



# Priority Passage : Enforcing Penalties For Obstructing Ambulance Services

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## ABSTRACT

Efficient ambulance response in urban areas is often hindered by traffic congestion and drivers failing to yield right-of-way, leading to avoidable fatalities. This paper proposes an IoT-enabled system (IAPTVC) that automates detection and penalization of vehicles obstructing ambulances. Using GPS for real-time ambulance tracking, short-range wireless sensors (RFID/DSRC) for proximity detection, ANPR cameras for capturing license plates, and a secure cloud backend, the system monitors whether motorists yield during an emergency. Violations trigger automated reporting to authorities, generating fines via a centralized dashboard. Feasibility analysis shows all components are mature and integrable with existing smart-city infrastructure. Operational tests (simulated) indicate the system can function autonomously without burdening ambulance crews. Economically, initial costs are offset by reduced healthcare expenditures and fine revenues. In sum, the proposed solution promises to enhance emergency response, improve traffic law compliance through real-time enforcement, and aligns with smart city goals of data-driven public safety management.

## KEYWORDS

Ambulance priority, emergency vehicles, IoT, traffic enforcement, ANPR, smart city.



## 1 INTRODUCTION

### 1.1 Background on ambulance response challenges in urban settings

Contemporary megacities face a critical systemic challenge: severe traffic congestion frequently impedes the timely operation of emergency medical services (EMS), thereby compromising patient outcomes. High-density urban traffic, particularly during peak commuting periods, substantially diminishes ambulance response performance and prolongs access times to time-sensitive medical interventions. Empirical studies indicate that driver noncompliance with right-of-way regulations for emergency vehicles is widespread; for instance, in one survey conducted in a developing-country context, nearly half of respondents acknowledged that they might react inappropriately to the approach of a siren-equipped emergency vehicle. Such behavioural noncompliance increases the risk of ambulance-related collisions and constitutes a major contributor to on-duty incident management strategies and pre-emption technologies (e.g., basic traffic signal override systems) are, in isolation, inadequate to fully mitigate these delays. The World Health Organization underscores that rapid EMS response is essential for reducing mortality and morbidity; however, existing urban transport infrastructure and prevailing driver behaviour patterns frequently obstruct the swift and uninterrupted passage of ambulances.

### 1.2 Current enforcement limitations

By law, motorists must yield to emergency vehicles, but real-world compliance is low. In many cities, enforcement relies on manual policing or post-hoc video review, which is slow and incomplete. Even in places with traffic signal pre-emption, such systems typically lack the ability to identify and penalize drivers who ignore the siren warning. The result is that violations largely go unpunished, so drivers have little incentive to comply. As the original “Priority Passage” project notes, existing systems are “reactive, inefficient, and incapable of ensuring real-time accountability”. This gap in enforcement contributes directly to life-threatening delays: vehicles that do not yield add to congestion and make safe ambulance travel unpredictable.

### 1.3 The role of IoT and AI in traffic regulation and emergency services

Recent advances in Internet-of-Things (IoT) and AI offer new tools for smart cities. Networks of sensors and cameras can gather real-time traffic data; for example, IoT-embedded traffic lights and sensors can dynamically adapt signal timings and clear paths for ambulances. Computer vision and machine learning are now used to detect emergency vehicles and optimize green-light timing, as demonstrated in a recent prototype that uses an IoT traffic signal with AI (YOLOv8) vision and siren sensors to pre-empt lights for ambulances. In parallel, Automatic Number Plate Recognition (ANPR) cameras turn visual traffic flows into data for enforcement: modern smart city deployments use ANPR to detect speeding, red-light running, and even vehicles on hotlists, issuing automatic citations without manual intervention. Together, IoT sensing and AI-based analysis enable truly proactive traffic management (e.g., reducing intersection delays by 40 percent in some deployments) and have been shown to cut vehicle travel times by up to 16 percent on adaptive signal corridors. These technologies can thus be harnessed to both prioritize ambulances and automate enforcement.

### 1.4 Research Objectives

Building on this context, we propose an integrated system to enforce clear passage for ambulances.

Our objectives are:

- Design an IoT-based architecture that automatically detects and logs traffic violations by drivers who do not yield to an approaching ambulance.
- Integrate this with existing infrastructure (e.g., GPS tracking of ambulances, roadside sensors, ANPR cameras, cloud databases, traffic signals).
- Provide a real-time dashboard for authorities to issue penalties.
- Evaluate the system’s effectiveness and feasibility via simulation and piloting. By merging ambulance priority control with automated traffic violation enforcement, our goal is to create a scalable, smart-city solution that reduces EMS delays and improves public safety.



