Integration of QR Code Technology on National Highways: A Step Towards Smart Transportation in India.

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doi.org/10.64643/IJIRTV12I6-186453-459

***Abstract*—The rapid digitization of infrastructure is transforming transportation systems worldwide. In India, the integration of QR (Quick Response) code technology on national highways presents a unique opportunity to streamline operations, enhance safety, and create a smarter transportation network. This paper explores the potential applications, benefits, and challenges of implementing QR codes across India's extensive highway network, and adds detailed case studies and references to support practical deployment and future research.**

***Index Terms*—QR Code, Smart Transportation, National Highways, Traffic Management, India, Digital Infrastructure, NHAI**

I. INTRODUCTION

India has one of the largest road networks in the world, with national highways playing a pivotal role in facilitating trade, travel, and logistics. With increasing vehicular traffic and the need for efficient management, technology-driven solutions are critical. QR code technology, prevalent in sectors like retail and payments, offers promising applications in transportation, particularly in enabling seamless communication between commuters and infrastructure systems.

II. BACKGROUND

QR codes are two-dimensional barcodes that can store significant amounts of data and can be easily scanned using smartphones or specialized scanners. Unlike traditional barcodes, they can encode links, text, and other forms of information. Their low cost, ease of generation, and versatility make them suitable for wide-scale deployment. Advances in mobile internet penetration and smartphone adoption in India make QR-based interventions increasingly viable.

III. POTENTIAL APPLICATIONS OF QR CODES ON NATIONAL HIGHWAYS

3.1 Toll Booth Automation

- Implementation of QR codes for digital toll payments, allowing vehicles to pass through without stopping.
- Reduced congestion and lower operational costs compared to some legacy systems; acts as a

complement to FASTag for cashless users or occasional travellers.

Figure 1: QR Code-Enabled National Highway Ecosystem

3.2 Emergency Services

- QR codes placed at regular intervals provide drivers and first responders with instant access to emergency contacts, nearest service stations, and hospitals, along with the exact chainage (location) for quick dispatch.

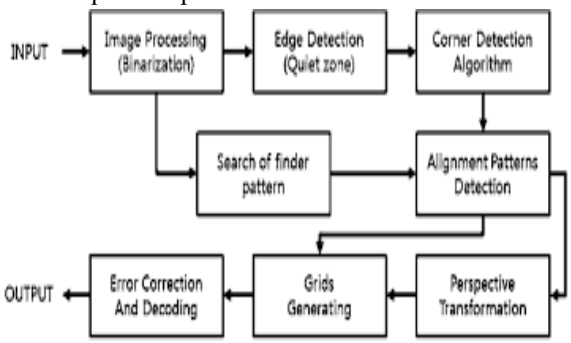

Figure 2: Workflow of QR-Based Emergency Response

3.3 Traffic and Navigation Assistance

- Dynamic QR codes can offer real-time traffic updates, alternative route suggestions, and weather/road condition alerts when linked to live feeds.

3.4 Smart Signage and Transparency

- Road signs integrated with QR codes can provide multilingual support and project-specific information (project authority, contractor, timelines), increasing transparency and accountability.

3.5 Vehicle and Driver Verification (Supplementary)

- QR stickers linked to vehicle registrations or e-receipts can be used in auxiliary scenarios (e.g., automated toll lanes or access-controlled freight corridors) while addressing privacy and security concerns.

IV. BENEFITS OF QR CODE INTEGRATION

- Cost-Effective: Minimal hardware requirements and low deployment costs compared with more complex sensor networks.
- Scalability: Easy to implement across diverse geographic regions and varied traffic environments.
- User-Friendly: Most smartphones can scan QR codes without additional apps; UPI/Pay wallets already familiar to users support quick transactions.
- Data-Driven Insights: Usage analytics, with appropriate privacy safeguards, can help authorities in planning and resource allocation.

V. CHALLENGES AND LIMITATIONS

- Digital Divide: Not all road users may have smartphones, up-to-date OS versions, or continuous internet access.
- Maintenance & Durability: QR signs must be vandal- and weather-resistant; horizontal pavement markings face wear from traffic.
- Security Risks: Tampering, spoofing, or malicious redirects must be prevented through cryptographic verification, certificate pinning, and short-lived signed URLs.
- Human Factors: Designing QR placement and messaging to avoid driver distraction is crucial; QR actions must be primarily for stopped users or passengers.

VI. DETAILED CASE STUDIES

6.1 National Highway Authority of India (NHAI) — National Rollout (Oct 2025)

Overview: In October 2025 NHAI announced a national rollout of vertical QR code project-information signboards across national highways. The boards are planned for placement at toll plazas, wayside amenities, rest areas, truck lay-byes and at

project start/end points. The QR codes link to project-specific information including highway number, chainage, project length, construction/maintenance timelines and emergency helpline numbers (including 1033). Contact information for highway patrol, toll managers, resident engineers and related offices will be available via scanning.

Implementation specifics:

- Signage type: Vertical project-information boards with prominently placed QR codes.
- Content: Project metadata (highway, chainage, contractor details), nearby amenity locators (hospitals, petrol pumps, e-charging stations), emergency contacts, and links to complaint/grievance portals.
- Expected impacts: Improved traveler information, faster emergency response (through precise chainage), and higher transparency about project accountability.

