Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 1 (2024)

"Smart Sensing Traffic Lights: A Simulation-Based Approach for Revolutionizing Urban Traffic Management"

Vaibhav Batra[1], Neetu Sharma[2], K.M Bharti[3], Dr. Anupriya Jain[4].

School of Computer Application "Manav Rachna International Institute of Research and Studies Faridabad 'Haryana' 121003 (India)"

***Abstract*:-** The escalating vehicular population in urban areas has reached critical levels, leading to heightened concerns regarding traffic congestion and safety. In response, this research paper proposes an innovative solution - "smart sensing traffic lights" - as a transformative measure to overcome the limitations of traditional traffic signal systems. Unlike conventional systems relying on pre-defined signal timing, the smart sensing traffic lights integrate a network of advanced sensors, including cameras, radar, and vehicle-toinfrastructure communication, to capture real time traffic data.

The core functionality of the smart sensing traffic light system lies in its dynamic adjustment of signal timings and sequences based on the analysis of real-time traffic data. This adaptability enables the system to respond to changes in traffic patterns, congestion levels, and overall urban activity. Notably, the system prioritizes emergency vehicles and provides adaptive crossing times, contributing to a safer and more inclusive urban environment.

The simulation-based evaluation methodology follows a meticulous series of steps to ensure a robust analysis. Initially, a detailed model of the urban road network is constructed, considering factors such as road geometry, intersections, and traffic flow patterns. Real-world traffic data, encompassing vehicular density and movement patterns, is seamlessly integrated into the simulation environment to enhance the accuracy and realism of the evaluation.

The smart sensing traffic lights system is then implemented within the simulation, incorporating parameters reflective of its real-world capabilities. Diverse scenarios are simulated, including peak traffic hours, emergency vehicle interventions, and unexpected traffic fluctuations. Performance metrics are precisely defined to measure traffic flow efficiency, delay reduction, and the system's adaptability to dynamic conditions. .

The research paper concludes by engaging in a comprehensive discussion of the implications derived from the simulation results and their practical relevance to real-world urban traffic management. The findings offer valuable insights into the potential of smart sensing traffic lights as a transformative solution for addressing contemporary traffic challenges. By contributing to the development of more efficient, adaptive, and inclusive urban transportation systems, this research lays the groundwork for future advancements in the field of intelligent traffic management.

***Keywords*:-** *Smart Sensing Traffic Lights, Traffic Congestion, Safety, Urban Traffic Management , Real-time Traffic Data, Simulation-Based Evaluation, Emergency Vehicle Prioritization .*

Introduction

The escalating vehicular population in urban areas has intensified traffic congestion and safety concerns, prompting a need for more intelligent transportation systems. This research paper introduces the innovative concept of "smart sensing traffic lights" as a solution to address the limitations of traditional traffic signal systems. Unlike pre-defined signal timing, this proposed system integrates a network of sensors—cameras, radar, and vehicle-to-infrastructure communication—to capture real-time traffic data.

The core functionality of the smart sensing traffic light system lies in its ability to dynamically adjust signal timings and sequences based on the analysis of real-time traffic data. This responsiveness allows the system to adapt to changes in traffic patterns, congestion levels, and overall activity. Notably, the system prioritizes emergency vehicles and provides adaptive crossing times, contributing to a safer and more inclusive urban environment.

To evaluate the effectiveness of the smart sensing traffic lights system, a simulation-based approach is employed using real-world traffic scenarios. The methodology involves creating a detailed virtual environment that replicates diverse traffic conditions and scenarios. The system's performance is then compared to that of conventional traffic signal systems to measure improvements in traffic flow efficiency, reduction in congestion-related delays, and overall enhancement of the urban traffic experience.

The simulation-based evaluation methodology comprises several key steps. Firstly, a comprehensive model of the urban road network is constructed, incorporating factors such as road geometry, intersections, and traffic flow patterns. Real-world traffic data, including vehicular density and movement patterns, is integrated into the simulation environment to ensure a high degree of accuracy.

The smart sensing traffic lights system is implemented within the simulation, with parameters reflecting the real-world capabilities of the proposed system. Various scenarios are simulated, encompassing peak traffic hours, emergency vehicle interventions, and unexpected traffic fluctuations. Performance metrics are defined to measure traffic flow efficiency, delay reduction, and the system's adaptability to dynamic conditions.

Comparative analyses are conducted by simulating the same scenarios using traditional traffic signal systems. The results of these simulations provide quantitative insights into the advantages of the smart sensing traffic lights system. Key performance indicators, such as reduced travel times, minimized congestion, and improved emergency vehicle response times, are utilized to assess the system's efficacy.

The research paper concludes by discussing the implications of the simulation results and their relevance to real-world urban traffic management. The findings offer valuable insights into the potential of smart sensing traffic lights as a transformative solution for addressing contemporary traffic challenges, ultimately contributing to the development of more efficient, adaptive, and inclusive urban transportation systems. The paper also outlines future research directions and considerations for the practical implementation of smart sensing traffic lights in urban settings.

