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BARRIERLESS TOLLING IN INDIA

TOWARDS EFFICIENT, SUSTAINABLE & INNOVATIVE INFRA

APPROACH PAPER RELEASE BY
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TABLE OF CONTENTS

Message from Hon'ble Minister of Road Transport & Highways

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सत्यमेव जयते

आज़ादी का अमृत महोत्सव

Message

It gives me immense pleasure to learn that Primus Partners and Think Infra have taken the initiative to bring together stakeholders through this thoughtful approach paper on Barrier less tolling—a revolutionary step towards seamless, barrier-free travel powered by satellite technology.

Under the inspiring leadership of our Hon'ble Prime Minister, India's highways have evolved far beyond roads. They are now lifelines that connect people, ideas, and opportunities, fueling the spirit of a progressive and vibrant nation. These highways not only drive economic growth but also foster innovation and social equity.

Our journey towards continuous improvement has always been guided by the principles of innovation and adaptability. Satellite based tolling is yet another step in our mission to build a smarter, more efficient future for India's highways.

I extend my heartfelt best wishes to Primus Partners and Think Infra for this initiative. I'm confident this effort will contribute significantly to shaping the highways of tomorrow.

(Nitin Gadkari)

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Prologue

India's highways are evolving into more than just roads—they are becoming the lifelines of a thriving nation, connecting people, ideas, and opportunities. These vital arteries of progress form the foundation of economic growth, social equity, and innovation.

Over the last decade, India has emerged as a global leader in highway development. Expanding our national highway network to over 1.46 lakh kilometers and launching transformative initiatives like FASTag have streamlined travel, reduced emissions, and revolutionized toll collection. Projects like the iconic Delhi-Mumbai Expressway exemplify our commitment to building world-class corridors that empower both mobility and connectivity.

Today, We are delighted to comment on our latest leap forward - GNSS-based tolling. This revolutionary, barrierless tolling system is powered by satellite technology and will transform the way we experience our highways. By eliminating toll plaza congestion and enabling fair, distance-based tolling, this system promotes environmental sustainability and enhances commuter convenience.

We take this opportunity to express my appreciation for the launch of this landmark report. This report is a testament to the dedication of our experts, engineers, and policymakers who have envisioned a smarter, more efficient highway system for India. It provides the way ahead for adopting GNSS-based tolling for cutting-edge technological developments in our infrastructure sector.

The GNSS-based tolling initiative is uniquely built on the strength of India's NavIC satellite system, a homegrown technology that addresses local challenges while meeting global standards. Integrated with intelligent traffic systems, increased electric vehicle adoption, and resilient infrastructure, it aligns perfectly with our vision for sustainable development and climate action.

This is not just a technological advancement but a bold step toward creating highways that are smarter, greener, and better equipped for the future. It reflects our unwavering commitment to transforming India's highways into next-generation mobility solutions that drive progress, prosperity, and inclusivity.

Together, let us embrace this movement and work toward a future where our highways lead not just to destinations but to boundless opportunities.

Thank you.

Shri Davinder Singh Sandhu
Co-Founder & Chairperson of
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Executive Summary

India's highways are undergoing a transformational evolution to become the lifelines of a thriving, modern nation. Managing the world's largest road network of over 6.3 million kilometers, the Ministry of Road Transport and Highways (MoRTH) has consistently embraced innovative solutions to enhance infrastructure, streamline traffic, and improve user experience. Building on the success of Electronic Toll Collection (ETC) through RFID-based FASTag, the Ministry now aims to revolutionize tolling systems with Global Navigation Satellite System (GNSS)-based barrierless tolling.

The Case for GNSS-Based Tolling

Challenges with Existing Tolling Systems:

- Time Delays: Traditional toll plazas cause congestion, with an average wait time of 10-12 minutes in 2012.
- Fuel Wastage: Prolonged idling and slowdowns result in an annual economic loss of approximately ₹87,000 crores.
- Environmental Costs: Carbon emissions from vehicles idling at toll plazas exacerbate environmental degradation.

Proven Impact of Technology Interventions:

- Post adoption, the average wait time dropped to 30 seconds.
- Pilots of barrierless tolling systems demonstrated benefits such as a 20% increase in traffic flow (Delhi-Noida-Direct flyway) and a 50% reduction in waiting time (Chennai airport).

Key Features of GNSS-Based Tolling

- Barrierless Tolling: Eliminates toll plazas, enabling seamless traffic flow.
- Distance-Based Charges: Transition from fixed fees to usage-based tolling, ensuring fairness.
- Leveraging NavIC Technology: Utilizes India's indigenous NavIC satellite system for real-time and accurate toll calculations.

- Integration with Allied Services: Facilitates additional services such as GIS-based road safety, logistics tracking, dynamic insurance, and enhanced traffic analytics.
- Environmental Sustainability: Supports India's climate goals by reducing emissions and fuel wastage.

Implementation Strategies

The GNSS-based tolling system is envisioned as a nationwide initiative requiring robust planning. Key strategies include:

- Transition Management: A phased approach starting with pilot projects and scaling up incrementally.
- Public Incentives: Providing free On-Board Units (OBUs) to early adopters.
- Hybrid Operations: Integrating GNSS with FASTag during the transition period.
- Robust Privacy Framework: Ensuring data privacy through anonymization and user consent mechanisms.
- Stakeholder Collaboration: Involving central and state governments, private toll operators, and technology vendors to ensure seamless implementation.
- Public Awareness Campaigns: Educating citizens on the benefits of barrierless tolling to promote adoption.

Outcomes and Benefits

1. Improved Traffic Flow and User Experience:

- Traffic Flow: Eliminates delays, reducing travel time by 20-30%.
- Time Savings: Saves 8-10 minutes per toll point on average.
- User Convenience: Enables hassle-free payments with integration of UPI and FASTag.

2. Environmental Sustainability:

- Reduced Emissions: Lowers carbon emissions by 5 million tons annually.
- Cost Savings: Saves approximately ₹12,000 crores annually in fuel expenses.

3. Enhanced Revenue and Operational Efficiency:

- Revenue Growth: Increases toll collection efficiency by 15-20%, adding up to ₹10,000 crores annually.
- Transparency: Centralized tolling ensures real-time monitoring and reduced revenue leakages.

4. Advanced Technology Integration:

- Real-Time Operations: OBUs calculate tolls based on distance traveled, ensuring accuracy.
- Secure Systems: Implements robust cybersecurity measures to prevent fraud.
- Scalability: Enables cost-effective expansion to new highways and urban corridors.

5. Value-Added Services:

- Offers enhanced driver assistance, traffic analytics, and dynamic tolling services, creating a modern and user-friendly ecosystem.

Conclusion

The GNSS-based barrierless tolling system represents a transformative leap in modernizing India's highway infrastructure. By reducing congestion, promoting environmental sustainability, and enhancing user convenience, this initiative aligns seamlessly with India's vision of smart, sustainable, and inclusive development. A phased rollout supported by innovative technology, robust policies, and active public participation will position India as a global leader in advanced transportation systems.

Existing Ecosystem

1. Existing Ecosystem Highway Commute

1.1 Key Stakeholder Roles & Responsibilities

The **Ministry of Road Transport & Highways** envisages to implement Global Navigation Satellite System (GNSS) based Electronic Toll Collection (ETC) in India to increase the efficiency of the Tolling operation in line with the global practices. In this regard, the **National Highways Authority of India (NHAI)** through its promoted Company **M/s Indian Highways Management Company Ltd (IHMCL)**, which oversees the National Electronic Tolling Collection (NETC) program, has been entrusted with the responsibility to devise the action plan and implement the GNSS based ETC across India.

The Centralized Toll Charger ensures Map Making of GNSS stretch, Correlation / Validation of Chainage and Geo-Reference, Receiving Anonymised Pings from AIS AIS 140 VLT Device (OBU), **Map Matching, Network based Digital Routing, distance estimation, toll parameter,**

Acquirer Bank - The Toll Charger shall send the calculated User Fee to be charged to a GNSS Vehicle to the Acquirer Bank which will then follow same payment protocol as FASTag system. The Toll Charger will also facilitate the road user to see the path travelled by their GNSS vehicle on a map by clicking a link shared to them by Issuer Entity through SMS.

Tag Holder : The Tag Holder is the vehicle owner (also referred to as the road user) who enrolls for an NETC Tag (FASTag) with the issuing bank by providing a bank account number (Saving, Current, Prepaid Account etc.) that is linked to the NETC Tag ID.

Issuer Bank: The Issuer Bank is a member of the National Payment Corporation of India (NPCI) network and issues the NETC Tag to vehicle owner for the payment through NETC System. The issuer bank 'owns' the customer by managing the account including the providing of customer services like dispute management.

NPCI : NPCI facilitates NETC Transactions among all member banks participating in 'NPCI network'. Further NPCI acts as centralized clearing and settlement body to settle the transactions and fee amount among the member banks.

Toll Plaza Operator/Concessionaire : The Toll Plaza is the location where the vehicle identification record for toll payment is generated. To enable the same the Toll Plaza Operator /Concessionaire sets up a Toll Management System at the Toll Plaza that includes infrastructure like the RFID transceiver, Automatic Vehicle Classification system, Weigh in Motion system, CCTV Cameras and Toll Plaza Server for the acceptance of NETC Tag for the payment through NETC Payment System.

System Integrator : The System integrator provides the Toll Management system for the Toll Plaza Operator / Concessionaire

Central to the operation is the **Telematics Billing Centre (TBC)**, which ensures the accurate calculation of tolls based on the "**Pay as You Use**" principle. The TBC manages **map creation**, correlation of chainage and geo-references, and processes anonymized vehicle data received from GNSS-enabled On-Board Units (OBUs – Eg. AIS 140 VLT Device). It also oversees **enforcement mechanisms** such as **Automatic Number Plate Recognition (ANPR)** and **geofencing** while providing users with toll details via issuer entities.

Financial institutions, including **acquirer banks** and **issuer entities**, are

responsible for processing toll payments, resolving disputes, and managing customer interactions. The GNSS system integrates seamlessly with existing **payment protocols**, offering a user-friendly experience. The TBC shall send the calculated User Fee to be charged to a GNSS Vehicle to the Acquirer Bank which will then follow same payment protocol as FASTag system. The TBC will also facilitate e the road user to see the path travelled by their GNSS vehicle on a map by clicking a link shared to them by Issuer Entity through SMS.

Hardware vendors, particularly **OBU manufacturers**, play a critical role by developing **tamper-resistant and reliable devices** tailored for Indian road conditions. These **OBUs** interact with **satellite systems**, including India's **NavIC**, ensuring precise geolocation and toll computation.

SATCOM vendors support uninterrupted satellite communication, leveraging **GNSS constellations** to deliver robust and scalable services ensuring accurate vehicle tracking and data transmission. It acts as redundancy to address potential connectivity issues.

Existing toll operators collaborate during the transition to integrate their infrastructure with GNSS systems, facilitating a **hybrid tolling phase** that accommodates both **FASTag** and **GNSS tolling**. **Technology providers** develop the platforms necessary for **data processing**, **billing**, and **compliance with privacy standards**, while **telecom providers** enable seamless **real-time data transmission**.

Law enforcement agencies ensure compliance with tolling regulations, addressing violations such as **bypassing toll routes** or **tampering with devices**. These agencies utilize tools like **ANPR**, **geofencing**, and the **VAHAN system** to enforce penalties and maintain system integrity.

