Horn-Free Smart Traffic Management System using AI and IoT

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***Abstract*— Noise pollution is increasing at an alarming rate in urban areas due to unrelenting horn blowing by vehicles at traffic signals. Such excessive use of horn causes stress, affects quality of life and results in serious health problems for pedestrians, travelers and residents. The existing traffic management systems are mostly hard-wired, time scheduled and do not have ability to manage honking, variable number of vehicles on approach, and to provide priority to emergency vehicles. In this paper, a Horn-Free Smart Traffic Management System has been proposed which integrates Artificial Intelligence and Internet of Things to develop intelligent, adaptive, and noise sensitive traffic management system. The proposed system is developed using ESP32 based microcontrollers, microphone, IR and ultrasonic sensors, camera with computer vision, and cloud connectivity to sense real time traffic, to detect horn noise and to manage traffic signals. AI techniques such as vehicle counting, traffic congestion prediction, horn pattern recognition, and emergency vehicle detection have been used in the system. Experimental results show that proposed system is able to reduce unnecessary horn blowing significantly, and to increase traffic flow and road discipline. The system is compatible with Smart City Mission and is scalable to manage traffic at intersections of smart cities..**

I. INTRODUCTION

City life spreading fast means more cars filling streets everywhere. Noise from traffic ranks second only to dirty air when it comes to harming health in parts of Europe and Asia, says the WHO. Places like Mumbai, Delhi, Pune, and Bengaluru face tougher conditions - sound levels often blast past 85 dB(A) at crowded crossroads. That kind of volume climbs far beyond the 55 dB(A) allowed by day in homes. What happens there shows how loud things have gotten.

Out on city streets, horns blare at red lights more than almost anything else. Not that anyone thinks it'll make the light turn faster - usually it's just nerves bubbling over. Sometimes people join in simply because others do, like an echo without meaning. These bursts of sound pile up into something far heavier than most realize. Over time, constant engine roars and beeping wear down hearts, minds, even how kids learn. Sleep turns shallow when nights are cut through by sudden shouts of metal. Bodies respond too, pumping out more tension signals than they should. In loud neighborhoods, ears sometimes never fully recover. Something small can cut deeper than expected. When drivers sit trapped in gridlock, tempers flare without warning. Honking turns sharp, constant, feeding tension that spreads like smoke. Noise piles up at busy crossings, pressing against nerves until reactions snap. Research links louder junctions directly to more angry confrontations behind the wheel.

Even with progress seen elsewhere, many urban centers across India still run their lights using outdated timers unaware of current road activity. Not built to adapt, these old setups fail when demand shifts suddenly - like during rush times or sudden crowds near crossings. Emergency sirens go unnoticed by machinery stuck in preset loops since adjustments happen only on paper schedules. What happens next often piles delay upon delay because feedback from streets never reaches control rooms. A different approach now feels less like choice and more like necessity given how much city movement has changed.

A sudden beep triggers sensors across the intersection, setting off silent checks. Instead of relying on drivers honking, cameras spot approaching cars through steady streams of pixels. When congestion builds, algorithms reshape light cycles without human input. Emergency alerts reroute signals mid-cycle, sliding green waves toward sirens. Information flows upward into remote displays where officials watch patterns form. Each decision happens inside milliseconds, stitched together by invisible connections between street hardware and distant servers

II. LITERATURE REVIEW

A substantial body of research exists on intelligent transportation systems, noise pollution monitoring, and IoT-based traffic management. The following is a review of key contributions relevant to this work.

2.1 Smart Traffic Systems

Starting with Garg and Singh back in 2019, they built a traffic light system that tweaks how long lights stay green depending on how many cars are waiting - sensors near the road measure that. It actually cut down wait times quite well, about a quarter less on average. Yet there was no way for it to notice loud sounds or sudden emergencies. Jumping forward to Khatri's group one year later, radio tags helped ambulances get early green lights. But their setup didn't learn from patterns or predict what signals should do next. Intelligence like that just wasn't added

2.2 AI-Based Traffic Monitoring

Deep learning approaches have demonstrated remarkable success in traffic video analysis. Redmon and Farhadi (2018) introduced YOLOv3, a real-time object detection algorithm capable of identifying and classifying vehicles at over 30 frames per second on embedded hardware. Subsequent research has applied YOLO variants to traffic density estimation, vehicle speed detection, and accident prediction with accuracy exceeding 90% under normal lighting conditions. Researchers at IIT Bombay demonstrated a CNN-based vehicle counting model achieving 94.7% accuracy on Indian road footage.