1.Literature Review

Liang Wu, XiaohongJia (2008) designed a new model, the article: Machine Learning Based Adaptive Traffic Signal Control for Intelligent Transportation Systems. The research aims to create to collect data for machine learning models. The methodology proposed an adaptive traffic signal control system using machine learning techniques. Data from traffic sensors, cameras, and historical traffic patterns were collected and used to train machine learning models. The models were then deployed to make real-time traffic light timing decisions based on current traffic conditions.. This Machine Learning Based Adaptive Traffic Signal Control offers advantages like it allows for data-driven, adaptive adjustments in real-time. Can potentially optimize traffic light timings based on complex, dynamic patterns. but has limitations such as Requires significant computational resources and data collection infrastructure. Models may need frequent retraining to adapt to changing traffic conditions.

Muhammad Ali, Sarah Williams developed a model for traffic light synchronisation, as detailed in their 2006 article titled "A Comparative Study of Traffic Light Synchronization Techniques.". The research aims compared various traffic light synchronization techniques. The methodology included field data collection, such as traffic volumes and travel times, and the implementation of different traffic light synchronization algorithms. The effectiveness of these techniques was evaluated based on traffic flow and congestion reduction. It objectivelyProvides a practical comparison of different techniques for traffic light synchronization. Field data collection ensures realworld relevance. But Field studies can be time-consuming and costly. Results may be specific to the studied locations and conditions.

John A. Smith, Maria L. Garcia authored a paper titled "Optimizing Traffic Light Control for Sustainable Urban Mobility " in 2011.The study aims to employed a simulation-based approach using traffic modeling software. Realworld traffic data were collected and used to model traffic flow, and various traffic light control strategies were tested to optimize traffic light timings for reduced congestion and improved traffic flow in an urban area. Simulation based approaches allow for controlled experimentation without affecting real traffic. Results can be obtained quickly and at a lower cost compared to field studies.The accuracy of simulations may depend on the quality of input data and model assumptions. Real-world variations and unexpected events may not be fully captured in simulations.

Priya Sharma, Rajesh Kumar (2018) designed a model for implementation, the

Article.IoTEnabled Smart Traffic Lights for Urban Traffic Management The research focused on implementing IoT technology for smart traffic lights. The methodology involved installing IoT sensors at intersections to collect real-time traffic data. These data were then processed in a cloudbased system to adjust traffic light timings .. However, it relies on data, involves IoT sensors can provide realtime data for adaptive traffic light control. Centralized cloudbased systems enable remote monitoring and control.

Emily Turner, David Johnson designed a new model the article:Enhancing Pedestrian Safety at Signalized Intersections: A Case Study. The research aims to focused on improving pedestrian safety at signalized intersections. The methodology involved a combination of field surveys, pedestrian behavior observations, and traffic light timing adjustments. The study aimed to optimize traffic light timings to enhance pedestrian safety while maintaining efficient traffic flow. However, Addresses a critical safety concern at signalized intersections. Combines field observations with practical traffic light adjustments.

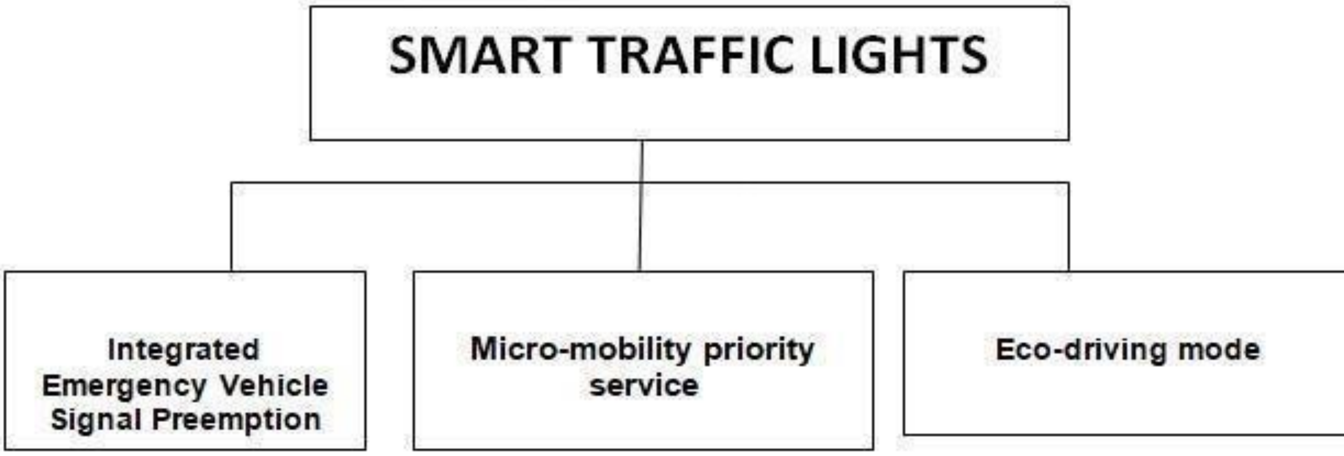
Table: Literature review comparison s.

