

- Government & Traffic Authorities make the big decisions on funding and policies.
- Engineers & Developers bring the idea to life.
- Traffic Management ensures it runs smoothly.
- Drivers & Businesses provide real-world feedback.
- Law Enforcement & Emergency Services ensure it works safely.

3. **What are the main interests and concerns of each stakeholder?**

- Authorities & Traffic Departments want efficiency and cost-effectiveness.
- Engineers focus on tech reliability.
- Drivers want less waiting time.
- Businesses worry about road accessibility.
- Emergency Services need priority passage.
- Environmental Groups want lower emissions.

4. **How much influence does each stakeholder have on the outcome of the project?**

- High: Government, traffic authorities, engineers.
- Medium: Emergency services, law enforcement, environmental agencies.
- Low to Medium: Businesses, residents, and daily commuters.

5. **What is the level of engagement or support expected from each stakeholder?**

- Very engaged: Government, traffic departments, engineers.
- Moderately engaged: Law enforcement, emergency services, environmental groups.
- Less engaged but informed: Drivers, businesses, and residents.

6. **Are there any conflicts of interest between stakeholders? If so, how can they be addressed?**

- Yes. Drivers want faster commutes, but businesses fear traffic pattern changes.
- Solution: Pilot testing and public feedback before full rollout.
- Emergency services need priority, which may disrupt flow.
- Solution: Integrate an emergency override system.

7. **How will you communicate and collaborate with stakeholders throughout the project?**

- Regular updates for key stakeholders.
- Public awareness campaigns to inform drivers.
- Online feedback systems for businesses and commuters.
- Pilot programs to test and refine the system before full implementation.

8. **What potential risks do stakeholders bring to the project, and how can these be mitigated?**

- Delays in funding/approval – Engage authorities early.
- Technical failures – Run extensive tests.
- Public resistance – Educate on benefits and gather feedback.
- Law enforcement concerns – Involve them in planning.

Meeting Schedule and Reports:

1. First Meeting: Government & Traffic Authority Official

Geotag photo

Questions asked:

1.What are the key challenges in managing traffic congestion in the city?

2. How does the government currently prioritize traffic flow at intersections?

3. What regulations or approvals are needed for implementing a smart traffic system?

4. What are the expectations from this system in terms of efficiency and safety?

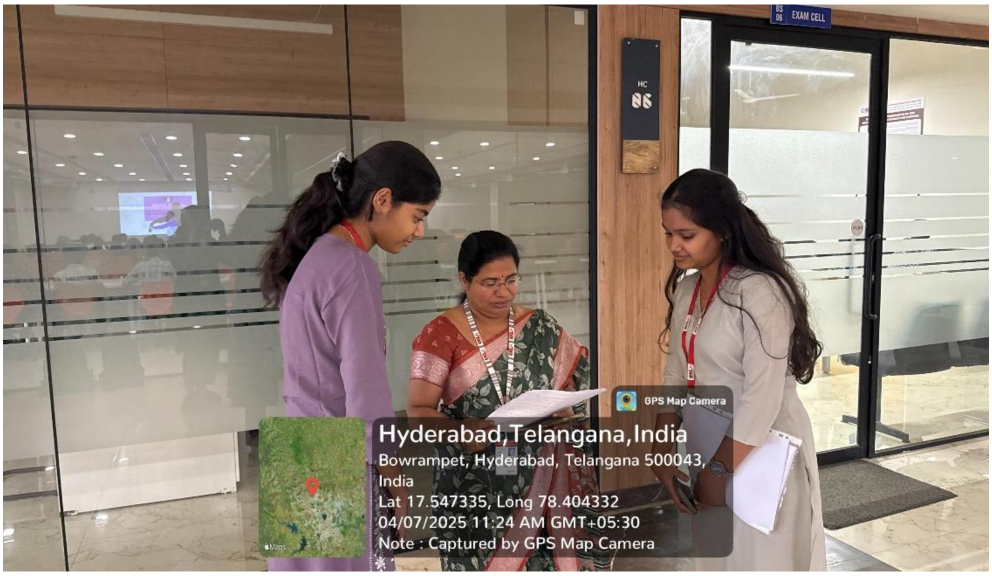
5. How can we ensure smooth collaboration between different city departments for this project?

Summary:

The official highlighted that traffic congestion is a major issue, especially during peak hours. Current traffic signals follow fixed timers, which do not adapt to real-time vehicle density. Government approvals will be necessary, including safety and environmental assessments. The primary expectation is reduced congestion and improved road safety. Collaboration between city departments and law enforcement will be key to successful implementation.

2. Second Meeting: Engineers & Technology Providers

Geotag photo



Questions asked:

1. What are the best technologies to detect vehicle density in real time?

2. How will the system integrate with existing traffic infrastructure?

3. What are the biggest technical challenges in implementing this system?

4. How can we ensure minimal downtime and maintenance requirements?

5. What security measures should be in place to prevent system tampering or failures?

Summary:

Engineers recommended using AI-powered cameras and IoT sensors for real-time vehicle detection. Integration with current infrastructure is possible but may require hardware upgrades. The main challenge is ensuring system accuracy in different weather conditions. Regular maintenance and cloud-based monitoring can reduce downtime. Cybersecurity measures like encryption and access control are essential to prevent hacking or unauthorized changes.

3. Third Meeting: Law Enforcement & Emergency Services

Geotag photo

Questions asked:

1. What are the major traffic-related issues faced by law enforcement?

2. How can this system assist emergency vehicles in reaching destinations faster?

3. What concerns do you have regarding automated traffic control?

4. How can we integrate emergency overrides without disrupting normal traffic flow?

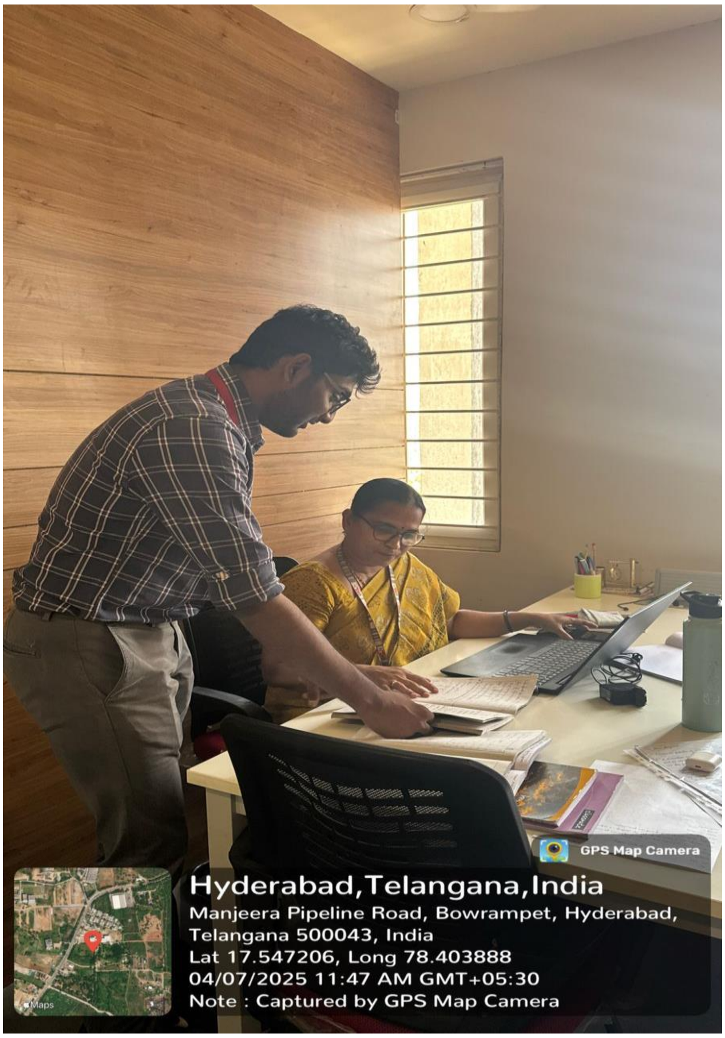
5. What training or preparation will officers need for this system?

Summary:

Law enforcement officials stated that congestion delays emergency response times. They support a system that prioritizes ambulances and fire trucks. However, they are concerned about possible malfunctions or hacking risks. A manual override feature for emergency services would be essential. Officers may need training on how the system operates and how to handle traffic adjustments.

4.Fourth Meeting: Local Businesses & Residents

Geotag photo



Questions asked:

1. How does current traffic congestion impact businesses and daily life?

2. What are your concerns about a new automated traffic system?

3. Would you support this system if it reduced traffic congestion in your area?

4. How can we ensure that local businesses are not negatively affected?

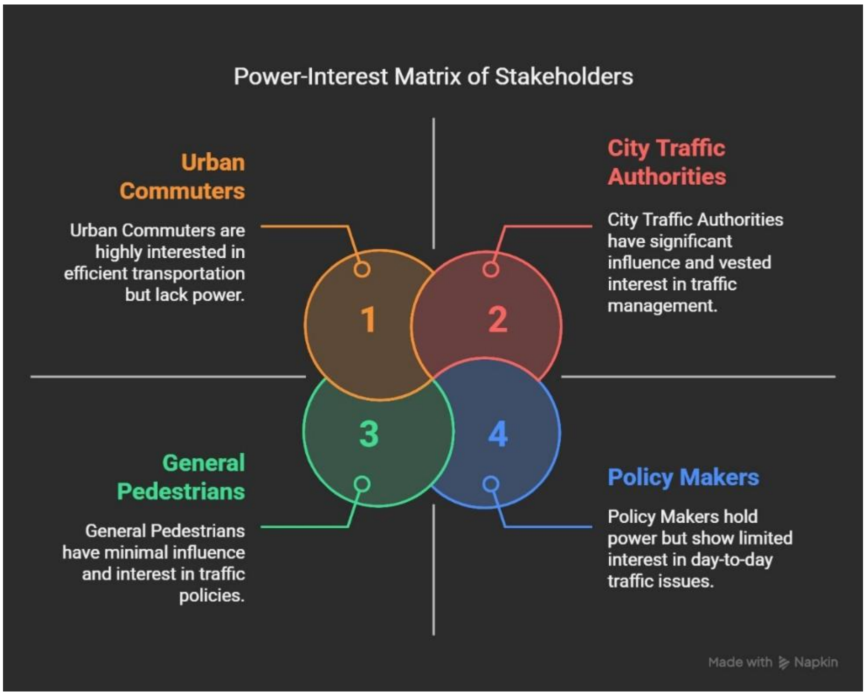
5. What feedback or suggestions do you have for improving this system?

Summary:

Business owners and residents complained that traffic congestion affects deliveries and customer access. Some are worried that changes to traffic flow might reduce foot traffic. However, most support the idea if it leads to smoother commutes. They suggested allowing community feedback during pilot testing to ensure adjustments are made based on real-world experience.

Power Interest Matrix of Stakeholders

Power Interest Matrix:



- High Power, High Interest: City Traffic Authorities, Government Agencies
- High Power, Low Interest: Policy Makers, Urban Development Organizations
- Low Power, High Interest: Urban Commuters, Public Transportation Users
- Low Power, Low Interest: General Pedestrians, Occasional Road Users

Empathetic Interviews

Conduct Skilled interview with at least 30 citizens/Users by asking open ended questions (What, why/How etc) and list the insights as per the format below

I need to know (thoughts, feelings, actions)	Questions I will ask (open questions)	Insights I hope to gain

Thoughts	What do you think about the current traffic light system?	Understanding whether people find current traffic signals efficient or problematic.
Thoughts	How do you believe technology can improve traffic management?	Gaining insights into public perception of AI and IoT-based traffic solutions.
Feelings	How do you feel when you are stuck at a red light with no cross traffic?	Identifying frustration levels and emotional responses to inefficient signals.
Feelings	What concerns do you have about using AI-based traffic control?	Understanding fears about reliability, fairness, and safety of automated systems.
actions	What do you usually do when you are stuck in heavy traffic?	Learning about driver behavior, such as finding alternative routes or breaking signals.
actions	How do you think traffic congestion can be reduced in your city?	Gathering potential user-driven solutions and ideas for improvement.

