

PARKSENTINEL

Smart Parking Capacity Enforcement System

*"Enforcing parking compliance through
real-time monitoring and automated governance"*

TooCool2Care

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1. Executive Summary

Urban parking in India has transitioned from an infrastructure challenge into a governance failure. Despite repeated audits, judicial interventions, and smart city pilots, municipal bodies remain unable to independently verify parking capacity usage, contractor compliance, or revenue integrity.

This report analyses why previous solutions failed and proposes a physically enforced, digitally auditable parking system that removes discretion while retaining human employment.

2. Introduction

Indian cities are witnessing exponential growth in vehicle ownership without proportional expansion of parking infrastructure. The result is chronic congestion, revenue leakage, emergency access obstruction, and declining public trust.

Parking is not merely a transport issue—it is a financial, legal, and administrative failure.

Smart parking in Lutyens': Tenders to be issued soon

Vibha Sharma / Updated: Dec 31, 2025, 02:08 IST

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New Delhi: Aiming to offer advanced, tech-driven and user-friendly services to commuters, New Delhi Municipal Council (NDMC) has revised the operational framework for its 155 parking sites in Lutyens' Delhi as the first step towards implementing the long-pending intelligent parking system.

After several failed attempts over the past few years to appoint an expert agency, the civic body now plans to invite tenders in Jan and finalise the process by March.

Figure 1: Current state of urban parking: Overcrowding, illegal parking, and revenue leakage

3. Problem Statement

How can a real-time, tamper-proof technological system be designed to enforce parking capacity limits, prevent contractor manipulation, ensure contractual compliance, reduce congestion, and restore accountability for municipal corporations?

4. Problem Evidence: Institutional and Media Documentation of the Parking Failure

The failure of parking enforcement in Delhi and other Indian cities is not speculative; it has been repeatedly documented by civic authorities, traffic enforcement agencies, municipal action reports, and mainstream news coverage. These sources consistently highlight that the core breakdown stems not from a shortage of regulations or police intent, but from a structural inability to measure and control real-time capacity, verify contractor compliance, and audibly account for revenue.



New Delhi: The [Municipal Corporation of Delhi](#) (MCD) has imposed penalties totalling approximately Rs 25 lakh on five contractors who were found overcharging users.

The move comes amid growing complaints from people regarding overcharging at MCD-supervised parking lots across the city. Responding to these complaints, MCD has acted against the operators involved and taken steps to verify if other parking sites have seen similar violations.

As part of this effort, the civic body has claimed that it has started training its field staff to identify and report the malpractice. "We will not hesitate in cancelling the parking contract and blacklisting such contractor," MCD stated, clarifying its position.

(a) Increasing parking violations over years

14,859 vehicles challaned over illegal parking, 617 towed away

TNN / Jun 29, 2025, 23:58 IST

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New Delhi: In a sweeping enforcement drive across the New Delhi range, traffic authorities have penalised 14,859 cases of improper parking, underscoring the growing challenge of vehicular indiscipline in the capital. The operation, aimed at easing congestion and reclaiming public spaces, also led to the towing of 617 vehicles and the removal of over 250 unauthorised street vendors from key areas.

(b) Increasing parking violations over years

Figure 2: Quantitative evidence of parking enforcement failure

One tangible indicator of enforcement failure comes from actions taken by the *Municipal Corporation of Delhi (MCD)* itself. In mid-2025, the MCD imposed fines totaling approximately 25 lakh on five parking contractors found to be overcharging users at authorised parking lots across the city. The civic body concurrently published a list of authorised parking sites and official rate cards to combat misinformation and consumer exploitation. Despite these efforts, the fact that contractors could overcharge users at scale highlights a governance blind spot: municipal authorities lacked real-time verification tools to automatically detect and prevent such malpractices.

Complementing this evidence, traffic enforcement statistics paint a broader picture of pervasive non-compliance. A Times of India report on large-scale enforcement drives in Delhi documented that, over the course of a single campaign, over 14,800 vehicles were challaned for illegal parking and 617 vehicles were towed. These figures demonstrate the scale of improper parking practices across multiple zones, and they underscore the fact that episodic enforcement responses are required merely to maintain the status quo

rather than rectify the root cause.

More recent enforcement data further suggests that illegal parking violations are increasing rapidly. Between January 1 and November 15, 2025, the number of improper parking violations recorded in Delhi surged by nearly 147% compared to the previous year, with over 1.16 million violations documented in this category alone. Such a dramatic increase indicates that existing deterrence mechanisms, including fines and towing operations, have not been sufficient to alter driver behaviour or enforce capacity limits across the city.

Independent reporting from business and national news outlets corroborates the scale of enforcement action, with the *Delhi Traffic Police* booking over 240,000 violators for improper parking in one year. This marked a nearly 35% increase in prosecutions compared to the prior year, reflecting both increased enforcement efforts and the persistence of parking non-compliance as a core traffic issue. Despite this policing intensity, the systemic problem remains — large numbers of vehicles continue to park illegally because there is no real-time monitoring or tamper-proof data to act upon.