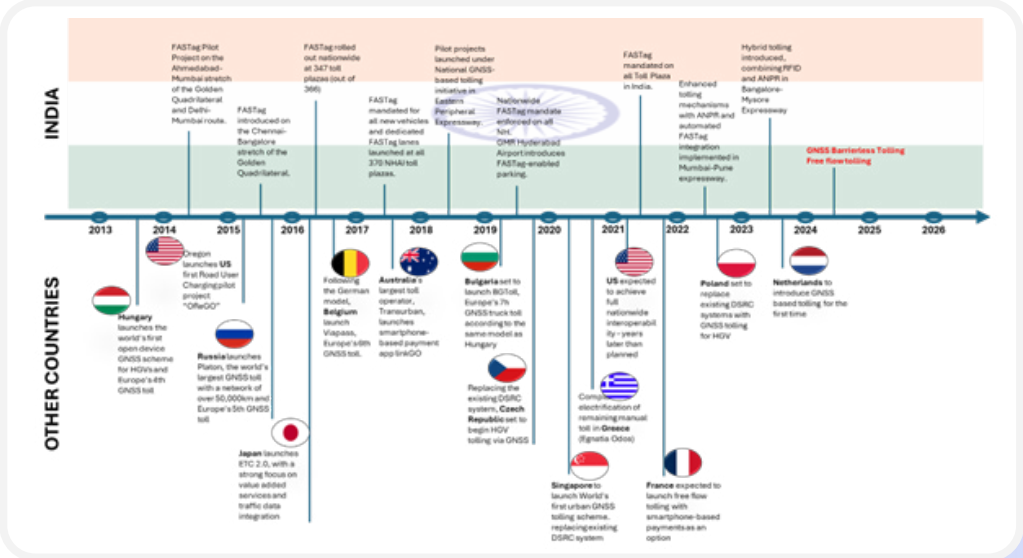
Stakeholders from the **automotive**, **insurance**, and **logistics sectors** are instrumental in the adoption of GNSS tolling. **Automotive OEMs** ensure vehicle compatibility with GNSS systems, while **insurance companies** leverage data for innovative products like **pay-as-you-drive schemes**. **Logistics operators** benefit from distance-based tolling, enhancing fleet efficiency and cost management.

By involving a comprehensive network of stakeholders, India's **GNSS-based tolling system** is set to revolutionize tolling operations, reinforcing the country's position as a leader in **transportation innovation**.

1.2 Electronic Toll Collection – Global Journey footprint

Electronic Toll Collection Global Study in mid-2015, the electronic tolling landscape has changed markedly in almost every region of the world:

- November 2015, Russia launched the (then) world's largest HGV toll; collecting per km fees via GNSS across a network of more than 51,000 kms of road.
- April 2016, Belgium launched nationwide tolling for HGVs using GNSS technology based on the German model.
- Japan introduced ETC 2.0, a new national tolling system with data-driven, value-added services at its heart.
- Australia became the first toll operator to enable GNSS/geolocated payments with the launch in late 2017.
- February 2018, Audi became the first passenger car OEM to announce full integration of an interoperable ETC device in the US.
- same month, Chile began the mass replacement of annual payment booths with ETC to decrease congestion and increase the adoption of ETC devices.
- July 2018, Atlantia signed an agreement with Fiat Chrysler Automobiles to enable full integration of Telepass devices into new Jeep models.
- India mandated the sale of RFID ETC tags with all new 4 wheeled vehicles and their use in all commercial vehicles.
- South Korea began replacing all manual toll plazas with a nationwide 'smart tolling' infrastructure based on ANPR charging alongside the existing DSRC or OBUs.
- Singapore is switching over from DSRC-based tolling system, used primarily for congestion pricing, to GNSS Free flow tolling in the year 2020 that will have an island-wide coverage



1.3 Electronic Toll Collection – India's Journey so far.

In 2012, India decides to the embrace Electronic Toll Collection (ETC) Approach, the flowing are various generations of the ETC journey in India.

Generation 1: Manual Tolling & Cash Collection

Generation-2: **Vignette / Toll Sticker and** A printed sticker on the vehicle identified as proof of pre-paid toll

Generation-3 : On-Board electronic device for automatic vehicle identification, Passive RFID-Tag affixed / DSRC OBU installed on vehicle that is detected by readers located in toll lanes or mounted on gantries, Video ANPR recognition of vehicle

Generation 4: **GNSS-based OBU installed on vehicle,** OBU tracked centrally by a Telematics Billing Centre for determining journey distance and toll calculation based on a 'per km' tariff.

1.4 Electronic Toll Collection – Process Workflow

The above diagram illustrates transaction flow of the NETC system. The Transaction from the Toll Plaza is sent to the acquiring system. The Acquiring System validates these transactions and send it to NETC Switch. NPCI route these transactions to the respective Issuer Bank which in turn debit the tag holder account.

1. Whenever the vehicle passes through the ETC lane of the Toll Plaza, the Toll Plaza system captures the FASTag details like (Tag ID, TID, Vehicle class, etc.) and sends it to the Acquiring bank for processing.
2. The Acquiring bank sends a request to the NETC Mapper to validate the tag details.
3. Once the Tag ID is validated, NETC Mapper responds with details like Vehicle class, VRN, Tag Status etc. If the Tag ID is absent in NETC Mapper, it will respond that the Tag ID is not registered.
4. After successful validation of Tag ID from NETC Mapper, acquirer host calculates the appropriate toll fare and initiate a debit request to NETC system.
5. NETC System will switch the debit request to the respective issuer bank for debiting the account of the customer.
6. Issuer host shall debit the linked tag holder account and sends a SMS alert to the tag holder. The Issuer host shall send the response message to NETC system. If the response is not sent within the defined TAT, the transaction are considered as Deemed Accepted.
7. NETC system will notify the response to acquirer host.
8. Acquirer host will notify to respective toll plaza system.

1.5 Existing Tolling Ecosystem

India's tolling ecosystem has undergone a significant transformation, evolving from manual toll collection systems to advanced electronic methods. It is a critical component of its rapidly expanding road network, which has grown by 59% over the past nine years, reaching 6.6 million km in 2023. This progression reflects the country's commitment to enhancing efficiency, reducing congestion, and aligning with global best practices. Comparative insights from global tolling models can further contextualize India's progress and areas for improvement. Alongside tolling advancements, there is an urgent need to address road safety concerns, as the country loses over 1,50,000 people annually to road accidents, with the majority being productive working-age individuals.

India's early toll collection systems were predominantly manual, resulting in inefficiencies such as long wait times, revenue leakages, increased fuel consumption, and environmental pollution. The lack of standardized toll calculation mechanisms compounded these challenges. By contrast, countries like Germany and Singapore had already begun adopting automated tolling systems, emphasizing India's technological lag during that period.

As per the Ministry of Road Transport and Highways (MoRTH) Year-End Review 2023, India's extensive highway network spans 3,25,680 kilometers[1], comprising:

National Highways (NH): 1,46,145 kilometers (45% of the total network).

State Highways (SH): 1,79,535 kilometers (55% of the total network).

The total number of toll plazas stands at 1,375 (994 on National Highways and 381 on State Highways).

1.5.1 Toll Revenue-to-Population Ratio: A Global Perspective

The toll revenue generated in India, though impressive, reveals an untapped potential when compared to global benchmarks:

- **India**: Toll revenue in FY 2022-23 stood at approximately **₹54,144 crore (USD ~6.7 billion)** for a population of 1.4 billion, translating to a per capita contribution of USD ~4.78 annually.
- **United States**: With a population of 331 million and toll revenue exceeding **USD 20 billion annually**, the per capita contribution is approximately **USD 60.42**—over 12 times higher than India.
- **Singapore**: Despite its smaller population of 5.5 million, Singapore's advanced Electronic Road Pricing (ERP) system generates approximately **USD 150 million annually**, equating to **USD 27.27 per capita**.
- **Dubai (UAE)**: The Salik toll system in Dubai generates about **USD 350 million annually** for a population of 3.5 million, translating to **USD 100 per capita**.

1.5.2 Toll Revenue as a Percentage of GDP

Comparing the contribution of toll revenues to national GDP offers further context:

- **India:** Toll revenue contributes ~1% of GDP, with projections to increase to 1.5% by 2030.
- **United States:** Toll revenue constitutes approximately 0.15% of GDP, reflecting the extensive reliance on federal funding for highway projects.

1 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1993425#:~:text=National%20Highways:%201%2C46%2C145%20km,Other%20Roads:%2063%2C45%2C403%20km

- **Singapore and Dubai:** Toll revenues represent ~0.4% of GDP, showcasing how smaller nations with high-tech tolling systems effectively monetize road infrastructure.

1.5.3 Journey of FASTag in India

To address these inefficiencies, the National Electronic Toll Collection (NETC) program, branded as FASTag, was launched as a flagship initiative by the Ministry of Road Transport and Highways (MoRTH) and the National Highway Authority of India (NHAI). The FASTag program, initiated in 2010 and developed with the guidance of a committee led by Nandan Nilekani, leverages Radio Frequency Identification (RFID) technology to enable seamless electronic toll payments.

The FASTag journey includes:

2012: Indian Highways Management Company Limited (IHMCL) was formed to implement and manage electronic tolling systems. A closed-loop electronic toll system was piloted between Mumbai and Ahmedabad

2016: Introduction of NETC FASTag, an interoperable RFID-based system enabling seamless toll collection across highways, managed by NPCI.

2017: Government mandated FASTags for all new vehicles and deployment of dedicated FASTag lanes at National Highway toll plazas.

2018: Transition of all National Highway fee plaza lanes to FASTag-enabled lanes.

2020: Mandating FASTag for all vehicles, including those sold before December 2017, and integrating FASTag ID into vehicle insurance renewals from April 2021.

1.5.3.1 Expansion and Current Status

The FASTag system now covers:

- **Coverage:** Over 1,200 toll plazas (994 National Highway toll plazas and 339 State Highway toll plazas) support FASTag operations.
- **Transaction Penetration: Over 98% penetration** in toll transactions by FY 2022-23, with over 1 crore daily transactions in February 2023. The total number of FASTAG issued is **8.38 Cr**. The **Cumulative ETC transaction** from 2016-17 to 2022-23 is **1146 Cr** with a total **revenue of INR 1.92 Lakh Crore**.
- **Revenue Growth:** Significant revenue growth, with collections rising from INR **3,352 crore in FY 2018** to INR **54,144 crore in FY 2023**. As per MoRTH, Tolling revenue is projected to contribute **1-1.5% of GDP,** reaching approximately **₹1.3 lakh crore by 2030**.
- **Reduction in wait times:** Average wait time at toll plazas dropped from 734 seconds in 2014 to just 47 seconds in 2023.
- **Economic savings:** Estimated annual fuel savings of INR 70,000 crore.
- **Environmental impact:** Reduction of CO2 emissions by 978,000 tonnes annually.
- **40+ member banks** participating in the NETC ecosystem as issuers or acquirers.
- In addition to tolling, FASTag has been extended to **parking payments** and integrated with systems like **GSTN and ULIP** for multi-purpose use, reflecting its versatility and widespread adoption.
- Environmental benefits include reduced idle time at toll plazas, **saving fuel worth INR 70,000 crore** annually and **cutting CO_2 emissions by 978,000 tonnes.**

Globally, countries like the United States and Canada utilize GNSS-based tolling systems, offering seamless "pay-as-you-go" solutions. While India's FASTag program provides a strong foundation, transitioning to advanced systems could unlock further benefits.

1.5.4 Innovations and Expansions: Building on the Foundation

Building on FASTag's success, India is exploring the next phase of tolling innovations:

1. **GNSS-Based Tolling:** Trials on major corridors like the Delhi-Mumbai expressway are demonstrating the feasibility of satellite-enabled, barrierless tolling systems.
2. **Integration with Value-Added Services:** FASTag is now used for parking payments, vehicle tracking, and GST e-way bill integration, illustrating its multifunctionality.
3. **Advanced Traffic Management:** IoT-powered Toll Monitoring and Control Centers (TMCC) provide real-time analytics, enhancing operational efficiency.
4. **Barrierless Tolling Solutions**: Efforts like hackathons have explored GPS-based tolling and Intelligent Traffic Management Systems (ITMS), which aim to eliminate barriers at toll plazas and enable "pay-as-you-use" models.

1.5.4.1 The Path Ahead: Barrierless Tolling and Beyond

The transition from RFID-based systems to GNSS-enabled tolling promises to redefine India's tolling ecosystem. By adopting barrierless tolling, India aims to:

- **Eliminate congestion:** Enable seamless vehicle movement without physical toll plazas.
- **Enhance fairness:** Introduce distance-based tolling for equitable charges.
- **Boost revenue:** Improve collection efficiency while reducing leakages.

1.5.4.2 Tackling Challenges: A Collaborative Approach

While the journey has been transformative, challenges such as data privacy, scalability, and user adoption remain. Proposed solutions include:

- **Free OBU distribution campaigns**, similar to initial FASTag promotions.
- **Phased implementation:** Focus on commercial vehicles in Phase 1, with gradual expansion to private vehicles.
- **Stakeholder engagement:** Collaboration with state governments, insurance companies, and technology partners for a unified approach.

1.5.4.3 Revenue Leakage Mitigation Framework

- **Source Leakages:**

Identify unmonitored alternative routes → Deploy GNSS-based systems.