SKILLED INTERVIEW REPORT

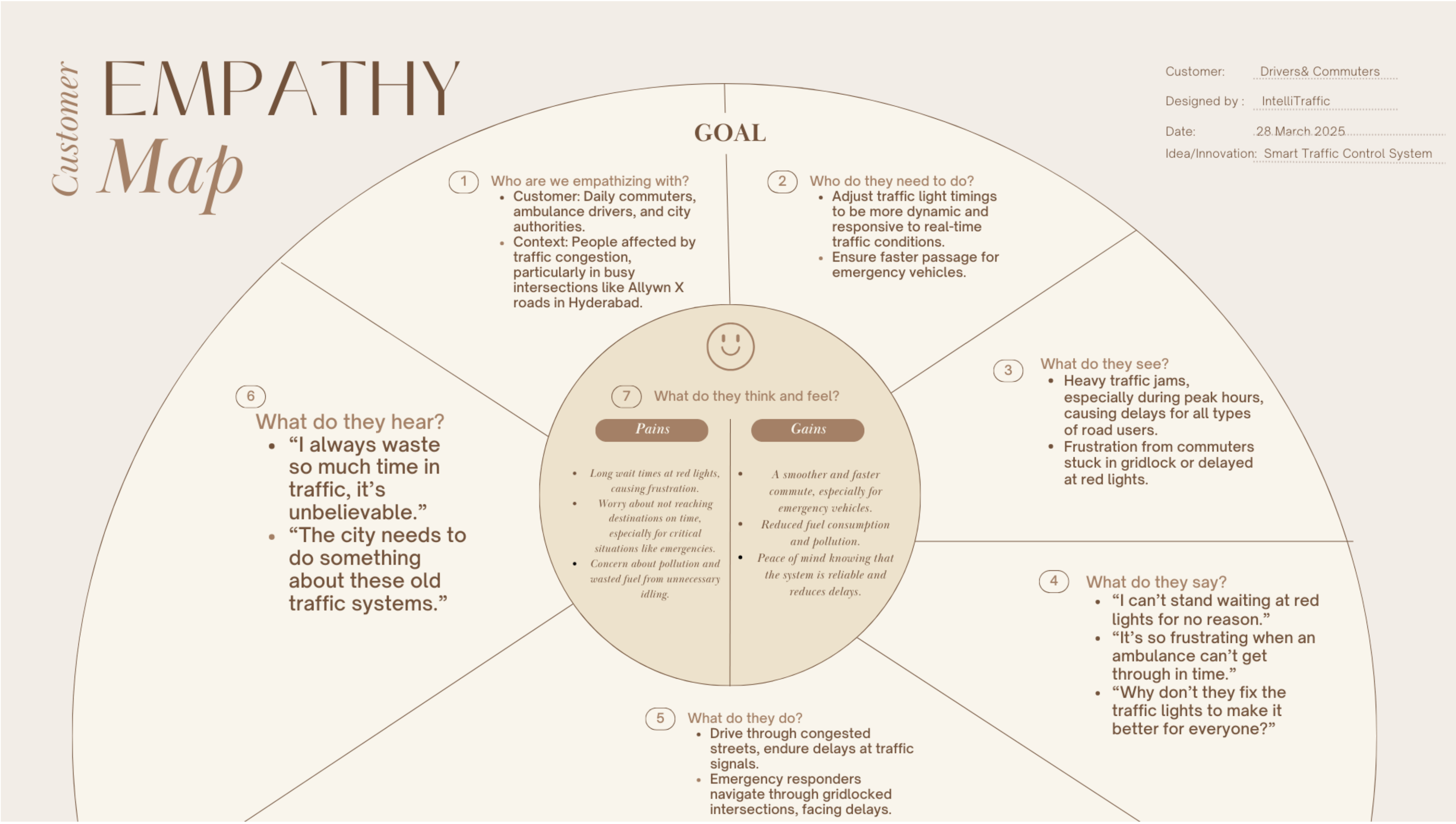
User/Interviewee	**Questions Asked**	**Insights gained (NOT THEIR ANSWERS)**
Rahul, Daily Commuter	How do you feel about the current traffic signal system?	Many commuters find fixed-timer traffic lights inefficient and frustrating, especially when roads are empty.
Priyadarshini, Traffic Police Officer	What challenges do you face in managing traffic manually?	Traffic officers struggle with congestion, especially during peak hours, and often manually override signals.

Arjun, City Planner	How do you think smart technology can improve traffic flow?	Urban planners believe AI-based signals could reduce congestion, but funding and infrastructure integration are concerns.
Sneha, student	What impact do traffic jams have on the environment?	High fuel consumption due to idling at traffic signals contributes significantly to pollution and carbon emissions.

Key Insights Gained:

- Commuters are frustrated with inefficient traffic signals that cause unnecessary waiting.
- Traffic police manually adjust signals to manage congestion, indicating the need for automation.
- City planners support AI-driven systems but are concerned about implementation challenges.
- Traffic congestion contributes heavily to pollution, making smart traffic lights an eco-friendly solution.

Empathy Map


Customer
EMPATHY
Map
Customer: Drivers& Commuters
Designed by : IntelliTraffic
Date: 28 March 2025
Idea/Innovation: Smart Traffic Control System
GOAL
1 Who are we empathizing with?
• Customer: Daily commuters, ambulance drivers, and city authorities.
• Context: People affected by traffic congestion, particularly in busy intersections like Allywn X roads in Hyderabad.
2 Who do they need to do?
• Adjust traffic light timings to be more dynamic and responsive to real-time traffic conditions.
• Ensure faster passage for emergency vehicles.
3 What do they see?
• Heavy traffic jams, especially during peak hours, causing delays for all types of road users.
• Frustration from commuters stuck in gridlock or delayed at red lights.
4 What do they say?
• "I can't stand waiting at red lights for no reason."
• "It's so frustrating when an ambulance can't get through in time."
• "Why don't they fix the traffic lights to make it better for everyone?"
5 What do they do?
• Drive through congested streets, endure delays at traffic signals.
• Emergency responders navigate through gridlocked intersections, facing delays.
6 What do they hear?
• "I always waste so much time in traffic, it's unbelievable."
• "The city needs to do something about these old traffic systems."
7 What do they think and feel?
Pains
• Long wait times at red lights, causing frustration.
• Worry about not reaching destinations on time, especially for critical situations like emergencies.
• Concern about pollution and wasted fuel from unnecessary idling.
Gains
• A smoother and faster commute, especially for emergency vehicles.
• Reduced fuel consumption and pollution.
• Peace of mind knowing that the system is reliable and reduces delays.

a. Who is your Customer?

Our primary customers are urban commuters, traffic authorities, and city planners. These include daily drivers, public transport users, and logistics companies that struggle with traffic congestion. Their main goal is to experience smoother, faster, and more efficient traffic flow while minimizing fuel consumption and emissions.

b. Who are we empathizing with?

We are empathizing with daily commuters, taxi drivers, transport companies, and traffic management officials who deal with inefficient traffic signals every day. Their biggest challenge is long waiting times at signals, unpredictable traffic conditions, and fuel inefficiency. They need a system that dynamically adapts to real-time vehicle density to reduce unnecessary delays and improve traffic movement.

c. What do they need to DO?

Commuters need to reach their destinations faster without being stuck in unnecessary traffic jams. Traffic authorities need to optimize the flow of vehicles and ensure safety on the roads. City planners must find ways to integrate smart traffic technology with existing urban infrastructure while considering future expansion.

d. What do they SEE?

They constantly witness long queues of vehicles at signals, waiting even when there is no cross traffic. Drivers see others breaking signals out of frustration and often experience gridlock during peak hours. They also observe alternative solutions like manual traffic control by police officers and smart city projects in other countries that use AI-driven traffic management.

e. What do they SAY?