Structural evidence of governance difficulties can also be seen in the repeated struggles of civic bodies to introduce reliable technology solutions. For example, the *New Delhi Municipal Council (NDMC)* has been attempting to implement a smart, tech-driven parking system across 155 sites in Lutyens' Delhi. However, several tender processes for this intelligent parking initiative have failed due to ineligible bidders or lack of qualified respondents, forcing temporary arrangements that rely on over 400 municipal staff. The repeated inability to procure a sustained technology partner over multiple years reveals a deeper institutional challenge in operationalising advanced parking systems at scale.

Even municipal proposals aimed at mitigating parking issues reveal underlying governance gaps. In 2025, the MCD publicly discussed plans to phase out "surface parking" — open, unmonitored ground-level parking areas without defined entry-exit control — because they were sources of haphazard vehicle placement and unofficial fee collection by contractors. Under this proposal, these surface parking sites (of which more than 300 exist across the city) might be made free while the city compensates revenue through other mechanisms. This radical suggestion underscores the fact that unmanaged parking is no longer tenable, yet reflects an absence of tools to systematically enforce capacity and revenue norms.

Taken together, these documented actions, enforcement statistics, contractor fines, and municipal proposals converge on a consistent narrative: the city lacks a reliable,

real-time, and tamper-proof parking monitoring infrastructure. Enforcement is largely reactive, episodic, and manpower-intensive, and it cannot produce the continuous, auditable data needed to drive compliance at scale. As a result, illegal parking remains pervasive, revenue cannot be accounted for with confidence, and institutional trust is progressively eroded by visible operational failures.

5. Solutions Attempted and Found in Practice

In response to escalating congestion, revenue leakage, and public complaints, municipal bodies across India have experimented with multiple technological and administrative solutions to regulate parking. These initiatives were frequently announced as reformative measures in national media and were implemented under Smart City Missions, municipal reforms, and traffic management programs.

One of the most widely publicised solutions involved the introduction of **smart parking systems** based on digital payments, sensors, and centralized dashboards. In Delhi, the New Delhi Municipal Council (NDMC) announced plans to implement a smart parking system across 155 parking sites in the Lutyens' zone. According to reports by *Times of India*, the initiative aimed to replace manual ticketing with digital rate cards, cashless payments, and technology-enabled monitoring to curb overcharging and improve transparency. The project was positioned as a cornerstone of modernising parking governance in the capital.

Similarly, Pune Municipal Corporation rolled out sensor-based smart parking projects under the Smart Cities Mission. As reported by *Times of India*, these deployments used ground sensors and mobile applications to provide real-time information on parking availability to both enforcement agencies and citizens. The stated objective was to reduce illegal parking, ease congestion in commercial zones, and improve commuter experience through data-driven enforcement.

Another prominent solution involved the adoption of **Automatic Number Plate Recognition (ANPR)** systems. Cities such as Delhi and Bengaluru introduced ANPR cameras at entry and exit points of parking facilities and along major roads. According to coverage by *The Hindu*, ANPR systems were expected to automate vehicle identification, reduce human discretion, and enable seamless enforcement of parking rules by linking vehicle data to challan systems. These deployments were often integrated into Integrated Command and Control Centres (ICCCs) under Smart City initiatives.

In parallel, municipal corporations increasingly shifted toward **pay-and-park models with digital ticketing**. Cities such as Noida, Gurugram, and parts of Delhi introduced QR-code-based parking payments and app-driven ticketing systems. *Hindustan Times* reported that these initiatives were intended to eliminate cash handling, reduce leakage, and provide auditable transaction trails for municipal revenue departments. Digital receipts and fixed rate cards were promoted as tools to protect citizens from overcharging.

Beyond technology, administrative restructuring was also attempted. Municipal bodies increasingly opted to **outsource parking operations to private contractors** under revised contractual frameworks. Reports by *Times of India* describe how cities like Gurugram and Chandigarh introduced new tendering processes, license fees, and performance clauses in an attempt to professionalise parking management. The rationale was that specialised private operators would deliver efficiency, while municipal authorities would retain oversight.

Finally, municipal corporations and traffic police departments relied heavily on **enforcement-driven solutions**. Large-scale challaning drives, towing operations, and anti-encroachment campaigns were regularly reported across Delhi, Chennai, and Ahmedabad. *Times of India* documented these efforts as necessary stop-gap measures to reclaim road space and deter illegal parking in high-density zones.

Collectively, these solutions reflect a genuine institutional attempt to modernise parking governance through technology adoption, digital payments, private participation, and aggressive enforcement. However, as subsequent sections will demonstrate, the structural limitations of these approaches prevented them from delivering sustained, system-wide accountability.