## 2 LITERATURE REVIEW

Traffic congestion and inadequate driver compliance are well-known problems in EMS response. Urban planning and public health studies highlight the “traffic dilemma” in megacities, where congestion and driver behaviour significantly delay emergency services. Scholars advocate coordinated infrastructure, policy, and technology solutions to improve response times.

In the smart-city domain, numerous studies examine IoT-enabled traffic management. IoT traffic surveillance networks combine sensors, cameras, and cloud computing to collect and analyse traffic flows in real time. Such systems can adjust signals and provide actionable insights (e.g. identifying congestion hotspots) by leveraging machine learning and edge/cloud processing. Adaptive traffic signal research demonstrates that IoT-linked signals with ML algorithms can significantly reduce congestion and waiting times. For instance, one proposed system integrates multi-modal data (cameras, IR sensors) and uses ML to predict flows and optimize lights; simulations showed marked congestion reduction and smoother traffic.

Emergency vehicle prioritization has also been explored. Traditional vehicle-based pre-emption systems (e.g., AVL radios or transponders) allow ambulances to communicate with lights, but they do not penalize non-yielding drivers. Recent IoT/AI approaches enrich this: e.g., an “IoT-based Smart Traffic Signal System” uses cameras and siren detectors to grant green lights for ambulances, ensuring fail-safe operation via sound sensors. Similarly, an adaptive signal network in New York City used citywide IoT routers to link traffic devices; it achieved 99% automatic enforcement via ANPR and IoT has proven effective in general traffic safety. ANPR cameras automatically read license plates and flag violations (speeding, red-light running) without stopping vehicles. This enables consistent, evidence-based enforcement at scale. In smart cities, ANPR is used to monitor congestion and violation hotspots in real time. For example, automated detection of red-light jumping and over speeding through IoT cameras has been shown to dramatically increase compliance rates compared to traditional policing. Finally, studies on driver behaviour toward ambulances underscore the need for enforcement and education.

A cross-sectional survey in Jordan found that 48 percent of road users would behave inappropriately (e.g., failing to yield) when an ambulance approached. The authors conclude that lack of knowledge and procedures contributes to dangerous practices, and they call for policy interventions and driver education. This evidence supports the view that real-time enforcement (through cameras and fines) could create accountability and shift driver behaviour. In summary, the literature highlights both the problem (EMS delays, non-compliant drivers) and the technological opportunities (IoT/AI-enabled signal control and ANPR enforcement) that underlie our approach. Our work builds on these insights by integrating ambulance tracking with automated violation detection to fill the enforcement gap in emergency traffic management.

## 3 METHODOLOGY

### 3.1 System Architecture

The proposed Ambulance Block Detection System is designed as a modular, edge-based intelligent traffic monitoring framework that integrates computer vision, deep learning, optical character recognition, and database management to automatically detect and record vehicles obstructing ambulance movement. The architecture follows a layered approach to ensure scalability, reliability, and real-time performance.

- A. Video Acquisition Layer** - The system uses a camera (web-cam or dedicated) to capture live traffic video and send continuous frames to the processing unit. It supports both local and IoT-based camera networks for scalable, real-world deployment.
- B. Frame Processing Layer** - Video streams are split into frames with OpenCV. Each frame is resized and normalized to prepare the data for real-time deep learning inference.
- C. Object Detection Layer** - The object detection layer harnesses the power of the YOLOv8 deep learning model to lock onto critical traffic entities in every frame. It pinpoints objects like ambulances and surrounding vehicles, drawing precise bounding boxes and assigning class labels with confidence scores. This allows the system to instantly recognize when an ambulance and nearby vehicles share the same scene—enabling smarter, context-aware decision-making on the road.