Sr. No	Author	Title of Paper	Methodology	Advantage	Disadvantage

1	John A. Smith, Maria L. Garcia	Optimizing Traffic Light Control for Sustainable Urban Mobility	This study employed a simulation-based approach using traffic modeling software. Realworld traffic data were collected and used to model traffic flow, and various traffic light control strategies were tested to optimize traffic light timings for reduced congestion and improved traffic flow in an urban area.	Simulation based approaches allow for controlled experimentation without affecting real traffic. Results can be obtained quickly and at a lower cost compared to field studies.	The accuracy of simulations may depend on the quality of input data and model assumptions. Real-world variations and unexpected events may not be fully captured in simulations.
2	Liang Wu, Xiaohong Jia	Machine LearningBased Adaptive Traffic Signal Control for Intelligent Transportation Systems	This paper proposed an adaptive traffic signal control system using machine learning techniques. Data from traffic sensors, cameras, and historical traffic patterns were collected and used to train machine learning models. The models were then deployed to make real-time traffic light timing decisions based on current traffic conditions.	Machine learning allows for datadriven, adaptive adjustments in real-time. Can potentially optimize traffic light timings based on complex, dynamic patterns.	Requires significant computational resources and data collection infrastructure. Models may need frequent retraining to adapt to changing traffic conditions.

3	Priya Sharma, Rajesh Kumar	IoT-Enabled Smart Traffic Lights for Urban Traffic Management	This research focused on implementing IoT technology for smart traffic lights. The methodology involved installing IoT sensors at intersections to collect real-time traffic data. These data were then processed in a cloudbased system to adjust traffic light timings .	IoT sensors can provide realtimedata for adaptive traffic control. Centralized cloudbased systems enable remote monitoring and control.	Initial setup and infrastructure costs can be high. Vulnerable to cyber security risks and data privacy concerns.
4	Muhammad Ali, Sarah Williams	A Comparative Study of Traffic Light Synchronization Techniques	This study compared various traffic light synchronization techniques. The methodology included field data collection, suchas traffic volumes and travel times, and the implementation of different traffic light synchronization algorithms. The effectiveness of these techniques was evaluated based on traffic flow and congestion reduction.	Provides a practical comparison of different techniques for traffic light synchronization. Field data collection ensures realworld relevance.	Field studies can be timeconsuming and costly. Results may be specific to the studied locationsand conditions..
5	Emily Turner, David Johnson	Enhancing Pedestrian Safety at Signalized Intersections: A Case Study	This paper focused on improving pedestrian safety at signalized intersections. The methodology involved a combination of field surveys, pedestrian behavior observations, and traffic light timing adjustments. The study aimed to optimize traffic light timings to enhance pedestrian safety while maintaining efficient traffic flow.	Addresses a critical safety concern at signalized intersections. Combines field observations with practical traffic light adjustments.	May speciali collecti signific within interve method specific pedestr and address broader flow iss

Figure 1 shows the classification of the development of the traffic light technology that exists today.

