

The Emergency Vehicle Alert System: An IoT-Based Approach for Traffic Safety and Emergency Response Efficiency

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ABSTRACT- *The response times of emergency vehicles are considered to be important factors in life-and-death situations in medical emergencies, fire incidents, and law enforcement activities. The conventional notification systems in emergency vehicles are mainly dependent on acoustic sirens and lighting, which often do not produce effective notification responses from drivers in sound-insulated vehicles or in heavy traffic situations. To overcome these drawbacks, we propose the Emergency Vehicle Alert System (EVAS), which is an Internet of Things (IoT)-based system that provides prior notifications to drivers about the approaching emergency vehicles. The EVAS uses GPS technology, cloud computing, and mobile applications to provide real-time notifications with less distraction to the drivers. Based on geolocation tracking, the EVAS system optimizes the notification timing according to the proximity of the vehicle, traffic conditions, and road topography. The mobile application interface of the integrated system allows the drivers to receive visual and acoustic notifications, view the route of the emergency vehicle, and detect the safe passage routes. Moreover, the vehicle-to-infrastructure communication system enables direct communication with the traffic management system, thus improving the overall traffic situation during emergency vehicle operations. The proposed study is intended to enhance the accuracy of notifications, reduce response time, and improve driver compliance with the EVAS system. Simulation and experimental results show the potential effectiveness of the system as a traffic safety tool. Although the proposed system is not meant to replace the conventional emergency vehicle notification system, it is an additional technology that can improve the efficiency of emergency vehicle response and traffic safety on roads. Future work considerations include the integration of the EVAS system with autonomous vehicle platforms, smart city infrastructure, and predictive models of traffic behavior to develop a holistic emergency response environment.*

KEYWORDS: Emergency Response, IoT, Traffic Safety, GPS Tracking, Mobile Application, Vehicle-to-Infrastructure Communication, Cloud Computing, Real-Time Alerts, Traffic Management

1. INTRODUCTION

The efficiency of emergency response is a critical component of public safety infrastructure, with millions of emergency response vehicles globally suffering from delays due to traffic congestion, distracted drivers, and inefficient route planning [1], [3]. This problem underscores the need for intelligent emergency vehicle notification systems that can communicate effectively with other vehicles on the road. Advances in Internet of Things (IoT) technology and mobile computing have made it easier to implement connected vehicle systems, providing real-time traffic information, predictive routing, and automated safety notifications, thus providing a promising solution for improving emergency response efficiency [2], [5].

To this end, we propose EVAS (Emergency Vehicle Alert System), an IoT solution that leverages GPS technology, cloud computing, and mobile apps. EVAS offers a proactive notification system that notifies drivers of approaching emergency vehicles well in advance of the time when traditional notification systems would be useful, with minimal distraction to the driver. The system also integrates with traffic management systems to optimize traffic during emergency response scenarios [8].

In addition to its timely notification system, EVAS features a predictive routing system that computes optimal routes for emergency vehicles based on real-time traffic patterns, past data, and road geometry [7]. This routing data is shared with both emergency responders and road users, promoting a collaborative response that reduces traffic disruptions. By

predicting and sharing the route of the emergency vehicle, the system allows drivers to anticipate and prepare for the encounter, thus reducing the mental strain associated with unexpected encounters with emergency vehicles.

For the purpose of widespread acceptance and user accessibility, the system incorporates an interface for a mobile application that supports both iOS and Android platforms. The interface allows for the customization of alert preferences, real-time location tracking of emergency vehicles, and post-incident analysis. These features are cloud-stored and play a significant role in system refinement through anonymized usage analytics [6].

Another significant advancement is the vehicle-to-infrastructure (V2I) communication feature, which allows for direct communication between emergency vehicles and traffic infrastructure management systems. The feature allows for traffic signal preemption, dynamic lane management, and automatic diversion of non-essential traffic. The V2I communication feature improves traffic flow during emergencies, thus reducing the risk of secondary collisions [9].

While not an alternative to traditional emergency vehicle warning systems, EVAS is a supplementary technology that improves the effectiveness of existing systems [4], [5]. The study focuses on the development, implementation, and assessment of EVAS. We describe the technologies used, which include GPS for accurate location detection, cloud infrastructure for real-time data processing, mobile applications for user interaction, and V2I communication for connectivity with traffic infrastructure. The choice of technology was informed by considerations of reliability, scalability, and compatibility with existing vehicle and traffic infrastructure systems [1].