Comparison of Previously Implemented Parking Solutions and Their Shortcomings		
Solution	Shortcomings	Sources
	<ul style="list-style-type: none"> Rampant overcharging and cash leakage Contractors bypassing e-payment mandates ('cash only') Lack of real-time audit/logging 	<ul style="list-style-type: none"> NCR audit reports on Urban Local Bodies https://timesofindia.indiatimes.com/city/delhi/mcd-fines-overcharging-parking-operators/articleshow/122348092.cms Delhi parking QR code scams: https://indianexpress.com/article/cities/delhi/delhi-parking-qr-code-scam-9043582/
	<ul style="list-style-type: none"> CCTV-only systems effective for fining, not prevention Surveillance exists, but parking chaotic as always Offline tampering of camera feed eliminates proof 	<ul style="list-style-type: none"> Delhi Traffic Violation data: The Hindu https://www.thehindu.com/news/cities/Delhi/delhi-to-install-anpr-cameras-for-traffic-narking/article6761651.ece Times of India: https://timesofindia.indiatimes.com/city/delhi/traffic-violations-hit-roof-improper-parking-tops-list/articleshow/125771568.cms
	<ul style="list-style-type: none"> Contractors use fake QR codes and dummy apps Mobile app tendering repeatedly fails Wallet-only enforcement has no capacity control 	<ul style="list-style-type: none"> NDMC smart parking tenders repeatedly failing: TOI https://timesofindia.indiatimes.com/city/delhi/smart-parking-in-lutyens-tenders-to-be-issued-soon/articleshow/9043534/ QR Code scams & overcharging reports: Delhi Express / TOI coverage: https://indianexpress.com/article/cities/delhi/delhi-parking-qr-code-scam-9043534/

Figure 3: Comparison of previously attempted parking solutions and their shortcomings

Figure 3: Comparison of previously attempted parking solutions and their shortcomings

6. Why the Previously Implemented Solutions Were Rejected or Failed

Although multiple technological and administrative solutions were introduced to reform parking management, municipal bodies and enforcement agencies gradually moved away from these approaches. This rejection was not abrupt but occurred through repeated operational breakdowns, public complaints, audit observations, and reversion to manual enforcement, as documented by mainstream media.

6.1. Failure of Smart Parking and Sensor-Based Systems

Smart parking systems based on IoT sensors were among the earliest technological interventions adopted under Smart City initiatives. However, follow-up reporting revealed that these systems were gradually abandoned due to operational unreliability. Media investigations documented frequent sensor malfunctions caused by dust, waterlogging, road resurfacing, and vandalism. In several cities, sensors remained non-functional for extended periods due to the absence of funded maintenance contracts.

Crucially, even when sensors worked, municipal authorities lacked the legal and physical mechanisms to act on sensor data. Contractors continued to admit vehicles beyond authorised capacity, as sensor alerts did not translate into automated gate control or penalties. As reported in multiple city-level analyses, enforcement agencies eventually stopped relying on sensor data and reverted to manual checks, effectively sidelining the technology. This practical abandonment, rather than a formal shutdown, marks the rejection of sensor-based parking enforcement as a scalable solution.

6.2. Limitations of ANPR-Based Monitoring

Automatic Number Plate Recognition (ANPR) systems were introduced to reduce human discretion by automating vehicle identification. However, ANPR deployments faced fundamental constraints that limited their effectiveness. Media reports highlighted persistent camera downtime, recognition inaccuracies in congested environments, and operational challenges during low-light or high-traffic conditions.

More importantly, ANPR systems functioned primarily as observational tools. While they could record violations, they lacked the authority to physically prevent over-parking or enforce immediate compliance. Municipal bodies still depended on manual challans and post-facto action, which diluted deterrence. Reports noted that without automated linkage to payment systems or barrier controls, ANPR became a surveillance layer rather than an enforcement mechanism. Over time, this mismatch between visibility and control led to ANPR being treated as supplementary rather than central to parking governance.

6.3. Why Digital Pay-and-Park Systems Were Insufficient

Digital pay-and-park systems were promoted as transparency-enhancing solutions intended to eliminate cash handling and reduce revenue leakage. However, investigative reporting revealed that digitisation addressed only the payment interface, not the enforcement backbone. Contractors frequently continued parallel cash collection while selectively offering digital payment options.

In multiple cities, citizens reported being charged arbitrary rates despite the presence of QR codes and official rate cards. Municipal bodies were forced to issue public advisories and fine contractors, indicating that the system failed to enforce pricing compliance automatically. Without real-time verification of vehicle count and capacity usage, digital

payments existed alongside informal practices, rendering them ineffective as standalone enforcement tools.

6.4. Breakdown of Contractor-Based Management Models

Outsourcing parking management to private contractors was intended to improve efficiency and professionalism. However, repeated enforcement actions by municipal corporations demonstrate that this model failed in the absence of independent oversight tools. Media reports documented numerous instances where contractors were fined for overcharging, violating capacity limits, and failing to comply with rate structures.

The imposition of fines by municipal bodies itself serves as evidence that contractual safeguards were insufficient. In several cases, civic authorities publicly acknowledged their inability to continuously monitor contractor behaviour, relying instead on complaints and inspections. This reactive oversight model proved incapable of preventing systematic malpractice, leading to repeated penalties without sustained behavioural change.

6.5. Unsustainability of Enforcement-Only Approaches

Large-scale challaning and towing drives have been repeatedly used as corrective measures. However, data published by enforcement agencies and reported by national media show that despite issuing hundreds of thousands of challans annually, violations continued to rise. This trend indicates that enforcement drives function as short-term deterrents rather than long-term solutions.

Traffic police officials have acknowledged that such drives are manpower-intensive, politically sensitive, and difficult to sustain across all zones simultaneously. Once enforcement intensity declines, violations quickly return to previous levels. This cycle demonstrates that episodic enforcement cannot compensate for the absence of continuous, automated capacity control.