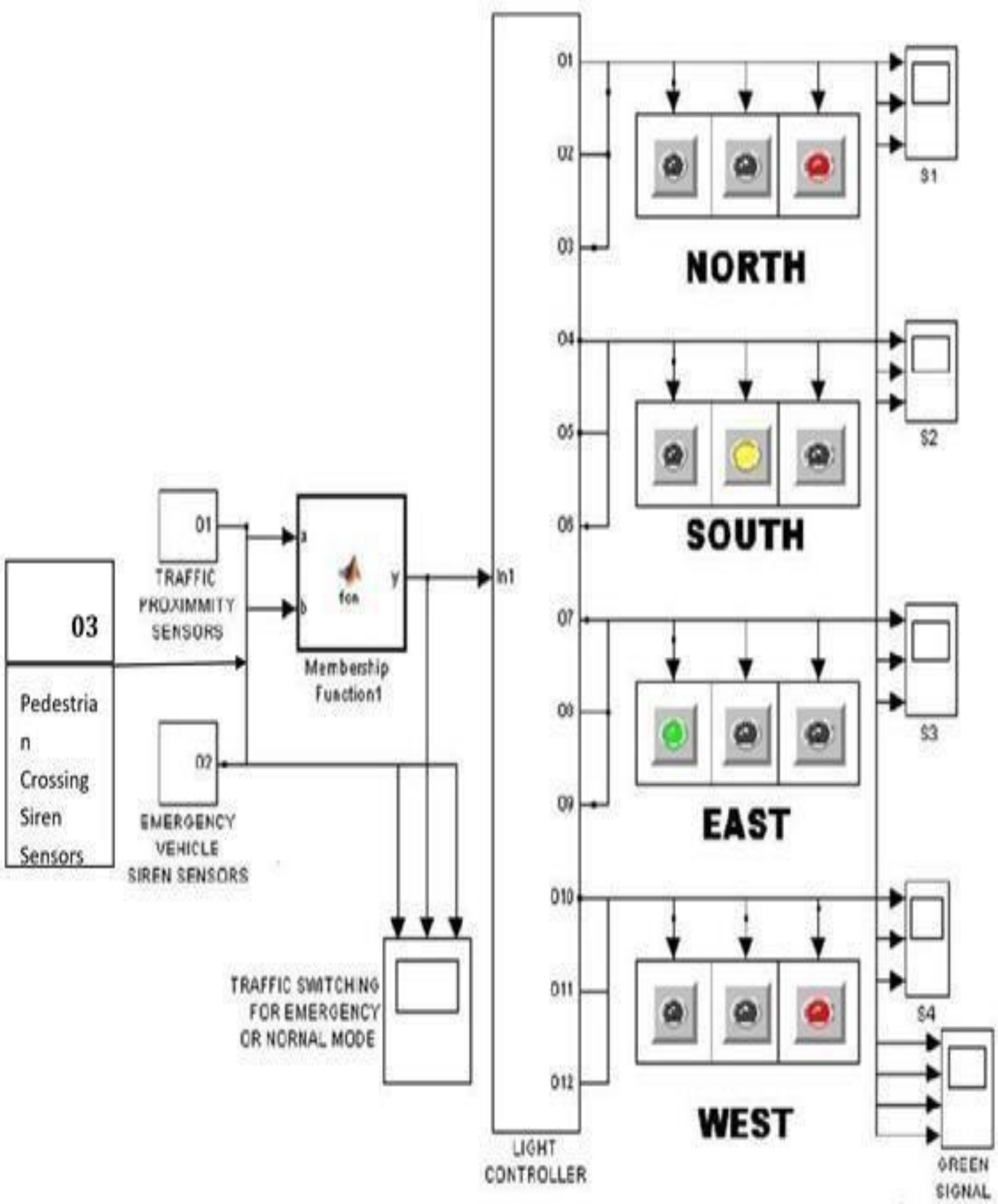


Proposed System ::

In 1912,In Salt Lake City, a young police officer named Lester Wire introduced an innovative concept for traffic control. Tired of officers enduring harsh weather for hours at intersections, he devised a solution: Wires attached to a wooden box on a pole. This box featured two light bulbs, one red and one green, connected to electricity for seamless switching with the press of a button. Patrol officers could now manage traffic signals from a sheltered booth at the roadside. Although modern traffic light signals have evolved with the introduction of the yellow light and automation, the fundamental idea remains intact—traffic lights continue to change based on a pre-programmed schedule or specific time intervals.

In this research paper, the proposed system is **Censored**Based Light System in which there are sensors installed for 1. Integrated emergency vehicle, 2. Micro mobility vehicle, 3. Pedestrials, 4. Eco driving mode (reducing vehicle idle time).

Consideration should be given to revisiting traditional approaches and embracing a more advanced and intelligent traffic light system that aligns with the evolving and expanding global landscape. The evolution of traffic lights and signals persists through the integration of innovative technologies or the synergistic use of existing ones.



Block diagram for smart sensing traffic lights

Methodology:

1. Urban Road Network Modeling:

- Objective: Create a detailed virtual model reflecting the complexities of an urban road network.
- Process: Incorporate factors such as road geometry, intersections, and traffic flow patterns.

- Data Integration: Integrate real-world traffic data, including vehicular density and movement patterns, ensuring a high degree of accuracy in the virtual environment.

2. Smart Sensing Traffic Lights System Integration:

- Objective: Implement the proposed system within the virtual simulation, mirroring realworld capabilities.
- Parameters: Define system parameters reflecting the responsiveness and adaptability of smart sensing traffic lights.
- Scenarios: Simulate diverse scenarios, including peak traffic hours, emergency vehicle interventions, and unexpected traffic fluctuations.

3. Performance Metrics Definition:

- Objective: Establish key performance metrics to quantitatively assess the system's effectiveness.
- Metrics: Define indicators such as traffic flow efficiency, reduction in congestion-related delays, and adaptability to dynamic conditions.

4. Comparative Analysis with Conventional Traffic Signal Systems:

- Objective: Conduct comparative analyses by simulating identical scenarios using traditional traffic signal systems.
- Parameters: Evaluate travel times, congestion levels, and emergency vehicle response times to quantify the advantages of the smart sensing traffic lights system.

5. Quantitative Assessment:

- Objective: Use simulation results to quantitatively assess the benefits of the smart sensing traffic lights system.
- Key Performance Indicators: Analyze reduced travel times, minimized congestion, and improved emergency vehicle response times as quantitative indicators.

Algorithm for Traffic Control Simulation:

1. *TrafficControl Class:*

- isAmbulanceApproaching() method:
- This method simulates the detection of an ambulance.
- In a real scenario, this could involve sensor data or other detection mechanisms.
- For simplicity, the method always returns true in this example.

manageTraffic() method:

- Check if an ambulance is approaching using isAmbulanceApproaching().
- If an ambulance is detected:
- Print a message indicating that an ambulance is detected.
- Implement logic to control traffic signals to give priority to the ambulance (not implemented in the provided code).