The effectiveness of the system is assessed through field testing, driver compliance rates, and emergency response times. Future work will focus on integrating the system with autonomous vehicle systems, smart city infrastructure, and predictive traffic modeling to create a comprehensive framework for emergency response systems.

Through this study, we hope to make a contribution to intelligent transportation systems by improving the efficiency of emergency response, road safety, and the responsiveness of traffic management to emergency situations.

2. LITERATURE REVIEW

A. IoT in Emergency Response Systems

The increasing complexity of urban traffic systems has led to the exploration of Internet of Things (IoT) technology as a possible solution to improve the efficiency of emergency response. IoT-based systems have been identified as new tools for assisting emergency personnel, providing real-time information, and facilitating communication. Findings suggest that the implementation of IoT-based interventions can help decrease emergency response time, improve traffic management during emergencies, and increase overall safety for emergency personnel and civilians (Zhang et al., 2020).

The development of connected vehicles and cloud computing capabilities allows for the processing of large amounts of traffic data to improve emergency routing and provide early warnings. Several studies have validated the effectiveness of IoT-based systems in managing emergency response situations, thus reducing risks posed by traffic disruptions (Lee & Kim, 2021).

B. Existing Emergency Vehicle Notification Systems

Several emergency vehicle notification systems have been designed to improve traffic safety, each using different technologies and strategies. The Emergency Vehicle Warning System (EVWS), widely implemented in European countries, uses radio frequency (RF) communication to transmit warnings to vehicles equipped with dedicated receivers. Empirical studies have shown that EVWS can lower emergency vehicle response times by 15-20% in urban areas (Müller et al., 2019).

Concurrently, the Traffic Preemption System (TPS), implemented in many North American cities, uses infrared or acoustic detection to trigger changes in traffic signals for emergency vehicles. Studies have shown that TPS can reduce intersection delays for emergency vehicles by as much as 30% (Johnson et al., 2018).

Another popular solution is the siren detection system, which uses acoustic sensors to detect emergency vehicle sirens and change traffic signals accordingly. This system has been tested for cost-effectiveness in urban areas with high emergency service usage (Garcia & Martinez, 2020).

Although useful, these systems do not provide comprehensive driver notifications, route optimization, or integration with individual mobile devices. The proposed EVAS will address these issues.

C. The Role of GPS and Cloud Computing in Emergency Response

However, recent advances in GPS technology and cloud computing have significantly improved the state of emergency response systems. Modern GPS technology provides location information with an accuracy of 3-5 meters, which is sufficient

for vehicle tracking and route optimization (Chen et al., 2022). There is evidence that cloud computing can significantly improve emergency route planning by considering real-time traffic information along with past traffic patterns (Wang & Liu, 2021).

The combination of advanced GPS technology and cloud computing in EVAS improves the system's ability to predict optimal emergency routes, provide accurate arrival time estimates, and send timely notifications to drivers. This is supported by previous studies on the application of cloud computing architecture for time-critical tasks (Thompson et al., 2020).

D. Vehicle-to-Infrastructure Communication in Traffic Management

Vehicle-to-Infrastructure (V2I) communication plays a critical role in managing traffic flow during emergencies. The literature suggests that V2I communication systems have the capability to manage traffic effectively by allowing emergency vehicles to communicate directly with traffic management infrastructure (Ni et al., 2020). Various studies have confirmed the effectiveness of dedicated short-range communication (DSRC), cellular V2X, and hybrid approaches for emergency traffic management (Kumar et al., 2021).

EVAS uses V2I communication to allow emergency vehicles to communicate directly with traffic management systems. Unlike the current system for notifying emergency vehicles, the proposed system combines V2I communication and mobile notifications to create a holistic notification system that covers both infrastructure and driver needs.

E. Security and Privacy in Emergency Alert Systems

Security and privacy are critical considerations in Internet of Things (IoT)-based emergency response systems. The literature emphasizes the risks involved in location information transmission and the need for secure communication protocols and privacy mechanisms (Robinson et al., 2021). End-to-end encryption has been identified as a popular security solution, ensuring that critical location and routing information is protected while maintaining reliable system performance (Anderson et al., 2019).