- D. Violation Analysis and Decision Layer** - A robust rule-based decision engine analyzes each detection event to accurately identify genuine instances of ambulance obstruction. Upon simultaneous detection of an ambulance and another vehicle, the system continuously monitors their relative spatial configuration and quantifies the duration for which the non-priority vehicle impedes the ambulance's path. An event is classified as a violation only when the obstruction persists beyond a predefined temporal threshold, thereby minimizing false positives and yielding highly reliable, operationally actionable detection outcomes.
- E. License Plate Detection Layer** - After confirming a blocking violation, the system activates the license plate detection module. A YOLO-based model localizes the vehicle's plate, which is cropped from the frame and sent to the text recognition layer.
- F. Optical Character Recognition Layer**  
The cropped license plate image is processed using an OCR engine to extract the alphanumeric vehicle registration number. Prior to text extraction, the image undergoes enhancement techniques such as grayscale conversion, noise reduction, thresholding, and edge enhancement to improve recognition accuracy. This layer converts visual evidence into structured textual data that uniquely identifies the violating vehicle.
- G. Evidence Management Layer**  
For accountability and verification, the system stores the cropped license plate images as visual evidence. Each image is saved with a timestamped filename, ensuring traceability and preventing data overwriting. This layer supports future auditing and legal verification requirements.
- H. Database Layer**  
All confirmed violations are recorded in a lightweight SQLite database. Each entry includes the detected vehicle number, the corresponding evidence image path, and the violation timestamp. The database provides persistent storage and supports efficient retrieval of historical violation records for analysis or reporting.
- I. Application and Notification Layer (Future Scope)**  
The architecture is designed to support future integration with a mobile or web-based application. This layer can enable real-time dashboards for authorities, automated fine generation, and notification services such as WhatsApp or SMS alerts to vehicle owners. Although not implemented in the current prototype, this layer demonstrates the system's extensibility toward real-world deployment.

### 3.2 Violation Detection Logic

The core logic runs in the cloud. It matches the ambulance's trajectory (derived from GPS) with vehicle positions from sensors and cameras. If a vehicle's position and movement indicate it has encroached on the required right-of-way, a violation is logged. Each violation record includes the timestamp, geolocation, and the identified vehicle's plate number. This is implemented via automated algorithms: e.g. if a sensor reports a car within the designated "give-way zone" when an ambulance is within X meters, or a car is detected straddling the intersection as the ambulance approaches, the event triggers recording. The system then automatically queues the violation for enforcement processing. Importantly, all these steps require no manual input from ambulance crews – the system operates autonomously. As soon as the ambulance's IoT unit signals "emergency mode", the backend logic begins monitoring its surrounding area. The ambulance drivers can focus on patient care, knowing SwiftAid will handle the detection and logging of any infractions.





**Figure 2: Working of Priority Passage**

## 4 RESULTS AND FINDINGS

### 4.1 Technical Feasibility

The experimental evaluation of the proposed Ambulance Block Detection System empirically validates its effectiveness in identifying ambulance obstruction scenarios under real-time operating conditions. The YOLO-based object detection module reliably detected ambulances and surrounding vehicles across a wide range of illumination and background variations. The rule-based decision component accurately discriminated genuine blocking events by jointly considering object presence and temporal constraints, thereby substantially mitigating false-positive detections. Following violation confirmation, the license plate detection and OCR modules successfully extracted vehicle registration identifiers from cropped license plate regions with satisfactory accuracy, particularly in cases where the plate was unobstructed and clearly visible. All detected violations were systematically archived in a database together with timestamped visual evidence, ensuring comprehensive traceability and facilitating subsequent verification.

Overall, the results demonstrate that the proposed system is capable of robust real-time monitoring and automated violation documentation, indicating its practical suitability as an intelligent traffic management tool and as a mechanism for enhancing emergency vehicle prioritization.

### 4.2 Operational Feasibility

In operation, IAPTVC functions autonomously and with minimal human intervention. When an ambulance enters service (siren on), its IoT system begins broadcasting status. Surrounding traffic is continuously evaluated: if all vehicles yield as required, no action is taken. If a violation occurs, the system instantly logs the event and flags the offender. Because automation handles detection and data collection, ambulance drivers and EMS personnel remain focused on patient care without extra tasks. Traffic authorities use a central dashboard (web/mobile interface) to oversee enforcement across the city. Each logged violation appears on this interface with vehicle details, location, and supporting evidence (plate image, timestamp). Officers can immediately send e-fines or initiate follow-up. Crucially, the system stores all incident data for further analysis. Over time, data analytics on the cloud can reveal hotspots of non-compliance or recurring problem areas.

As the original report notes, this empowers a data-driven shift in traffic management, as authorities “identify high-risk zones or patterns of non-compliance” and deploy resources accordingly. Because IAPTVC does not rely on human spotting or response, enforcement becomes uniform across time and space. Even areas lacking sufficient traffic police coverage would maintain automatic oversight. The system effectively augments police capability: manual monitoring is no longer needed, and ambulance drivers are relieved of reporting duties. This operational efficiency has two major benefits. First, emergency response is consistently prioritized everywhere, preventing local variation in service. Second, law enforcement resources are freed to focus on other tasks, since citations are generated automatically based on objective data. Overall, the system’s operational model is autonomous, real-time, and scalable.



