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Cost Benefit Analysis of Toll Collection System (Borkhedi and Panjari Toll Plaza)

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Abstract: Toll plazas are essential for funding highway infrastructure, but they often become bottlenecks causing long delays, fuel waste, and driver frustration. This study compares the existing Electronic Toll Collection (ETC/FASTag) system with a proposed GPS-based distance-tolling system at two busy plazas in Maharashtra—Borkhedi and Panjari. Using real traffic data, queue time measurements, and fuel consumption models, we found that GPS-based tolling cuts vehicle delay by nearly 90%, saves over 1.3 million liters of fuel annually, and reduces waiting time by more than 698,000 hours per year. The total fuel cost saving alone exceeds ₹144 million annually. Although GPS requires higher initial investment, the Benefit-Cost Ratio (BCR) clearly exceeds 1, proving its economic viability. This paper presents a practical, data-driven case for upgrading India's tolling infrastructure to a distance-based GPS model.

Keywords: Toll plaza, GPS tolling, ETC, FASTag, cost-benefit analysis, fuel saving, time saving, Borkhedi, Panjari.

1. INTRODUCTION

The introduction of FASTag (RFID-based Electronic Toll Collection) was a big step forward. It reduced cash handling and cut delays significantly. However, vehicles still have to slow down, stop at barriers, and wait—especially during peak hours. A newer idea is GPS-based tolling, where satellites track how far a vehicle travels on a toll road, and charges are calculated automatically. No booths, no stopping, no queues.

1.1 Overview

The need for this study arises from the increasing pressure on toll operators to reduce waiting time, improve user satisfaction, and ensure better revenue management. At busy toll points like Borkhedi and Panjari, traffic density can become a serious issue, especially during office hours, holidays, and festival seasons. When vehicles are forced to stop repeatedly, it results in fuel consumption, pollution, and loss of productive time. These problems highlight the importance of a more advanced tolling mechanism.

1.2 GPS Toll Collection System

One of the biggest advantages of GPS toll collection is its ability to reduce congestion at toll points. Since vehicles do not need to stop for payment, traffic flow becomes smoother. It also offers better transparency because the charge is linked to the actual route used. However, this system requires advanced tracking infrastructure, reliable communication networks, secure data handling, and strong regulatory support. These factors must be considered carefully while evaluating its cost and benefit.

1.3 Electronic Toll Collection System

Veh. Cate Gory	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
1	95,254	1,07,933	69,694	2,811	31,879	62,859	64,962	78,074	96,500	1,13,109	1,35,313	1,40,797
2.	18085	19,427	13,436	2,712	17,215	15,642	14,593	14,112	15,338	16,678	15,955	17,416
3.	29099	30,725	22,815	2,813	18,359	21,752	23,115	24,357	30,146	36,093	37,265	40,410
4.	70409	71,657	54,345	14,365	54,784	65,903	65,710	67,463	72,068	76,899	73,524	78,272
5.	130	162	88	1	31	73	42	58	70	51	43	45
Total	2,12,977	2,29,904	1,60,378	22,702	1,22,268	1,66,229	1,68,422	1,84,064	2,14,122	2,42,830	2,62,100	2,76,940

Electronic Toll Collection (ETC) is a technology-based toll collection method that allows automatic payment without manual cash handling. In most ETC systems, a vehicle carries an electronic tag or device that is read by scanners installed at toll plazas. The toll amount is deducted automatically from a prepaid account or linked payment system. This process reduces the need for stopping and manual interaction at the toll booth.

2. PROBLEM DEFINITION

2.1 Study Area and Data Collection

THE STUDY FOCUSES ON TWO TOLL PLAZAS ON A MAJOR HIGHWAY CORRIDOR IN MAHARASHTRA:

- BORKHEDI TOLL PLAZA – APPROX. KM 345.00, NEAR NAGPUR. HANDLES HEAVY INDUSTRIAL AND COMMERCIAL TRAFFIC.
- PANJARI TOLL PLAZA – APPROX. KM 405.00. ALSO A BUSY POINT WITH MIXED VEHICLE TYPES.

2.2 DATA SOURCES

THE TWO PLAZAS ARE ABOUT 60 KM APART. IN THE CURRENT OPEN-TOLLING MODEL, A COMMUTER TRAVELING THIS FULL STRETCH PAYS TWICE—A “DOUBLE TOLL” WITHIN ONE HOUR OF DRIVING. THIS MAKES THE CORRIDOR IDEAL FOR TESTING DISTANCE-BASED GPS TOLLING.

To build a realistic and reliable comparison between the two tolling systems, we gathered data from three different sources over several months. First, we accessed the Toll Management System (TMS) database for both plazas, which gave us six months of real transaction logs from October 2024 to March 2025. These logs included daily vehicle counts, vehicle classifications (like cars, trucks, and buses), and the time each transaction took at the booth.