- **Technology Upgrade:**

Passive RFID → Active Monitoring via GNSS.

- **Operational Inefficiencies:**

Optimize toll plaza layouts → Reduced manpower dependency.

1.5.4.4 Transition to Advanced Tolling Ecosystems

Current System (FASTag) → GNSS Integration → Dynamic Pricing Model Implementation → Continuous Monitoring and Optimization

RFID vs. GNSS: RFID provides data only at specific checkpoints, while GNSS enables continuous tracking and tracing. Integrating GNSS with ANPR systems offers seamless monitoring.

Satellite Communications and GNSS: India's **NAVIC** satellite system offers greater accuracy (1-2 meters) compared to GPS (5 meters). Combining L-band and S-band frequencies provides redundancy and minimizes ionospheric interference. Global collaborations on GNSS ensure robust and reliable systems, as seen in Europe's Galileo and China's BeiDou.

Dynamic Pricing and Data Analytics: Dynamic pricing models, based on demand and congestion, are gaining traction globally. India's toll operators could leverage large datasets for predictive analytics, akin to Google and OpenAI's capabilities, to optimize toll collection and road usage.

The **amalgamation** of FASTag and GNSS ensures a **smooth transition**. FASTag balances could be utilized for GNSS **payments**, ensuring continuity. **Standardization of processes** and **integration with banks and payment gateways** are critical for scalability and efficiency.

1.5.4.5 Impact Analysis: Moving to GNSS

- **Setup Costs:** GNSS reduces costs by 20-30% compared to traditional toll plazas.
- **Environmental Savings:** Annual CO_2 emissions drop by over 3 million tons.
- **Revenue Growth:** Projected annual increase of ₹15,000 crore post-leakage mitigation.

1.5.5 Road Safety: A National Imperative

In 2023, the country recorded approximately 1.73 lakh (173,000) fatalities due to road accidents, averaging 474 deaths daily, or nearly one death every three minutes[2]. This marks the highest annual toll since national record-keeping began. Additionally, around 4.63 lakh (463,000) individuals sustained injuries in these incidents, reflecting a 4% increase from 2022.

Highways, including national and state routes, are particularly hazardous. National highways and expressways accounted for 39.2% of road accidents and 36.2% of deaths, while state highways contributed to 23.1% of accidents and 26.8% of fatalities[3]. This data underscores the urgent need for enhanced safety measures on these major roadways.

2 https://timesofindia.indiatimes.com/india/474-lives-were-lost-daily-in-road-crashes-in-2023-says-govt-data/articleshow/114359854.cms

3 https://www.orfonline.org/expert-speak/why-are-road-accidents-in-india-on-the-rise

Recognizing the socio-economic impact of road accidents, the Centre of Excellence for Road Safety (CoERS) at IIT Madras, in collaboration with the Greater Chennai Traffic Police (GCTP), has spearheaded transformative initiatives to enhance road safety awareness and driver behaviour.

Key initiatives include:

1. **Zero Accident Day (ZAD) Campaign**:
    a. A comprehensive 20-day campaign aimed at achieving zero road accidents, involving capacity-building workshops for diverse stakeholders, including bus drivers, schoolteachers, students, and the general public.
    b. Simulator-based training for Metropolitan Transport Corporation (MTC) drivers to improve hazard perception and driving etiquette.
    c. Community engagement through activities like gamified learning for children, flash mobs, and creative competitions to promote road safety awareness.
2. **Scientific Crash Investigations**:
    a. Training 69 Investigating Officers (IOs) to perform scientific crash analyses, enabling root cause identification and actionable insights to prevent future accidents.
3. **Technology-Driven Solutions**:
    a. Development of innovative GNSS and ANPR-based tolling systems by KritiLabs, in collaboration with CoERS, to ensure barrierless tolling while enhancing safety through advanced vehicle tracking and video evidence systems.
4. **Stakeholder Engagement**:
    a. Partnerships with e-commerce platforms, IT firms, and residential associations to promote responsible driving practices.
    b. Incentivizing compliance with road safety norms such as wearing helmets, using seatbelts, and adhering to traffic signals.

1.5.5.1 Data-Driven Insights for Safer Roads

The integration of tolling data and road safety systems provides an opportunity for predictive analytics and proactive interventions:

- **Accident Analytics**: Leveraging toll and vehicle tracking data to identify high-risk areas and deploy safety interventions.
- **Real-Time Monitoring**: GNSS-based tolling systems offer centralized tracking, allowing authorities to respond swiftly to incidents and optimize traffic management.

1.5.5.2 Global Comparisons and Road Safety Models

India's road safety initiatives can be contextualized against global benchmarks:

- **Singapore**: The Electronic Road Pricing (ERP) system not only ensures seamless tolling but also reduces congestion, leading to fewer accidents.
- **Sweden**: Vision Zero campaigns emphasize behavioral change and safer infrastructure to minimize road fatalities, serving as a model for India's Zero Accident Day.
- **Germany**: Advanced crash investigation frameworks and GNSS-integrated tolling systems improve enforcement and accident prevention.

1.6 Key Challenges in the Ecosystem

Resource Dependencies

- **Infrastructure and Manpower:** India has 1,192 toll plazas as per IHMCL Annual report 2022-23 with 853 toll plazas in national highway and 339 toll plazas in state highway, requiring significant infrastructure and personnel for operations. Approximately 70% of toll plazas face operational inefficiencies due to outdated technology or lack of skilled manpower.
- **Technology Adoption:** The adoption level of technology in Indian infrastructure projects is limited, resulting in inefficiencies and increased operational costs. This technological lag hampers the modernization of toll collection systems and affects overall project execution. Only 60% of toll plazas in India are equipped with ETC (Electronic Toll Collection) infrastructure as of 2023, indicating a gap in technology adoption.

Passive Monitoring vs. Active Monitoring

The current toll collection system relies heavily on passive monitoring methods, which are less effective in real-time enforcement and detecting violations. Toll revenue losses in India were estimated at ₹15,000 crore annually in 2022 due to ineffective enforcement mechanisms like passive monitoring. This includes vehicles bypassing toll plazas through unmonitored alternative routes. The limitation of Passive monitoring leads to revenue leakages and challenges in maintaining system integrity. While the real-time active monitoring could reduce toll revenue leakages by up to 30%, highlighting the need for dynamic enforcement systems.

Fixed Stretch Charging vs. Prorated Usage Charging

India's existing toll system predominantly employs **fixed stretch charging**, where users pay a set fee regardless of the actual distance travelled. This approach lacks fairness and does not accurately reflect road usage, potentially leading to user dissatisfaction and revenue inefficiencies. Approximately **25% of highway users travel partial stretches** but are charged for the entire tollable stretch, leading to widespread dissatisfaction. A pilot study on the **Delhi-Mumbai corridor using GNSS-based prorated tolling** showed a **20% increase in user satisfaction** and a **15% reduction in toll disputes**.

High Costs of Replication and Scalability

The current toll infrastructure involves significant capital expenditure for the construction and maintenance of toll plazas, as well as the deployment of manpower. The average cost for setting up a single toll plaza is around **₹50-60 crore**, excluding operational and maintenance costs. The current ETC model incurs **15-17% of total revenue in operational costs**, compared to GNSS-based systems, which could reduce this to 10-12%. These high costs pose challenges for replication and scalability, especially in remote or less economically viable areas.

Sustainability in Remote Areas

Implementing and maintaining toll collection systems in remote regions is often unviable due to high operational costs and low traffic volumes. This unsustainability leads to inadequate infrastructure development in these areas, affecting regional connectivity and economic growth. Approximately 30% of India's highways pass through remote or low-traffic regions where toll revenue fails to justify operational costs. For instance, toll plazas in such regions often operate at a **deficit of ₹2-3 crore annually**.

Revenue Loss from Leakages

It has been estimated that India loses **12-15% of its toll revenue annually** (₹12,000-₹15,000 crore) due to toll evasion by vehicles using alternative routes like local roads and villages. This evasion undermines the financial viability of toll projects and leads to inequitable road usage. On the **Eastern Peripheral Expressway**, **toll leakage was reduced by 25%** after implementing **GNSS-based monitoring systems** in a pilot program.

Increased Waiting Times and Associated Impacts

- **Fuel Consumption:** Manual toll collection methods result in longer waiting times at toll plazas, leading to increased fuel consumption for idling vehicles. This inefficiency not only raises operational costs for users but also contributes to environmental pollution. Vehicles idling at toll plazas consume an estimated **1.4 billion litres of fuel annually**, resulting in a financial loss of over **₹2,000 crore** and emitting **3 million tons of CO2**.
- **Driver Fatigue and Road Safety:** Extended waiting times contribute to driver fatigue, which is a significant factor in road accidents on Highways in India. The lack of efficient toll collection systems exacerbates this issue, compromising road safety and increasing the risk of accidents.

Addressing these challenges requires a comprehensive overhaul of the toll collection system in India, focusing on technological integration, efficient resource management, and the implementation of fair usage-based charging mechanisms to enhance efficiency, reduce revenue leakages, and improve user satisfaction.

Delayed settlement times

These issues stem essentially from the system being an 'Off-line' system with the vehicle identification records up-loaded to the Acquirer and the Exception lists (Blacklists) downloaded from the Acquirer only at periodic intervals. Depending on the quality of data connectivity between the Toll Plaza server and the Acquirer system, an element of latency is introduced into the system resulting in a delayed settlement as well as the situation when blacklisted vehicles are allowed through the plaza as the updated blacklist has still not reached the toll plaza server.

Further, inadequate presentation of vehicle evidence to NPCI by the toll plaza operator, caused by inadequate accuracy of the AVC system & quality of image capture, also results in delayed settlements.

Although NPCI has introduced a feature that can result in on-line transfer of vehicle identification records to the Acquirer, the implementation of the same by Toll Management System providers has hardly progressed.

1.7 Pilot Interventions

- **Dwarka Expressway (2024)[4]:** Inaugurated in March 2024 by Prime Minister Narendra Modi, this expressway exemplifies India's move toward modern tolling systems. The project **leverages FASTag readers** and **overhead ANPR cameras** to enable automatic toll deduction for vehicles traveling at speeds of **up to 100 kilometers per hour**. This intervention significantly reduced travel delays, congestion, and environmental impact while ensuring operational efficiency.
- **Bangalore-Mysore Expressway (2023)[5]:** Another landmark project, this expressway employs hybrid tolling mechanisms, combining RFID and ANPR technologies. The system calculates tolls based on entry and exit points, providing a seamless and efficient experience for commuters. The pilot highlighted the potential of hybrid solutions in improving tolling accuracy and reducing operational costs.
- **Mumbai-Pune Expressway (2022)[6]:** The Mumbai-Pune Expressway has enhanced tolling mechanisms with ANPR and automated FASTag integration, focusing on improving compliance and ensuring toll revenue accuracy, alongside reducing congestion during peak hours.
- **Delhi-Mumbai Corridor GNSS Pilot (2020)[7]:** India's first large-scale GNSS-based tolling pilot was conducted on this corridor. Utilizing NavIC, India's satellite navigation system, combined with international GNSS constellations, the system calculated toll charges based on the distance traveled within geofenced zones. This initiative demonstrated the feasibility of eliminating toll plazas and highlighted benefits such as fair toll charges, reduced congestion, and streamlined operations.
- **Eastern Peripheral Expressway (2018)[8]:** Designed as India's first highway with an advanced ETC system, this expressway combines RFID-based FASTag with AI-powered video analytics. The system supports multi-lane free-flow tolling, reducing vehicle idling time and emissions. The pilot successfully demonstrated the integration of high-speed traffic with electronic tolling systems.

