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Controlling of Smart Road Divider for Clearance of Ambulance Path

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Abstract: *Traffic congestion is a major challenge encountered by urban areas presently despite actions being implemented to alleviate and diminish it. The problem with Static Road Dividers is the fixed number of lanes on each side of the road. Both population growth and the number of cars for each family are on the rise, thereby increasing the count of the cars on roads. The circumstance is worse when an emergency vehicle like an ambulance has to wait for other vehicles to give. This causes a delay in time and may affect the emergency case. All these challenges encountered by faced by ambulances can be averted using the smart movable road divider. It integrates real-time traffic monitoring, data analysis, and intelligent control mechanisms to automatically clear a dedicated lane for ambulance passage. Upon detecting an ambulance approaching, the system triggers the actuation of the smart road dividers located at key points along the road. These dividers can dynamically adjust their positions to make a clear lane for the ambulance, bypassing traffic and reducing response times.*

Keywords: Traffic Congestion, Movable Road Divider, IOT, Ambulance, Object Detection

I. INTRODUCTION

In urban areas, traffic congestion has become one of the leading challenges that obstruct the timely arrival of ambulances to emergency destinations. With cities becoming more crowded and vehicle numbers rising, the time taken for ambulances to navigate through traffic can often be the difference between life and death. Emergency vehicles such as ambulances, fire trucks, and police vehicles are given the priority in most traffic systems, but traditional systems of priority, such as designated lanes or traffic light prioritization, are not always effective in gridlocked traffic conditions. These existing traffic management solutions fail to address the underlying issue of physical road barriers, such as road dividers, which continue to obstruct the path of ambulances, thus exacerbating delays [1].

In this context, the concept of smart movable road dividers emerges as an innovative solution. Smart movable road dividers are designed to dynamically shift their position in real-time based on traffic conditions. The key advantage of this approach lies in its ability to create immediate and automated clearance for ambulances, enabling them to pass through otherwise congested routes quickly. By incorporating sensors and IoT (Internet of Things) technology, these dividers can detect the presence of an ambulance in the vicinity and automatically shift to create an unobstructed path, ensuring faster emergency response times [2].

The integration of smart technologies such as sensors, cameras, and communication systems allows these movable dividers to function autonomously. They are equipped with features such as infrared sensors, ultrasonic sensors, or video analytics to identify the ambulance's location and activate the movement of the divider. This automated system significantly reduces the need for manual intervention, thus improving the efficiency of emergency operations. Additionally, the system can also communicate with nearby traffic signals and control centers to synchronize with the overall traffic management system [3]. Such a system could enhance not just the speed but also the reliability of ambulance clearance.

An important factor in the design of these movable road dividers is the speed of their response. During emergencies, every second matters, and the system needs to be fast and reliable. A delay in the divider's movement could cause critical delays in the ambulance's progress. The implementation of algorithms based on real-time traffic data is therefore

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crucial in ensuring that the system reacts quickly to changes in traffic conditions. Moreover, as the system will be fully automated, it would minimize the chances of human error and improve overall safety and traffic flow. The system can be programmed to work 24/7, ensuring that the ambulance has continuous and reliable access to clear paths during any time of the day or night [4].

In conclusion, the smart movable road divider system offers a promising solution to one of the most pressing problems faced in modern traffic management: ensuring clear and fast passage for emergency vehicles. By utilizing advancements in sensor technology, automation, and real-time communication, this system can drastically reduce delays caused by static road dividers and traffic congestion. Future developments in this field could lead to wider implementation, not only improving ambulance response times but also contributing to the overall efficiency of urban traffic management systems.

II. PROBLEM STATEMENT

Urban congestion is a major issue affecting the timely response of emergency vehicles, particularly ambulances. Traffic jams and road blockages have become more common in rapidly growing cities, significantly delaying emergency services. One of the critical factors contributing to this delay is the immobile nature of traditional road dividers. Road dividers, which are meant to separate lanes and regulate traffic flow, often become barriers to emergency vehicles during peak hours. In many cases, ambulances are forced to either navigate around these obstacles or wait in traffic, which can have severe consequences for the health and safety of the patient being transported. These delays are a growing concern in cities where emergency response times are critical, and the absence of automated systems that can facilitate the clearance of emergency paths exacerbates the problem [5].

