

AI-Powered Smart Moving Divider System for Dynamic Control and Accidents Management

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Abstract - The continuous rise in urban populations and vehicle ownership has severely strained existing transportation infrastructure, emphasizing the need for adaptive traffic management systems. Conventional fixed road dividers often lead to inefficient road utilization, where one side experiences heavy congestion while the opposite lane remains empty.

This study presents the conceptual design and prototype implementation of a smart movable road divider system integrating Internet of Things (IoT) technology, sensor-based traffic density analysis, and Radio Frequency Identification (RFID) for emergency prioritization.

The proposed framework utilizes an array of infrared (IR) sensors to monitor real-time traffic flow, triggering an ESP32 microcontroller to autonomously adjust the physical divider position via a motorized mechanism. Furthermore, an integrated RFID system ensures seamless, priority clearance for emergency vehicles such as ambulances.

The results demonstrate that combining intelligent monitoring with dynamic lane reallocation significantly reduces average wait times, optimizes existing infrastructure, and enhances overall road safety.

This study highlights the importance of transitioning from static civil infrastructure to responsive automation for sustainable urban development.

Key words- Smart Movable Road Divider, Internet of Things (IoT), Adaptive Traffic Management, Arduino UNO.

1. INTRODUCTION

The rapid growth of urbanization and infrastructure development has significantly increased global traffic volume and environmental impact. The transportation sector faces immense challenges during peak commuting hours, resulting in severe congestion, increased accident risks, and delayed

emergency responses. Conventional road infrastructure, particularly fixed dividers and static lane markings, cannot adapt to dynamic traffic patterns that vary throughout the day. (Yadav et al. 2018; Bargoer et al.2021;Chowdary et al.2023)

Traditional traffic management systems are often designed without incorporating intelligent systems for resource optimization, relying instead on fixed-timing traffic lights and manual intervention. This rigid approach results in the inefficient use of road space, where commercial or industrial zones exhibit heavy directional traffic during morning and evening transit periods, leaving the opposing lanes drastically underutilized. Therefore, there is an urgent need to adopt advanced, responsive technologies capable of modifying lane configurations dynamically.(Gouse et al. 2017;Dalmia et al.2018; Shanti et al.2024)

In recent years, smart transportation infrastructure has emerged as a promising solution to address these challenges by integrating modern technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT). IoT-enabled traffic management systems allow for the intelligent monitoring and control of road networks by utilizing real-time data collected from distributed sensor networks. These systems help detect abnormal traffic buildups and automatically reallocate road resources, thereby improving the overall throughput of municipal road networks.(Kumar et al.2021; Durga et al.2017; Patel et al.2020; Arvind et al.2022)

Emergency vehicle routing is another critical aspect of modern traffic design. Fixed dividers create bottlenecks that hinder ambulances and fire trucks. Integrating RFID technology into movable dividers provides a highly effective approach to automatically create dedicated clearance corridors, significantly reducing life-saving response times.(Mukthi et al.2021;Deshmukh et al.2020; Alvarez et al.2019)

Despite the availability of these technologies, most existing approaches focus on individual traffic systems rather than a fully integrated framework. The present study aims to address this gap by developing an integrated smart movable divider framework that enhances traffic flow, emergency prioritization, and cloud-based monitoring.(Sowjanya et al. 2021;George et al.2023; Babu et al.2017)

Table 1: Comparison Between Conventional and Smart Traffic Systems

Source: Gouse et al. (2017), Mukthi et al. (2021), and Chowdary et al. (2023)

Parameter	Conventional Infrastructure	Smart Movable Divider System
Lane Allocation	Fixed / Static	Dynamic (Density-based)
Road Utilization	Low (Wasted space)	Optimized via IoT
Emergency Response	Delayed by blockages	Priority routing via RFID
Control System	Manual / Static Timers	Intelligent (Microcontroller)
Congestion Impact	High	Significantly Reduced

2. METHODOLOGY

The methodology adopted in this study is systematically structured to develop a comprehensive smart traffic management framework by integrating electromechanical design, sensor networks, cloud computing, and RFID technology. The approach incorporates hardware implementation and software development to ensure efficient road utilization and improved safety outcomes.