Many people express frustration about inefficient traffic signals, questioning why they have to wait when there's no traffic on the other side. Drivers and commuters often say that traffic signals should be adaptive instead of running on fixed timers. Traffic authorities discuss the need for better technology to reduce congestion and improve urban mobility.

f. What do they DO?

To cope with traffic, drivers frequently search for alternate routes using navigation apps, and some even break signals when the roads appear empty. Traffic police sometimes override signals manually during peak hours to reduce congestion. City planners explore smart city innovations but often struggle with budget and implementation challenges.

g. What do they HEAR?

They hear complaints from fellow commuters about unnecessary delays and how traffic congestion is worsening. Media reports constantly highlight increasing traffic problems in urban areas. Government bodies and smart city initiatives promote the idea of AI-driven traffic management, sparking interest among city planners and policymakers.

h. What do they THINK and FEEL?

Many drivers and commuters feel frustrated by the amount of time wasted at traffic signals. They worry about rising fuel costs, increasing pollution, and inefficient city planning. Their biggest desire is a system that makes real-time decisions to reduce waiting times and improve overall traffic flow.

i. Pains and Gains

The biggest pains include wasted time, increased fuel costs, unnecessary idling, stress, and inefficiencies in traffic management. On the other hand, the main gain would be an intelligent traffic system that adapts in real time, leading to less congestion, lower fuel consumption, and a better commuting experience.

Persona of Stakeholders

Stakeholder Name:

Urban Commuters, City Traffic Authorities, Emergency Responders

Demographics:

- Urban commuters: Working professionals and daily travelers aged 18-60 from metropolitan areas.
- City traffic authorities: Government officials managing urban transport infrastructure.
- Emergency responders: Paramedics, fire services, and law enforcement personnel requiring quick and unhindered passage.

Goals:

- Urban commuters seek reduced travel time and seamless traffic flow.
- City authorities aim to enhance road efficiency and safety while minimizing congestion.
- Emergency responders require adaptive signal systems that prioritize their movement.

Challenges:

- Urban commuters face prolonged waiting times and unpredictable congestion.
- City authorities struggle with inefficient traffic management due to static signaling systems.
- Emergency responders experience delays due to unoptimized traffic light sequences.

Aspiration:

- Urban commuters desire a smoother, stress-free travel experience.
- City authorities seek a smart city infrastructure with minimal congestion.
- Emergency responders want traffic systems that prioritize urgent situations automatically.

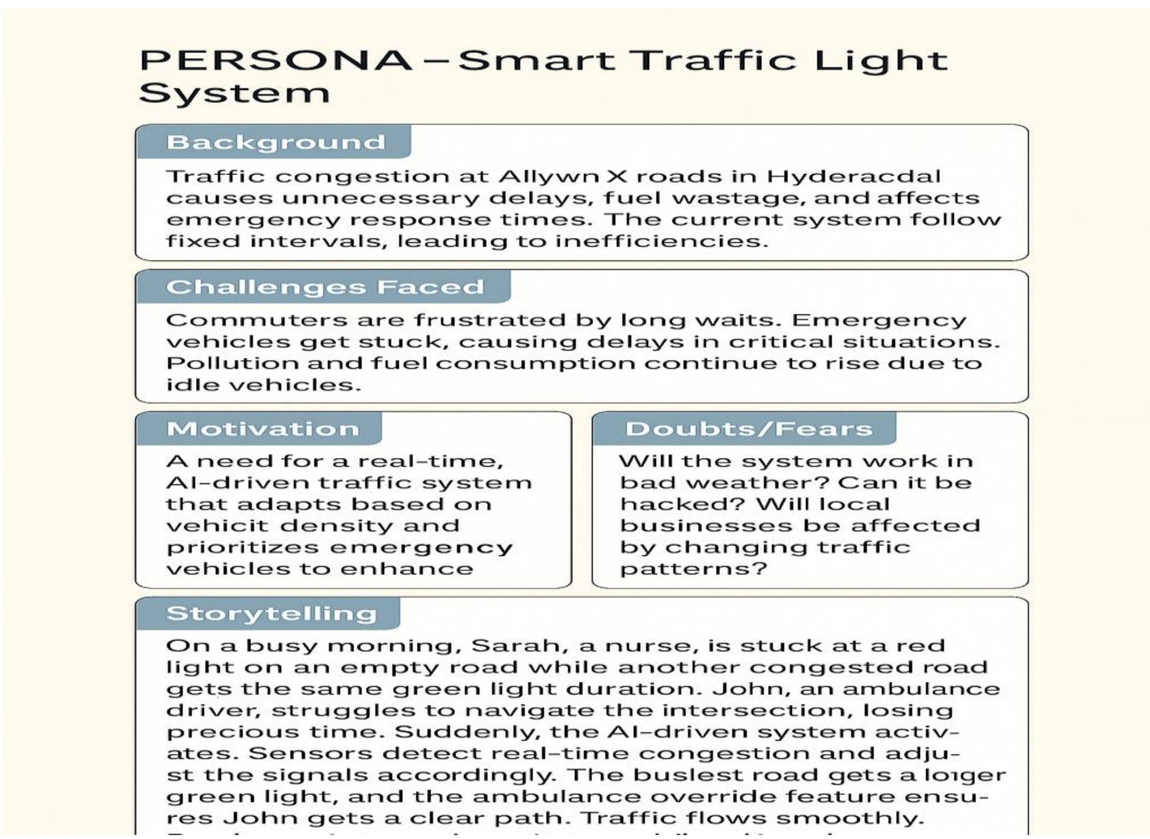
Needs:

- Real-time traffic data analysis to improve signal efficiency.
- AI-driven decision-making for dynamic adjustments.
- Reduced idling time to lower emissions and fuel consumption.

Pain Points:

- Traffic congestion leading to extended travel times.
- Inefficient traffic management causing unnecessary delays.
- Lack of emergency priority in conventional systems affecting response time.

Storytelling:



Common Themes, Behaviors, Needs, and Pain Points among the Users

Common Themes:

- Traffic Congestion Management: The need for a system that dynamically adjusts signal timings to reduce congestion.
- Efficiency and Adaptability: AI-driven real-time adjustments to improve traffic flow.
- Road Safety Enhancements: Prioritizing emergency vehicles and high-risk crossings.
- Environmental Sustainability: Reducing fuel wastage and emissions through optimized traffic flow.

Common Behaviors:

- Commuters experience long wait times at fixed-timing signals, leading to frustration and inefficiency.
- Drivers frequently idle in traffic, increasing fuel consumption and environmental impact.
- Emergency responders struggle to navigate congested roads due to unoptimized traffic light sequences.
- City authorities rely on outdated traffic management systems, causing inefficient traffic control.