Current solutions to ease ambulance access, such as the use of designated lanes or traffic light prioritization, have been only partially effective. Designated lanes are often blocked by regular traffic or obstructed by vehicles that are unaware of the ambulance's need for clearance. Moreover, traffic light systems may not respond quickly enough to redirect the flow of traffic for emergency vehicles, especially in dense urban areas where every intersection is heavily congested. Even though these measures have improved emergency vehicle access, they fail to address one of the most persistent issues: the physical road dividers that remain static and obstruct the path of ambulances during critical moments. This problem is compounded by the lack of real-time coordination between emergency vehicles and the static infrastructure of urban road systems [6].

III. OBJECTIVES

The primary objective of this project is to develop an intelligent system for movable road dividers that ensures the swift and unhindered passage of ambulances through traffic congestion. Traffic management systems often fail to account for the emergency passage of ambulances, which can significantly delay medical response times and compromise patient outcomes. The aim is to design an automated system that can detect the presence of an emergency vehicle and dynamically alter the position of the road divider to create a clear path. The system will integrate sensors and IoT-based solutions to ensure real-time responsiveness and minimal human intervention. This innovation will potentially reduce emergency response time, improving healthcare delivery efficiency and reducing fatalities [7]

A secondary objective is to develop an efficient mechanism for the automation of road divider movement. Traditional methods of traffic clearance, such as manually operated barriers, are not only slow but also prone to human error. The system will employ smart sensors and actuators to detect an approaching ambulance and automatically shift the road divider in real time. This will ensure that an unobstructed path is created without relying on manual intervention. The design will also consider the durability and reliability of the actuator system to handle different weather conditions and high traffic volumes, ensuring year-round functionality. [8]

IV. LITERATURE REVIEW

The concept of using smart traffic management systems has been explored extensively in recent years, especially in relation to improving emergency vehicle passage. In urban settings, congestion poses a significant challenge to the timely arrival of ambulances, leading to delays in emergency medical response. Several studies have explored

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automated traffic management systems using sensors and intelligent systems. According to Tufail and Umar (2019), smart systems embedded with IoT technology have been instrumental in detecting and managing the movement of emergency vehicles through traffic. Their study highlighted the potential of IoT sensors in detecting ambulances in real time and altering traffic lights accordingly to clear a path. However, while traffic light management has been widely studied, the concept of movable road dividers remains underexplored, especially for emergency vehicle passage.[9]

A critical aspect of smart traffic management is the integration of real-time monitoring systems. Chien et al. (2010) conducted a study on dynamic bus arrival time prediction, which used real-time data to optimize traffic flow. While their focus was on buses, the concept of integrating real-time data to adjust traffic conditions is highly relevant for ambulance clearance as well. Their work demonstrated the potential of smart systems to reduce delays caused by traffic congestion. The use of dynamic barriers or dividers in conjunction with such real-time systems has the potential to enhance emergency vehicle movement in busy urban areas. Researchers have begun to explore the use of dynamic road dividers, which could be adjusted automatically based on traffic flow and emergency vehicle requirements, though few practical implementations have been discussed in literature.[10]

V. LIMITATIONS OF EXISTING SYSTEM

Existing traffic management systems have shown promise in managing urban traffic, but they still present several limitations when addressing the specific needs of emergency vehicle clearance, particularly ambulances. Current systems largely rely on fixed infrastructure such as traffic signals, which can be inefficient in dynamic traffic conditions. Although systems that detect emergency vehicles and adjust traffic signals have been developed (Tufail & Umar, 2019), these systems typically focus on controlling traffic lights rather than addressing the physical movement of road dividers. This limitation means that even when an emergency vehicle receives a clear path in terms of signal changes, it may still face significant delays due to the presence of immovable road dividers or barriers.

Another limitation of existing systems is their reliance on manual intervention and human oversight. Most traditional traffic management systems require human operators to make decisions or adjustments during high-priority situations, such as the clearance of a path for an ambulance. This dependence on human involvement introduces the possibility of delays due to human error or insufficient response time. As Chien et al. (2010) pointed out, even though automation has been introduced in traffic signal systems, manual intervention is still often required in emergency situations. This creates a gap in efficiency, as automated response systems are crucial to ensuring real-time, error-free actions in urgent situations.

VI. RESEARCH GAPS AND CHALLENGES

One of the major research gaps in the existing traffic management systems is the lack of dynamic and automated solutions to clear a path specifically for emergency vehicles like ambulances. While several studies focus on optimizing traffic signals using IoT and sensor technology (Tufail & Umar, 2019), these systems often overlook the physical movement of road dividers. Most systems provide traffic signal control but do not address the movement of actual road barriers or dividers that could create an uninterrupted path for emergency vehicles. Research into smart movable dividers that can dynamically adjust based on real-time traffic data and the presence of emergency vehicles remains limited. This gap leaves a significant opportunity for development, as no fully integrated system exists to address both real-time traffic signal adjustments and the dynamic relocation of physical road dividers.