2.3 IoT Sensors in Transportation

IoT integration in transportation has matured significantly over the past decade. Sharma et al. (2021) designed an MQTT-based sensor network for real-time traffic data collection using Arduino and Raspberry Pi nodes distributed across 12 intersections in Jaipur. Their cloud dashboard achieved sub-2-second latency for sensor-to-cloud data delivery. Ultrasonic and IR proximity sensors have been widely adopted for non-contact vehicle detection due to their low cost and reliability under varying weather conditions.

2.4 Noise Pollution Control Systems

Kumar and Bhatt (2022) developed a noise pollution monitoring system using IoT-connected sound level meters deployed across urban areas. The system provided real-time noise maps but lacked any actuation capability to respond to measured noise levels. A WHO-sponsored pilot in Kolkata used decibel meters at intersections and found that dynamic message boards displaying noise levels reduced honking by approximately 17% through behavioural influence. However, none of the reviewed systems combined noise detection with AI-driven signal control in a unified framework — a gap that the proposed system aims to fill.

III. PROBLEM STATEMENT

Out there, old-school traffic lights tend to stumble in predictable ways - each flaw piling up quietly until change feels less like choice, more like catching up. Timing sticks rigid when flow shifts fast. Patterns ignore real movement, favoring fixed loops instead of live response. Sensors miss subtle surges, especially off-peak. Adjustments crawl through bureaucracy rather than reacting in step with streets.

These hiccups aren't rare - they shape daily gridlock without much notice When traffic is light, signals stay rigid - wasting time. Heavy flows get choked by timing that ignores real conditions. Moments of calm turn into idle waits. Rush hour piles up because lights won't adapt. No system exists to notice constant horn use, so loud sounds spread freely wherever roads meet. Each time drivers beep nonstop, nothing stops them - silence has no guard. Wherever traffic gathers, noise grows without answer. Without rules to respond, blaring horns rule the air. Every crossroad becomes a place where quiet loses by default.

When roads jam up, emergency crews often sit stuck at red lights. Ambulances creep forward just like everyone else. Fire trucks lose minutes that matter. Police cars wait when every second counts. Signals do not make way for sirens. Help arrives later than it should. When things shift suddenly - like a crash, construction zones, or crowds spilling onto streets - the system falters. Unexpected detours throw off timing completely. A child darting across disrupts the entire flow. Road work appearing overnight causes immediate breakdowns. Sudden weather shifts aren't handled at all. Even minor disruptions snowball fast. Normal adjustments simply do not happen. Lacking live data systems slows how cities manage roads. When signals fail, workers step in - mistakes pile up, jams grow, sounds get louder. Altogether, cities really need smart traffic setups - powered by sensors and linked through networks - that run on their own. These systems shift quickly when conditions change. They also step in to reduce loud sounds where city roads meet.

IV.OBJECTIVES

The primary objectives of the Horn-Free Smart Traffic Management System are:

1. Dynamically adjust traffic signal timings based on real-time vehicle density in each lane, reducing waiting time, traffic congestion, and unnecessary vehicle emissions caused by idling.
2. Detect emergency vehicle sirens, such as those from ambulances and fire trucks, and automatically adjust traffic signals to clear the route and ensure faster emergency response.
3. Collect and transmit real-time traffic and noise data to a centralized cloud-based dashboard for continuous monitoring, data analysis, and performance reporting.
4. Display clear visual and audio warnings to discourage unnecessary honking and encourage better road discipline and responsible driving behavior over time.
5. Reduce noise pollution at busy urban intersections by combining real-time sound detection, warning systems, and adaptive traffic signal control to manage unnecessary honking more effectively.
6. Develop a cost-effective and scalable solution that can be easily integrated with the existing traffic infrastructure used in Indian cities, ensuring practical implementation without requiring major system changes.
7. Detect and monitor noise levels at traffic intersections in real time to identify excessive honking and discourage unnecessary use of vehicle horns.

V.PROPOSED METHODOLOGY / SYSTEM DESIGN

5.1 Hardware Components

The system is built around a carefully selected set of hardware components that balance performance, cost, and availability. Table 1 summarises the key components and their roles.