Common Needs:

- A smart system that reduces travel time and wait times at signals.
- Real-time, AI-based adjustments to traffic lights based on vehicle density.
- Priority signaling for emergency vehicles to improve response times.
- Integration of IoT sensors and machine learning for accurate traffic predictions.

Common Pain Points:

- Fixed-time traffic lights lead to unnecessary delays and congestion.
- High fuel consumption due to prolonged idling at signals.
- Unoptimized pedestrian and emergency vehicle crossings increase safety risks.
- Lack of real-time adaptability in current traffic management systems.

Defining Needs and Insights of Users

User Needs:

- **Functional Needs:** Users require a system that reduces wait times, improves traffic flow, and adapts dynamically to real-time traffic conditions.
- **Emotional Needs:** Frustration due to long waiting times and unpredictable congestion needs to be alleviated by a more efficient traffic management system.
- **Societal Needs:** Reduced fuel consumption and emissions contribute to a more sustainable urban environment, benefiting the wider community.

User Insights:

- **Behavioral Observations:** Drivers experience significant delays at fixed-timing traffic lights, leading to increased travel times and fuel wastage.
- **Motivations:** Commuters prefer shorter travel times and smoother traffic movement, while city planners seek more efficient infrastructure solutions.
- **Pain Points:** Unpredictable congestion, excessive idling, and safety concerns at intersections frustrate both drivers and pedestrians, necessitating an intelligent solution.

POV Statements

PoV Statements	Role-based or Situation-Based	Benefit, Way to Benefit, Job TBD, Need (more/less)	PoV Questions (At least one per statement)
When I drive to work during peak hours, I want to avoid long waiting times at intersections so I can reach my office on time.	Situation	The intelligent traffic light system detects high vehicle density and dynamically adjusts green light durations, reducing congestion at busy intersections.	How can we design a system that prioritizes high-density roads without disrupting traffic flow? What AI algorithms can optimize real-time decision-making for traffic lights?
As an ambulance driver, I need a way to get through intersections quickly so I can reach patients and hospitals faster	Role-based	The smart system detects emergency vehicles via IoT sensors or GPS data, giving them priority by adjusting traffic signals in their favor.	How can the system differentiate between regular and emergency vehicles? What safeguards can prevent misuse of emergency prioritization?
When I drive home late at night, I don't want to stop unnecessarily at empty intersections so I can reach my destination faster.	Situation	Using real-time data, the system minimizes wait times for vehicles at low-traffic hours by dynamically switching lights when no cars are detected on cross streets.	What type of sensors can detect vehicles accurately in low-traffic scenarios? How can we ensure pedestrian safety while optimizing late-night traffic lights?

As an environmentalist, I want to reduce fuel consumption and emissions from idling vehicles at traffic lights to improve air quality.	Role-based	The AI-driven system reduces unnecessary waiting time, lowering fuel wastage and emissions from vehicles at intersections.	How can the system balance fuel efficiency with smooth traffic flow? What real-time data can be used to measure emission reductions?
As a bus driver, I want traffic signals to adapt to bus schedules so that I can reach stops on time and improve passenger satisfaction.	Role-based	The system prioritizes public transport vehicles by adjusting signal timing when a bus approaches an intersection, reducing delays and improving reliability.	How can the system integrate with public transport tracking for better coordination? What technology can help optimize bus routes and traffic light timing simultaneously?

Transforming Insights into Opportunities for Design

Task:

User Need/Insight	"How Might We" Question
Traffic congestion causes long commute times and frustration among drivers.	How might we optimize traffic signals in real-time to reduce congestion and improve travel efficiency?
Emergency vehicles often get stuck in traffic, delaying response times.	How might we create a smart traffic system that prioritizes emergency vehicles and reduces delays?
Pedestrians and cyclists feel unsafe due to inefficient traffic signal timing.	How might we design a traffic management system that improves safety and accessibility for pedestrians and cyclists?
Traditional traffic light systems do not adapt to fluctuating vehicle density.	How might we implement AI-driven traffic control to dynamically adjust signals based on real-time traffic patterns?
Drivers waste fuel and increase pollution due to unnecessary idling at traffic lights.	How might we develop a system that minimizes vehicle idling to reduce fuel consumption and lower emissions?

Crafting a Balanced and Actionable Design Challenge

Design Challenge: How might we develop an AI-driven intelligent traffic light system that dynamically adapts to real-time vehicle density, prioritizes emergency vehicles and pedestrians, and reduces congestion, fuel consumption, and emissions by at least 20% in urban areas?

Stakeholder/User Feedback:

Stakeholder/User	Role	Feedback on Problem Statement	Suggestions for Improvement
Traffic Management Authority	City Traffic Engineer	The issue of parking chaos in urban zones is well-known. A real-time solution is critical.	Consider integrating live data feeds from traffic signals or congestion APIs.
Local Government	Urban Planner	Absolutely relevant. Parking issues affect urban design and zoning efficiency.	Include scalability plans for expanding across multiple city zones.
Law Enforcement	Traffic Police Officer	Yes, improper parking often leads to traffic rule violations and chaos.	Add alerts or flagging mechanisms for illegal parking spots.

Drivers & Commuters	Daily Vehicle Users	Yes, we waste a lot of time circling around from lanes to lanes, especially during peak hours.	Add a mobile app for slot booking and real-time updates on availability.
Local Businesses & Residents	Shop Owners / Apartment Residents	Yes, unorganized parking blocks our driveways and reduces foot traffic to businesses.	Include features for reserved parking zones and time-limited access control.

Ideation

Ideation Process:

Idea Number	Proposed Solution	Key Features/Benefits	Challenges/Concerns
Idea 1	**AI-Based Adaptive Traffic Lights** – Use AI and real-time vehicle density data to control traffic lights dynamically.	-Reduces congestion and travel time. - Optimizes signal timing based on real-time traffic conditions. - Improves emergency vehicle response times.	-Requires high initial investment. - Potential integration issues with existing infrastructure. - Sensor accuracy may be affected by extreme weather
Idea 2	**IoT-Enabled Smart Traffic Sensors** – Install IoT sensors at intersections to detect vehicle flow and pedestrian movement.	- Provides real-time traffic monitoring. - Enhances road safety by prioritizing pedestrians. - Reduces fuel consumption and emissions.	- Data privacy concerns. - Requires continuous maintenance and calibration. - Risk of cyber threats to the system.
Idea 3	**Vehicle-to-Infrastructure (V2I) Communication** – Allow vehicles to communicate with traffic lights for smoother flow.	- Enables adaptive traffic light control based on approaching vehicle data. - Reduces waiting time at signals. - Supports autonomous vehicle integration.	- Requires widespread adoption of V2I technology. - Compatibility issues with older vehicles. - High infrastructure upgrade costs.
Idea 4	**Traffic Flow Prediction Using Machine Learning** – Predict congestion patterns	- Enhances proactive traffic management.	- Requires large datasets for accuracy.

	using historical and live traffic data.	- Reduces bottlenecks by adjusting traffic flow in advance. - Supports better urban planning.	- High computational power needed. - Unexpected events (accidents, weather) may impact predictions.
Idea 5	**Integration with Public Transport and Emergency Vehicles** – Give priority to buses and ambulances using GPS-based tracking.	- Reduces delays for public transport. - Improves emergency response times. - Encourages public transit use, reducing traffic congestion.	- Risk of system abuse if not properly regulated. - Need for coordination with multiple agencies. - Possible delays in signal adaptation.