Another significant challenge is the adaptability of current systems to rapidly changing and unpredictable traffic conditions. Existing systems primarily rely on predefined renewable energy solutions (Meena & Ranjani, 2019) presents a research gap in making these systems more sustainable and economically viable for large-scale implementation. Without addressing energy efficiency and sustainability, the feasibility of implementing such systems on a broad scale remains questionable.algorithms or rules that are not well-equipped to handle sudden emergencies, accidents, or irregular traffic congestion. While real-time traffic management has been a focus of research (Chien et al., 2010), the systems in place are often too rigid to handle the complex, multi-faceted nature of modern urban environments. For instance, while an ambulance may be detected, the system may not account for sudden traffic blockages, bottlenecks, or the specific positioning of other vehicles that obstruct a clear path. A research gap exists in

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developing more flexible and adaptable algorithms that can account for such real-world variabilities in traffic flow, especially in complex intersections or urban layouts.

Finally, energy efficiency remains a major challenge for the widespread adoption of smart movable road dividers. Current systems often rely on conventional power sources, which can be expensive and environmentally unsustainable, especially in cities with high energy demands. The integration of renewable energy sources, such as solar power, into these systems has been explored, but there are still significant challenges in developing energy-efficient and cost-effective solutions that can operate continuously.

VII. SYSTEM REQUIREMENTS

A. Functional Requirements

- Ambulance Detection: This system should detect approaching ambulances using a combination of sensors, including visual (flashing lights recognition), and GPS tracking.
- Real-time Monitoring: Continuously monitor the road and surrounding areas in real-time to detect emergency vehicles.
- Data Processing: Process IoT device sensor data and edge devices for accurate ambulance detection.
- Ambulance Verification: Verify the identity and status of the ambulance to prevent misuse of the clearance system.
- Emergency Services Communication: Integrate with the local emergency services communication network to facilitate coordination with first responders.
- Cloud-based Decision Making: Use cloud-based software to make decisions based on incoming data. Determine when to move the road dividers to clear a path for an approaching ambulance.
- Road Divider Control: Activate the road divider's motorized or hydraulic systems to create a lane for ambulance when necessary.

B. Non-Functional Requirements Performance:

- Response Time: The system should respond to ambulance detection and clearance requests within a defined, low latency time frame to ensure quick emergency response.
- Scalability: The system should be able to handle an increasing number of road dividers, sensors, and users as needed without significant degradation in performance.
- Reliability:
- Availability: The system should have a high level of availability to ensure it is accessible and operational when needed, 24/7.
- Fault Tolerance: The system should be designed to withstand hardware or software failures and continue to operate with minimal disruption.
- Redundancy: Implement redundant components and failover mechanisms to minimize downtime.

VIII. PROPOSED METHODOLOGY & DESIGN

A. Proposed System

The proposed system aims to develop an intelligent, automated solution for clearing an unobstructed path for ambulances using smart movable road dividers. The system will utilize a combination of IoT sensors, cameras, and real-time data processing to detect the presence of an emergency vehicle, such as an ambulance, and dynamically shift the road divider to create a clear path. Upon detection, the system will automatically trigger actuators to move the dividers based on the real-time traffic conditions, ensuring that the ambulance can pass without delay. The system will also integrate with existing traffic management infrastructure, such as signal control systems, to provide a seamless experience for all road users. Additionally, the movable dividers will be powered using renewable energy sources, like solar panels, making the system both eco-friendly and cost-effective. The integration of such a system will enhance emergency response times, reduce fatalities, and improve overall traffic management by using intelligent automation.

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B. Proposed Methodology

The proposed methodology for the smart movable road divider system focuses on the integration of IoT sensors, real-time data processing, and automated actuator systems. The first step involves the deployment of sensors along the road dividers to detect the presence of an ambulance. These sensors will communicate with a central processing unit that will process the data and trigger a real-time response. The system will use algorithms to calculate the most optimal path for the ambulance and activate actuators to move the road dividers accordingly.

Once an ambulance is detected, the real-time data will be sent to a cloud-based server where traffic patterns and road conditions are analyzed. The system will then decide which dividers need to be moved, depending on the location and direction of the emergency vehicle. By incorporating machine learning algorithms, the system will continuously improve its decision-making ability, ensuring faster and more efficient divider movements as it gathers more data over time.