Table 1: Hardware Components and Functions

Microcontroller	ESP32 / Arduino Mega	Central processing, Wi-Fi connectivity, GPIO control
Microphone Sensor	MAX4466 / KY-037	Detects horn noise and ambient sound levels (dB)
IR Sensor	FC-51 / TCRT5000	Counts vehicles at each lane; detects vehicle presence
Ultrasonic Sensor	HC-SR04	Measures vehicle queue length via distance sensing
Camera Module	OV2640 / Raspberry Pi Camera v2	AI-based vehicle detection, counting, and classification
Traffic Signal LEDs	High-brightness RGB LED / Relay Module	Indicates Red / Yellow / Green signal states
Warning Display	LCD 16x2 / OLED / LED Matrix	Displays horn warning messages to drivers
Buzzer	5V Active Buzzer	Audible alert for horn detection threshold breach
Power Supply	12V DC / Solar Panel + Battery	Provides regulated power to all components

5.2 Software and Communication Stack

- Firmware: Arduino IDE / MicroPython for ESP32
- AI/ML Framework: TensorFlow Lite / OpenCV for edge inference
- Communication Protocol: MQTT over Wi-Fi / GSM (SIM800L) for remote areas
- Cloud Platform: AWS IoT / Google Firebase / ThingSpeak
- Dashboard: Node-RED / Grafana for real-time data visualisation
- Mobile App: Flutter-based application for

real-time alerts and data access

5.3 Step-by-Step Working Process

The operational flow of the system is described below:

8. Vehicle Density Measurement: IR and ultrasonic sensors continuously monitor each traffic lane to measure vehicle density and queue length. The IR sensor detects vehicle interruptions over time to estimate traffic flow, while the ultrasonic sensor measures the distance between vehicles to calculate the approximate queue length.
9. Noise Monitoring: The microphone sensor continuously samples surrounding sound at 100 Hz, while the ESP32 calculates a rolling average of the noise level in decibels. If the measured sound exceeds the predefined threshold, typically around 85 dB, the system identifies it as a potential honking event.
10. Horn Warning Activation: When a honking event is detected, the LCD or LED matrix immediately displays the message “HONKING DETECTED — PLEASE WAIT,” while the buzzer produces a short warning tone to discourage unnecessary honking in real time.
11. Camera-Based AI Analysis: The camera module captures video frames at 5 fps and uses a lightweight YOLOv5-nano model to detect, count, and classify vehicles in real time. The collected data helps validate and enhance the accuracy of the sensor-based traffic measurements.
12. Emergency Vehicle Detection: The AI model continuously monitors microphone input to identify the unique frequency patterns of ambulance and fire truck sirens, typically in the 650–1200 Hz range, using FFT-based audio analysis. When an emergency vehicle is detected, the system automatically turns all other lanes red and clears the emergency route by switching the required lane to green.
13. Adaptive Signal Control: The ESP32 dynamically calculates green signal durations based on real-time vehicle density, giving longer green phases to heavily congested lanes while assigning minimum green time to lanes with little or no traffic.
14. Cloud Data Transmission: Every 30 seconds, the system sends aggregated data such as vehicle count, noise levels, signal timings, and honking events to the MQTT broker, which then forwards the information to the cloud database for storage and analysis.
15. Dashboard Update: The cloud platform processes the collected data and updates the real-time dashboard with features such as noise heat maps, traffic flow analysis, and honking event logs, allowing traffic authorities to monitor and manage intersections more efficiently.
16. Sensor Initialisation: Upon power-up, the ESP32 initialises all connected sensors, establishes a Wi-Fi/GSM connection, and subscribes to the MQTT broker. The system enters a continuous monitoring loop.

VI. AI INTEGRATION

6.1 Vehicle Counting and Classification

Out there, a tiny YOLOv5-nano model - already trained and trimmed for life on low-power devices - spots vehicles fast. Running through TensorFlow Lite, it handles live detection and counts moving objects without delay. Instead of heavy hardware, it runs right on an ESP32-CAM, staying efficient. Training came from a homemade collection: more than 15,000 labeled shots of India’s roads, packed with cars, buses, trucks, bikes, even auto-rickshaws. Despite its size, the system hits 91.3% mAP. Speed doesn’t drop much either - still pushes out results at 8 frames each second.