Idea Evaluation

Evaluate the Idea based on 10/100/1000 grams

Idea	Impact (10/100/1000 grams)	Feasibility (10/100/1000 grams)	Alignment (10/100/1000 grams)	Total Weight
Idea 1	**1000**	**800**	**900**	**2700**
Idea 2	**900**	**700**	**850**	**2450**
Idea 3	**950**	**750**	**920**	**2620**
Idea 4	**850**	**650**	**890**	**2390**
Idea 5	**920**	**720**	**940**	**2580**

Solution Concept Form

---

1. Problem Statement:

Traditional traffic light systems follow fixed timers, causing unnecessary delays, congestion, and emergency response setbacks. This leads to increased fuel consumption, pollution, and commuter frustration. The proposed Smart Traffic Light System uses AI and IoT sensors to dynamically adjust signals based on real-time vehicle density. This ensures smoother traffic flow, prioritizes emergency vehicles, and reduces environmental impact, creating a more efficient and safer urban transport system.

---

2. Target Audience:

The main beneficiaries of the Smart Traffic Light System include daily commuters, who will experience reduced travel times and smoother traffic flow. Emergency services such as ambulances, fire trucks, and police will benefit from prioritized signals, ensuring faster response times. City authorities and traffic management departments will gain an efficient, data-driven solution for urban mobility. Additionally, local businesses will see improved accessibility, and environmental agencies will benefit from reduced emissions due to minimized vehicle idling.

---

3. Solution Overview:

The Smart Traffic Light System is an AI-powered solution that dynamically adjusts traffic signals based on real-time vehicle density. Using IoT sensors and AI-driven cameras, the system prioritizes roads with heavier traffic while ensuring smooth flow for emergency vehicles. In cases of equal density, it follows a systematic time-based approach. This technology reduces congestion, improves commute times, enhances road safety, and lowers emissions, making urban traffic management more efficient.

---

4. Key Features:

Feature	Description
Real-Time Traffic Detection	Uses AI-powered cameras and IoT sensors to monitor vehicle density and adjust traffic signals dynamically.

Feature	Description
Emergency Vehicle Priority	Automatically detects ambulances, fire trucks, and police vehicles, granting them immediate green light access to clear congestion.
Adaptive Signal Timing	Adjusts signal durations based on real-time traffic flow, reducing unnecessary waiting times and improving overall traffic efficiency.

5. Benefits:

Benefit	Description
Improved Traffic Flow	The system dynamically adjusts signal timings based on real-time traffic density, reducing congestion and ensuring smoother traffic movement.
Enhanced Emergency Response	By prioritizing emergency vehicles with green lights, the system ensures faster response times for ambulances, fire trucks, and police, saving lives and improving public safety.
Environmental Impact Reduction	By reducing vehicle idling and optimizing traffic flow, the system lowers fuel consumption and emissions, contributing to cleaner air and a more sustainable urban environment.

6.Unique Value Proposition (UVP):

The Smart Traffic Light System is unique because it combines real-time traffic detection and emergency vehicle prioritization to optimize traffic flow in an adaptive manner. Unlike traditional fixed-timer systems, it offers dynamic solutions that respond to actual road conditions, reducing congestion and ensuring faster emergency response. Its ability to cut emissions and improve safety will appeal to commuters, emergency services, and city authorities, creating a more efficient, sustainable, and user-friendly traffic management system.

---

7. Key Metrics:

Metric	Measurement
Traffic Flow Efficiency	Measure the reduction in congestion and average commute times at key intersections, comparing before and after implementation.
Emergency Response Time	Track the average time it takes for emergency vehicles to clear intersections with and without the priority system.

8. Feasibility Assessment:

The Smart Traffic Light System is highly achievable and practical, as it leverages existing technologies like IoT sensors and camera systems, which are already in use in many urban areas. Implementation requires moderate resources for installation and integration with current traffic infrastructure, but the technology is mature and scalable. The timeline for deployment can vary based on city size, but with proper planning, it can be implemented in phases, ensuring gradual adoption and minimal disruption.

9. Next Steps:

The next steps for developing the Smart Traffic Light System include conducting a pilot project in a select area to test real-time traffic detection and emergency vehicle prioritization. This will involve collaborating with local traffic management authorities for system integration and obtaining necessary approvals. Additionally, a comprehensive evaluation of the technology's performance will be done to refine the system before broader deployment. Following successful testing, scalability plans will be created for city-wide implementation.

6. HARDWARE AND SOFTWARE REQUIREMENTS

Hardware Requirements:

IoT Sensors – Detects vehicle density at intersections.

AI-Powered Cameras – Monitors and analyzes real-time traffic flow.

Traffic Signal Controllers – Adjusts signal timings based on data.

Emergency Vehicle Detectors – Prioritizes ambulances, fire trucks, and police vehicles.

Communication Modules (5G/Wi-Fi) – Transmits real-time traffic data.

Software Requirements:

Traffic Management Software – Controls and optimizes signal timing.

IoT Platform (AWS IoT, Google Cloud IoT, etc.) – Manages sensor data.

Data Analytics Tools – Monitors system performance and traffic trends.

Cybersecurity Protocols – Ensures data protection and prevents hacking.

Web/Mobile Interface – Allows authorities to monitor and manage traffic remotely.