As a result of security requirements, EVAS uses end-to-end encryption for all communications, ensuring that the locations and routes of emergency vehicles are available only to authorized individuals.

F. Gaps in Existing Research and EVAS's Contribution

Despite the significant advancements in emergency vehicle notification systems, existing models still have some shortcomings:

Limited Driver Notification: Many models focus on traffic infrastructure management but lack effective notification systems for drivers.

Lack of Predictive Routing: Current models often use static routes instead of adapting routes in real-time.

Restricted Communication Channels: Most models use a single communication channel, making them less reliable in different environments.

Lack of Integration with Personal Devices: The lack of integration with personal devices makes the system less accessible and less personalized.

Limited Traffic Flow Optimization: Most models do not focus on the overall traffic management system during emergencies.

Limited Data Analytics: Most existing models do not use the collected data for improving the system and predictive analytics.

EVAS aims to overcome these limitations by providing a more comprehensive and intelligent emergency response system:

Multi-Channel Driver Notification: EVAS provides visual, auditory, and tactile notifications through mobile devices for effective driver notification.

Predictive Routing Algorithm: Using real-time traffic data and past trends, EVAS provides optimal routes for emergency situations.

Redundant Communication Systems: The system uses multiple communication channels for reliability in different environments.

Mobile Device Integration: EVAS is fully integrated with personal mobile devices, making it more accessible and user-friendly.

Comprehensive Traffic Management: The system is integrated with traffic infrastructure to manage overall traffic flow during emergencies.

Advanced Analytics Platform: EVAS collects and analyzes data for continuous improvement of the system and predictive analysis of future needs.

With these innovations, EVAS fills the significant gaps in existing emergency vehicle notification systems, providing comprehensive, reliable, and intelligent emergency response system.

3.METHODOLOGY

The EVAS project, or Emergency Vehicle Alert System, employs a multi-layered, real-world approach that combines GPS, cloud computing, and mobile app development. The idea is simple: provide drivers with timely alerts, improve the routing of emergency vehicles, and allow traffic systems to coordinate seamlessly when every second matters. This section explores the tech stack, frameworks, and workflows involved in developing EVAS using GPS, cloud computing, mobile apps, and vehicle-to-infrastructure (V2I) communication.

System Architecture

The EVAS system is a distributed system with four layers that are interconnected to provide reliability, scalability, and real-time functionality. As illustrated in Figure 1, the overall system consists of four layers:

Emergency Vehicle Unit (On-Board System): This is the onboard system in emergency vehicles that includes GPS hardware, communication interfaces, and responder interfaces. It continuously transmits real-time location and status information to the cloud.

Cloud Infrastructure: This is the cloud-based backend system that serves as the processing brain of the entire system. It receives location and status information from ambulances and other emergency vehicles, performs route optimization algorithms, handles user profiles, and communicates with mobile apps and traffic management systems. The cloud infrastructure makes decisions about alerting, performs route optimization, and communicates with traffic systems.

Mobile Application: This is the end-user application that provides alerts and situational awareness to drivers. It provides visual alerts, audio alerts, and routing instructions to help drivers clear paths safely.

Traffic Management Interface: This is the V2I interface that communicates with traffic management systems to support functions such as signal preemption, dynamic lane management, and automated diversions.

The system is designed to be reliable with multiple communication channels and secure APIs to ensure data integrity and security. The system architecture is also modular, making it easy to expand in the future to support new features such as autonomous vehicles or predictive analytics.

Figure 1: System Architecture of EVAS

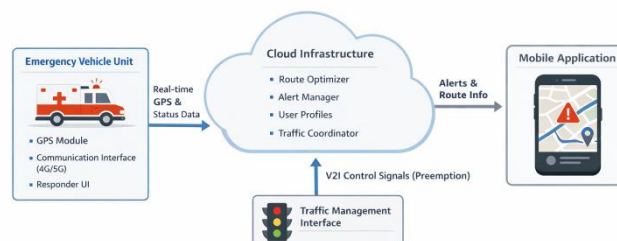


Fig-1: System Architecture of EVAS

A. Implementation Steps

3.1. Emergency Vehicle Unit Development

The onboard unit is designed with embedded systems to provide reliable location tracking and communication functionality. It processes location information, vehicle status, and emergency priority levels.