6.6. Institutional Retrenchment and Policy Reversal

The clearest indicator of solution rejection is institutional retrenchment. Municipal bodies such as NDMC have repeatedly re-issued tenders for smart parking after earlier attempts failed to attract qualified bidders or deliver sustained performance. In parallel, MCD

has publicly discussed phasing out unmonitored surface parking areas due to persistent mismanagement.

These actions reflect an implicit acknowledgement that earlier models failed to deliver enforceable, scalable outcomes. Rather than expanding existing solutions, authorities have paused, restructured, or abandoned them altogether, reinforcing the conclusion that the core enforcement gap remains unresolved.

6.7. Synthesis of Rejection Factors

Across all categories, previous solutions were rejected for common structural reasons: they improved visibility but not control, digitised payments but not capacity enforcement, and relied on contractors without independent verification. Most critically, none of the solutions embedded enforcement into physical infrastructure, leaving manual discretion intact.

As a result, municipal bodies were forced to rely on fines, advisories, and enforcement drives rather than continuous compliance mechanisms. This systemic mismatch between policy intent and operational capability ultimately led to the rejection or abandonment of earlier approaches.

7. Proposed Solution: Real-Time, Tamper-Proof Parking Capacity Enforcement System

The proposed solution is designed as a corrective response to the structural failures identified in existing parking governance models. Rather than introducing another observational or payment-layer technology, this system redefines parking enforcement by embedding accountability directly into the physical and digital control points of parking operations.

The central principle of the solution is simple: parking rules must be enforced by design, not by discretion. Every vehicle interaction with a parking facility—entry, occupancy, and exit—must generate a verifiable digital event that cannot be bypassed manually.

7.1. Core Design Philosophy

Previous solutions failed because they focused on visibility rather than control. Sensors observed occupancy, cameras recorded violations, and digital payments logged transactions, but none of these systems could physically prevent rule violations.

The proposed system shifts enforcement from post-event detection to real-time prevention. It does so by integrating three layers:

- Physical enforcement (automated entry and exit barriers)
- Digital verification (FASTag/RFID and government-linked payment systems)
- Audit-grade data logging (immutable records of every parking event)

By tightly coupling these layers, the system ensures that no single stakeholder—contractor, operator, or user—can bypass compliance.