4 https://timesofindia.indiatimes.com/travel/travel-news/dwarka-expressway-to-introduce-indias-first-free-flow-tolling-system/articleshow/113883435.cms

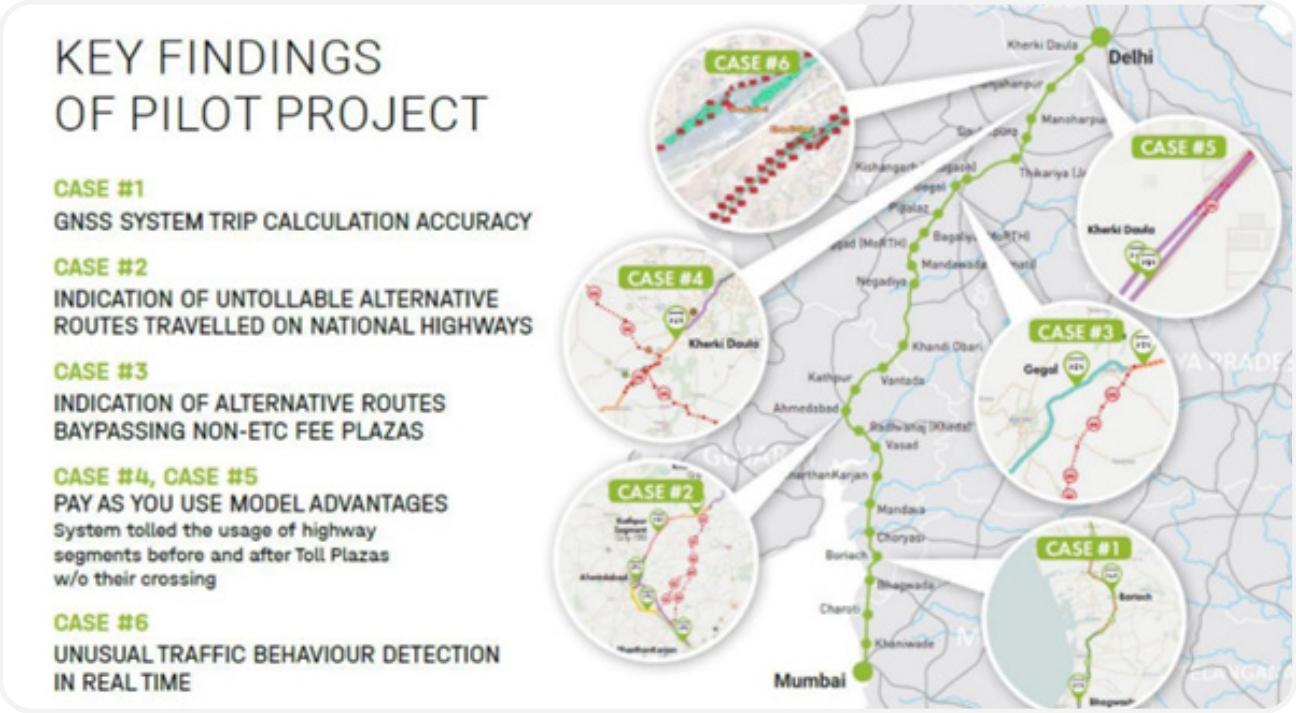
5 https://dwello.in/news/bangaloremysore-expressway-updates-key-facts-latest-toll-rates

6 https://housing.com/news/mumbai-pune-expressway

7 https://nhai.gov.in/nhai/sites/default/files/2021-06/Business-Today-70-MoRTH.pdf

8 https://swarajyamag.com/news-brief/cdpq-backed-maple-highways-acquires-nhais-eastern-peripheral-expressway-for-rs-6267-crore-in-largest-asset-monetisation-transaction-in-highway-sector

1.8 Key findings of the Pilot Project



Envisaged Solution

2. Envisaged Indigenous Framework from Global Learnings

The proposed Indian GNSS based Tolling Solution is a hybrid system in which the existing Toll Plazas will have two or more dedicated "GNSS Lanes" wherein the default position of barriers will be open for free flow of GNSS Vehicles. The lanes will have advance readers to identify GNSS vehicles. Additional fees will be charged from non-GNSS vehicles entering GNSS lanes. The GNSS Multi-lane Free-Flow envisaged workflow is pasted below

The Toll Plaza will itself act as the Stationary Enforcement Gantry in the system. The system architecture includes a Centralized Toll Charger responsible for distance & toll calculation of GNSS vehicles travelling on GNSS stretch. The Toll Charger will receive pings (distance and time stamp) of GNSS vehicles through On-Board-Unit (OBU) fitted in the GNSS vehicles. The OBUs of GNSS vehicles will be onboarded with the Toll Charger through Fintechs to be called "Issuer Entity" similar to the Issuer Banks under FASTag System. The payment mechanism shall be similar to the existing FASTag ecosystem. It is also envisaged to start GNSS based Tolling with Commercial Vehicles then extended to Private Car/Jeep/Van for own use in a phased manner.

The deployment of GNSS-based tolling systems in India presents a significant opportunity to design a solution that is both efficient and adaptable, while keeping in mind India's unique road networks and transportation needs. Using a Fit-for-Purpose approach, this system will integrate global best practices with solutions tailored specifically to the Indian context, ensuring that the tolling system is scalable, effective, and sustainable for the long term.

Key Components of the Indigenous GNSS-Based Tolling Framework

GNSS encompasses multiple alternate satellite various countries as indicated below.

User-Focused Tolling Experience:

The new GNSS-based tolling system will put the user experience at the forefront, ensuring that vehicles, regardless of their type or age, can seamlessly participate in the tolling process. By focusing on simplicity, affordability, and scalability, the system will make tolling convenient for all vehicle owners across India. The goal is to make toll payments faster and more efficient while offering clear payment options that ensure ease of use for both vehicle owners and toll authorities.

Real-Time Data Infrastructure:

One of the core features of the framework will be a cloud-based platform integrated with cutting-edge technologies like big data analytics and machine learning. This platform will monitor and analyze traffic patterns, vehicle behaviors, and road conditions in real time to determine toll rates dynamically. This flexibility ensures that toll rates can be adjusted based on traffic density, road type, or peak hours, making the tolling system fair and efficient for users across different regions of the country.

National Integration with Existing Systems:

The framework will also ensure that the system is interoperable across state borders, with seamless integration into existing tolling systems like FASTag. By aligning with NETC standards, India can provide a unified tolling experience, allowing vehicles to pass through toll booths without facing delays or confusion. This integration ensures that there is no disruption to the millions of vehicles already using FASTag, making the transition to GNSS tolling easier for users.

Affordable Indigenous Devices:

A crucial part of the indigenous framework will be the development of cost-effective GNSS-enabled devices. These devices will be designed specifically for the Indian market, keeping in mind the diverse range of vehicles and varying income levels of vehicle owners. The devices will be easy to install, durable, and affordable, ensuring that even vehicles on the lower end of the economic spectrum can benefit from the tolling system.

Support and Collaboration with Local Technologists:

The system will be built with the help of local technology partners, ensuring that it is not only technologically advanced but also adapted to Indian needs. Collaboration with homegrown tech companies will allow for greater flexibility, faster troubleshooting, and local support, making the system more sustainable and manageable over time.

Incorporating Global Learning and Best Practices

While this framework is designed with India in mind, there are many lessons to be learned from global best practices that can improve the system's efficiency and future potential.

Global GNSS Implementation Models:

Germany and Switzerland are examples of countries that have successfully implemented distance-based tolling systems using GNSS. By charging vehicles based on how far they travel, the system ensures fairness, as tolls are linked to actual usage. This approach can be replicated in India's busy highways to manage congestion and ensure a more efficient toll collection process.

Singapore's Electronic Road Pricing (ERP) system, which uses a combination of GNSS and onboard devices to charge vehicles based on their location and time of travel, can serve as a model for managing urban traffic in cities like Delhi, Mumbai, and Bangalore, where congestion is a major issue. This system has successfully reduced traffic jams and improved air quality by encouraging more efficient driving.

Futureproofing for Scalability:

One of the biggest advantages of the GNSS tolling system is its ability to scale and evolve over time. Drawing from global examples, the Indian system can be designed to grow alongside advancements in technology. This includes potential future upgrades like 5G connectivity, which could enable real-time communication between vehicles and toll systems, allowing for smart city integration.

The system should also be adaptable to emerging technologies such as electric vehicles (EVs), ensuring that tolling remains effective and fair as the transportation landscape evolves in India.

Data Privacy and Security:

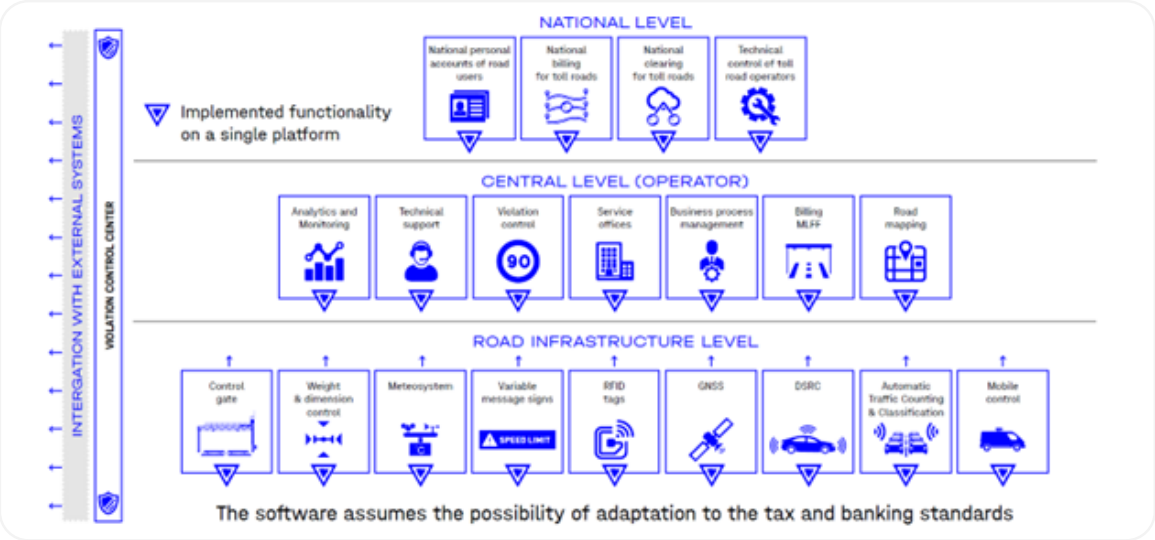
With data privacy being a key issue in many parts of the world, India's tolling system must prioritize data protection. Global examples, especially from the European Union, emphasize the importance of handling personal and payment data securely. The Indian system must ensure that vehicle data is protected and that users' privacy is respected, creating trust among vehicle owners and encouraging widespread adoption of the system.

Environmental Sustainability:

A key benefit of GNSS tolling systems is the reduction in vehicle idle time, which leads to lower emissions. This is particularly important for India, where air pollution is a growing concern. By reducing the time vehicles spend idling at toll plazas, the system can help improve air quality. Additionally, the tolling system could reward vehicles that follow eco-friendly driving patterns, thus promoting sustainable transportation.

2.1 Tolling System Framework for India

The National Highways Authority of India (NHAI) is poised to implement a GNSS-based tolling system, marking a transformative shift in toll collection on national highways. This initiative builds on the success of the FASTag system and supports the government's vision for a seamless, efficient, and technology-driven tolling mechanism. The proposed framework offers a phased and systematic approach to ensure successful adoption while addressing key technological and operational challenges.



Framework for Implementing GNSS-Based Tolling

1. Pilot Implementation

- To validate the efficiency and feasibility of GNSS-based tolling, NHAI will:
- Launch pilot projects on high-traffic corridors such as the Delhi-Mumbai route, testing free-flow tolling via GNSS technology.
- Establish centralized Automatic Toll Collection Monitoring Centers for real-time data management and reconciliation during the pilot phase.
- Analyze pilot outcomes to assess technical performance, cost-effectiveness, and user experience.
- Test interoperability between GNSS systems and existing tolling infrastructure to ensure seamless integration.
- Gather feedback from stakeholders, including drivers and transport operators, to fine-tune operations.

2. Hybrid Model Rollout

A hybrid approach ensures a smooth transition to GNSS tolling:

- Introduce GNSS-enabled lanes alongside existing FASTag infrastructure at toll plazas.
- Continue FASTag operations for vehicles not equipped with GNSS technology, allowing a gradual shift.
- Develop a phased plan for increasing GNSS lane coverage at major toll plazas.
- Offer incentives for early adopters of GNSS-based tolling, such as discounts or priority services.

- Conduct trials to ensure the coexistence of GNSS and FASTag systems without operational conflicts.

3. Vehicle Equipment

To enable GNSS tolling, NHAI will focus on:

- Deploying On-Board Units (OBUs) for accurate geo-position tracking and automated toll calculations.
- Setting up Points of Sale (POS) for registration, distribution, and top-ups of GNSS-based tolling devices.
- Introduce a user-friendly mobile application for monitoring toll charges and managing accounts.
- Establish quality standards and certification processes for OBUs to ensure reliability.
- Develop partnerships with vehicle manufacturers to integrate OBUs directly into new vehicles.