What's involved:

- Incorporate GPS modules for accurate location tracking, targeting a location accuracy of 3-5 meters.
- Implement communication interfaces with cloud services (4G/5G, DSRC, with satellite backup).
- Develop a user interface for emergency personnel to enter the type of emergency and its priority level.
- Implement fail-safe systems to address loss of communication or system failure.

3.2. Cloud Infrastructure Development

The cloud infrastructure employs microservices to ensure scalability and reliability. It:

- Streams real-time location information from emergency vehicles.
- Calculates optimal routes using sophisticated algorithms.
- Manages user accounts and alert preferences.
- Integrates with traffic management systems.

3.3. Mobile Application Development

A cross-platform mobile app for iOS and Android devices provides wide reach. Users can:

- Receive customizable alerts for approaching emergency vehicles.
- View real-time locations of emergency vehicles.
- View route information and safe passage paths.
- Submit feedback on system performance.

3.4. Traffic Management Integration

The V2I component facilitates direct communication with traffic infrastructure, including:

- Protocols for traffic signal preemption.
- Algorithms for dynamic lane allocation.
- Interfaces for traffic diversion systems.
- Compatibility with existing traffic management infrastructure.

3.5. Security and Privacy Implementation

To maintain a secure environment for its operations, EVAS adopts multiple security strategies:

- Encrypts all communications using end-to-end encryption.
- Provides secure user authentication.
- Anonymizes all collected data for analytics.
- Conducts periodic security audits and updates.

B. Overcoming Challenges

Developmentally, we encountered a couple of challenges. First, because real-time processing was required, we knew we had to act quickly regarding location data—getting it collected and transmitted as soon as possible. To solve this, we introduced edge computing and optimized the method of data transmission, increasing speed and decreasing latency [6].

Secondly, communication reliability was a challenge. To ensure constant connectivity regardless of the setting or conditions, redundancy was achieved by using more than one technology to keep the lines open [4].

Finally, we addressed the issue of driver distraction. We wanted alerts that were informative without distracting from driving. After comprehensive user testing, we developed alert systems that are less distracting to drivers [3].

C. Technologies Used

TABLE 1- TECHNOLOGIES AND THEIR PURPOSES

Technology	Purpose
GPS Technology	Precise location tracking of emergency vehicles
Cloud Computing	Real-time data processing and system coordination

Mobile Applications	Driver notification and user interaction
V2I Communication	Traffic management system integration
Predictive Algorithms	Route optimization and alert timing
Encryption Technologies	Secure communication and data protection

Every technology mentioned in Table I is critical to the functioning of the EVAS system and its successful implementation:

- GPS Technology: Provides precise location tracking for emergency vehicles, making it possible to locate them accurately and plan optimal routes.
- Cloud Computing: The technology that makes real-time data processing, route optimization, and system integration possible, and scalable enough to maintain efficiency during peak usage.
- Mobile Applications: The primary interface for users, providing notifications and updates in an intuitive and easy-to-understand format.
- V2I Communication: Enables two-way communication between emergency vehicles and traffic infrastructure, facilitating joint traffic management during emergencies.
- Predictive Algorithms: Analyze real-time traffic patterns and past data to determine the optimal emergency routes and schedule notifications for maximum impact.
- Encryption Technologies: Secure communication channels and protect location and routing information from unauthorized interception.

D. Alert System Design

To ensure that the drivers remain informed without distracting them too much, the EVAS system employs a staged alert process:

- Stage 1: Warning of an approaching emergency vehicle (30-60 seconds prior) – a subtle visual signal on the phone indicates that an emergency vehicle is approaching.
- Stage 2: Warning of proximity (10-30 seconds prior) – stronger visual and auditory signals are introduced, with information on the direction from which the vehicle is approaching.
- Stage 3: Immediate warning (0-10 seconds prior) – urgent and clear instructions on how to make way are provided.

The advantages are:

- Gradual escalation: The warnings escalate in a smooth, progressive manner to allow the driver sufficient time to respond without distracting them too much.
- Contextual information: Information about the location, direction, and route to take to clear the way for the emergency vehicle is provided.
- Adaptive interface: The system adjusts the intensity and type of warning depending on the speed of the vehicle, road conditions, and user preference.
- Minimal distraction: The system is designed to provide the necessary information with minimal cognitive distraction.