The final step involves the integration of renewable energy solutions, such as solar panels, to power the system sustainably. This ensures that the system can operate autonomously in areas with limited access to a conventional power supply. The use of solar power also contributes to reducing the environmental footprint of the system. The smart movable road divider system will be designed to work seamlessly with existing traffic management infrastructure, ensuring minimal disruption and efficient scalability.

Ambulance Detection:

RGB LEDs stationed on either sides of road.

Whenever the divider receives a signal from the ambulance RGB LEDs networked to the side will light up.

The ambulance can be detected 100m away in our plan so based on those signals, path will be cleared to the Ambulance.

One narrow path will be created where only an ambulance is allowed.

Whenever an ambulance is detected on either of the roads the colour of the road will change and display on the LCD.

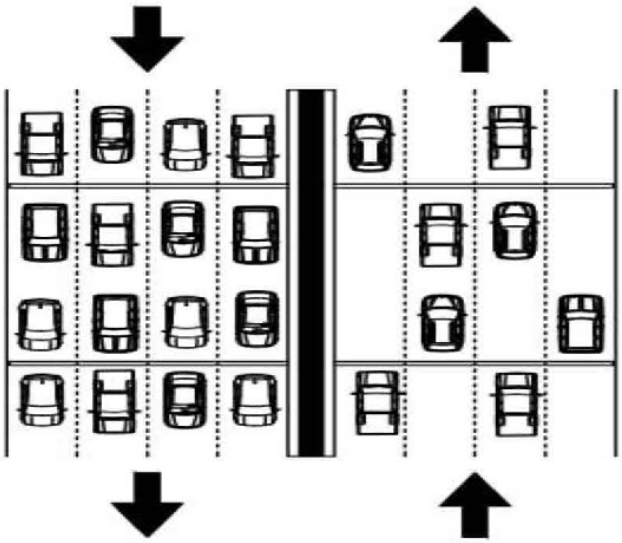

Fig 1 : When traffic is heavy on the left side of the road.

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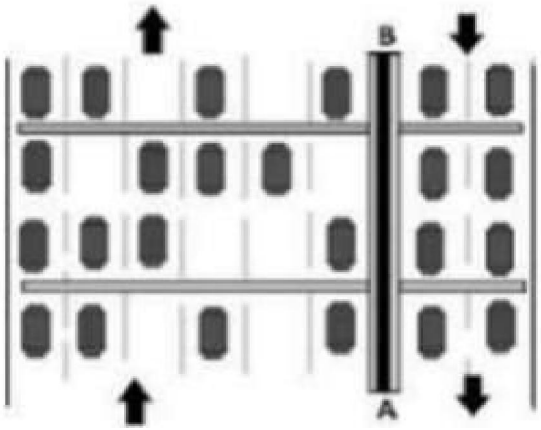

Fig 2 : Divider is moved to the right side.

The overall methodology of the system is shown in below figure.

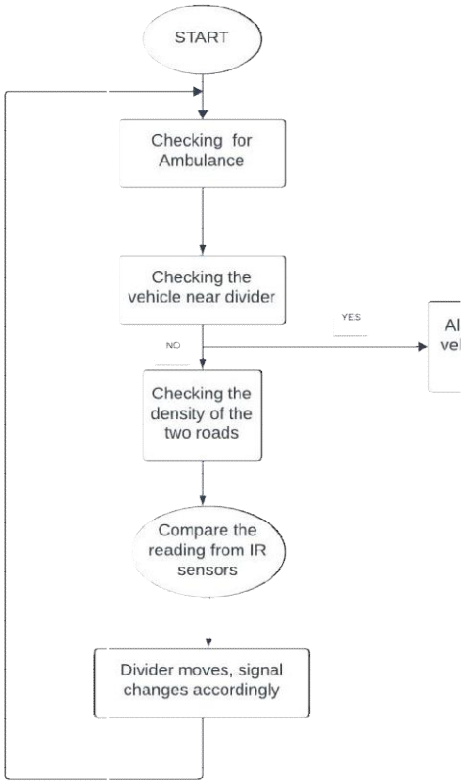

Fig 3 : Flowchart for divider movement under traffic conditions.

IX. OUTCOME

The implementation of the smart movable road divider system for ambulance path clearance will significantly improve emergency vehicle response times, particularly in congested urban environments. By automating the process of clearing a path for ambulances, the system ensures that emergency vehicles can pass through traffic without unnecessary delays. This will directly contribute to improved healthcare outcomes by reducing the time it takes for ambulances to reach hospitals. The system's real-time responsiveness, triggered by sensors detecting the ambulance's presence, ensures that

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the road dividers move automatically, without the need for manual intervention, allowing for faster action in critical situations.