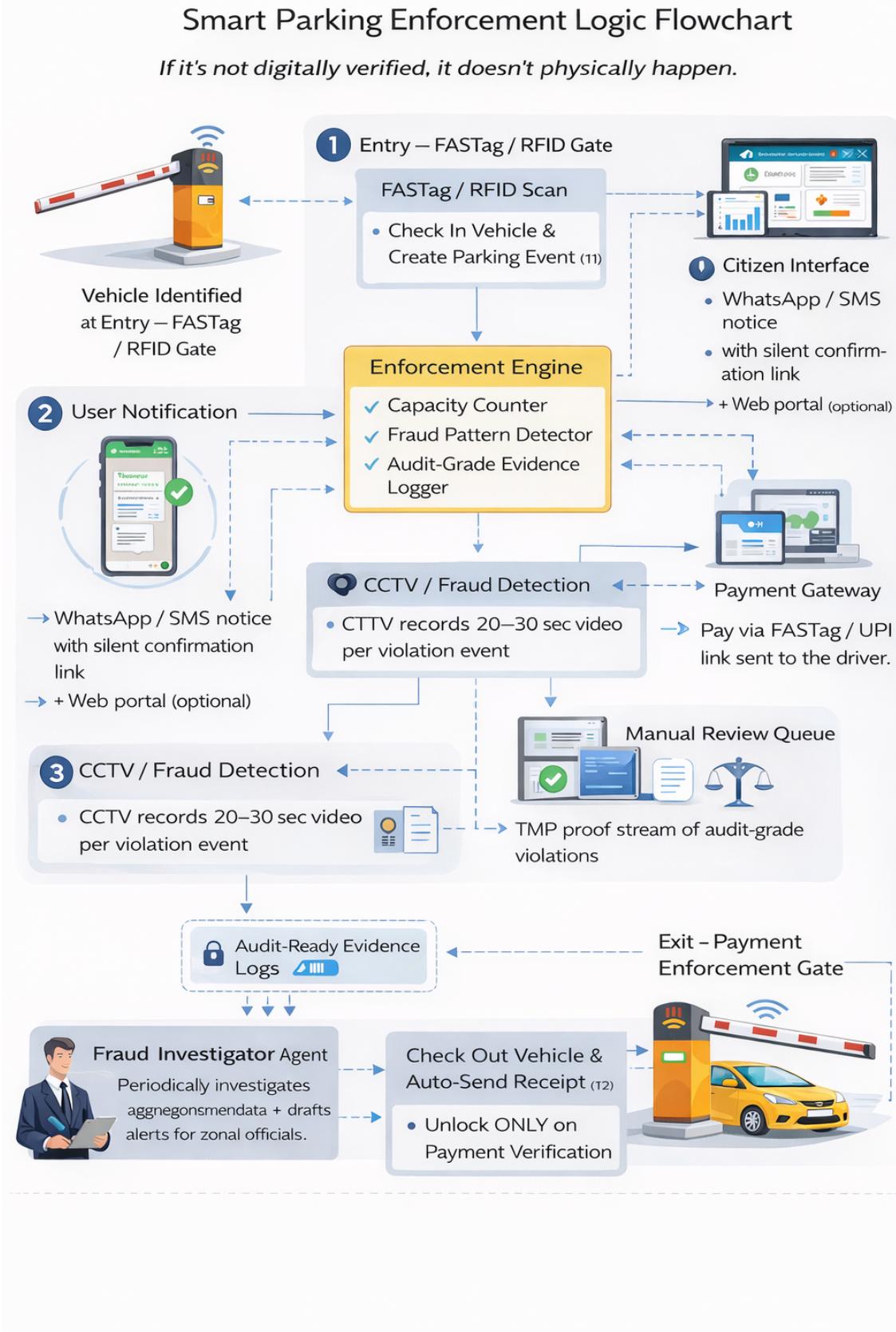


Figure 4: Architecture of the proposed smart parking enforcement system

7.2. Phase 1: Entry Enforcement — Establishing Ground Truth

At the entry point, the system uses FASTag or RFID scanning to uniquely identify each vehicle attempting to enter the parking facility. Entry is not permitted unless a digital record is successfully created in the system database, capturing the vehicle number, timestamp, and parking site identifier.

The boom barrier remains physically locked until this record is written. This eliminates undocumented entry, a failure mode observed repeatedly in contractor-managed parking systems.

Immediately after successful entry, a digital parking session is initiated. The vehicle owner receives a WhatsApp and SMS notification containing a link to their live parking session. This session displays the official rate card, entry time, and continuously updated parking duration. The same information is accessible via a web portal, ensuring transparency and auditability.

If the driver is not the registered owner, the contractor must enter the vehicle number, triggering a verification link to the driver. The session is activated only after acknowledgement, ensuring explicit user awareness. This mechanism prevents contractors from creating ghost entries or misreporting vehicle counts.

7.3. Phase 2: Parking Enforcement — Continuous Capacity Control and Evidence Generation

Once inside the facility, the system performs two parallel functions: capacity enforcement and behavioural monitoring.

Capacity enforcement is achieved by maintaining a live count of active parking sessions. When the authorised capacity limit is reached, entry gates are automatically locked across the facility. This directly addresses one of the most persistent failures in existing systems—over-parking beyond sanctioned limits. Unlike sensor-based systems, this mechanism does not infer occupancy; it enforces it at the access point.

Behavioural monitoring is conducted through CCTV infrastructure configured not merely for surveillance, but for evidence generation. The system detects predefined violations such as blocking fire exits, parking in restricted zones, or occupying non-designated areas.

When a violation occurs, the system captures a short video clip and cryptographically hashes it to prevent tampering. This clip is stored as legally admissible digital evidence and is immediately shared with the vehicle owner via WhatsApp and the web portal in the form of a violation notification. This resolves a key weakness identified by courts and enforcement agencies: the absence of reliable, contest-proof evidence.

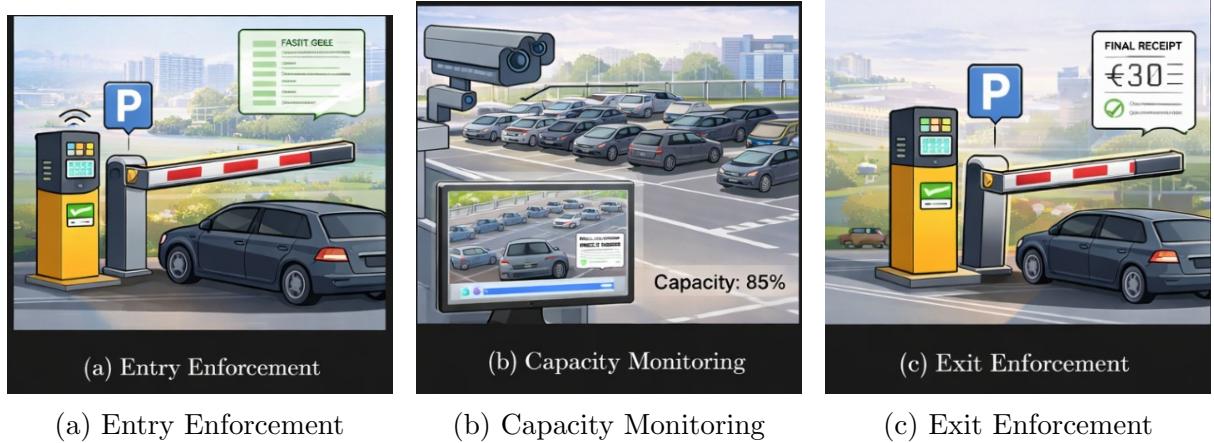


Figure 5: Three-phase enforcement process of the proposed system

7.4. Phase 3: Exit Enforcement — Eliminating Payment Discretion

The exit phase is the most critical component of the system and directly addresses the failure of digital pay-and-park models.