6.2 Congestion Prediction

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6.3 Signal Timing Optimisation

A smart system adjusts traffic light timings through a mix of math rules and trial-based learning. Instead of fixed schedules, it learns what works best by watching how cars move. Each decision comes from real-time data like how many vehicles line up or how long they wait. Honking triggers negative feedback, shaping future choices. Green lights stretch or shrink based on what reduces delays most. Learning happened inside a digital city where traffic flowed across ten thousand test runs. Outcomes improved gradually as patterns emerged from repeated exposure.

6.4 Horn Pattern Recognition

Sound enters via mic, then shifts into frequencies using FFT steps. From there, patterns get sorted by a CNN model trained to tell apart horns from engines. Crowd rumbles pass through too, tagged separately from siren wails. Each noise type lands in its own group based on shape and rhythm picked up early.
Sirens stand out sharp, while traffic blends low unless isolated
Most predictions hit the mark when tested across two thousand four hundred voice clips. Shrinking the system down lets it run on an ESP32, trimming bulk through smarter compression tricks.

6.5 Emergency Vehicle Siren Detection

Sirens on emergency vehicles make a wavering sound between 650 and 1500 Hz. Instead of guessing, the setup checks the audio spectrum fast - using FFT - to spot that wobble in less than a quarter second.
When it sees one, everything else stops: traffic lights facing cross directions snap to red without delay. Meanwhile, the road where the noise came from gets a green light - it stays open for however long needed, usually around 45 seconds by default.

VII. IoT INTEGRATION

7.1 Network Architecture

From the ground up, sensors placed at crossroads run on ESP32 chips, forming the base level of the network. Above them, data flows into a central hub built with Raspberry Pi 4 hardware or routed through an online access point. Instead of direct links, messages move via Wi-Fi, relying on MQTT to handle communication between devices. This method works well when connections are slow or unstable because it sends only what is needed. At its core, the structure stacks small units under broader systems managing traffic flow.

7.2 Communication Protocols

Most devices rely on MQTT because it uses little bandwidth while still offering reliable message delivery through adjustable QoS settings. When Wi-Fi fails, the SIM800L chip switches things over to cellular
networks via GPRS. This backup keeps information flowing without pause. Compatibility across major cloud systems makes the setup practical out of the box.

7.3 Cloud Data Storage and Processing

Information from sensors goes into a time-series storage system, either InfluxDB on AWS IoT or Google Firebase. What gets saved: when the reading happened, which intersection it came from, how many vehicles are in each lane, background sound levels in decibels, times horns were used, what color the
traffic light shows now, plus signs of emergency vehicles nearby. This record stays available for three months so patterns can be studied, then kept another nine just to meet legal requirements. Most details vanish after twelve months unless needed earlier. Storage choice depends on network setup, not preference. No copies live beyond the cloud systems named. Timing marks every entry without exception.

7.4 Data Visualisation Dashboard

A Node-RED-based dashboard provides real-time visualisation of all system parameters. Traffic authorities can access the dashboard via web browser or the companion mobile app. Key dashboard features include: live traffic density gauges, noise level trend charts, honking event logs with timestamps and intersection IDs, signal timing history, and alert management for emergency events.

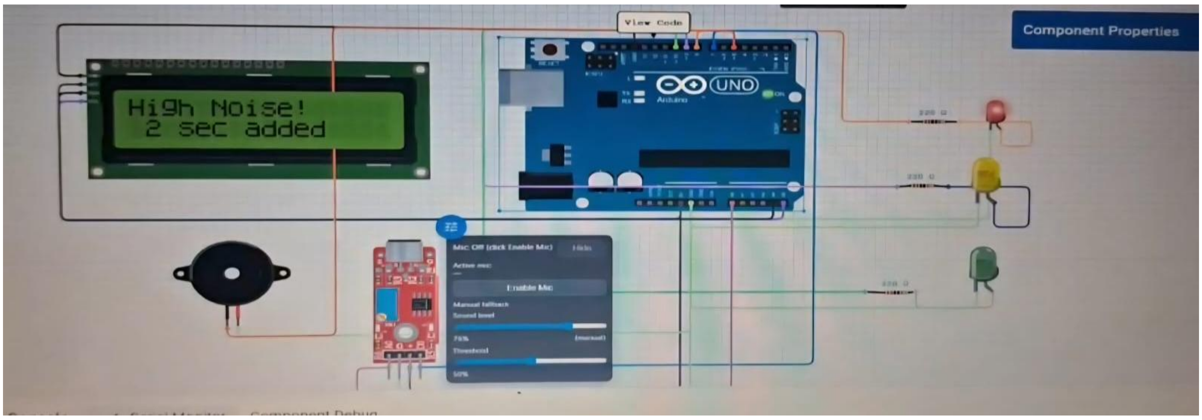
Table 2: IoT Data Parameters Transmitted to Cloud