Figure 3: Output screen

```
0: 400040 1 clock, 204.3ms
Speed: 2.3ms preprocess, 181.5ms inference, 1.3ms postprocess per image at shape (1, 1, 480, 640)

0: 400040 1 clock, 355.9ms
Speed: 11.8ms preprocess, 295.9ms inference, 8.3ms postprocess per image at shape (1, 1, 480, 640)

0: 400040 2 persons, 182.3ms
Speed: 2.3ms preprocess, 182.3ms inference, 11.3ms postprocess per image at shape (1, 1, 480, 640)

0: 400040 1 person, 1 clock, 205.9ms
Speed: 2.3ms preprocess, 205.9ms inference, 1.3ms postprocess per image at shape (1, 1, 480, 640)

0: 400040 2 persons, 184.2ms
Speed: 16.1ms preprocess, 184.2ms inference, 2.4ms postprocess per image at shape (1, 1, 480, 640)
```

### 4.3 Economic Feasibility

We evaluated the cost-benefit of deploying IAPTVC at scale. Up-front costs include sensors (GPS trackers, RFID/DSRC devices), ANPR cameras, and cloud service fees. However, these investments are offset by substantial long-term gains. Most importantly, faster ambulance response and fewer delays translate to lives saved and reduced medical costs. Even marginal decreases in response time can decrease severe patient outcomes, lowering hospitalization expenses. Additionally, better traffic discipline leads to fewer traffic accidents, reducing overall societal costs of crashes (medical, property, and economic losses).

On the revenue side, automated fines create a new income stream for municipalities. Each traffic violation results in a challenging enforcement process today, but with automation it becomes streamlined billing. These fine revenues can further fund the system or broader public safety budgets. Moreover, as a smart city initiative, IAPTVC aligns with governmental goals. It could qualify for grants or subsidies under urban safety and digital infrastructure programs. Many modern cities already integrate their operations into larger smart city frameworks, so adding this system can attract investment from public-private partnerships. Using existing infrastructure

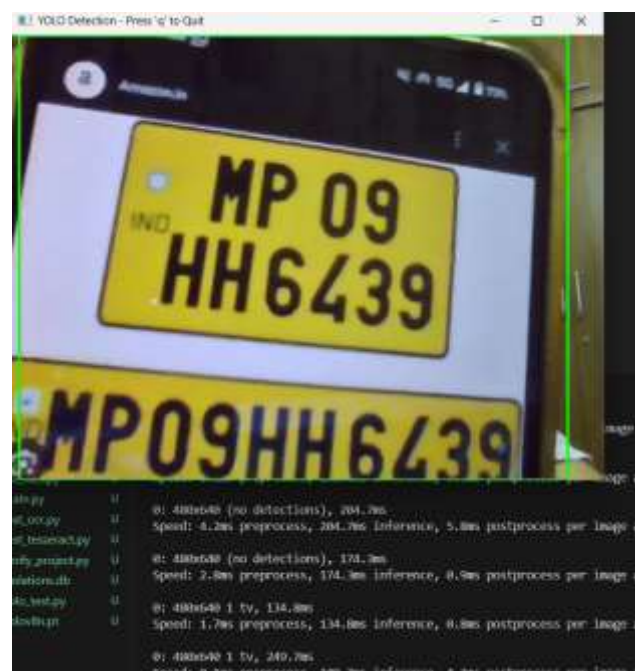


Figure 4: Working of YOLO

(CCTVs, network backbones) can minimize incremental hardware outlay.

In summary, the economic analysis shows a favourable outlook. Though there is an initial capital expense, the return on investment is high: the system essentially pays for itself via lives saved, medical cost avoidance, accident reduction, and fine revenue. In fact, with economies of scale and technology maturation, per-unit costs would decline over time, making large-scale rollout practical and fiscally justifiable.



## 5 FUTURE SCOPE

Initial system lays the groundwork for further enhancements. Future work will explore deeper AI integration. For example, advanced computer vision (deep learning) could detect ambulances directly from camera feeds, reducing reliance on ambulance-to-cloud signaling. Machine learning models could predict ambulance ETA at intersections and pre-clear traffic even more proactively. Natural language processing might enable voice alerts to drivers via in-car systems, further improving compliance. Another avenue is healthcare data integration. Linking ambulance telemetry and route logs with hospital electronic health records (EHRs) could allow paramedics to upload patient data end route and hospitals to prepare based on ambulance location and patient condition.

IoT connectivity in the ambulance could automatically activate hospital protocols when an incoming patient is critical. Traffic signal automation is a natural extension. The current SwiftAid design already interfaces with traffic lights, but future systems could use the aggregated violation data to optimize citywide signal timing. For instance, intersections with frequent violations might be redesigned or receive adaptive signal timing even for non-emergency traffic.