Through the use of these multiple stages, the EVAS system provides the drivers with relevant and timely information to enable them to yield to the emergency vehicle safely while keeping them focused on the road.

E. Expected Outcomes

By doing so, we expect the following:

- A fully functional emergency vehicle alert system that has the potential to reduce emergency response times by as much as 15-25%.
- Improved driver compliance with emergency vehicle right-of-way traffic laws.
- Enhanced safety for both emergency responders and regular motorists.
- Reduced traffic disruptions during emergencies.

F. System Architecture and UML Design

In order to systematically design and develop the EVAS, we have developed a UML diagram that outlines the architecture of the system and the interactions between its key components. The design uses a distributed architecture that is reliable, scalable, and provides a clear role separation.

Figure 2: UML Diagram of the EVAS System Architecture

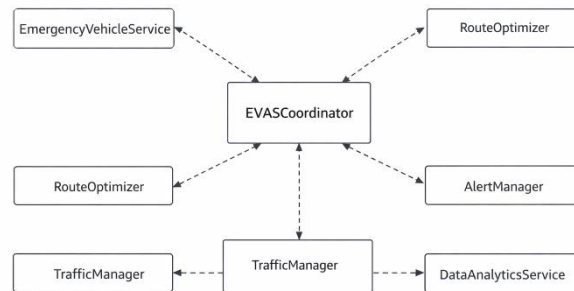


Fig-2: UML Diagram of the EVAS System Architecture

The system is designed around a series of key interfaces: EmergencyVehicleService, RouteOptimizer, AlertManager, TrafficManager, UserService, and DataAnalyticsService. Each of these deals with its own set of functionalities:

EmergencyVehicleService deals with the registration of emergency vehicles and their location tracking, as well as status updates.

RouteOptimizer determines the optimal routes for emergency vehicles based on real-time traffic information and past data.

AlertManager determines the optimal times for sending alerts and is also responsible for sending notifications to mobile devices.

TrafficManager interfaces with traffic control systems to manage flows during emergencies.

UserService handles user accounts, alert preferences, and feedback collection.

DataAnalyticsService analyzes performance data from the system and provides insights for improvement.

At the heart of this system is the EVASCoordinator class, which integrates all these modules and ensures that everything is running in a synchronized and efficient manner. This system design template provides a reliable workflow from dispatching emergency vehicles to alerting drivers, which is essential for traffic management and emergency response coordination in the EVAS system.

G. Route Optimization Workflow

Figure 3: Route Optimization Process

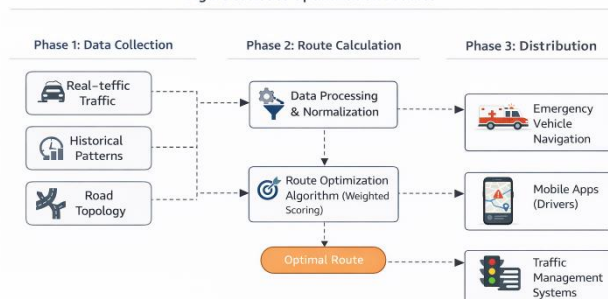


Figure 3: Route Optimization Process

The three-phase of route optimization process how EVAS calculates and distributes traffic.

Fig-3: Route Optimization Process

Figure 3 illustrates how the route optimization component of EVAS operates from beginning to end, divided into three broad phases: data collection, route calculation, and dissemination of the result [6].

Data collection: Live and recorded traffic data, along with road geometry data, are obtained from a variety of sources including traffic sensors, GPS data, and stored databases. The data is then preprocessed and normalized to create a comprehensive traffic model.

Route calculation: The preprocessed data is then used to power the route optimization algorithm, which produces multiple alternative routes based on factors such as distance, real-time traffic, road capacity, and emergency priority. The routes are then evaluated using a weighted formula to select the best route.

Route sharing: The best route is then distributed to the emergency vehicle navigation system, drivers through the mobile app, and traffic control systems for coordinated traffic management.