4. Infrastructure Development

Robust infrastructure is critical for the success of GNSS tolling:

- Expand satellite and digital networks, including data centers, to support GNSS operations.
- Develop secure and efficient backend systems for real-time transaction processing and data handling.
- Set up disaster recovery and redundancy measures to ensure uninterrupted tolling operations.
- Deploy network monitoring tools to identify and address connectivity issues proactively.
- Invest in cybersecurity measures to safeguard sensitive user and transaction data.

5. Stakeholder Collaboration

Partnerships will be key to successful implementation:

- Collaborate with technology providers for GNSS devices, vehicle manufacturers for compatibility, and telecom companies for network support.
- Work with state and central authorities to ensure compliance with regulatory standards.
- Engage with logistics companies, public transport agencies, and fleet operators to address operational requirements.
- Establish advisory committees with representatives from academia and industry for expert guidance.
- Coordinate with international organizations to adopt global best practices in GNSS-based tolling.

6. Public Awareness Campaign

To ensure widespread acceptance and usage:

- Conduct large-scale awareness initiatives to educate highway users on the benefits and operation of GNSS tolling.
- Train toll operators and support staff on the new technology and processes.
- Develop multilingual educational materials to reach diverse user groups across India.
- Use digital platforms, including social media and mobile apps, to spread information effectively.
- Organize roadshows and on-ground campaigns to demonstrate GNSS functionality and benefits.

7. Scalability and Full-Scale Rollout

Building on the pilot's success, NHAI plans to:

- Gradually expand GNSS-based tolling to all national highways, ensuring nationwide coverage.
- Decommission traditional toll plazas, achieving a fully barrier-free tolling experience.
- Introduce regional rollout strategies based on traffic density and readiness.
- Provide financial assistance or subsidies to encourage the adoption of GNSS OBUs by smaller vehicle owners.
- Create a task force to oversee the nationwide implementation and address challenges in real time.

8. Monitoring and Optimization

- Continuous improvement will enhance system effectiveness:
- Monitor performance metrics and user feedback to refine the system.
- Incorporate dynamic pricing models and AI-driven traffic management for greater efficiency and user convenience.
- Develop a feedback loop with real-time alerts for operational inefficiencies.
- Use predictive analytics to forecast toll revenue and manage traffic flow effectively.
- Implement periodic audits and evaluations to ensure compliance with operational standards.

This framework provides a structured roadmap for NHAI to modernize toll collection through GNSS technology. It ensures a seamless transition, addressing the technical, operational, and user-related aspects of the implementation. By adopting this advanced tolling system, NHAI is set to redefine highway infrastructure and tolling standards, driving India's highways into a new era of smart mobility.

2.2 Advantages of an Indigenous GNSS Framework

1. **Efficiency in Toll Collection**: The GNSS system calculates tolls based on kilometres travelled, which is more equitable than flat fees, reducing the burden on short-distance travellers.
2. **Scalability**: The system's design allows for easy expansion as vehicular density increases. The framework must also consider India's highly diverse highway network, ensuring seamless integration of different toll domains into one interoperable system.
3. **Sustainability**: By eliminating the need for vehicles to stop at toll booths, the framework will reduce emissions caused by idling vehicles, contributing to India's climate goals.

Game Changing Strategic Implementations

3. Game Changing Strategic Implementations

Transforming the existing toll collection system into a barrierless, satellite-based tolling system requires robust policy and technological innovations. It necessitates coordination between central and state governments, a rethinking of toll-charging models, and addressing user adoption challenges. Below are some key policy and technology considerations that will shape the success of this transformation.

This mammoth intervention considered one of world largest implementation needs to hold '**Game-Changing Implementation Strategy' (GCIS)** for comprehensive and successful implementations. Some of the select such GCISs are as follows,

- **GCIS#1: Transition management Strategy** – Adopt the approach of "*Think-Big, Start-Small and Scale-Fast*" to ensure a smooth transition to GNSS based tolling. Pilot projects with limited deployment to be launched, evaluated, and scaled incrementally to avoid system disruptions.
- **GCIS#2: Incentives & Change Management** – Unlike the cost-effective RFID based FASTag solution, GNSS based On-Board-Units (OBUs) are very dearer and possess data privacy apprehensions due to active-active type i.e. near-to-real-time location data. Similar to the RFID based FASTag transition strategy, one lakh Free-of-Cost OBUs for the **early-bird adapters**.
- **GCIS#3: Telematics and communication Strategy adaption** – Implement robust telematics systems to enable real-time tolling while ensuring strict data privacy measures. Focus on anonymizing location data to build trust among private vehicle users who may be hesitant to share their location details.
- **GCIS#4: Road Safey and value-added services** – The OBU can be complemented with edge intelligence, such that, in case of prolonged non-movement, it shall proactively engage with driver for identification of any challenges and report for necessary support in case of no response.
- **GCIS#5: Environmental, Social and Governance (ESG) framework –** In the barrierless GNSS approach, seamless movement with near to zero waiting time has been envisaged. The carbon release from the toll infrastructure, CO release from incomplete combustion of fuels during non-cruising period and slow-down of vehicles in and around the toll plaza will be reduced.

- **GCIS#6: amalgamation with existing proven technologies** – Integrate GNSS-based systems with proven technologies like FASTag for hybrid tolling operations, ensuring compatibility with existing infrastructure and allowing phased migration.
- **GCIS#7: Hybrid Lane operations –** Implement hybrid lanes that accommodates both FASTag and GNSS based system during the transition phase. This will ensure service continuity and minimize the user disruption.
- **GCIS#8: Deviceless solution** – Part of Europe post the initial operation OBU based GNSS solution framework now have transcending into a software-based offering which leverage on smartphones to do the work for us.
- **GCIS#9: Single System Operator or Empanelled vendor approach** - Appoint a single system operator or empanel multiple vendors to streamline system implementation and ensure uniform service delivery standards across the network.
- **GCIS#10: Phased Implementation -** Beginning with commercial vehicles (79% highway road usage contributor), to ensure success and scalability and then focusing on the private self-owned vehicles (21% highway road usage contributor).
- **GCIS#11: Existing Vs New Vehicle OBU commissioning -** Mandate GNSS OBUs for all new vehicles during manufacturing, while retrofitting existing vehicles in a phased manner through partnerships with hardware vendors and service centres.
- **GCIS#12: Stakeholder Collaboration**: Engage government authorities, private toll operators, technology vendors, and users to align interests, address concerns, and facilitate smooth deployment.
- **GCIS#13: Policy and Legal Framework**: Develop robust policies for data privacy, user consent, and opt-in/ opt-out mechanisms. Establish legal enforcement for non-compliance and ensure users' rights are protected.
- **GCIS#14: Public Awareness Campaigns** - Educate users on the benefits of GNSS-based tolling, such as reduced emissions and congestion, through awareness programs, advertisements, and community engagement.
- **GCIS#15: Central-State Joint operations -** Foster collaboration between central and state governments to address regional needs, enforce tolling regulations uniformly, and ensure seamless integration of national and local tolling systems.
- **GCIS#16: Potential Value-Added Benefits (Add-Ons basis on citizen interest & consent) -** Offer services like golden-hour emergency assistance, dynamic insurance premium adjustments using actuarial science, and data-based traffic analytics to enhance user value and adoption.
- **GCIS#17: Anomalies management -** Set up automated systems to detect and manage discrepancies in tolling data, user transactions, or map matching. Use AI-driven analytics for quick issue resolution.

- **GCIS#18: Data privacy and consent** - Incorporate strict data privacy norms like anonymization of personally identifiable information (PII), "right to be forgotten" options, and transparent consent mechanisms for data sharing. Anonymization happens at the
- **GCIS#19: Reconciliation, Dispute resolution** - Create a centralized system for reconciling toll transactions and addressing disputes. Use AI tools for automated tracking, resolution, and escalation management.

3.1 Policy Considerations

1. **Barrierless Toll – Atmanirbhar Solution Design** The new system should prioritize self-reliance in its design, promoting Indian vendors and technology providers. This aligns with the Atmanirbhar Bharat initiative, ensuring that critical components, such as OBUs, GNSS hardware, and software platforms, are either sourced locally or developed with strong local collaboration. This will build national capacity, boost employment, and secure India's technological independence.

2. **Centre and State Government Joint Operations** The GNSS-based toll system will require close collaboration between the central and state governments. While the central government would oversee policy formulation and system standards, state governments will manage local enforcement and data-sharing protocols. Incentives like revenue-sharing arrangements can encourage states to adopt the system swiftly. Additionally, central support in infrastructure funding will ease the financial burden on states.

3. **Technology Choice – Single or Multiple Options?** A major decision is whether to opt for a single technology (e.g., GNSS) or to support multiple tolling technologies, including device-less solutions like ANPR (Automatic Number Plate Recognition). A single technology simplifies the system and reduces administrative costs, but supporting multiple technologies allows flexibility for different regions and vehicle types. However, this could complicate interoperability, requiring careful management.

4. **Equipment Purchase from Single or Empanelled Vendors** Whether equipment should be sourced from a single vendor, or an empanelled list remains an important policy question. Empanelment of multiple vendors ensures competitive pricing, innovation, and avoids monopolistic risks, fostering a healthy market ecosystem. However, it also requires stringent quality control and adherence to standardization.

5. **Toll Charging Policies: Target Audience** Another key consideration is whether to charge only commercial vehicles or all vehicles, including private ones. Globally, some countries, like Germany, only charge heavy commercial vehicles based on their higher road wear. However, charging private vehicles as well could boost revenue and incentivize efficient highway use. A phased approach, starting with commercial vehicles, could ease adoption.

6. **Value-Added Services (VAS)** The toll system can provide several value-added services that improve user experience and safety. These include vehicle tracking, theft protection, insurance integrations, and real-time traffic alerts. Such services can be integrated into the OBU system, providing additional value to users.

7. **Satellite Tracking Solution Governance** Decisions on whether the satellite tracking system (both hardware and software) should be managed by a single player, or multiple vendors need careful policy framing. A single vendor simplifies management but can risk monopolies, while multiple vendors increase competition but add complexity in coordination.

8. **Compliances with AIS Standards** Any new system must comply with Indian standards, such as AIS 146 for vehicle location tracking, ensuring security and quality across the ecosystem. Such compliance fosters interoperability, enhances security, and ensures data protection.

9. **Addressing Data Privacy Concerns** The GNSS-based system will rely heavily on collecting and processing vehicle movement data, which raises significant data privacy concerns. Policy frameworks must ensure anonymization of data and robust protection mechanisms against misuse, following national standards on data privacy.

10. **Phased or Big-Bang Implementation:** A phased approach, piloting the system in union territories (UTs) before scaling it to states, ensures smoother adoption. Lessons learned from smaller-scale implementations can guide more efficient rollouts across larger states.

3.2 Technology Considerations

GNSS-Based Tolling Approach

GNSS-based tolling relies on satellite navigation to track a vehicle's location, allowing tolls to be calculated based on distance travelled. This system is particularly well-suited for long-distance highways and expressways, where a distance-based tolling model is ideal. The implementation of GNSS for barrierless tolling offers significant advantages, including:

- **Dynamic Tolling**: GNSS-based tolling provides the flexibility to implement dynamic pricing, where tolls can vary depending on the time of day, traffic congestion, or vehicle type. This is beneficial for managing peak-hour traffic and improving road usage efficiency.

- **Seamless Travel**: GNSS technology enables toll collection without the need for physical toll booths or barriers, reducing congestion at toll plazas. It allows vehicles to pass through toll points without stopping, enhancing overall traffic flow and minimizing delays.

- **Integration with FASTag**: GNSS can be integrated with the existing FASTag system. Since FASTag is already linked to the vehicle's registration details, it can be used to authenticate the vehicle's location, ensuring that toll payments are accurately processed. The integration can make use of the existing infrastructure and user base, avoiding the need for widespread changes in the toll payment process.

However, there are challenges with GNSS-based tolling, particularly in terms of vehicle hardware requirements. Vehicles would need GNSS-enabled devices to communicate with the system, which might create an adoption barrier for older vehicles or for users who do not want to equip their cars with additional devices. Moreover, GNSS requires reliable satellite connectivity, which may face issues in remote or densely built-up areas with poor signal reception.