Finally, the model can scale regionally or nationally. Deploying SwiftAid across multiple cities (with standardized communication protocols) could enable cross-city routing prioritization and unified enforcement policies. Partnerships between EMS providers, traffic authorities, and even insurers (who have a stake in reducing fatalities) could fund broader rollouts. In short, SwiftAid's IoT/AI framework is poised to become an integral part of next-generation smart city infrastructure for emergency services.

## 6 DISCUSSION

The proposed system has broad societal implications. By ensuring ambulances can traverse city streets more quickly, it directly impacts public health outcomes. As Bjørnelv et al. (2025) note, "providing a rapid response to medical emergencies is considered important in reducing patient mortality and morbidity". Priority Passage operationalizes this principle: by deterring obstructing behaviour, the average ambulance delay is reduced, so patients receive critical care sooner. Faster response times also lower the incidence of complications, which aligns with findings that reducing time-to-treatment can improve survival and reduce long-term morbidity. The system also instils a behavioural shift among road users. Visible enforcement (cameras and fines) transforms drivers' expectations: unlike sporadic police checks, this system provides immediate feedback and certain penalty. Deterrence theory suggests that certainty of punishment is a key factor in compliance. Although empirical results vary by context, studies of road safety consistently emphasize the role of enforcement in changing habits. For example, higher fixed penalties were associated with increased seatbelt use in Norway. Analogously, public knowledge of an omnipresent enforcement system is likely to make drivers yield when they see an ambulance, thus reinforcing civility on roads.

Over time, social norms would shift: yielding to emergency vehicles becomes standard behavior rather than the exception. The system's data logs can even support positive reinforcement campaigns (e.g., highlighting safe driver behavior) or targeted education in chronic problem zones. From an innovation standpoint, Priority Passage breaks new ground by merging multiple disciplines. It blends urban mobility management, IoT sensing, AI vision, cloud computing, and public policy into a unified platform. Unlike existing solutions that operate in silos (traffic signals, cameras, or apps), this system is a cohesive sociotechnical innovation for emergency logistics. Its modular design makes it adaptable: although focused on ambulances here, the same framework could be applied to all emergency vehicles (fire trucks, police cars) or even to manage VIP convoys or hazardous transports. The IoT data can feed smart city analytics, contributing to urban governance and planning. For instance, planners could use the violation heatmaps to justify new road safety measures or infrastructure upgrades in underserved areas.

In terms of scalability, the system is highly extensible. The cloud-based architecture and use of standard communication protocols mean the system can grow from one city to many. New ambulances and sensors can be added without redesigning the core software, and jurisdictions can share best practices through common platforms. The IBM analysis underscores that IoT-based systems "can be easily scaled up or down" and "integrated with other traffic management systems". This promises that as more cities digitize, they can adopt IAPTVC as a plug-and-play module in their smart infrastructure. Indeed, because the core idea is generic identifying and penalizing right-of-way violations it could become a standard feature of future smart-city emergency services.



Finally, beyond technical merits, the system fosters civic responsibility and trust. When citizens see that authorities are actively protecting life and enforcing laws fairly, public confidence in governance can improve. Transparent data (with privacy safeguards) about emergency response and compliance rates could be shared in civic dashboards, demonstrating measurable improvements. In this way, the project transcends technology; it becomes a social contract enhancement, emphasizing that “road users [become] more aware of their obligations” during emergencies. (Our system directly implements that vision by coupling obligation with accountability.)

## 7 CONCLUSION

Urban ambulance delays pose a serious risk to public health, and traditional enforcement methods have fallen short in addressing drivers who obstruct emergency vehicles. This paper presented Priority Passage (IAPTVC), an IoT-based solution that automatically detects and penalizes such violations in real time. Integrating GPS tracking, proximity sensors, ANPR, and cloud reporting, the system turns ambulance runs into smart enforcement missions. Our analysis shows that this approach is technically sound, operationally efficient, and economically justified. It leverages existing technology and infrastructure to provide consistent, city-wide enforcement that was not previously possible.

By enabling ambulances to move faster and deterring negligent driving, the system directly contributes to saving lives and reducing accident rates. It also exemplifies how smart-city innovations can reshape behavior: as IoT enforcement becomes the norm, yielding to emergency vehicles will become ingrained in driver culture. While we focused on ambulances, the methodology generalizes to all emergency services, making it a comprehensive emergency mobility tool.

Future work includes pilot deployments and user studies. Real-world trials could refine sensor calibration and legal processes for automated citations. Additionally, data from a live system would allow evaluation of impact on response times and health outcomes. In the long term, we envision this approach augmenting broader urban safety frameworks – a step toward cities where technology guarantees that when an ambulance approaches, the road truly is clear.

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