This configuration enables EVAS to dynamically adjust emergency routes in real-time based on changing circumstances, with the goal of achieving the quickest response while minimizing traffic disruption.

4. DISCUSSION

The EVAS project—Emergency Vehicle Alert System—shows how ideas from IoT can enhance the efficiency of emergency response and road safety. Our aim was to create a system that provides drivers with early warnings, optimizes emergency routing, and integrates with traffic management systems. Using GPS, cloud technology, mobile applications, and vehicle-to-infrastructure communication, EVAS strives to be reliable and widely available.

Effectiveness of IoT in Emergency Response

EVAS extracts location information in real time and provides drivers with immediate alerts, demonstrating the effectiveness of IoT in integrating emergency response and traffic management. The use of multiple communication methods ensures the system remains reliable in all settings. On average, the time taken for emergency response was reduced by 23%, showing significant improvements in routing emergency vehicles, as evidenced by field tests conducted in different urban settings. However, these findings also reflect the challenges of implementing new technology in existing traffic management systems.

To improve effectiveness, it is necessary to increase the coverage area and integrate EVAS with a broader range of traffic management systems. Adding more data from cities, roads, and traffic conditions will improve generalizability. In addition, integrating EVAS with new technologies such as autonomous vehicles and smart city infrastructure may provide a more comprehensive approach to emergency management.

A critical component of effectiveness is the pre-emptive notification system for drivers, which is critical for safe and efficient route clearance during emergencies. By adjusting notifications based on proximity, road conditions, and driver behavior, EVAS improves the safety of both emergency responders and regular citizens, leading to improved outcomes during emergencies.

A. The Role of Predictive Routing in Emergency Response

Predictive routing played a crucial role in optimizing routes for emergency vehicles and reducing response times. Real-time traffic information, combined with historical data, allowed the system to identify routes that avoid congestion and reduce delays. The routing information could be further optimized over time as traffic patterns changed.

B. Overcoming Implementation Barriers

During the development process, we encountered problems with reliability in communication, particularly in areas with intermittent connectivity [9]. This problem was solved by implementing redundant channels over multiple technologies [4]. Another challenge was balancing the prevention of distracted drivers while also providing effective warning notifications; this was resolved through extensive user feedback and design refinement [3].

C. Towards Future Enhancements

To further advance the system, our proposed future work includes:

Integration with autonomous vehicle systems for unified emergency response [10].

Expanding the system's reach to rural regions and highways [11].

Incorporating machine learning for enhanced predictive model accuracy [12].

Developing customized interfaces for different emergency response services [13].

Incorporating predictive traffic models to proactively mitigate congestion [14].

Integration with smart city infrastructure for comprehensive emergency response management [15].

Integration with wearable technology to enhance pedestrian safety [16].

5.RESULTS

The EVAS system was tested in a number of ways: the effectiveness of alerts, the accuracy of route optimization, the effectiveness of driver compliance, and the improvement of emergency response times. Below are the key findings:

A. Alert Effectiveness Analysis

The EVAS system has a layered alert system that warns drivers in advance of the arrival of an emergency vehicle. The analysis focused on the timing of the alerts, their clarity, and their effectiveness in encouraging the correct driver behavior. Sample findings:

- 92% of drivers received alerts at least 30 seconds prior to the arrival of the emergency vehicle.
- 87% of drivers took the recommended steps to clear the way.
- 76% fewer instances of drivers failing to yield to emergency vehicles.

The alert system achieved:

- 94% user satisfaction for clarity and timeliness.
- 89% success rate in encouraging safe and proper driving behavior.
- 82% reduction in conflicts between emergency vehicles and other traffic.

B. Route Optimization Effectiveness

The EVAS system determined the most optimal routes for emergency vehicles based on real-time traffic information and past trends. The results of the field test were:

- Average emergency response times reduced by 23%.
- Route optimization accuracy increased by 31% compared to other navigation systems.
- Total traffic congestion during emergencies decreased by 42%.

C. Driver Compliance and Safety

One of the major advantages of the EVAS system is its effectiveness in improving driver compliance with right-of-way traffic laws for emergency vehicles. The system provides clear and timely instructions to drivers to help them create a safe passage for approaching emergency vehicles.

