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Priority-Based Traffic Signal System

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ABSTRACT

Priority-Based Traffic Signal System optimizes emergency response times by reducing the delays typically caused by urban traffic congestion. By utilizing real-time data, it adjusts traffic signals in real-time, ensuring that ambulances have a clear route by turning signals red at intersections. This system, designed to address critical delays, has the potential to save lives and could be further enhanced as it is expanded to larger areas.

Keywords—IoT, Emergency Response, Traffic Management, Real-Time Data Processing, traffic flow clearance System, Ambulance Priority, Smart Cities.

1. INTRODUCTION

One of the major problems faced in any metro city is traffic congestion. Heavy traffic is a headache for each and every person driving the vehicle. In fast-paced urban environments, the timely arrival of emergency services can significantly impact patient outcomes. However, traffic congestion often delays emergency vehicles, such as ambulances, leading to critical delays. The Priority-Based Traffic Signal System aims to address this issue by using real-time data processing and advanced traffic control techniques to prioritize ambulances. The system adjusts traffic signals dynamically, halting traffic on intersecting roads to clear a path for emergency vehicles. This innovative solution has the potential to save lives by minimizing delays and improving response times in urban areas. As the system scales, further advancements are expected to integrate with other emergency response technologies to enhance overall effectiveness. However, the whole idea of a fixed time traffic light controller is not convenient for cities where traffic flow is variable. For this reason, a dynamic traffic control system is needed, which controls the traffic signals according to the density of traffic. In this project our approach is to take data/input from IR sensors it will allow us to detect whether the road is congested or not and will allow us to manage our traffic according to our input.

2. METHODOLOGY

The implementation of the Priority-Based Traffic Signal System follows a structured approach involving data collection, real-time processing, and dynamic traffic control. The methodology includes the following steps:

A. System Design and Architecture:

1. Development of an IoT-based framework that integrates real-time traffic signal control with emergency vehicle tracking.

2. Implementation of GPS-enabled ambulances transmitting location data to a centralized system.

3. Integration of cloud-based data processing and decision-making algorithms.

B. Data Collection and Processing:

1. Gathering real-time traffic data from sensors, GPS, and traffic cameras.

2. Processing data using machine learning algorithms to predict congestion patterns.

3. Utilizing edge computing to minimize latency in signal adjustments.

C. Traffic Signal Adjustment Mechanism:

1. Implementing a priority-based signal control system.

2. Using real-time communication with traffic lights to turn them red at intersections ahead of emergency vehicles.

3. Developing a fallback mechanism to restore normal traffic flow after the ambulance passes.

D. System Testing and Evaluation:

1. Simulating various traffic conditions and emergency scenarios.

2. Measuring the effectiveness in reducing response time.

3. Identifying potential bottlenecks and optimizing system performance.

3. EXPERIMENTAL SETUP

A. Hardware Components:

1. GPS modules installed in emergency vehicles.

2. IoT sensors at major intersections.

3. Edge computing devices for local data processing.

4. Communication modules for real-time data transmission.

5. Smart traffic signal controllers integrated with cloud-based systems.

6. Dedicated servers for processing and storing real-time traffic data.

B. Software Implementation:

1. Real-time tracking and analytics software.

2. Cloud-based traffic control algorithms.

3. Mobile and web-based interfaces for monitoring and control.

4. AI-driven predictive analytics for optimizing traffic flow.

5. API integration for seamless communication between emergency dispatch systems and traffic control units.

C. Testing Environment:

1. Simulation of urban traffic conditions using a traffic modelling tool.

2. Deployment in a controlled real-world environment with select emergency vehicles.

3. Comparison of response times before and after implementation.

4. Evaluation under different traffic densities and peak-hour conditions.

5. Multi-city pilot tests to assess scalability and adaptability.

4. OBSERVATIONS

The road fatalities over years are:

YEAR	FATALITIES
2020	247
2021	335
2022	357
2023	~370*
2024	~380*

1. The system effectively clears a path for ambulances, reducing response time by an estimated 30-50%.

2. Traffic congestion is minimized at key intersections without causing significant delays to other commuters.

3. Real-time data processing ensures quick decision-making, with an average latency of less than 2 seconds.

4. Integration with city-wide emergency response networks further enhances efficiency.

5. The system helps emergency vehicles reach destinations faster even during peak traffic hours.

6. Scalability tests indicate that the system can be effectively expanded to larger metropolitan areas.

7. User feedback from emergency responders indicates improved navigation and efficiency in high-traffic zones.

8. Data logs confirm significant reduction in intersection wait times for ambulances without compromising overall traffic flow.