Camera-Based Tolling Using ANPR

Camera-based tolling relies on Automatic Number Plate Recognition (ANPR) technology to identify vehicles and calculate toll charges based on entry and exit points. This approach is ideal for urban and peri-urban areas, where fixed tolling points are more common. Key benefits of the ANPR-based system include:

- **Non-requirement for Vehicle Hardware**: Unlike GNSS, ANPR does not require vehicles to be equipped with any special devices. The tolling system can capture license plates using high-definition cameras installed at strategic locations, making it an easier solution for widespread adoption without the need for extensive hardware investments from road users.
- **Integration with FASTag**: The camera system can also integrate with FASTag, where the system can cross-check the FASTag for payment verification once the license plate is read. This integration enhances the existing infrastructure and ensures a smooth transition to barrierless tolling for users who already possess a FASTag.
- **Multi-Functionality**: In addition to toll collection, ANPR systems can support other functionalities such as **traffic law enforcement**, **congestion management**, and **vehicle tracking**. This multi-purpose utility makes ANPR systems an attractive option for urban road networks that require comprehensive monitoring.

However, camera-based tolling has its own set of challenges. ANPR systems depend heavily on high-quality imaging to ensure accurate recognition, which can be impacted by environmental conditions such as poor lighting, weather conditions, and dirty or obstructed license plates. Additionally, camera-based systems are more suited for fixed-point tolling rather than dynamic, distance-based tolling, limiting their scalability in highways or long-distance roads where GNSS may be a better fit.

Fit For Purpose Approach

The transition to barrierless tolling in India presents a unique opportunity to modernize the toll collection system, improve traffic flow, and reduce operational inefficiencies. This requires a robust and adaptable technological framework that incorporates the best of existing infrastructure and emerging solutions. In this context, a "fit-for-purpose" approach needs to be adopted, particularly when evaluating the use of Global Navigation Satellite System (GNSS)-based tolling and camera-based tolling using Automatic Number Plate Recognition (ANPR) technology. Both solutions must be examined in conjunction with the existing FASTag system, which is already a key component of India's tolling ecosystem.

When implementing an integrated tolling system involving GNSS, ANPR, and FASTag, several technological factors need to be carefully considered to ensure the solution's effectiveness and sustainability. Below is an in-depth look at each of these considerations.

Scalability

Scalability is one of the key challenges in implementing a tolling system in India, given the vast and rapidly growing road network. The system must be able to handle

- **Large Traffic Volumes:** The road

network in India spans urban and rural areas with varying traffic densities. A tolling system must handle millions of vehicles without performance degradation.

- **Multiple Toll Points:** A hybrid system involving GNSS, ANPR, and FASTag must be designed to support a large number of toll points across different states, regions, and types of roads (expressways, highways, rural roads).
- **Future Expansion:** The system should be flexible enough to expand as traffic volumes increase, with the capability to integrate new toll points and vehicles seamlessly.

Scalability demands robust cloud infrastructure, high-speed data processing, and real-time analytics to handle vast amounts of data generated by vehicles at toll points. Additionally, ensuring that the system can handle both urban and rural areas means developing infrastructure that caters to diverse conditions and needs.

Interoperability

Interoperability between the three technologies (GNSS, ANPR, and FASTag) is essential for smooth operation across the tolling ecosystem. It refers to the ability of different systems and components to work together seamlessly, regardless of the technology or toll operator. This includes:

- **Device and System Standardization**: A unified communication protocol and system design must be adopted across all toll operators, road operators, and vehicle owners. Standardizing hardware (e.g., GNSS devices, ANPR cameras) and software platforms ensures that vehicles can pass through toll plazas without issues, even if they are using different technologies (GNSS, ANPR, or FASTag).
- **Payment Systems Integration:** While FASTag is based on RFID technology, GNSS uses satellite data and ANPR captures plate images. These systems need to integrate with centralized payment systems that allow for seamless toll payment and validation across multiple toll plazas. This ensures that a vehicle can use any technology, regardless of the toll point, and still receive the correct toll charge.
- **Cross-Region Functionality:** In India, different states may have different toll operators with varying systems and standards. The system must be able to interoperate across regions without requiring users to re-register or modify their tolling accounts.

Interoperability challenges also include the need for real-time data exchange between toll operators, enforcement agencies, and road authorities to ensure accurate tracking and enforcement of tolls. A common standard, as set by the government or a regulatory body, will be crucial for ensuring that all systems work together.

Environmental Resilience

Tolling systems need to function effectively under varying environmental conditions. India's diverse weather conditions—from extreme heat in the desert regions to heavy rains and fog in coastal and mountainous areas—pose significant challenges to the reliability of technology. Specific considerations include:

- **GNSS Resilience:** GNSS (Global Navigation Satellite System) works by receiving satellite signals to determine a vehicle's location. However, satellite signals can be disrupted by weather conditions like heavy rain, fog, or forested areas, leading to inaccuracies in location tracking. To mitigate this, using L-band signals (which are less susceptible to interference

compared to other bands) is one solution. Additionally, ensuring redundancy (such as using multiple satellite systems) can help improve GNSS accuracy. Also Geostationary Navigation Overlay Services to enhance the accuracy of the GNSS system since the system uses the radio signals it needs line of site for high accuracy. Especially in urban areas the accuracy can be affected by high building covering the road.

- **GAGAN** is an SBAS that supports flight navigation over Indian airspace. The system is based on three geostationary satellites, 15 reference stations installed throughout India, three uplink stations and two control centres. This system can be used to improve the accuracy of the GNSS system.

- **ANPR Camera Performance:** Automatic Number Plate Recognition (ANPR) relies on high-resolution cameras and advanced image processing algorithms to read vehicle license plates. These cameras must be able to operate effectively in various lighting conditions (e.g., bright sunlight, night-time driving) and extreme weather (e.g., rain, fog, snow). Weatherproof cameras with night vision, infrared capabilities, and automatic exposure control can ensure high performance in diverse conditions.

- **Hardware Durability:** The equipment used at tolling points, including GNSS devices, ANPR cameras, and toll collection hardware, must be built to withstand outdoor elements. This includes ensuring that devices are weatherproof, dustproof, and capable of operating in high temperatures or humidity.

The system must be designed with durable and weather-resistant infrastructure that guarantees continuous and accurate tolling even under adverse environmental conditions.

Cost

The implementation of an integrated tolling system requires significant initial investment in infrastructure, technology, and maintenance. Here are the major cost-related considerations:

- **Initial Investment:** Setting up a nationwide tolling system with GNSS, ANPR, and FASTag will involve significant capital costs. This includes the installation of GNSS tracking systems, ANPR cameras, RFID infrastructure, and cloud-based data processing systems. The integration of multiple technologies also requires specialized software development, which increases initial development costs.

- **Ongoing Maintenance and Upgrades:** As with any technological system, maintenance is essential to ensure that the tolling infrastructure continues to operate smoothly. Maintenance costs can include regular software updates, hardware servicing, and ensuring system upgrades to accommodate technological advances (e.g., updating ANPR algorithms for new plate designs).

- **Cost Efficiency:** While the upfront costs might be high, the long-term benefits of implementing this system (such as reduced congestion, fewer toll booths, and more accurate revenue collection) could lead to cost savings and improved efficiency for toll operators. The system can reduce the need for manual toll collection, minimizing labour costs, and reducing the wear and tear on infrastructure. Moreover, it enables dynamic pricing, which can optimize revenue based on traffic patterns and congestion.

To balance these costs, governments and toll operators may need to seek partnerships or investments from technology providers, and potentially introduce phased or pilot implementations to test the system in specific regions before full deployment.

Data Management and Security

Since the integrated system relies on collecting and processing large amounts of sensitive data—such as vehicle location, travel time, registration details, and toll payments—data management and security are crucial:

- **Data Privacy:** GNSS and ANPR technologies will collect information related to vehicle movements and registration numbers, which are considered personal data. It is essential to ensure compliance with data privacy regulations (e.g., GDPR or local Indian privacy laws). Users must be informed about how their data will be used, stored, and shared. Consent from vehicle owners should be obtained, and data should be anonymized or encrypted to prevent unauthorized access.
- **Real-Time Data Processing:** A robust data infrastructure is necessary to process real-time data from GNSS, ANPR, and FASTag systems. This infrastructure needs to be secure, with the ability to handle large volumes of data efficiently and with minimal latency. Data storage should be designed to store large amounts of vehicle-related data securely.
- **Cybersecurity:** Given the integration of multiple technologies, cybersecurity is a critical factor to protect the system from threats, such as data breaches, cyberattacks, or fraudulent activities. Security measures must be implemented at every level, from network security to encrypted data storage, to safeguard the system and user data.

Way Forward and Key Takeaways

4. Way Forward and Key Takeaways

As India moves toward a barrierless tolling system, the road ahead must be meticulously planned to ensure smooth implementation, scalability, and sustainability. The goal is not only to address current challenges but also to future-proof the system against increasing vehicular density, technological advancements, and growing user expectations. This section outlines the strategy, key aspects of inclusiveness, monetization, and value-added services that will be critical to the success of this transformation.

4.1 Unique Selling Proposition (USP) - Value-Added Services Offering-

The GNSS-based tolling system presents a unique opportunity to offer value-added services (VAS) that can enhance the experience of users, going beyond mere toll collection:

1. **AIS 140 Compliance and ADAS Support**: Vehicles equipped with AIS 140 compliant tracking devices can integrate Advanced Driver Assistance Systems (ADAS) to improve road safety and optimize travel routes. This will be especially beneficial for commercial fleets.
2. **Vehicle Theft and Accident Insurance**: With real-time tracking of vehicles through the GNSS system, insurance providers can offer tailored solutions that monitor vehicle movements and alert authorities in case of theft or accidents. Such services can be integrated seamlessly with the tolling system, providing an added layer of security to road users.
3. **Track and Trace for Nominees During Disaster Situations**: In the case of natural disasters or accidents, the system can provide real-time location tracking, allowing emergency services to reach the location quickly and track missing individuals.
4. **Other Services**: Potential integration with EV charging stations, parking management systems, and route optimization tools can further enhance the utility of the system for both commercial and private users.

4.2 Strategy for Inclusiveness

To ensure the success of the barrierless tolling system, it must be inclusive and cater to all types of users-commercial fleet operators, private vehicle owners, and public transport services:

1. **Product-Based Approach**: The tolling system must be designed as a scalable product that can be expanded as new vehicles join the system. An ecosystem that accommodates different types of vehicles, including two-wheelers, cars, trucks, and buses, ensures inclusiveness.
2. **Economies of Scale**: By embracing a national rollout, the system can benefit from economies of scale, reducing the cost of deployment and operation. A large user base will also help to recover the initial investment more quickly.
3. **Phased Rollout**: Initially, the system can target commercial vehicles, which contribute significantly to road usage and wear. Once the system proves successful, it can be expanded to private vehicles.

4.3 Contract Execution Strategy and Monetization

A robust contract execution strategy will be essential to the rollout of the new tolling system:

1. **Outsourcing to Toll Service Providers**: The role of Toll Service Providers (TSPs) will be critical in executing the project. These providers will manage toll collection, enforcement, and VAS delivery. Outsourcing this to TSPs with proven capabilities in technology and operations will ensure seamless execution.
2. **Monetization of the System**: The new tolling system can be monetized through several channels:
    - **Commercial Vehicles**: Initially, tolls can be charged based on kilometres travelled by commercial vehicles. This will provide a reliable revenue stream.
    - **Value-Added Services**: Offering additional services like fleet management, route optimization, and real-time tracking can provide additional revenue.
    - **Subscriptions for VAS**: Fleet operators and private users can subscribe to services like theft protection, route optimization, and insurance, generating recurring revenue.

4.4 Sustainability Considerations

The shift to a barrierless tolling system will contribute to India's sustainability goals:

1. **Reduced Emissions**: By eliminating the need for vehicles to stop at toll plazas, the system will reduce fuel consumption and lower carbon emissions.
2. **Smart Traffic Management**: With real-time traffic data, authorities can better manage congestion, leading to more efficient travel and reduced overall environmental impact.

4.5 Key Industry Takeaways

While this marque intervention is not just limited to road sector but to various allied industries, some of Key Industry Takeaways (KIT) such are as follows.