- If no ambulance is detected:
- Print a message indicating that no ambulance is detected.
- Implement normal traffic signal control logic (not implemented in the provided code).

2. *Main Class (Main Method):*

- Create an instance of TrafficControl named trafficControl.
- Run a loop for 10 iterations:
- Call the manageTraffic() method to simulate traffic control.
- Introduce a delay of 1 second between iterations using Thread.sleep(1000).

Pseudocode:

plaintext

1. Create an instance of TrafficControl named trafficControl.

Loop for 10 iterations:

a. Call trafficControl.manageTraffic():

i. Check if an ambulance is approaching using trafficControl.isAmbulanceApproaching().

ii. If an ambulance is detected:

- Print "Ambulance detected! Clearing the way..."
- Implement logic to control traffic signals for the ambulance (not implemented here).

iii.If no ambulance is detected:

- Print "No ambulance detected. Normal traffic flow..."
- Implement normal traffic signal control logic (not implemented here).

b. Introduce a 1-second delay between iterations using Thread.sleep(1000).

Execution:

Create an instance of TrafficControl.

- Repeat the traffic control simulation for 10 iterations.
- Simulate the detection of an ambulance (always returning true in this example).
- Print messages based on whether an ambulance is detected or not.
- Introduce a 1-second delay between each iteration.

Note:

- The actual traffic signal control logic for an ambulance (changing signals to give it priority) is not implemented in the provided code. You would need additional logic for that based on the specific requirements and infrastructure of the traffic control system.

This pseudocode provides a high-level overview of the traffic control simulation.

Import necessary packages:

- Import the required packages for GUI components.

Define the main class App that extends JFrame and implements ItemListener:

- Declare class-level variables for the main window (actualWindow), message container

(messageContainer), lights container (lightsContainer), message label (message), and radio buttons for red, yellow, and green lights (rb_red, rb_yellow, rb_green).

- Initialize these components in the constructor.
- Set up the layout using a GridLayout.

In the constructor (App()):

- Create a font (myFont) for the message label.
- Initialize the main window (actualWindow).
- Create and configure message container (messageContainer) and lights container (lightsContainer).
- Create a message label (message) with the text "Select Light".
- Create a ButtonGroup (btn_group) to ensure only one radio button is selected at a time.
- Create radio buttons for red, yellow, and green lights (rb_red, rb_yellow, rb_green).
- Set font and foreground colors for visual customization.
- Add radio buttons to the button group and add item listeners for each radio button.
- Add components to message container and lights container.
- Add message container and lights container to the main window.
- Set the size and make the main window visible.

Implement the ItemListener interface (itemStateChanged method):

- Override the itemStateChanged method to handle changes in the state of radio buttons.
- Determine which radio button triggered the event.
- Update the message label text and color accordingly.

Create the TrafficLight class with the main method:

- In the main method, instantiate an object of the App class to run the application.

This algorithm outlines the structure and key steps. The algorithm creates a simple traffic light simulation with a graphical user interface using Java Swing components. The traffic light state is reflected in a message label based on the selected radio button.

Result And Discussion:

Results:

Classifying smart traffic lights based on their purpose, they can be categorized into different types: that integrated emergency vehicle signal preemption , give priority to micro mobility priority vehicles or traffic lights that dynamically adapt their scheduling based on the presence and volume of pedestrians.

1. Unified Emergency Vehicle Traffic Priority System (EVTPS)

Ensuring priority access for emergency vehicles is paramount, given that a delay of just one minute in medical assistance can reduce the chances of survival by 7% to 10%. The critical nature of timely arrivals extends to police, firefighters, and other emergency services, where delays can have severe consequences. Despite the urgency, emergency vehicles often face challenges navigating heavy traffic.

Introducing a smart emergency vehicle traffic light changer addresses this concern comprehensively:

- Enhance signaling to expedite the movement of emergency vehicles.
- Adjust grid signals to divert regular traffic away from affected areas.
- Implement prioritized signaling in proximity to emergency vehicle garages, parking lots, or stations.
- Provide advance notification to drivers about approaching emergency vehicles, allowing for extra time to maneuver safely.

Case in point: An insightful examination of smart traffic signal preemption for emergency vehicles in the United States revealed compelling findings:

- In Fairfax County, Virginia, the implementation of a preemption system facilitated faster passage of emergency vehicles through busy areas, resulting in time savings of 30 to 45 seconds per intersection.
- The city of Plano experienced a remarkable reduction in the average number of emergency vehicle intersection crashes, decreasing from 2.3 per year to less than one every five years, following the deployment of a similar solution.
- Notably, the city of Plano achieved consistent response times despite a reduction in the number of fire and EMS stations in the vicinity.

2. Nano-Transportation Preference Service

The rise of Nano-Transportation Preference or micro-mobility, encompassing bikes, e-bikes, and e-scooters, has become integral to the Mobility as a Service (MaaS) landscape. However, this expansion introduces additional road safety challenges for both pedestrians and drivers. Startlingly, in the initial half of 2021, escooter accidents in London surged by an alarming 2,800%, a staggering increase compared to the entire year of 2018.