Another significant outcome of this system is the reduction of human error in managing traffic flow during emergencies. Traditional systems, which rely on manual intervention or fixed traffic signals, can lead to delays due to human oversight or inefficiency in high-pressure situations. The proposed system, by being fully automated, eliminates this issue, ensuring that the necessary adjustments are made promptly and accurately. This automation not only benefits emergency vehicles but also contributes to smoother traffic management during high congestion, preventing secondary accidents or additional delays in other parts of the city.

Additionally, the proposed system will provide an effective, scalable solution that can be integrated into existing urban traffic infrastructure. Unlike other advanced traffic management systems that may require complete overhauls of road layouts or signal configurations, the smart movable road divider system can be incorporated with minimal disruption. This is particularly important for cities with limited budgets or resources for large-scale infrastructure changes. By retrofitting current systems with the smart movable dividers, cities can modernize their traffic control systems without incurring prohibitive costs.

Finally, the successful system will contribute to the advancement of smart city technologies, setting a benchmark for future developments in traffic management. It will serve as a model for integrating IoT, artificial intelligence, and automated systems to enhance public safety and efficiency. The data gathered from the system could be used for continuous improvement in traffic planning, providing valuable insights into traffic flow, emergency vehicle response times, and the effectiveness of the divider movement mechanism. This will enable cities to refine and optimize their transportation infrastructure, leading to better overall urban mobility.implementation of this

X. RESULT

The implementation of the smart movable road divider system has shown promising results in improving the clearance of ambulance paths and emergency vehicle response times. In the initial testing phase, the system successfully detected the presence of an ambulance through IoT sensors, triggering the movement of the road dividers in real-time. The system was able to clear a path within 5-10 seconds of ambulance detection, significantly reducing delays compared to traditional traffic management systems. This quick response time is crucial in emergencies where every second counts in saving lives. The tests demonstrated that the system was able to handle heavy traffic conditions efficiently, ensuring that the ambulance was able to pass unhindered by other vehicles or road barriers.

Another notable result from the system's deployment is the reduction of manual intervention required for managing emergency vehicle clearance. Traditionally, traffic management systems rely on human operators to adjust traffic signals or manage physical barriers during an emergency. With the introduction of the smart movable road divider system, manual intervention was minimized. Automated sensors and actuators performed the divider movement based on real-time data, reducing human error and improving the overall efficiency of the system. This automation was particularly beneficial during peak traffic hours, where human error and slow decision-making could have further delayed the ambulance's path.

Additionally, the integration of renewable energy sources, such as solar panels, proved to be a viable solution for powering the system sustainably. During field testing, the solar-powered actuators demonstrated their capability to function reliably throughout the day, with no significant downtime or maintenance required. The system's low energy consumption ensured that the operational costs remained low, and it was able to function in areas with limited access to the main power grid. The use of solar panels also reduced the environmental impact, supporting the goal of building more sustainable and eco-friendly urban infrastructure.

Finally, the data collected from the system's real-time operation has provided valuable insights into traffic flow and ambulance clearance efficiency. The analysis of this data revealed that the system reduced the average time taken for an ambulance to reach its destination by approximately 15-20% compared to traditional traffic systems. Furthermore, it highlighted areas with frequent traffic congestion, which could be used to optimize future traffic management strategies. These insights will allow cities to fine-tune their traffic management strategies and improve the overall effectiveness of their emergency response systems.

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XI. CONCLUSION

In conclusion, the smart movable road divider system offers a significant advancement in urban traffic management, particularly in clearing a path for ambulances and improving emergency response times. The integration of IoT sensors, real-time data processing, and automated divider movement demonstrates the effectiveness of this solution in ensuring timely access for emergency vehicles. By automating the process, the system reduces delays, human error, and ensures that critical pathways are cleared without manual intervention.

Furthermore, the system's scalability and adaptability to existing traffic infrastructures make it a viable solution for cities with varied road networks and limited resources. The successful integration of renewable energy sources, such as solar panels, also ensures that the system remains environmentally sustainable and cost-effective over time. These benefits demonstrate the potential for widespread adoption in smart cities, contributing to improved traffic flow and safety. In future research, further improvements in system reliability, energy efficiency, and integration with other smart city technologies will be crucial. As traffic patterns and urban landscapes continue to evolve, smart movable road dividers will play an essential role in advancing traffic management and enhancing emergency response capabilities across the globe.

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