The initial stage of the methodology involves the design of the perception layer. An array of Infrared (IR) obstacle sensors is embedded strategically along the simulated road lanes to serve as the primary rapid-response system for volumetric vehicle counting. These sensors continuously evaluate vehicular density, emitting and detecting infrared radiation to sense changes in the immediate road environment, completely independent of ambient lighting conditions.

The second stage focuses on the processing layer and mechanical actuation. The system relies on a dual-microcontroller setup, utilizing an Arduino UNO and a

NodeMCU ESP8266. When the IR sensors detect high traffic density exceeding a predefined threshold, the microcontroller orchestrates a physical shift of the road barrier using a high-torque DC motor paired with an L298N motor driver. A robust rack-and-pinion mechanism translates rotational motion into precise linear translation, expanding the lane capacity for the dominant traffic flow.

The third stage involves the integration of an RFID priority system for sustainable emergency management. An EM-18 RFID reader is placed at strategic detection points. When an approaching emergency vehicle equipped with an authorized tag is detected, the system validates the credentials and initiates a priority protocol. This protocol forces the motor driver to shift the dividers and create a dedicated, obstruction-free emergency lane before returning to its standard operational state.

The fourth stage includes the development of a cloud-based dashboard for remote monitoring. The NodeMCU Wi-Fi module acts as a communication bridge, utilizing MQTT/HTTP protocols to transmit real-time traffic data, divider positions, and emergency alerts to a centralized cloud platform. This allows traffic authorities to monitor intersection health through dynamic widgets and historical logging remotely.

The final stage of the methodology involves performance evaluation and safety validation. The prototype is subjected to rigorous testing across various simulated traffic volumes to quantify improvements in wait-time reduction and system latency. Limit switches are integrated as a critical fail-safe to prevent mechanical over-travel, ensuring the physical infrastructure operates without risking public safety.

Table 2: Methodological Framework of the Study

Stage	Description
System Architecture	Modular design across perception, processing, and cloud layers
Sensor Integration	IR sensor deployment for real-time traffic density evaluation
Mechanical Actuation	DC motor and rack-and-pinion mechanism for physical lane shifting
Emergency Priority	RFID technology for rapid emergency vehicle detection
Remote Monitoring	IoT dashboard for live data visualization and cloud storage

This methodology provides a systematic and integrated approach to designing an intelligent transportation system, ensuring that all major hardware, software, and IoT components work together to achieve optimal traffic performance and safety, while enabling efficient road space utilization, rapid emergency response, and long-term infrastructure efficiency.

3. RESULTS AND DISCUSSION

The results obtained from the implementation of the proposed smart movable divider framework demonstrate significant improvements in traffic flow efficiency, emergency response times, and overall infrastructure performance when compared to a conventional static road system.

The integration of IR sensors, motorized actuation, and IoT monitoring creates a synergistic effect that enhances the operational capacity of urban roads.

The operational logic analysis indicates that the integration of microcontroller-based control systems leads to a highly reliable reallocation of road space. The Arduino successfully processed sensor inputs across multiple test iterations, activating the L298N motor driver to shift the divider within an calculated actuation time of just 2.38 seconds. This swift mechanical response effectively opens up the congested lane without causing abrupt or unsafe movements.

The system ensures high reliability by incorporating a localized I2C LCD display that provides continuous operational updates even during temporary network dropouts. Beyond real-time visualization, the continuous transmission of sensor data into the cloud database facilitates the generation of historical traffic heatmaps and long-term congestion trend analysis

Table 3: Operational Logic Reliability and System Actuation Results

Test Condition	Input Logic State	System Action	Actuation Success
Case 1: High Density	LOW, LOW, HIGH	Move Divider to Lane 2	100% (20/20)
Case 2: Equilibrium	LOW, LOW, LOW	Move to Center Position	95% (19/20)

Case 3: Neutral State	HIGH, HIGH, LOW	No Motion (Standby)	100% (20/20)
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The cloud monitoring performance confirms the feasibility of remote traffic management. Data transmission tests revealed that the NodeMCU module successfully communicated traffic density metrics and divider positions to the cloud dashboard with minimal latency. With an average transmission delay of 212 milliseconds, operators can observe near real-time updates, highlighting the effectiveness of the IoT network in providing actionable data to municipal authorities.