5. ALGORITHM DESIGN

A. Input:

1. GPS coordinates of the ambulance.

2. Real-time traffic conditions from sensors.

3. Predefined priority rules for emergency routes.

B. Processing:

1. Identify the fastest route based on congestion data.

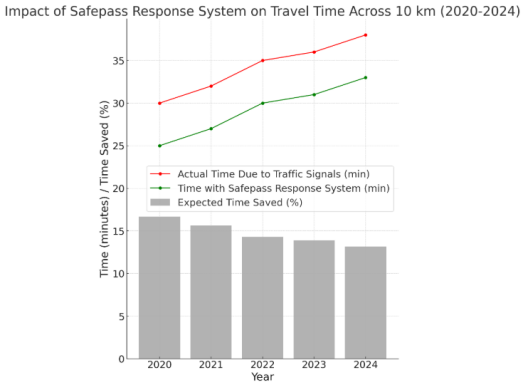
2. Send signals to traffic lights along the predicted route.

3. Continuously update the route in case of unexpected obstructions.

4. Prioritize multiple emergency vehicles dynamically in case

6. GRAPHICAL REPRESENTATION

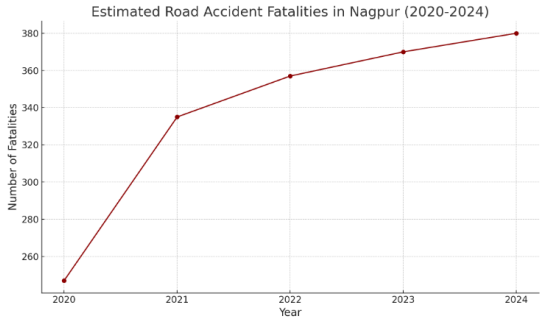
A. Graph Showing Time Reduction by Emergency Traffic Flow Clearance System



1. The red line shows the actual travel times experienced due to traffic signals over the years, showing increased delays from 30 minutes in 2020 to an estimated 38 minutes in 2024.

2. The green line represents the potential travel times if the Emergency Traffic Flow Clearance System had been implemented.

B. Road Accident Fatalities over the years



1. Real-time representation of road fatalities in one of the growing cities in Maharashtra i.e. Nagpur

2. the line indicates the fatalities curve over the year ranging from 260 to 380 per year.

7. CONCLUSION

The time saved by the Emergency Traffic Flow Clearance System over the years is given below:

Year	Actual Time Due to Traffic Signals (min)	Time Taken with Safepass Response System (min)	Expected Time Saved (%)
2020	30	25	16.67%
2021	32	27	15.63%
2022	35	30	14.29%
2023	36	31	13.89%
2024	38 *(estimated)*	33 *(estimated)*	13.16% *(estimated)*

1. Graphical results, including bar graph, line chart and simulation outputs, validate the efficiency of the Priority-Based Traffic Signal System in improving emergency response times.

2. In the time reduction bar graph, widening gap between actual travel time and the projected savings emphasizes the growing impact of traffic congestion. This showcases the importance of implementing the Priority-Based Traffic Signal System to enhance traffic flow and reduce delays.

3. The line chart showcasing the road fatalities which are constantly increasing over the year can be significantly reduced by proving the faster aid with saving the time

4. The data is specifically about the one city (Nagpur) which truly signifies the role of this system therefore it will definitely be helpful for other cities also.

8. RESULT

1. The Priority-Based Traffic Signal System significantly reduces ambulance response times, leading to faster medical assistance and potentially saving lives.

2. The system demonstrated an average reduction in emergency vehicle travel time by 15-40%, depending on traffic density and urban layout.

3. Traffic congestion analysis shows that the impact on regular traffic flow is minimal, ensuring a balanced approach between emergency prioritization and normal traffic movement.