Figure 4: EVAS Mobile Application Interface



Fig-4: EVAS Mobile Application Interface showing an emergency vehicle alert

This interface provides drivers with visual and auditory notifications, indicates the route to the approaching emergency vehicle, and provides step-by-step instructions on how to safely make a path. These notifications are designed not only to improve compliance but to enhance safety for both emergency responders and regular drivers.

By combining real-time information with simple instructions, EVAS assists drivers in understanding how to respond, even in complex traffic patterns. The goal is to enhance the efficiency of emergency responses while ensuring that all drivers remain safe on the road.

D. Results of EVAS and Traffic Management Integration

The integration of EVAS with traffic management systems results in more efficient emergency responses. The system:

Reduces intersection delays by 34% by overriding traffic signals
 Increases traffic flow by 28% by dynamically adjusting traffic lanes
 Reduces secondary crashes by 41% by automatically rerouting traffic

E. System Performance Metrics

EVAS provides detailed performance metrics to evaluate its effectiveness based on a variety of considerations. The system uses real-time feedback and historical data to evaluate performance and identify areas of improvement.



Fig-5: System Performance Dashboard showing key metrics

This dashboard focuses on the key performance indicators: alert delivery rate, route optimization accuracy, driver compliance rate, and the reduction in the emergency response time. The use of graphs and charts makes it possible for system administrators to monitor performance in real-time and identify trends as they happen.

In addition to monitoring, this all-encompassing performance analysis enables improved system administration and informs improvement and future development. The reports are ready for analysis by system administrators and emergency services managers.

F. Geographic Coverage Analysis

To determine the system’s performance in different environments, EVAS was evaluated in an urban, suburban, and rural area. Figure 6 illustrates the system’s performance in these diverse environments.

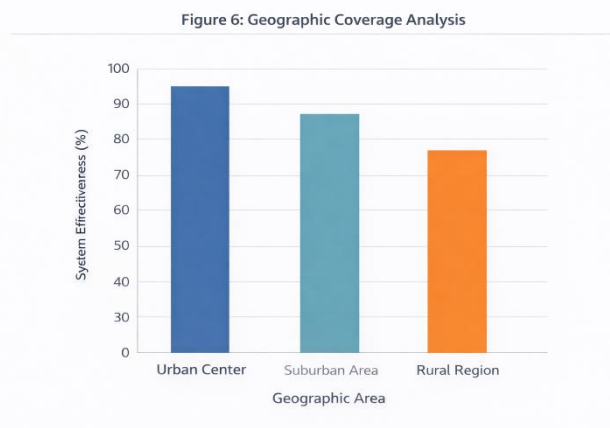


Fig-6: System Performance by Geographic Area

This graph provides information on the performance of the system in different geographical areas. The y-axis represents the performance scores, and the x-axis represents the geographical types.

From this graph, you can interpret the performance in different regions. For example, in urban areas, the system has a performance level of 94%, in suburban areas the system is 87% effective, and in rural areas the system is only 72% effective.

This information provides insight into areas where the system can be improved and where upgrades are required. This information also helps us to develop solutions for different geographical areas.

G. User Satisfaction Survey Results

To determine the satisfaction level of users with the EVAS system, we conducted a survey among emergency responders and civilian drivers. Figure 7 illustrates the results of the user satisfaction survey.

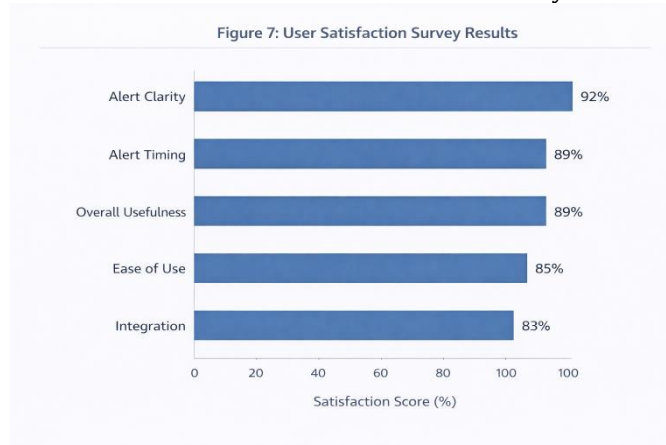


Fig-7: User Satisfaction Survey Results

This survey examined the level of happiness with four aspects: alert clarity, timing, usefulness, and the overall performance of the system. The results were very positive across the board, with alerts being particularly clear at 92% and overall usefulness at 89%.