- **KIT#1: Data Analytics & Predictive** market would deep data lake of near-to-real-time vehicular data across tollable roads. Large synthetic data that gets churned from such engines would be Monetizable and act as a potential revenue source in future.
- **KIT#2:** Backward integration for **Insurance Agencies plays** – As part of rapid customer accusation strategy the OBU are offered with Value Added Services (VAS) such as data exchange platform
- **KIT#3: Dynamic Toll usage pricing** – 'cruising-period' – in western services the navigation services are offered as a value-added services whereby when driver share the destiny location
- **KIT#4: Advanced Driver Assistance Systems** (ADAS) - help drivers operate a vehicle safely driver behaviour & Journey Risk Management, driver credit rating
- **KIT#5: GIS Spatial based offering** – existing road geometry, accidents layers data, alternative routes for untollable route segment, Traffic behaviour and roadside assistance, enforcements
- **KIT#6: Product to Software model** - Provides a green field for software based GNSS solution on mobile – SATag mobile compatible software solutions which are cost-effective and easy to use. These solutions are extensively used in European countries.
- **KIT#7: AI & LLM market** - assisted driving service and support in anomaly detection and management for e.g. 1) Whenever Vehicle crosses the influence length of particular Toll Plaza(s) 2) Whenever vehicle makes a U-Turn 3) Whenever vehicle leaves the GNSS stretch 4) Whenever OBU turns red (no balance/OBU malfunctions) 5) Vehicle Stopped on Highway beyond defined time limit 6) Any other occasion decided by the Authority

5. Annexure

5.1 Annexure A: Voice of Market (VoM)

"India is now taking its latest leap forward with GNSS-based tolling. This revolutionary, barrierless tolling system powered by satellite technology will transform the way we experience our highways.By eliminating toll plaza congestion and enabling fair, distance-based tolling, this system promotes environmental sustainability and enhances commuter convenience."

Shri Davinder Singh Sandhu
Co-Founder & Chairperson of Primus Partners Private Limited

"Kapsch is challenging the limits of mobility for creating a healthy world without congestion by creating innovative transportation solutions like GNSS tolling for sustainable mobility to enable users to arrive at their destination conveniently, on time, safely, efficiently, and with minimal environmental impact."

Shri George Kapsch
Chairman and Global CEO, Kapsch Group

"Telematics is revolutionising India's transportation sector, with the commercial telematics market projected to grow from ₹14.55 billion in 2023 to ₹61.52 billion by 2032, exhibiting a CAGR of 16.8%."

Shri Alexander Bondarenko
DG, Telematika

"Coexisting RFID and GNSS tolling in India offers an efficient blend of cost-effective simplicity and scalable flexibility, ensuring convenient toll collection. With Skytoll's 'Make in India' commitment, innovation drives economic growth and enhanced commuter experience."

Shri Peter Polakovic
Chief Strategy and Business Development Officer, Skytoll Private Limited

"This approach paper outlines a transformative roadmap for India's logistics, where GNSS tolling will enable barrierless toll collection through satellite tracking. By eliminating toll booths and streamlining routes, this will reshape the future of transportation, enhance safety and efficiency, and create a seamless, future-ready logistics network."

Shri Akhilesh Srivastava
President, ITS India Forum

"NavIC, India's satellite navigation system, offers superior accuracy and reliability for GNSS-based tolling. Its dual-frequency approach and optimised architecture make it ideal for strategic applications. Successful adoption requires addressing integration challenges, phased implementation, value-added services, policy mandates, industry collaborations, and data privacy concerns."

Shri Rajeev Gambhir
Deputy Director General, SatCom Industry Association (SIA-India)

"28 April 2023 - NETC FASTag system reached an all-time high of ₹193.15 crore, with 1.16 crore transactions in a single day,"

Shri Sandeep Pawar
MD & CEO, KENT Intelligent Transportation Systems (India) Private Limited

"The implementation of GNSS-based tolling demands robust legal safeguards that ensure user privacy and compliance with India's new privacy law. Aspects such as informed consent, data minimization and purpose limitation should be factored in by all players involved, as these are likely to help in faster adoption and fostering pulic trust in such innovations."

Shri Aman Gera
Partner, AZB Partners

"FASTag to SATag" – India, world's largest road network to embrace GNSS based Barrierless Toll Collection, with the 2 new 'service-excellence' mantras viz. 1) "time-to-serve" and 2) "ease-of-use" to create 1.4+ billion USD market by 2032..."

Arun Moral
Manag Director, Primus Partners

"GNSS tolling data can empower insurers to offer pay-as-you-drive policies, track driving patterns, and detect anomalies. This enhances underwriting precision, reduces fraud, and enables tailored insurance plans, benefiting both customers and insurers with accurate premiums and proactive claims support."

Shri Rajiv Gupta
President, PB Fintech Ltd. (Policy Bazaar and Paisa Bazaar)

"Barrierless tolling marks a transformative step toward efficiency, transparency, and sustainability for India's roads. By modernizing tolling infrastructure, optimizing revenue collection, and reducing congestion, it enhances road user experience while paving the way for world-class infrastructure. A seamless transition requires collaboration, robust data security, and a transparent regulatory framework to unlock its full potential and deliver lasting benefits to all stakeholders."

Col Rajeev Sood (Retd)
Secretary General, Highway Operators Association (India)

Vishal Chauhan
IHMCL

"It is heartening to see Industry, Academia, and various think tanks aligning with IHMCL in our shared commitment to advancing the Government's vision of enhancing logistical efficiency through state-of-the-art tolling technologies. As a step towards this vision, IHMCL has already initiated the process by inviting bids for implementing barrierless tolling using existing RFID and ANPR technologies at selected toll plazas. This initiative not only marks a significant milestone in modernizing India's tolling ecosystem but also underscores our dedication to creating seamless and efficient transit experiences across the nation's highways."

Rahul Choube
Head of Urban Mobility-India & South Asia, VISA

"At Visa, we are excited about Government of India and Ministry of Road Transport and Highways' initiative to launch the Global Navigation Satellite System (GNSS) based toll collection in India. This will not only accelerate the digitization of toll payments but also drive greater efficiency, transparency and better allocation of resources. We look forward to contributing to this initiative with our global transit experience and payment solutions, to enable a seamless experience for customers on highways."

Vaibhav Dange
Public Policy Expert on Infrastructure, Green Fuels & Sustainable Mobility, Think Infra

"India's highways are transforming into smart corridors of progress—where innovation drives seamless, sustainable travel and opportunities abound. The GNSS-based tolling system powered homegrown technology, marks a monumental shift towards smarter, greener mobility, unlocking boundless opportunities for every commuter and every corner of our nation."

5.2 Annexure B: Select Envisaged Gazette notifications

The proposed Gazette notifications for the implementation of GNSS-based tolling in India

S.No.	Requirement	Change	Responsible
1.	On-Board Unit AIS-140 shall be compulsory for all Commercial Vehicles	In case the OBU AIS-140 is not installed, a penalty shall be generated	MoRTH
2.	One dedicated 'Free Flow Lane' shall be given for Satellite Tolling System Equipment for Enforcement	Along with FASTag, another ETC lane shall be introduced at each Toll Plaza for GNSS Toll System	MoRTH
3.	AIS-140 Requirements for Hardware and Software System shall be amended	• Additional Controller shall be added for GPS/NavIC module • To enable the tolling, the Device Firmware shall be updated	MoRTH
4.	Forbid to drive a vehicle without a positive (above the threshold) amount on the System Wallet	New Gazette Notification shall be issued to forbid for the system users to enter a National Highway without a positive (above the threshold) amount on the System Wallet. The user shall pay a double amount of the stretch cost at each toll plaza which will be generated by the Satellite Tolling System as E-Challan and immediately send to the Parivahan	MoRTH

5.3 Annexure C : Reference Standards and Compliance

5.3.1 Typical Functional GNSS OBU Specifications

1. The on-board Unit must ensure:
   a. automatic collection, generation, storage and transmission of data on the movement of a vehicle;
   b. transmission of monitoring information about the state (status) of the OBU;
   c. changing control parameters and executing commands transmitted from the Central software system;
   d. updating software during operation;
   e. unambiguous identification of the on-board device in the system by their identification (serial) number.
2. The on-board device must provide round-the-clock operation.
3. The on-board device must perform the following functions:
   a. generation of information about the current coordinates and direction vector of movement of the vehicle in which the device is installed, by receiving and processing signals from GLONASS/GPS + NAVIC satellite navigation systems;
   b. registration of internal events related to the on-board device operation, including the passage of checkpoints;
   c. registration of facts of violation of the integrity of the casing (blocks) of the on-board device and execution of the sequence of actions adopted in the system;
   d. accumulation and storage of information in the internal non-volatile memory about the movement of the vehicle for at least 30 days;
   e. periodic transmission of information via channels of mobile radiotelephone networks of GSM-900/GSM-1800/UMTS standards;
   f. conducting self-diagnostics.
4. Operating temperature range from -40 to +80 C.
5. The on-board device must register and record into the internal non-volatile memory information about the location of the vehicle in which it is installed, based on the event and/or time.
6. The execution of the software update procedure must not disrupt the normal operation of the on-board device in any of the modes; in particular, the device must not interrupt the collection, processing, storage and sending of data to the system, as well as the execution of system commands, with the exception of the period of rebooting (switching) the software.
7. The navigation receiver shall ensure that the first navigation launch is achieved within:
   a. no more than 40 seconds - for a cold start;
   b. no more than 10 seconds - for a hot start.

8. The frequency of output of navigation data by the navigation receiver must be not less than 1 Hz.
9. The on-board device must:
    a. ensure the operation of the device in all modes, as well as charging of the on-board device battery;
    b. ensure the operability of the on-board device when the on-board network voltage changes from 9 to 50 V;
    c. ensure the operation of the on-board device in full functionality when the external power supply is disconnected and the maximum power consumption from the built-in battery is at least 30 minutes;
    d. switch the device to energy saving mode 5 minutes after disconnecting from the on-board power supply when the vehicle is not moving;
    e. switch the device to power from the built-in battery when the on-board network voltage drops below 9 V;
    f. ensure protection of the device from reverse polarity of the external supply voltage and ensure the operability of the device after exposure to a supply voltage of reverse polarity of 50 V for at least 5 minutes;
    g. provide protection against conducted interference in power supply circuits.
10. The on-board device battery must be designed for at least 1000 charge cycles.
11. Visual indicators of on-board device must provide mandatory information to the driver about:
    a. the inability of the on-board device to collect, process or transmit data on the movement of the vehicle;
    b. changing the current state of the on-board device (mode/ submode);
    c. occurrence or detection of malfunctions of the on-board device and (or) its modules.

OBU TYPES SPECIFICATIONS

Vehicle type	 **OBU. Embedded** AIS-140 v2	 **OBU. In-cabin** Tolling Only	 **eOBU** Mobile Application
Commercial (N)	For new vehicles – free	For ALL types of vehicles – free	For further consideration
Passenger (M)	For further consideration	Paid (toll fee discounted)	Free
Specification	• Multi-GNSS constellation and NavIC required • Collecting GNSS positions every 1 second • Visual indications for driver • Storing data onboard for 30 days • Robust in not losing data after failures (rebooting, connection lost etc) • Encryption		Specification defined by System operator

12. Resources of the sound warning system of the on-board device must ensure mandatory notification of the driver about a decrease in the battery charge to a level at which the device will operate for less than 30 minutes in maximum energy consumption mode.
13. Restoring the operation of the on-board device after a failure must be carried out without losing the accumulated information.
14. The degree of housing shells protection of the on-board device from penetration of foreign bodies and water must be no worse than IP44.