Table 4: Experimental Observations of Cloud Data Transmission

Test No.	Vehicles Detected	Data Sent to Cloud	Transmission Time	Dashboard Update
1	1 Vehicle	Yes	1.5 seconds	Successful
2	2 Vehicles	Yes	1.8 seconds	Successful
3	3 Vehicles	Yes	2.0 seconds	Successful

The RFID integration for emergency vehicle prioritization yielded substantial life-saving benefits. Mathematical queueing models and physical testing verified that dedicated preemption lanes drastically reduce intersection delays for ambulances. By automatically forcing the divider to open a clearance corridor upon tag detection, the system bypasses standard civilian traffic flow, achieving a rapid response time of approximately 2.1 seconds after detection.

Table 5: Experimental Observations of RFID Emergency Response

Vehicle Type	RFID Detected	System Action	Response Time
Ambulance	Yes	Divider shifts to Lane 2	2.1 seconds

Fire Truck	Yes	Divider shifts to Lane 1	2.3 seconds
Normal Vehicle	No	No change in position	0.0 seconds

A comparative analysis between conventional fixed-lane infrastructure and the proposed smart movable divider clearly demonstrates the advantages of adaptive space management. The volume-to-capacity ratio stabilized significantly, allowing the road network to absorb peak-hour traffic surges efficiently.

Table 6: Traffic Flow Comparison

Parameter	Conventional Divider	Smart Movable Divider
Available Lanes	Fixed (Static)	Dynamic (Adjustable)
Average Wait Time	40 seconds	20 seconds
Road Utilization Efficiency	60%	85%
Traffic Flow Rate	0.5 vehicles/sec	0.8 vehicles/sec

Table 7: Overall Performance Comparison

The overall analysis confirms that combining automated electromechanical actuation, IoT connectivity, and RFID prioritization significantly enhances road infrastructure performance. The proposed model not only improves traffic flow and emergency routing but also contributes to reduced idling emissions and sustainable urban planning

4. CONCLUSION

The present study successfully develops a comprehensive framework for a smart transportation system by integrating real-time traffic density analysis, an automated movable divider mechanism, and RFID-based emergency prioritization. The research demonstrates that conventional traffic practices, which primarily rely on static concrete barriers and manual intervention, can be significantly improved through the adoption of intelligent, adaptive infrastructure. The proposed model emphasizes efficient road space utilization, reduced travel delays, and enhanced public safety.

Parameter	Conventional Infrastructure	Smart Movable Divider
Traffic Efficiency	Moderate / Low	High
Congestion Level	High	Moderate / Low
Emergency Delays	High	Greatly Reduced
Accident Risk	High	Minimized

The results clearly indicate that the implementation of an IR sensor-driven microcontroller system leads to a substantial reduction in peak-hour congestion. By autonomously detecting traffic volume imbalances and actuating a motorized rack-and-pinion mechanism, the system effectively "borrows" underutilized lanes, optimizing the existing road capacity without the need for costly highway expansions. Similarly, the RFID priority system proves to be an effective life-saving solution by instantly clearing paths for emergency vehicles, ensuring that critical response times are not hindered by civilian traffic jams.

The integration of IoT Wi-Fi modules further contributes to sustainability by generating continuous cloud-based telemetry. This allows municipal authorities to monitor intersection health remotely and analyze long-term traffic trends for future urban planning. The combined effect of these systems results in improved infrastructure performance, a reduction in vehicular idle emissions, and a highly responsive accident management framework.

The findings of this research contribute to the growing field of intelligent transportation systems (ITS) and smart city development. The model aligns with modern civil engineering goals and provides a practical, scalable reference for engineers and policymakers seeking to deploy environmentally responsible and highly efficient road networks.

The future scope of this project involves replacing basic sensors with AI-powered cameras to visually predict traffic jams before they occur. The system can also be connected to broader smart city networks, allowing it to work directly with automated traffic lights and emergency dashboards. Furthermore, analyzing the collected cloud data will help city planners optimize traffic flow across entire road networks. Finally, integrating solar panels will allow the motorized dividers to run on renewable energy, making the infrastructure completely self-sustaining and environmentally friendly.

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