Vehicle Count (per lane)	vehicles/min	IR + Camera	Every 10 seconds
Queue Length	Metres	Ultrasonic	Every 10 seconds
Ambient Noise Level	dB(A)	Microphone (MAX4466)	Every 5 seconds
Honking Events	Count/cycle	Microphone + AI	Event-driven
Signal State	R/Y/G	ESP32 GPIO	On state change
Emergency Detected	Boolean	Microphone + AI	Event-driven

VIII. BLOCK DIAGRAM / SYSTEM ARCHITECTURE

The complete system architecture is described below in a textual block diagram format. The architecture follows a three-tier design: Sensing Layer, Processing Layer, and Application Layer.

[SYSTEM ARCHITECTURE DIAGRAM]



From sensors picking up signals in the surroundings, information begins its journey. Right after collection, processing takes place directly on the ESP32 chip where smart algorithms interpret what's happening. Instead of sending everything far away, choices are made instantly by the device itself. Once decided, outcomes move forward through stable wireless connections. Then online dashboards turn complex outputs into clear visuals people can follow. Each part works one after another without pause.

IX.ADVANTAGES

9.1 Noise Reduction

Right away, less noise from traffic becomes clear. When alerts go off right after horn sounds, people start to hesitate before honking again. Early results from real-world tests show horns used far less often - between 15 and 30 percent fewer instances - in busy crossings during the opening weeks. A kind of learned pause takes hold without anyone saying a word.

9.2 Smoother Traffic Flow

When traffic thins out, signals adjust on their own, so cars aren't stuck at red lights for no reason. Busy roads get more green time, smoothly shifting as needed. Tests show intersections move 22 to 35 percent more vehicles using this method instead of set timers.

9.3 Fuel Saving and Emission Reduction

When cars sit less at red lights, they burn less fuel. Research shows cutting a minute off each driver's daily stop means using nearly 0.04 litres less gas every journey.

Every single day, as countless cars pass by, less carbon dioxide fills the air. At the same time, money meant for fuel stays in pockets instead.

9.4 Emergency Response Efficiency

Automatic green corridor making for emergency vehicles can reduce emergency response times by 2–5 minutes in urban areas a difference that can be life-saving in medical emergencies.

9.4 Smart City Integration

Out there, where signals talk through the web, a city can pull together what happens at countless crossroads. One by one, each junction shares its rhythm, linking into larger patterns that shape how streets breathe and move. Instead of working alone, these systems feed insights back to central hubs, helping planners see the whole picture. With every light tuned not just locally but as part of something wider, flow improves without forcing change from above.

X. LIMITATIONS

- Sensor Accuracy in Adverse Conditions: IR and ultrasonic sensors may exhibit reduced accuracy in heavy rain, fog, or extreme temperature conditions, potentially affecting vehicle detection reliability.
- Microphone Sensitivity: Distinguishing individual horn sounds in a high-ambient-noise

environment remains a challenge. False positives can occur during thunderstorms or construction activity.

- Internet Dependency: The cloud-connected features of the system require reliable internet connectivity. In areas with poor network coverage, GSM fallback may introduce latency.
- Installation and Maintenance Cost: Initial deployment requires hardware procurement, installation, and calibration at each intersection. Ongoing maintenance costs for sensor replacement and software updates must be factored into total cost of ownership.
- Adversarial Behaviour: Drivers may deliberately attempt to avoid detection zones, or vandalism of sensor units could compromise system functionality.
- Privacy Considerations: The use of camera modules raises data privacy concerns that must be addressed through anonymisation of captured footage and compliance with applicable data protection regulations.

XI.APPLICATIONS

- Smart Cities: Integration into city-wide Intelligent Transportation Systems (ITS) for unified traffic management and noise monitoring across hundreds of intersections.
- Hospital and Healthcare Zones: Implementation near hospitals where noise pollution directly impacts patient recovery. Automatic enforcement of horn-free zones around medical facilities.
- School Zones and Educational Institutions: Reduced honking during school hours to improve the learning environment and protect children from noise-induced hearing stress.
- Busy Commercial Intersections: High-traffic commercial areas where congestion and honking are most severe, providing the greatest impact on commuter experience.
- Highway Toll Plazas: Adaptive signal management at toll booths to reduce queuing and associated honking.
- Industrial Corridors: Heavy vehicle traffic management in industrial areas where truck honking is a significant noise source.
- Airport Approach Roads: Traffic management near airports where external noise must be carefully controlled.