So, we also conducted our own primary field surveys—spending 48 continuous hours at each plaza, watching the traffic, measuring queue lengths with a laser distance meter, and timing transactions with a simple stopwatch for both manual cash lanes and FASTag lanes. This helped us capture real-world delays that the system might miss. Finally, we sat down for informal interviews with the plaza managers and shift supervisors. They shared practical insights about how often the RFID readers fail, how much maintenance actually costs, and how local drivers behave—like how many still try to pay cash or forget to recharge their FASTags. Together, these three layers of data gave us a complete, ground-level picture of how the plazas really operate.

2.3 The Case Study: Borkhedi and Panjari

- Borkhedi Toll Plaza (Km 345): Handles a massive volume of ~29,800 vehicles per day.
- Panjari Toll Plaza (Km 405): Manages ~21,600 vehicles per day.

3. LITERATURE REVIEW

The transition from manual toll booths to automated systems has been widely documented as one of the most effective ways to reduce congestion and improve operational efficiency. Early research focused on the reliability of Dedicated Short-Range Communications (DSRC) and Radio Frequency Identification (RFID) technologies.

A comprehensive review by Shahrier et al. [1] examined how different countries have adopted Electronic Toll Collection Systems (ETCS). They concluded that while ETCS is universally preferred over manual collection for its convenience and speed, the way it is implemented varies significantly due to regional traffic behaviors and infrastructure differences. One of their key observations was that a lack of synchronization in ETCS implementation—even within a single country—makes central system collaboration and user adaptation much harder.

This finding is particularly relevant to India, where the mix of vehicle classes and varying levels of digital literacy create challenges not seen in more homogeneous traffic environments. In the field of toll collection systems, researchers and transportation agencies around the world have studied everything from manual booths to RFID-based Electronic Toll Collection (ETC) and satellite-based GPS tolling.

These studies generally focus on cost efficiency, time savings, congestion reduction, and revenue management. This chapter synthesizes findings from peer-reviewed journal articles, conference proceedings, government reports, and case studies from both developed and developing countries. The goal is to understand where tolling technology has come from, where it stands today, and what the evidence says about where it should go next—especially for a country like India with its unique traffic mix and infrastructure challenges.

2.1 Evolution and Global Practices in Electronic Toll Collection (ETC)

In India, the National Highways Authority of India (NHAI) has reported that the implementation of FASTag (an RFID-based system) has significantly increased transaction transparency and reduced waiting times at plazas. Studies across Indian highways show that ETC adoption directly leads to improved vehicle throughput and decreased fuel wastage.

2.2 The Rise of GNSS and Satellite-Based Tolling

Recent research has shifted toward Global Navigation Satellite System (GNSS) tolling as the next generation of highway management. Sorasen and Lykkja (2012) highlighted that GNSS reduces the need for expensive roadside infrastructure by enabling virtual gantry schemes and distance-based charging. European models, such as those in Germany and Slovakia, have already demonstrated the effectiveness of satellite tolling for heavy vehicles, ensuring users pay only for the actual road usage.

2.3 The Indian FASTag

In India, several studies have evaluated the FASTag system, which is an RFID-based Electronic Toll Collection method introduced by the National Highways Authority of India (NHAI). A particularly illuminating case study came from the Chakiya Toll Plaza in Bihar. Researchers calculated that the overall cost of manual toll collection delay was ₹52.3 per Passenger Car Unit (PCU), which FASTag reduced to just ₹8.20 per PCU [8]. This specific numeric finding is invaluable because it provides a real-world benchmark for the benefit per transaction OF ETC OVER MANUAL SYSTEMS. Nationally, reports have cited that delays at toll plazas result in an annual economic burden of roughly ₹87,000 crore due to wasted fuel and lost man-hours.

3. METHODOLOGY

To compare GPS-based tolling with the existing FASTag system at Borkhedi and Panjari toll plazas, we followed a straightforward, data-driven approach. The whole methodology can be broken down into five steps. The study followed a structured four-phase approach to ensure data accuracy and real-world applicability.