5.3.2 Typical Vehicle-to-Everything (V2X) Requirements

The GNSS solution can be complemented with V2X functionality. In this case the following International standards may be leveraged and cross-referenced

- ISO TC 204/WG 5:2022 (Fee and toll collection)
- ISO DTS 21719-3:2021 (Electronic fee collection — Personalization of on-board equipment (OBE))
- CEN TC 278/WG1 (Electronic Toll Collection and Access Control. Radio Signal Interference);
- BS EN 15509:2007 (Road transport and traffic telematics - Electronic fee collection - Interoperability application profile);
- EN 301 489-3:2005 (EMC standard for radio equipment and services;

5.4 Seven Steps to Barrierless Toll Plaza Implementation

1. Choosing roads - Choose and agree toll road stretches
2. Creating a digital road map – create digital toll road vector graph of chosen road stretches
3. Rolling out enforcement infrastructure - install stationery and rollout mobile enforcement, system adjustment
4. Customer care - prepare customer points of services and OBU delivery
5. Informing toll road users - launch public awareness campaign to inform and learn road users for 1-3 months before new System will replace old one on chosen road stretches
6. Starting System - after 1 month start new system (at first stage it should be longer - about 3 months) – stop toll plazas, open boom barriers on chosen road stretches
7. Removing Toll Plazas - dismantling Toll Plazas, the vacated land is used for other purposes

5.5 Annexure D: Case Studies

5.5.1 Case Study #1: Unified Tolling Across Europe: Implementation of the European Electronic Toll Service by Kapsch

Problem Statement:

The European tolling landscape lacked uniformity, with different countries using varied toll systems, creating operational inefficiencies and hindering cross-border travel. This fragmentation resulted in administrative hurdles, incompatible devices, and challenges in ensuring smooth mobility and optimal revenue collection.

Solution Implemented:

- **Integrated Tolling Framework:** A cohesive legal and technical framework was established to harmonize toll operations across European regions.
- **Single Tolling Device:** A universal device simplified tolling for users, reducing the need for multiple contracts.
- **Streamlined Operations:** Administrative processes were centralized, enabling Toll Service Providers to manage collections efficiently.
- **Dynamic Pricing Models:** The system incorporated distance- and time-based tolling, allowing for adaptive and equitable charges.

Benefits:

- **Revenue Growth:** Centralized processes improved toll revenue management for operators.
- **Simplified User Experience:** Travelers enjoyed cross-border mobility with fewer logistical constraints.
- **Operational Streamlining:** Unified systems minimized complexities for users and providers.
- **Economic & Environmental Boost:** Efficient transport mechanisms fostered regional commerce and sustainability.

5.5.2 Case Study #2: Bulgarian GNSS-Based Electronic Toll Collection System by Kapsch

Problem Statement:

Bulgaria's existing tolling framework lacked the scalability and efficiency required to handle increasing transit traffic and support infrastructure development. The reliance on traditional tolling methods led to operational inefficiencies, revenue leakages, and delays, creating a pressing need for a modernized system.

Solution Implemented:

- **GNSS-Based Toll Charging:** Introduced a technologically advanced tolling system using GNSS technology to ensure free-flow tolling without physical barriers.
- **Multi-Channel Payment Options:** Enabled users to purchase electronic vignettes through self-service terminals, mobile applications, and online platforms, ensuring accessibility and convenience.
- **Route Cards and GPS Trackers:** Provided alternative tolling options for heavy vehicles, including route-specific prepaid cards and GPS trackers integrated with National Service Providers.
- **User-Friendly Features:** Integrated functionalities such as notifications for expiring vignettes, correction of input errors, and real-time monitoring via web-based services.
- **Enhanced Monitoring and Enforcement:** Deployed stationary and mobile control points to ensure compliance and monitor tolling system effectiveness.

Benefits:

- **Revenue Growth:** Generated over 3.2 billion BGN in toll revenues between 2019 and 2024, supporting the maintenance of existing roads and the development of new infrastructure.
- **Efficient Road Usage:** Streamlined toll collection processes improved traffic flow, reduced vehicle emissions, and saved users valuable time.
- **Scalable and Interoperable Design:** Ensured compatibility with tolling systems in other European countries, facilitating seamless cross-border travel.
- **Enhanced Safety and Compliance:** Introduced features like average speed control and enforcement of technical inspections, improving road safety and regulatory compliance.
- **Data Utilization:** Leveraged tolling data for broader applications, including crime prevention, revenue tracking, and enhancing public service efficiency.

5.5.3 Case Study #3: Redefining Tolling in India with SkyToll's Smart Solutions

Problem Statement:

India's toll plazas were plagued by congestion, inefficiencies, and safety risks. Physical barriers led to delays, pollution, and increased operational costs, necessitating a modernized and eco-friendly tolling approach.

Solution Implemented:

- **Barrier-Free Tolling Mechanism:** AI-driven video technology enabled toll payments without vehicle stops, improving traffic flow.
- **Integrated Traffic Management:** Advanced analytics provided real-time insights to optimize road use and enforce regulations.
- **Data-Driven Enhancements:** Insights from traffic data informed strategic infrastructure upgrades and policy decisions.

Benefits:

- **Traffic Decongestion:** Removing barriers reduced wait times and improved vehicular movement.
- **Safety Assurance:** Advanced monitoring minimized accidents and promoted safer driving practices.
- **Environmental Gains:** Reduced emissions aligned with national sustainability goals.
- **Infrastructure Optimization:** Data utilization facilitated informed urban planning and investment.

5.5.4 Case Study #4: Tolling redefined in India with NETC FASTag by IHMCL

Problem Statement:

India's manual toll collection systems faced significant challenges, including long vehicle queues, revenue leakage, and increased pollution due to idling at toll plazas. These inefficiencies hindered the development of a seamless and transparent toll collection ecosystem, which was essential to support India's expanding road infrastructure.

Solution Implemented:

- **Introduction of NETC FASTag:** Collaborated with the National Payments Corporation of India (NPCI) to develop an interoperable RFID-based tolling solution, enabling automatic toll deductions via linked bank accounts or prepaid wallets.
- **Deployment Across National and State Highways:** Integrated NETC FASTag across 1,228 toll plazas nationwide, including 339 state toll plazas, ensuring broad adoption.
- **Centralized Clearing House:** Established a unified platform to process toll transactions in real time, enhancing operational transparency and efficiency.
- **Promotion and Policy Support:** Made NETC FASTag mandatory for all four-wheeled vehicles through government regulations, ensuring widespread adoption and compliance.
- **Ecosystem Expansion:** Extended NETC FASTag to additional use cases, including parking payments and vehicle tracking, fostering a comprehensive digital ecosystem.

Benefits:

- **Operational Efficiency:** Reduced average wait times at toll plazas from 8 minutes to 47 seconds, significantly decreasing fuel consumption and vehicle emissions.
- **Economic Impact:** Increased toll revenues from ₹3,352 crore in FY18 to ₹54,144 crore in FY23, contributing to infrastructure development and maintenance.
- **User Convenience:** Enhanced travel experiences with seamless, cashless toll payments, complemented by features like automatic top-ups and monthly passes.
- **Environmental Sustainability:** Achieved fuel savings equivalent to ₹2,800 crore annually and reduced CO2 emissions by 9,78,200 tonnes through minimized idling.
- **Digital Transformation:** Fostered digitization in associated domains, including parking and logistics, driving India's transition to a cashless economy.

5.5.5 Case Study #5: Implementation of GNSS-Based Tolling System in India by Telematika

Problem Statement:

India's FASTag-based tolling system, while an improvement over manual methods, faced challenges such as congestion at toll plazas, unfair toll calculation for partial highway use, and high operational costs. With the rapid expansion of highways and increasing vehicle count, there was a pressing need for a more advanced, scalable, and efficient tolling solution.

Solution Implemented:

- **GNSS-Based Tolling Technology:** Deployed a system leveraging India's NavIC satellite navigation and international GNSS constellations (e.g., GPS, Galileo) to enable distance-based tolling.
- **Onboard Units (OBUs):** Introduced secure and cost-efficient devices to calculate tolls based on the distance travelled, with options for smartphone-based implementations to maximize accessibility.
- **Geofencing Technology:** Ensured accurate tolling by activating OBUs only within toll-able highway zones, eliminating charges for adjacent service road users.
- **Data Privacy and Security:** Enforced stringent encryption protocols and ensured data usage strictly for tolling purposes, addressing concerns about user privacy.
- **Pilot Project on Delhi-Mumbai Corridor:** Successfully demonstrated the system's feasibility with reduced transit times, fair tolling practices, and improved citizen satisfaction.

Benefits:

- **Efficiency and Convenience:** Eliminated toll plazas and physical barriers, reducing vehicle idling, transit times, and fuel consumption.
- **Fair Tolling Practices:** Implemented distance-based tolling, ensuring users pay only for the exact road usage, as opposed to flat rates for entire stretches.
- **Environmental Impact:** Reduced CO2 emissions through minimized congestion and idling, aligning with India's sustainability goals.
- **Cost Savings for NHAI:** Reduced the total cost of operation to 10-12% of collections compared to 15-17% with FASTag.
- **Scalability and Future Readiness:** Designed a flexible system capable of integrating additional services with extended utility to parking management, EV charging stations, and other highway services.
- **Integration with Value-Added Services:** Enabled functionalities like vehicle tracking, pay-as-you-drive insurance, and roadside assistance.
- **Ease of Transition:** Offered innovative incentives like discounts for early adoption and backward integration with existing RFID systems for seamless user migration.

5.5.6 Case Study #6: Implementation of Toll Lane Booster in GNSS and FASTag Toll Lanes in India by KENT

Problem Statement:

India's toll plazas have long grappled with inefficiencies stemming from outdated processes. In FASTag lanes, barriers opening and closing result in long wait times, leading to traffic congestion, air pollution from idling vehicles, and frustration among users. In GNSS lanes, inaccuracies in vehicle detection disrupt payment collection and enforcement of penalties. These challenges compromise toll plaza efficiency, hinder smooth traffic flow, and undermine customer satisfaction.

Solution Implemented:

- **Early Detection System:** Installed TL_Booster devices 25 meters before the payment axis to detect vehicles using RFID readers and Weigh-In-Motion (WIM) sensors.
- **Queue Management:** Created virtual queues for validated vehicles in GNSS and FASTag lanes. Non-compliant vehicles in GNSS lanes were issued penalties, while invalid FASTag vehicles were stopped for payment collection.
- **Barrierless Tolling:** Enabled seamless tolling for validated FASTag users by removing barriers in 100% FASTag environments.
- **Phased Rollout:**
  - **Phase 1:** Focused on commercial vehicles to address immediate operational needs.
  - **Phase 2:** Targeted private vehicles with campaigns promoting GNSS adoption and free issuance of onboard units (OBUs).

Benefits:

- **Reduced Transaction Time:** Valid FASTag and GNSS users experience near-instant toll processing without stoppages.
- **Minimized Traffic Congestion:** Efficient queue management ensures smoother traffic flow.
- **Environmental Sustainability:** Lower emissions due to reduced vehicle idling at toll plazas.
- **Enhanced User Satisfaction:** Barrierless tolling offers a streamlined and hassle-free experience for commuters.
- **Optimized Revenue Collection:** Improved compliance minimizes revenue leakage and ensures accurate tolling.

5.5.7 Case Study #7: International Electronic Tolling Collection (ETC) Case Studies

Canadian ETC system uses RFID-equipped transponders attached to vehicles that engage with infrastructure to automatically deduct toll fees from prepaid accounts. The system aims for interoperability among provinces, allowing unified tolling accounts to enhance users' ease and seamless travel. Users manage ETC accounts online via dedicated websites/apps, for tasks like fund additions and reconciliation. Dynamic pricing adjusts toll rates based on live traffic, during peak hours to optimize traffic flow.

Malaysia's ETC system is known as "**Touch 'n Go**" (TNG) which supports a free-flow tolling system. RFID technology is used for the toll collection process. Vehicles are equipped with RFID tags/stickers on vehicles. User's pre-load credit into the RFID tags or link their tags to credit or debit cards for automatic top-ups.

Germany's ETC system is called "**Toll Collect**" which is primarily used for tolling of heavy goods vehicles (HGV's) on federal highways in Germany. The tolling system works on features and criteria like Distance-Based Tolling, On-Board Units (OBU), and Toll Road Networks, and is interoperable and integrated with neighbouring nations tolling systems, like Austria and Belgium which allows seamless travel and toll payment across borders.

Australia's e-TAG is used for building a free-flow toll collection system based on RFID-based transponders and Dedicated Short Range Communications (DSRC) protocol. It is interoperable and comprises of sensor & DSRC module used to gather user data at toll booths to detect the e-TAG, calculate the toll amount, and deduct it from the prepaid account. If the system does not detect the vehicle, License Number Plate Recognition is used to check registrations against the government database.

Singapore launched its **Electronic Road Pricing (ERP)** in 1998 which was based on both smart cards and RFID-based methods. The readers for the free flow are located along the side of the road and the user and vehicle data is read by making use of the smart card or the OBU. Every time the vehicle crosses the toll, money gets deducted based on the type/categorization of the vehicle. The smart card and OBU can be linked to prepaid accounts and users' bank accounts as well.

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