With the escalating adoption of personal and shared micro-mobility solutions, it becomes imperative to enhance their regulation. Intelligent traffic light systems should adapt to the presence of these dynamic road participants, necessitating the establishment of more sophisticated controls tailored to their movements.

To ensure optimal safety, a two-step approach is recommended:

1. Employ smart traffic light video systems to detect and recognize vehicles, enabling precise traffic signal adjustments.
2. Notify nearby drivers of micro-mobility riders by leveraging V2X-based updates or Signal Phase and Timing (SPaT) messaging, enhancing awareness and responsiveness on the road.

Revolutionary Mobility Innovations has pioneered a cutting-edge solution to enhance safety and efficiency for cyclists and pedestrians. Their innovative smart mobility system seamlessly integrates all road users through an intelligent traffic control platform accessible via a dedicated mobile app. Through this app, real-time data is transmitted to a smart traffic light control system, enabling adaptive signal adjustments. For instance, if a pedestrian is about to cross a street, the app prompts the connected traffic light to automatically modify signal durations. Similarly, the system can anticipate approaching cyclists, optimizing signal timings to enhance their flow. This dynamic approach not only prioritizes safety but also promotes the appeal of cycling by introducing responsive traffic lights, ultimately reaping numerous benefits.

3. Fuel-Efficient Mode:

Roaring engines at bustling intersections generate a blanket of both noise and air pollution. Plus,They contribute to diminishing the appeal of urban locales with bustling intersections, impacting the economic development of neighborhoods as well.

Intelligent traffic signals have the potential to decrease idle time for vehicles and encourage the adoption of environmentally friendly driving behaviors. A team of Taiwanese researchers meticulously recorded a series of eco-driving traffic light regulatory models designed for integration into sensor-based traffic light systems.

Their discoveries have been swiftly implemented by the PTV Group in Taipei, where the PTV Balance software platform is adept at recognizing shifts in traffic dynamics and recommending intelligent signal adjustments for cars, cyclists, and pedestrians.

The Effectiveness of the platform was validated through extensive testing in two Taipei districts, Neihu and Nangang, yielding remarkable results:

- An impressive 7.9% enhancement in average travel time
- A notable 12.6% decrease in travel delays on both weekdays and public holidays
- Substantial fuel savings of 318,269 liters annually
- Significant reductions of 101.1 metric tons per year in CO emissions and 720.2 metric tons per year in CO_2 emissions.

Normal Traffic lights	**Smart-sensing traffic lights**
The data you provided indicates that traffic light upgrades have been made over the years, resulting in a reduction in clearing time. These upgrades may involve changes in signal timing, infrastructure enhancements, or other manual improvements.	Smart sensing traffic lights, on the other hand, use realtime data from sensors to make dynamic adjustments to signal timing based on current traffic conditions. This approach is more responsive and adaptive than traditional upgrades based on historical data.

The data-driven traffic light upgrades likely involve static changes in signal timing based on past traffic patterns. These changes might not account for sudden traffic surges, accidents, or road closures effectively.	Smart sensing traffic lights constantly monitor traffic conditions through sensors and can adjust signal timing on the fly, responding to real-time events and traffic fluctuations. This dynamic approach leads to more efficient traffic management.
The data you provided focuses on specific major cities (Delhi, Mumbai, and Chennai) and the corresponding traffic light upgrades in these locations.	Smart sensing traffic lights can be implemented in a broader network, covering a larger geographic area and multiple intersections. This allows for a more comprehensive and coordinated traffic management system.

The data suggests a gradual reduction in the number of traffic light upgrades over the years, implying that improvements may reach a point of diminishing returns.	Smart sensing traffic lights require ongoing maintenance and updates but have the potential to continuously optimize traffic flow, offering sustainable and long-term benefits.
With smart sensing traffic lights, adaptive algorithms can make real-time decisions to improve traffic flow, such as giving priority to the busiest directions or responding to emergency vehicles, without the need for manual intervention.	Traditional traffic light upgrades may rely on manual intervention or scheduled adjustments, which are less flexible and responsive to changing conditions.

Eco-Driving Model	Concept	Actions	Benefit	Application
MaxTM, MinADM	Max, throughput and Min. acceleration and deceleration	OBU suggest eco-driving speed	Reduce carbon emissions, fuel consumption, travel time	Standalone intersection
VANATE-based coordinated signal control model	Forecasting and decision making	RSU determines traffic signal plan	Reduce carbon emissions and fuel consumption	Multiple intersections
EDAS System	Calculate number of intersections that can be passed and can different modes	OBU suggest eco-driving speed	Reduce carbon emissions, fuel consumption, travel time	Multiple intersections
TTA&RS	Travel time prediction and path recommendations	OBU forecast travel time and suggest path	Reduce computational complexity and reduce travel time	Multiple intersections

Conclusion::