At the exit gate, the vehicle is scanned again using FASTag or RFID. The system computes the final parking fee based on recorded entry time and the official rate structure. The boom barrier remains locked until payment is verified.

Payment verification occurs through one of two automated paths:

- Confirmation of prior digital payment made via the live parking session
- Automatic deduction from the vehicle's FASTag wallet if sufficient balance is available

If neither condition is satisfied, the vehicle cannot exit. Manual override is not possible without a successful payment event recorded in the system. Only after payment confirmation does the barrier unlock.

A final digital receipt is then sent to the user, completing a fully auditable transaction cycle. This hard-lock enforcement removes the discretion that enabled overcharging,

under-reporting, and cash leakage in earlier systems.

7.5. Why This Solution Succeeds Where Others Failed

This system directly addresses every structural weakness identified in prior approaches.

First, it eliminates reliance on inference. Unlike sensors or cameras that estimate occupancy, this system establishes ground truth at controlled physical access points.

Second, it removes manual discretion. Contractors cannot admit extra vehicles, alter rates, or bypass payments because critical actions are enforced by automated barriers linked to digital verification.

Third, it produces audit-grade data. Every entry, violation, and exit is logged with timestamps and identifiers, enabling independent verification by municipal authorities, auditors, and courts.

Fourth, it integrates seamlessly with existing national infrastructure. FASTag, UPI, and WhatsApp are already widely adopted, reducing implementation friction and improving scalability.

Finally, the system balances enforcement with social responsibility. Contractors are retained as operators, preserving employment, while their discretionary control is removed. Earlier ideas such as public shaming through violator images were deliberately rejected due to ethical and legal concerns. Instead, the system supports positive reinforcement mechanisms, such as incentives for compliant users.

7.6. Institutional and Legal Alignment

The proposed system aligns with the expectations expressed in audit observations, court rulings, and enforcement reports. It enables continuous compliance rather than episodic correction, and it transforms parking governance from a reactive process into a preventive one.

By embedding enforcement into physical infrastructure and linking it to tamper-proof digital records, the system provides municipal corporations with a tool capable of surviving audit scrutiny, judicial review, and large-scale urban deployment.

This design directly responds to the unresolved enforcement gap documented in prior

sections and offers a structurally sustainable path forward for municipal parking management in India.

8. Why the Proposed Solution Is Structurally Superior

The superiority of the proposed solution does not lie in the novelty of individual technologies, but in the way enforcement, verification, and accountability are structurally integrated. Unlike previous approaches that attempted to improve parking governance through partial digitisation or observational tools, this system resolves the core enforcement failure identified by audits, courts, and municipal action reports.

8.1. Shift from Observation to Enforcement

A fundamental limitation of earlier solutions was their reliance on observation rather than control. Sensor-based systems estimated occupancy, ANPR cameras recorded violations, and digital payment platforms logged transactions. However, none of these mechanisms could physically prevent a violation from occurring.

The proposed solution replaces observation-driven compliance with enforcement-by-design. Entry barriers do not open without a verified digital record. Exit barriers do not open without a confirmed payment event. Capacity limits are enforced through automated gate locking rather than inferred through data analytics. This physical enforcement capability is the single most important distinction between the proposed system and all prior implementations.

8.2. Elimination of Manual Discretion at Critical Control Points

Audit findings and media investigations repeatedly demonstrate that discretionary control exercised by contractors is the primary source of over-parking, overcharging, and revenue leakage. Previous systems left key decisions—vehicle admission, pricing enforcement, and exit clearance—under human control.

In contrast, the proposed system removes discretion at all critical control points. Contractors retain operational roles, but they cannot override entry, capacity, or exit

conditions. Every critical action is governed by automated rules enforced by hardware and verified digitally. This directly addresses the enforcement gap that rendered earlier contractor-based models ineffective.

8.3. Ground-Truth Establishment Instead of Inference

Sensor-based and camera-based systems infer parking occupancy indirectly and are therefore vulnerable to hardware failure, environmental degradation, and data inaccuracies. When inference fails, enforcement collapses.

The proposed solution establishes ground truth through controlled access. A vehicle is counted as parked only when it physically passes through an authenticated entry barrier, and it is removed from the count only when it exits through a verified payment-controlled gate. This eliminates ambiguity in vehicle counts and ensures that capacity data is accurate, real-time, and auditable.

8.4. Continuous, Audit-Grade Accountability

Previous solutions generated fragmented data—payment logs without capacity data, camera footage without enforcement linkage, or sensor readings without legal standing. As a result, municipal bodies lacked audit-grade evidence capable of withstanding scrutiny by auditors or courts.

The proposed system generates a continuous, immutable chain of records covering entry, duration, violations, payment, and exit. Each event is timestamped, linked to a unique vehicle identifier, and stored in a tamper-resistant manner. This enables independent verification by municipal authorities, auditors, and judicial bodies, directly addressing deficiencies highlighted by the Comptroller and Auditor General and the judiciary.

8.5. Integration with Existing National Infrastructure

Another key advantage of the proposed solution is its reliance on infrastructure already deployed at national scale. FASTag, UPI, and mobile messaging platforms are widely adopted, familiar to users, and institutionally supported.