7. IMPLEMENTATION

1. **Frontend:**

TrafficLight.css

```
.traffic-light {
   display: flex;
   flex-direction: column;
   align-items: center;
   justify-content: center;
   width: 100px;
   background: #222;
   padding: 15px;
   border-radius: 20px;
   margin: 15px;
   box-shadow: 0px 4px 10px rgba(0, 0, 0, 0.3);
 }

 .light {
   width: 50px;
   height: 50px;
   margin: 8px;
   border-radius: 50%;
   background: gray;
   transition: background 0.5s ease-in-out;
 }
```

```
.red.active {
  background: red;
  box-shadow: 0px 0px 15px red;
}
.orange.active {
  background: orange;
  box-shadow: 0px 0px 15px orange;
}

.green.active {
  background: green;
  box-shadow: 0px 0px 15px green;
}

.traffic-light-container {
  display: flex;
  justify-content: center;
  gap: 20px;
}

p {
  font-size: 18px;
  color: white;
  font-weight: bold;
}
```

TrafficLight.js

```
import React from "react";
import "./TrafficLight.css";

const TrafficLight = ({ direction, signal }) => {
  return (
    <div className="traffic-light">
      <div className={light red ${signal === "red" ? "active" : ""}}></div>
      <div className={light orange ${signal === "orange" ? "active" : ""}}></div>
      <div className={light green ${signal === "green" ? "active" : ""}}></div>
      <p>{direction.toUpperCase()}</p>
    </div>
  );
};
export default TrafficLight;
```

App.css

```
body {
font-family: "Times New Roman", serif;
background-color: white; /* White background */
color: black;
margin: 0;
display: flex;
justify-content: center;
align-items: center;
height: 100vh;
text-align: center;
}
h1 {
font-size: 2rem;
margin-bottom: 30px; /* Increased spacing below the main heading */
}
h2, h3 { margin-bottom: 20px; /* Adds spacing below subheadings */
}
.traffic-light-container {
display: flex;
justify-content: center;
align-items:center;
gap: 50px; /* More space between signals */
```

```
margin-top: 20px;
}
.controls { margin-bottom: 30px; /* More spacing before the inputs */
}
.density-inputs { display: flex;
 justify-content: center;
gap: 15px;
}
.density-row {
display: flex;
flex-direction: column;
align-items: center;
}
input {
padding: 8px;
font-size: 16px;
width: 60px;
text-align: center;
border: 1px solid #ccc;
border-radius: 5px;
margin-top: 10px; /* Space between label and input */
 }
```

App.js:

```
import React, { useState, useEffect } from "react";
          import TrafficLight from "./components/TrafficLight";

          import "./App.css";

          const App = () => {

            const [signal, setSignal] = useState("north"); // Default active direction

            const [densities, setDensities] = useState({ north: 1, south: 1, east: 1, west: 1 });

            const [lightStates, setLightStates] = useState({

              north: "red",

              south: "red",

              east: "red",

              west: "red",

            });


            useEffect(() => {

              const updateSignal = () => {

                // Determine highest density direction

                const maxDensityDirection = Object.keys(densities).reduce((a, b) =>

                  densities[a] > densities[b] ? a : b

                );


                if (signal !== maxDensityDirection) {

                  // Transition: Green → Orange (2s) → Red

                  setLightStates((prevState) => ({

                    ...prevState,

                    [signal]: "orange",

                  }));
```

```
      setTimeout(() => {
        setLightStates((prevState) => ({
        ...prevState,
          [signal]: "red",
        }));

        setTimeout(() => {
          setLightStates((prevState) => ({
            ...prevState,
            [maxDensityDirection]: "green",
          }));
          setSignal(maxDensityDirection);
        }, 500); // Small delay before next green
      }, 2000); // Orange light duration: 2 seconds
    }
  };

  updateSignal();
  const interval = setInterval(updateSignal, 5000);

  return () => clearInterval(interval);
}, [densities, signal]);

return (
  <div className="app">
    <h1>Smart Traffic Light System</h1>
```

```
      <div className="controls">
       <h2>Enter Vehicle Densities</h2>
       <div className="density-inputs">
        {Object.keys(densities).map((dir) => (
       <div key={dir} className="density-row">
          <label>{dir.toUpperCase()}:</label>
          <input
           type="number"
           min="1"
           value={densities[dir]}
           onChange={(e) =>
            setDensities({ ...densities, [dir]: parseInt(e.target.value) || 1 })
           }
          />
         </div>
        ))}
       </div>
      </div>

      <div className="traffic-light-container">
       {["north", "south", "east", "west"].map((dir) => (
        <TrafficLight key={dir} direction={dir} signal={lightStates[dir]} />
       ))}
      </div>
     </div>
    );
   };
export default App;
```

2.Backend:

STRUCTURE

```
📁 smart-traffic-light-backend
|── 📁 src
|   |── 📁 main
|   |   ├── 📁 java
|   |   |   ├── 📁 com.trafficlight
|   |   |   |   ├── 📁 controller
|   |   |   |   |   ├── TrafficLightController.java   # Handles API requests
|   |   |   |   ├── 📁 service
|   |   |   |   |   ├── TrafficLightService.java      # Business logic for traffic control
|   |   |   |   ├── 📁 model
|   |   |   |   |   ├── TrafficSignal.java            # Model for traffic signal
|   |   |   |   ├── 📁 config
|   |   |   |   |   ├── CorsConfig.java               # Configures CORS for frontend
communication
|   |   |   |   ├── SmartTrafficLightApplication.java # Main Spring Boot application
|   |   ├── 📁 resources
|   |   |   ├── application.properties            # Spring Boot properties (port, DB, etc.)
|── 📁 test
|   |── 📁 java/com.trafficlight
|   |   ├── TrafficLightControllerTest.java       # Unit tests for controller
|── 📁 target
|── .gitignore
|── pom.xml                                       # Maven dependencies
|── README.md
```

PROGRAM:

SmartTrafficLightBackendApplication.java

```
package com.trafficlight;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class SmartTrafficLightBackendApplication {

    public static void main(String[] args) {
        SpringApplication.run(SmartTrafficLightBackendApplication.class, args);
    }
}
```

CorsConfig.java

```
package com.trafficlight.config;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.web.servlet.config.annotation.CorsRegistry;
import org.springframework.web.servlet.config.annotation.WebMvcConfigurer;

@Configuration
public class CorsConfig {
    @Bean
```

```
    public WebMvcConfigurer corsConfigurer() {
        return new WebMvcConfigurer() {
            @Override
            public void addCorsMappings(CorsRegistry registry) {
                registry.addMapping("/").allowedOrigins("http://localhost:3000");
            }
        };
    }
}
```

TrafficLightController.java

```
package com.trafficlight.controller;

import org.springframework.web.bind.annotation.CrossOrigin;
import org.springframework.web.bind.annotation.GetMapping;
import org.springframework.web.bind.annotation.RequestParam;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RestController;

import java.util.Map;

@RestController
@RequestMapping("/signal")
@CrossOrigin(origins = "http://localhost:3000")
public class TrafficLightController {
    @GetMapping
    public String getSignal(@RequestParam Map<String, String> densities) {
```

```
        String highestDensityRoad = densities.entrySet()
            .stream()
            .max(Map.Entry.comparingByValue())
            .map(Map.Entry::getKey)
            .orElse("north");

            return "{ \"signal\": \"" + highestDensityRoad + "\" }";
    }
}
```