Lessons & research opportunities: Monitor scan rates, response-time improvements for emergencies, and changes in grievance resolution times. Assess digital inclusion strategies for users without smartphones.

6.2 QR-based Toll Systems — Pilot and Academic Implementations (2018–2020)

Overview: Several academic prototypes and small pilots (India, 2018–2020) explored QR-code-based automated toll collection as a low-cost alternative or complement to RFID systems. These systems typically used printed QR tickets or mobile-wallet QR payments scanned by fixed cameras or handheld scanners at toll plazas.

Representative findings from literature:

- QR implementations achieved meaningful throughput improvements over manual toll collection and were inexpensive to deploy in pilot contexts.
- Integrations that combined QR scanning with backend verification (vehicle registration, insurance/fc/licence checks) provided added value but raised privacy and data-retention issues.

Limitations observed:

- Camera-based scanning under adverse lighting or dirty surfaces reduced reliability; printed stickers require periodic replacement.
- User onboarding (issuing QR tokens or ensuring payment linkage) was a logistical challenge without interoperability standards.

Research opportunities: A controlled field trial comparing FASTag-only, QR-only and hybrid lanes focusing on transaction time, failure rates, and overall throughput would provide actionable data.

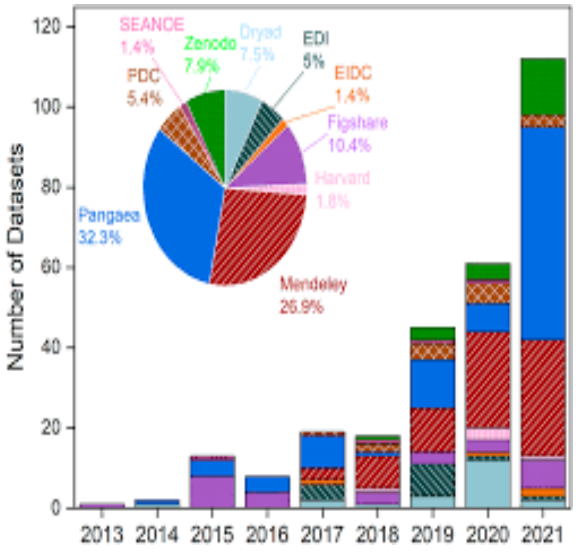

Figure 3: Comparative Throughput of Toll Collection Systems

6.3 International Example — QR Signage for Automated Driving Support (Japan/Research Prototypes)

Overview: Research exploring QR-code-based roadside signage demonstrated that encoded visual markers can support lane-level localization or provide machine-readable context to automated or assisted-driving systems, particularly in rural roads where high-precision maps are limited.

Findings applicable to India: QR signage can supplement digital map data for advanced driver-assistance systems (ADAS) and low-cost automation, but must be standardized in placement, size, and error correction capacity to be machine-readable under motion and environmental noise.

6.4 Private-sector Emergency Sticker Programs (Industry Pilot)

Overview: Startups and fleet-operators have piloted QR stickers linked to pre-registered emergency profiles for two-wheeler and commercial-vehicle riders. Scanning the sticker by a bystander or responder reveals owner emergency contacts and medical notes, expediting first response.

Results & constraints: These systems improved first-response coordination in several pilot deployments but

rely on voluntary registration, raising concerns about coverage equity and data accuracy.

VII. PROPOSED PILOT FRAMEWORK FOR LARGE-SCALE DEPLOYMENT IN INDIA

1. Phase 0 — Standards & Security: Define a national QR-data standard (fields, encoding, signed payloads) and minimum physical specs for signs/stickers (size, contrast, reflective coatings).
2. Phase 1 — Controlled Pilots: Deploy QR boards along selected corridors (urban-expressway, rural two-lane highway, and high-accident stretches) to measure scan-rates, emergency response delta, and user uptake.
3. Phase 2 — Integration: Integrate with emergency dispatch systems, toll-backends, national grievance portals and navigation apps through open APIs.
4. Phase 3 — Scale & Maintenance: Gradual nationwide rollout with a maintenance regime (inspection cycles, vandalism-replacements) and public-awareness campaigns.

VIII. PRIVACY, SECURITY AND ACCESSIBILITY CONSIDERATIONS

- Use signed URLs or digitally-signed payloads so scanning clients can verify authenticity and detect tampering.
- Minimize personal data stored in the QR payload; prefer pointers to authenticated backend services.
- Provide offline-capable content for areas with intermittent connectivity (compressed text, stored helpline numbers).
- Provide alternate non-digital access (prominent printed helpline numbers) to ensure accessibility for users without smartphones.

IX. CONCLUSION

QR code integration on national highways offers a pragmatic, low-cost pathway to enhanced traveler information, emergency responsiveness, transparency and selective automation. The NHAI national initiative (Oct 2025) positions India to be an early large-scale adopter of highway QR infrastructure; however, rigorous pilots, clear technical standards and attention to equity, security and maintenance are required to convert promise into measurable public benefits.

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