By building on existing systems rather than introducing proprietary or experimental

technologies, the solution reduces deployment friction, improves user acceptance, and enhances scalability. This contrasts with earlier projects that failed due to dependence on fragile hardware or bespoke platforms with limited institutional support.

8.6. Sustainability and Lifecycle Resilience

Many earlier parking technology initiatives failed due to neglect of operational lifecycle considerations, particularly maintenance and enforcement continuity. Sensors failed, cameras went offline, and systems decayed into manual processes.

The proposed system minimises reliance on distributed, failure-prone components. Enforcement is concentrated at entry and exit points, reducing hardware exposure and simplifying maintenance. Even in degraded conditions, the system fails safely by restricting access rather than allowing uncontrolled operation.

8.7. Alignment with Legal, Ethical, and Social Constraints

Some deterrence mechanisms considered in other contexts—such as public shaming through violator imagery—were consciously excluded from the proposed design due to privacy and legal concerns. Instead, the system emphasises lawful enforcement, user consent, and transparency.

Additionally, the solution avoids eliminating contractor roles, thereby preserving employment while removing opportunities for malpractice. This balances governance reform with social responsibility, increasing institutional acceptability.

8.8. Resolution of the Core Enforcement Gap

Ultimately, the proposed solution succeeds because it resolves the precise gap that rendered earlier solutions ineffective: the inability to enforce parking rules continuously, automatically, and independently of human discretion.

By embedding enforcement into physical infrastructure, linking it to real-time digital verification, and generating audit-grade records, the system transforms parking governance from a reactive, complaint-driven process into a preventive, self-enforcing mechanism.

This structural shift—rather than incremental technological enhancement—is what makes the proposed solution demonstrably superior and institutionally sustainable.

Comparative Benefits: Proposed Parking System vs. Traditional Approaches	
Proposed System	Traditional Approaches
 Tamper-Proof Digital System <ul style="list-style-type: none"> Entry, payment, and exit fully digital – no scope for cash leakage or contractor manipulation 	 Cash Leakage <ul style="list-style-type: none"> Manual cash handling drives undercharging and revenue leakage
 Outdoor CCTV Surveillance <ul style="list-style-type: none"> ZERO Violation Pilferage Audit-grade violations captured with auto-verified video – can't be ignored or erased 	 High Violation Pilferage <ul style="list-style-type: none"> Paper-slip and CCTV-only fines drive missed and unreported violations
 Revenue Assurance <ul style="list-style-type: none"> 100% Accurate Digital Ledger Automated entry/exit timestamps matched with payment records 	 Shady Manual Bookkeeping <ul style="list-style-type: none"> Underreported receipts and cash-collection fraud rife
 Enforcement Speed <ul style="list-style-type: none"> 100% Accurate Digital Ledger Automated entry/exit timestamps matched with payment records 	 Shady Manual Bookkeeping <ul style="list-style-type: none"> Underreported receipts and cash-collection fraud rife
 Human-AI Augmented Enforcement <ul style="list-style-type: none"> Agents only step in when violations unclear – no surveillance chain delays 	 Slow, Overwhelmed Officers <ul style="list-style-type: none"> Officers manually review complaints and often face staff shortages

Figure 6: Comparative benefits of the proposed system vs. traditional approaches

Figure 6: Comparative benefits of the proposed system vs. traditional approaches

9. Design Alternatives Considered and Rejected

During the solution design process, multiple alternative approaches were evaluated with the objective of eliminating parking mismanagement and ensuring compliance. While some of these approaches appeared effective at first glance, they were deliberately rejected after careful consideration of legal, social, ethical, and institutional constraints. Two such alternatives are discussed below.

9.1. Complete Elimination of Parking Contractors

One of the earliest alternatives considered was the complete removal of private parking contractors from municipal parking operations. Under this approach, all parking facilities would be directly managed by municipal bodies using fully automated systems, thereby eliminating human intermediaries and the possibility of contractor-led manipulation.

While this approach appeared attractive from a control perspective, it was ultimately

rejected for several reasons. First, parking contractors constitute a significant source of employment across urban centres. Abruptly eliminating these roles would lead to job losses and increase the operational burden on municipal corporations, which are already constrained by staffing limitations.

Second, municipal bodies are not structurally equipped to manage thousands of distributed parking sites entirely on their own. Shifting all operational responsibility to civic authorities would likely introduce new inefficiencies rather than resolving existing ones.

Most importantly, analysis revealed that the core problem was not the presence of contractors, but the discretionary power vested in them. Mismanagement occurred because contractors could admit vehicles beyond capacity, alter pricing, and bypass payment systems without immediate detection. Eliminating contractors would not inherently solve these issues unless enforcement mechanisms were redesigned.

As a result, this alternative was rejected in favour of a system that retains contractors as operational staff while removing discretionary control. In the proposed solution, contractors continue to perform logistical and supervisory roles, but all critical decisions—entry permission, capacity enforcement, and exit clearance—are governed by automated, tamper-proof systems.

9.2. Public Humiliation and Social Shaming as a Deterrence Mechanism

Another alternative explored involved the use of public humiliation as a behavioural deterrent. This concept proposed displaying images or video clips of parking violators on public dashboards or within the parking system interface, under the assumption that social embarrassment would discourage non-compliance.