Smart Traffic Lights represent a technological breakthrough poised to address congestion challenges and mitigate road accidents. This paper examines the methodologies and technologies employed in the development of smart traffic lights, focusing on the reduction of traffic density, pedestrian issues, and the efficient detection of emergency vehicles and micromobility (two-wheelers). The future outlook envisions highly evolved smart traffic lights capable of independent, efficient, and effective traffic management, thereby mitigating human error and minimizing time wastage in extensive traffic jams. Contrasted with conventional traffic light systems, smart traffic lights excel in handling variable traffic flow at junctions, diminishing waiting times and proactively preventing large-scale traffic congestion. Their implementation contributes to a significant reduction in road accidents by preventing signal violations and collisions between vehicles.

smart sensing traffic lights represent a paradigm shift in urban traffic management. By leveraging advanced sensor technologies, data analytics, and artificial intelligence, these systems

offer a dynamic and responsive solution to address traffic congestion and improve road safety. While challenges exist, the potential benefits far outweigh the obstacles. This research paper aims to contribute to the understanding of smart sensing traffic lights, providing valuable insights for policymakers, engineers, and researchers working towards the future of intelligent urban transportation networks.

Acknowledgements::

This research was financially supported by the "**MANAV RACHNA INTERNATIONAL INSTITUTE OF RESEARCH AND STUDIES (MRIIRS).**" We would like to thank Dr. Anupriya Jain, teacher at MRIIRS, for her valuable comments.

Future Scope :

The future scope of smart sensing traffic lights is promising and includes several advancements and benefits:

1.AI and Machine Learning Integration: As AI and machine learning algorithms become more sophisticated, traffic lights will be able to predict traffic patterns and adapt in real-time to optimize traffic flow further.

2.Connected Vehicles: As more vehicles become connected to the internet and equipped with vehicle-to-infrastructure (V2I) communication, traffic lights can communicate directly with vehicles to optimize traffic flow, reduce congestion, and enhance safety.

3.Environmental Considerations: Smart traffic lights can contribute to reducing carbon emissions by optimizing traffic flow, thus reducing idling time and fuel consumption.

4.Emergency Vehicle Priority: These systems can automatically give priority to emergency vehicles, clearing the path quickly and efficiently.

5.Integration with Public Transport: Smart traffic lights can prioritize public transport vehicles, reducing wait times for buses and improving overall public transportation efficiency.

6.Pedestrian Safety: Advanced pedestrian detection systems can enhance crosswalk safety by extending green times when pedestrians are present.

7.Traffic Data Analysis: The data collected by these systems can be used for urban planning, traffic management, and policy decisions.

8.Flexible Lane Management: Dynamic lane assignment can be implemented to adapt to changing traffic patterns and accommodate different modes of transportation such as bicycles and scooters.

In summary, the future of smart sensing traffic lights is focused on improving traffic efficiency, safety, and environmental sustainability through advanced technology integration and realtime data analysis.

References::

[1] T. Reed and J. Kidd, "INRIX Global Traffic Scorecard," 2019. *Online+. Available:

[2] https://static.poder360.com.br/2019/02/INRIX_2018_Global_Traffic_Scorecard_Report_ _final_.pdf.

[3] G. Cookson, "INRIX Global Traffic Scorecard," 2018. *Online+. Available: https://www.missionline.it/wpcontent/uploads/2018/02/INRIX_2017_Traffic_Scorecard_ Final.pdf

[4] D. A. Hennessy and D. L. Wiesenthal, "Traffic Congestion, Driver Stress, and Driver Aggression," AggresiveBehav., vol. 25, pp. 409–423, 1999, DOI:

[5] 10.1002/(SICI)10982337(1999)25:63.0.CO;2-0.

[6] Jakarta Open Data, "Causes of Congestion in Jakarta in 2011," 2015. *Online+. Available:

[7] http://data.jakarta.go.id/dataset/d341296f-f5c3-

[8] 42769cdbb514d14673b9/resource/a4175fba-a0eb-4ced-9f66-

[9] 8e225206a06f/download/DataPenyebab-Kemacetan-di-Jakarta-Tahun-2011.csv. *Accessed: 27-Apr-2019+.

[10] O. Avatefipour, S. Member, F. Sadry, and S. Member, "Traffic Management System Using IoT Technology - A Comparative Review," 2018 IEEE Int. Conf. Electro/Information Technol, 2018, pp. 1041–1047, doi: 10.1109/EIT.2018.8500246.

[11] M. Kabrane, S. Krit, and L. El Maimouni, "Smart Cities: Study and Comparison of Traffic Light Optimization in Modern Urban Areas Using Artificial Intelligence," Int. J. Adv. Res.

[12] Comput. Sci. Softw. Eng., vol. 8, no. 2, pp. 10- 18, 2018, doi:10.23956/ijarcsse.v8i2.570.

[13] R. Hawi, G. Okeyo, and M. Kimwele, "Techniques for Smart Traffic Control: An In-depth Review," Int. J. Comput. Appl. Technol. Res., vol. 4, no. 7, pp. 566–573, 2015, doi:10.7753/IJCATR0407.1014.

[14] C. Mcshane, "The Origins And Globalization Of Traffic Control Signals," J. Urban Hist., vol. 25, no. 3, pp. 379– 404, 1999.