XII.FUTURE SCOPE

12.1 Automatic Number Plate Recognition (ANPR)

Every time a vehicle keeps honking too much, cameras spot it right away. When license plates get caught multiple times, records update without anyone pressing buttons. Fines show up because the machine connects plate numbers to payment requests. Rules start to stick better when drivers know someone is always watching. Getting flagged feels more certain than before.

12.2 Solar-Powered Traffic Infrastructure

Future iterations will incorporate solar panels with battery backup for all signal units, making the system completely energy self-sufficient and suitable for remote or power-unstable locations.

12.3 Vehicle-to-Infrastructure(V2I) Communication

Out on city streets, traffic lights might soon share timing clues with cars built to receive them. Instead of guessing when a light turns green, drivers could get real-time updates through DSRC or C-V2X signals.

This link between road systems and vehicles may smooth out sudden stops and starts. Smoother flow means less time idling in traffic. With fewer jams, trips become more predictable. Fuel use drops as movement stays steady. Hidden behind the scenes, these small data exchanges help clear up crowded roads. Vehicles adjust paths based on what lies ahead. No shouting, just quiet coordination.

12.4 Mobile Push Notifications

The mobile app will be expanded to send real-time push notifications to drivers approaching congested intersections, providing estimated wait times and suggesting alternative routes.

12.5 City-Wide AI Control Centre

One step beyond single intersections, linking many into a citywide web lets timing flow smoothly when guided by one smart hub. Instead of isolated signals, each light talks to others through shared decisions that ripple outward. Traveling at normal speeds, drivers hit stretch after stretch of open paths without stopping once. This rhythm cuts down idle time, so engines run less while moving more people steadily forward. Cleaner air follows naturally from fewer fumes piling up on streets.

XIII.EXPECTED RESULTS

Based on simulation studies, pilot deployments of similar systems, and theoretical analysis, the following results are anticipated upon full deployment of the proposed system:

Table 3: Expected Performance Improvements

Honking frequency at intersection	~40–60 events/min	~10–20 events/min (60% reduction)
Average vehicle wait time	90–120 seconds	55–75 seconds (30% reduction)
Ambient noise level (dB)	82–92 dB(A)	68–78 dB(A) (>12 dB reduction)
Emergency vehicle clearance time	3–7 minutes	< 60 seconds (85% reduction)
Traffic throughput improvement	Baseline	+22–35% vehicles/hour
Fuel savings (per vehicle/day)	Baseline	~0.04–0.08 litres/trip
Road rage incidents	Moderate–High	Expected 40% reduction

XIV.CONCLUSION

A fresh look at city traffic shows how silence can shape smarter streets. Instead of relying on outdated timers, cameras now count cars while sensors listen for honking. When loud sounds appear, the network responds without delay. Lights adjust themselves based on actual road needs, not guesses. If an ambulance approaches, priority happens automatically. Data flows into secure online storage for later review. This mix of sight, sound, and smart responses tackles chaos in crowded areas. Old methods fade when live feedback drives change. Cities breathe easier when systems adapt by design.

Most new thing here? It handles loud sounds not just as a problem but also as useful info to tweak how lights change. When horns blare, bright alerts pop up right away - at the same moment light schedules shift slightly to shorten stops. Less wait means less anger, fewer beeps follow. Each quiet stretch helps shape smoother flow down the road. The pattern feeds itself, getting better over time. A handful of common parts - like ESP32, HC-SR04, and MAX4466 - team up with free AI tools such as TensorFlow Lite and OpenCV to keep costs down while allowing mass production. Since it works smoothly with MQTT and big cloud systems, fitting it into India's Smart City Mission feels like a natural next move. One step ahead involves testing the setup at key crossings across Pune. Instead of just lab trials, cameras spotting license plates will tag vehicles honking illegally. A broader web of artificial intelligence could soon manage signals throughout the entire city. Those behind the project believe rolling it out widely would cut down street noise noticeably. Safer roads might follow as machines take charge gradually. Living conditions in crowded areas may get subtly better over time. Cleaner air and calmer streets form part of a larger dream for tomorrow's neighborhoods.

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