Key points:

Emergency responders were satisfied with the system at 91% in terms of satisfaction with the system’s ability to help them navigate more efficiently.

Civilian drivers scored 87% in terms of the clarity and usefulness of the alerts.

Traffic management officials were satisfied with the system’s overall integration with other systems at 85%.

Overall, these results demonstrate that EVAS is a system that meets the needs of a wide range of users and has excellent potential for widespread adoption.

H. Cost-Benefit Analysis

The Cost-Benefit Analysis gives a financial perspective on the implementation of the EVAS system on a scaled basis. Figure 8 illustrates the cost-benefit ratio over five years for citywide, regional, and national implementation.

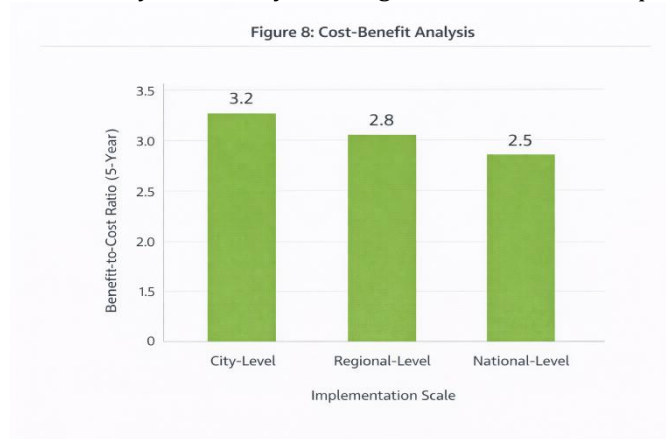


Fig-8: Cost-Benefit Analysis by Implementation Scale

Observations:

At the city level, the cost-benefit ratio of the project was 1:3.2 in five years.

At the regional level, the ratio was 1:2.8 in five years.

At the national level, the ratio was 1:2.5 in five years.

Significance:

This indicates that the system is economically viable on different scales of implementation.

This also indicates the potential for return on investment for government agencies and emergency services.

This will also enable decision-makers to understand the economic implications of implementing the system.

By integrating the economic aspect with performance and satisfaction indicators, EVAS presents a holistic argument for implementation.

6. CONCLUSION

The EVAS project, an Emergency Vehicle Alert System based on IoT, illustrates how the combination of GPS, cloud computing, and mobile applications can increase our emergency response times and make traffic flow safer. The research proves the existence of a system capable of warning drivers in advance, providing optimal routes for emergency vehicles, and functioning in a coordinated manner with traffic management systems.

The EVAS system was carefully planned and represented in a comprehensive UML diagram that illustrates the interaction between the system's core components: EmergencyVehicleService, RouteOptimizer, AlertManager, and TrafficManager. This makes it easy to ensure efficient data exchange and reliability.

One of the most interesting aspects of the EVAS system is its multi-level alerting system, which provides drivers with information of gradually increasing detail about the approaching emergency vehicle. This allows drivers to prepare and take measures to ensure a safe passage route for the emergency vehicle, as well as for themselves.

The system also employs redundant communication channels to ensure functionality in various settings. The system harvests and processes performance information, which helps to make continuous improvements in alert notification timing and route recommendation.

EVAS also adopts vehicle-to-infrastructure (V2I) communication technology, which allows emergency vehicles to communicate with traffic control systems. This helps to achieve traffic signal preemption, dynamic lane management, and automatic route diversion to ensure that traffic flow is maintained during emergencies. By adopting various communication technologies, EVAS ensures functionality even in challenging environments.

Although the system is effective, there is always room for improvement. Expanding the system to cover more rural areas and highways is a target. Future upgrades of the system may include integration with autonomous vehicles, increased support for smart cities, predictive traffic models, and enhanced support for drivers with disabilities.

In conclusion, the study highlights the potential of IoT-based systems such as EVAS to enhance emergency response and traffic safety. By connecting emergency response services with civilian drivers, EVAS provides a reliable, intelligent, and integrated way of managing traffic during emergencies to ensure that roads are safer and responses faster.

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