Although behavioural economics suggests that social deterrence can influence compliance, this approach was rejected due to serious ethical and legal concerns. Public display of identifiable images without explicit consent raises significant privacy issues and could violate data protection norms and constitutional rights.

Furthermore, the use of humiliation as an enforcement tool risks disproportionate harm, particularly in cases of unintentional violations or ambiguous circumstances. It also exposes municipal authorities to legal challenges, reputational risk, and public backlash.

Beyond legality, such an approach was found to undermine trust between citizens and

civic institutions. Rather than encouraging voluntary compliance, it could foster resentment and adversarial relationships, ultimately weakening long-term governance outcomes.

In place of punitive public exposure, the proposed system adopts a transparent, evidence-based enforcement mechanism combined with positive reinforcement. Compliant users may be eligible for incentives such as priority access, recognition badges, or reduced fees, aligning behavioural compliance with ethical governance standards.

9.3. Rationale for Final Design Choice

The rejection of these alternatives reflects a conscious design philosophy: effective governance systems must enforce rules firmly while remaining legally sound, socially responsible, and institutionally sustainable.

By rejecting contractor elimination and public humiliation, the proposed solution avoids creating new social or legal problems while directly addressing the root cause of parking mismanagement—unchecked discretion and lack of enforceable control.

10. Conclusion

This study demonstrates that parking mismanagement in Indian cities is not the result of isolated administrative lapses or insufficient technological adoption, but a persistent structural failure rooted in the absence of enforceable, real-time control mechanisms. Evidence drawn from municipal actions, traffic enforcement statistics, judicial observations, and sustained media reporting confirms that existing parking systems operate without reliable verification of capacity usage, contractor compliance, or revenue integrity.

Despite repeated attempts to address the problem through smart parking technologies, digital payment systems, ANPR surveillance, contractor outsourcing, and intensive enforcement drives, the core governance gap remains unresolved. These approaches improved visibility and digitisation but failed to translate observation into enforcement. As a result, violations continue to occur at scale, enforcement remains reactive, and accountability is established only after losses have already occurred.

The proposed solution directly responds to this unresolved gap by embedding enforcement into the physical and digital infrastructure of parking operations. By integrating automated entry and exit barriers with real-time digital verification, immutable record

generation, and government-linked payment systems, the solution transforms parking governance from a discretionary, complaint-driven process into a preventive, self-enforcing system. Crucially, it establishes ground truth at controlled access points rather than relying on inferred data or post-facto inspection.

Equally important is the solution's institutional viability. By retaining existing human roles while removing discretionary control, the system preserves employment and operational continuity without perpetuating avenues for malpractice. By rejecting ethically and legally problematic deterrence mechanisms such as public humiliation, it aligns enforcement with constitutional norms, data protection principles, and public trust.

The resulting framework is not merely a technological intervention but a governance architecture. It satisfies the evidentiary requirements highlighted by audit institutions, the enforcement expectations articulated by traffic authorities, and the accountability standards demanded by judicial scrutiny. Its reliance on nationally deployed infrastructure such as FASTag and UPI further enhances feasibility, scalability, and public acceptance.

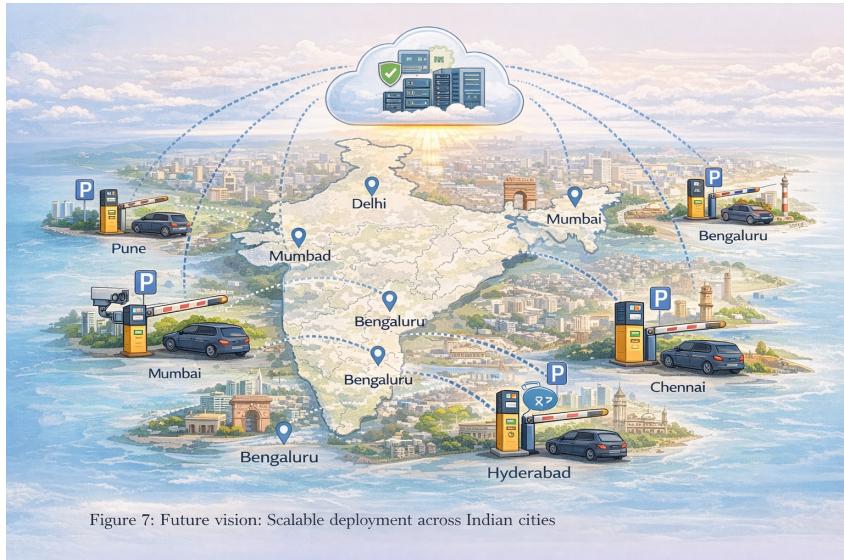


Figure 7: Future vision: Scalable deployment across Indian cities

Figure 7: Future vision: Scalable deployment across Indian cities

In conclusion, the proposed system offers a structurally sound, legally defensible, and operationally scalable path forward for municipal parking management in India. It replaces episodic enforcement with continuous compliance, ambiguity with verifiable data, and discretion with rule-based control. As urban vehicle density continues to rise, such enforcement-by-design solutions will be essential not only for parking governance, but for the broader credibility of urban public administration.