TrafficLight.java

```
package com.trafficlight.model;

public class TrafficLight {
    private String color;
    private int duration; // Duration in seconds

    public TrafficLight(String color, int duration) {
        this.color = color;
        this.duration = duration;
    }

    public String getColor() {
        return color;
    }

    public void setColor(String color) {
```

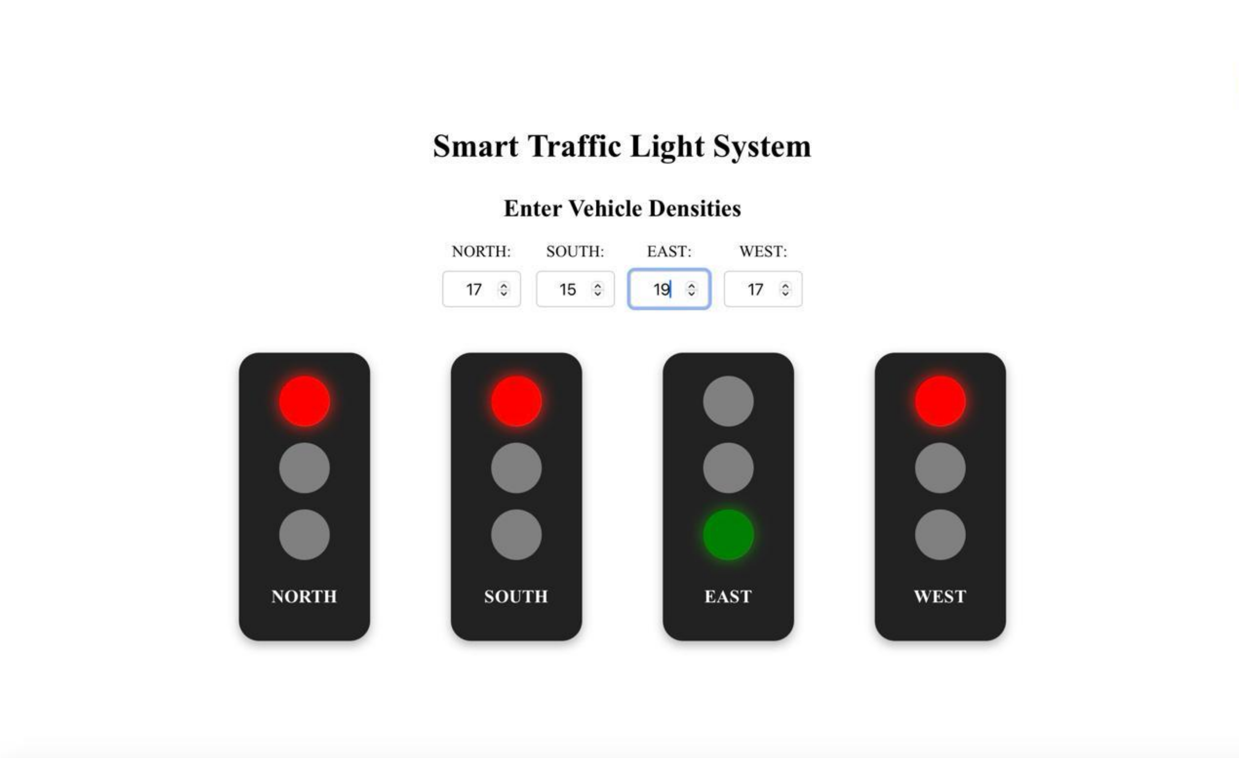
```java
        this.color = color;
    }

    public int getDuration() {
        return duration;
    }

    public void setDuration(int duration) {
        this.duration = duration;
    }
}
```

TrafficLightService.java

```java
package com.trafficlight.service;

import com.trafficlight.model.TrafficLight;
import org.springframework.stereotype.Service;

@Service
public class TrafficLightService {

    public TrafficLight getTrafficLightState(int vehicleDensity) {
        if (vehicleDensity > 50) { // High density
            return new TrafficLight("GREEN", 60);
        } else if (vehicleDensity > 20) { // Medium density
            return new TrafficLight("YELLOW", 10);
        } else { // Low density
```

```
            return new TrafficLight("RED", 30);
        }
    }
}
```

8. RESULTS & DISCUSSION



The Smart Traffic Light Control System displays four traffic signals, each representing a different road. Based on the user-input vehicle density, the system dynamically assigns the green signal to the road with the highest traffic for a longer duration. When the green signal changes, it smoothly transitions to orange (for 2 seconds) before turning red. The UI ensures all signals are properly aligned, centered, and visually resemble real-life traffic lights. The background is white, and the font is set to Times New Roman for a clean and professional look.

9. CONCLUSION & FUTURE SCOPE

The Smart Traffic Light Control System efficiently optimizes traffic flow by dynamically adjusting signal durations based on vehicle density. By integrating React (frontend) and Spring Boot (backend), it provides a user-friendly and visually accurate traffic light simulation. The system improves urban traffic management, reducing congestion and wait times.

For future enhancements, AI-based traffic prediction using real-time sensors and computer vision can be implemented. Additionally, cloud integration can enable large-scale deployment in smart cities. Mobile app support and IoT-based automation can further enhance its adaptability for real-world applications

10. REFERENCES

References for Smart Traffic Light Control System

React (Frontend)

1. React Docs - https://react.dev/

2. React Router Docs - https://reactrouter.com/

3. Redux Toolkit Docs - https://redux-toolkit.js.org/

4. How to Fetch API in React - https://developer.mozilla.org/en-US/docs/Web/API/Fetch_API

5. React Hooks (useState, useEffect) - https://react.dev/reference/react/useEffect

Spring Boot (Backend)

6. Spring Boot Docs - https://spring.io/projects/spring-boot

7. Spring Boot REST API Guide - https://spring.io/guides/gs/rest-service/

8. Handling CORS in Spring Boot - https://spring.io/blog/2015/06/08/cors-support-in-spring-framework

9. Spring Boot Controller Example - https://www.baeldung.com/spring-controller

Connecting React with Spring Boot

10. Full-Stack React + Spring Boot Guide - https://www.javaguides.net/2020/05/spring-boot-react-full-stack-example.html

11. React & Spring Boot Integration - https://dev.to/nareshbhatia/how-to-integrate-react-with-spring-boot-14bb

UI & CSS

12. CSS Flexbox (Centering Elements) - https://css-tricks.com/snippets/css/a-guide-to-flexbox/

13. Traffic Light CSS Design - https://www.w3schools.com/css/css3_buttons.asp

14. Google Fonts for React - https://fonts.google.com/

Tools Used

VS Code - https://code.visualstudio.com/

Postman for API Testing - https://www.postman.com/

Spring Tool Suite (STS) - https://spring.io/tools

Node.js (for React) - https://nodejs.org/en