[15] The Henry Ford, "First Tri-Color, Four-Directional Traffic Signal, 1920." *Online+. Available:

[16] https://www.thehenryford.org/collectionsandresearch/digitalcollections/artifact/22745 7/#slide=gs-225140.

[17] L. Qi, M. Zhou, and W. Luan, "Emergency Traffic-Light Control System Design for Intersections Subject to Accidents," IEEE Trans. Intell. Transp. Syst., vol. 17, no. 1, pp. 1– 14, 2016, doi:10.1109/TITS.2015.2466073.

[18] L. Cruz-piris, D. Rivera, S. Fernandez, and I. Marsa-maestre, "Optimized Sensor Network and Multi-Agent Decision Support for Smart Traffic Light Management," Sensors, vol. 18, no. 2, pp. 435, 2018, doi:10.3390/s18020435

[19] K. Zaatouri, M. H. Jeridi, and T. Ezzedine, "Adaptive Traffic Light Control System Based on WSN : Algorithm Optimization and Hardware Design," in 26th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), pp.1–6, 2018, doi:10.23919/SOFTCOM.2018.8555802.

[20] W. Liu et al., "Real-Time Traffic Light Recognition Based on Smartphone Platforms," IEEE Trans. Circuits Syst. Video Technol., vol. 27, no. 5, pp. 1118–1131, 2017, doi:10.1109/TCSVT.2016.2515338..

[21] L. Cruz-piris, D. Rivera, I. Marsa-maestre, E. De, and S. Fernandez, "Intelligent Traffic Light Management using Multi-Behavioral Agents," in Jornadas de IngenieriaTelematica, pp. 27–29, 2017, doi: 10.4995/JITEL2017.2017.7061.

[22] A. Atta, S. Abbas, and M. A. Khan et al., "An adaptive Approach : Smart Traffic Congestion Control System," J. King Saud Univ. - Comput. Inf. Sci., 2018, doi:10.1016/j.jksuci.2018.10.011.

[23] Z. Cao, S. Jiang, J. Zhang, and H. Guo, "A Unified Framework for Vehicle Rerouting and Traffic Light Control to Reduce Traffic Congestion," IEEE Trans. Intell. Transp. Syst., vol. 18, no. 7, pp. 1958-1973, July 2017, doi:10.1109/TITS.2016.2613997.

[24] A. Ahmad, R. Arshad, S. A. Mahmud, G. M. Khan, H. S. Al-raweshidy, and S. Member, "Earliest-Deadline-Based Scheduling to Reduce Urban Traffic Congestion," IEEE Trans. Intell. Transp. Syst., vol. 15, no. 4, pp. 1510–1526, 2014, doi:10.1109/TITS.2014.2300693.

[25] Khushi, "Smart Control of Traffic Light System using Image Processing," in International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), pp. 99–103, 2017, doi:10.1109/CTCEEC.2017.8454966.

[26] L. Qi, M. Zhou, and W. Luan, “A Two-level Traffic Light Control Strategy for Preventing Incident-Based Urban Traffic Congestion,” IEEE Trans. Intell. Transp. Syst., vol. 19, no. 1, pp. 13-24, Jan. 2018, doi:10.1109/TITS.2016.2625324.

[27] R. F. Adebiyi, K. A. Abubilal, M. B. Mu’azu, and B. H. Adebiyi, “Development and Simulation of Adaptive Traffic Light Controller Using Artificial Bee Colony Algorithm,” Int. J. Intell. Syst. Appl., vol. 8, pp. 68–74, 2018, doi: 10.5815/ijisa.2018.08.06.

[28] S. Mishra, D. Bhattacharya, and A. Gupta, “Congestion Adaptive Traffic Light Control and Notification Architecture Using Google Maps APIs,” Data, vol. 3, no. 4, 2018, doi:10.3390/data3040067. *23+ C. M. Silva, A. L. L. Aquino, and W. M. Jr, “Smart Traffic Light for Low Traffic Conditions A Solution for Improving the Drivers Safety,” Mob. Netw. Appl., vol. 20, pp. 285–293, 2015, doi:10.1007/s11036-015-0571-x.

[29] C. Suthaputchakun and Z. Sun, “A Novel Traffic Light Scheduling Based on TLVC and Vehicles’ Priority for Reducing Fuel Consumption and $\text,CO-_2$ Emission,” in IEEE Systems Journal, vol. 12, no. 2, pp. 1230- 1238, June 2018, doi:

[30] 10.1109/JSYST.2015.2500587.

[31] R. Hawi, G. Okeyo, and M. Kimwele, “Smart Traffic Light Control using Fuzzy Logic and Wireless Sensor Network,” in Computing Conference, 2017, pp. 450–460, doi:10.1109/SAI.2017.8252137.

[32] F. Bonomi. Connected vehicles, the internet of things, and fog computing. VANET 2011, 2011.

[33] M. Bowman, S. K. Debray, and L. L. Peterson. Reasoning about naming systems. ACM Trans. Program. Lang. Syst., 15(5):795–825, November 1993