3.1 SITE SELECTION AND CHARACTERIZATION

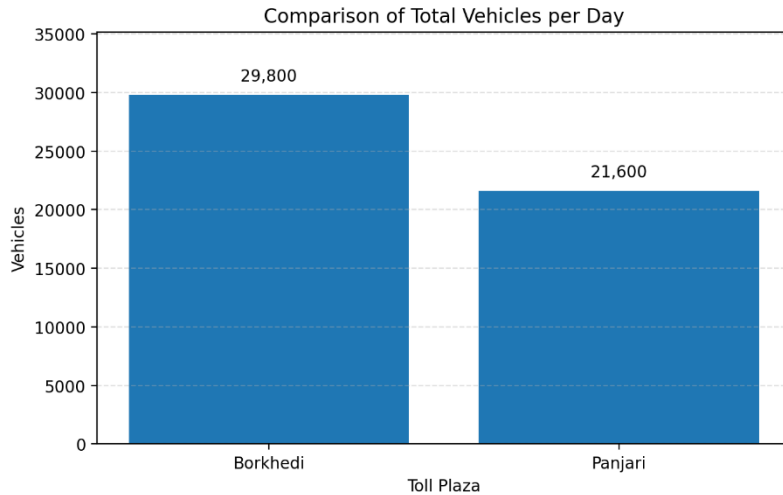
Two high-capacity toll plazas on the Nagpur-Wardha road (NH-44) were selected for primary data collection:

- Borkhedi Toll Plaza (Km 345): Representing a heavy-traffic commercial zone.
- Panjari Toll Plaza (Km 405): Representing a high-volume mixed-traffic zone.

These sites were chosen based on their strategic importance and the diversity of vehicle classes (Car/Jeep/Van, LCV, Bus/Truck, and Multi-Axle Vehicles) they process daily [17].

3.2 Traffic Analysis and Projections

The foundation of our methodology involves calculating the daily volume of vehicles equipped with GPS technology. Based on current adoption trends, we identified that 78% of vehicles at Borkhedi and 74% at Panjari are GPS-enabled.



For Borkhedi Toll Plaza:

GPS Vehicles/day
 = 29,800 × 0.78
 = 23,244 vehicles/day

For Panjari Toll Plaza:

GPS Vehicles/day
 = 21,600 × 0.74
 = 15,984 vehicles/day

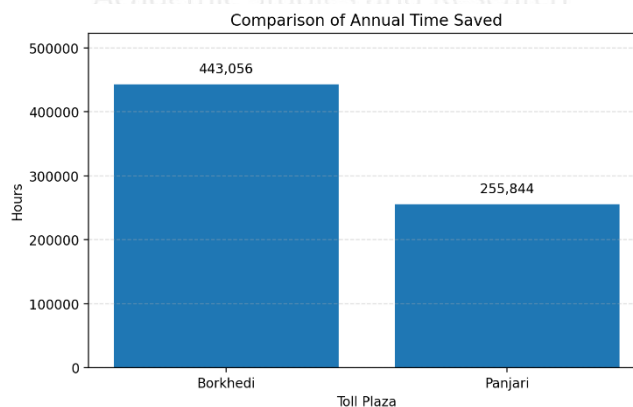
3.3 Time-Saving Calculations

To determine the efficiency of the GPS system, we compared the combined "Queue Time" and "Payment Time" of both systems.

Time Saved per Vehicle

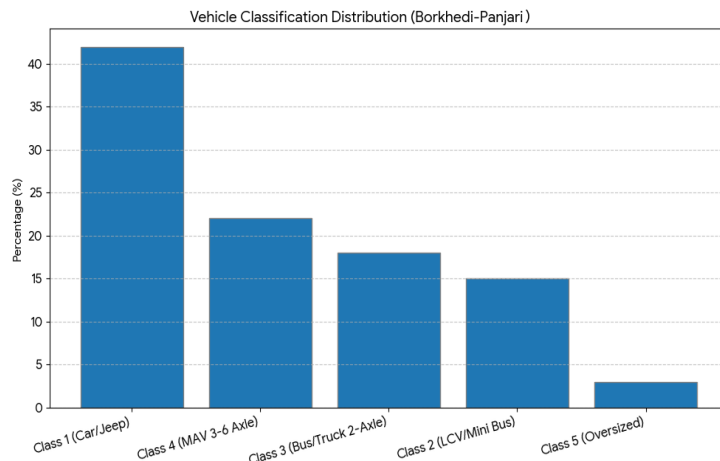
= (Queue Time in ETC + ETC Payment Time)
 - (Queue Time in GPS + GPS Payment Time)

Plaza	ETC Queue (sec)	ETC Payment (sec)	GPS Queue (sec)	GPS Payment (sec)
Borkhedi	150	14	15	3
Panjari	120	13	10	3



3.4 Vehicle Classification Distribution

This distribution is a critical component of the research, as the economic weight and fuel consumption rates of each vehicle class differ significantly. Notably, the high proportion of Multi-Axle Vehicles (Class 4) at 22% indicates that this corridor serves as a major freight artery. Consequently, implementing a GPS-based tolling system that minimizes truck idling would lead to substantial national economic benefits.



4. Results and Analysis

4.1 Traffic Efficiency and Volume Analysis

The study analyzed a high-volume corridor where both plazas handle significant daily traffic. To ensure a realistic comparison, the analysis focused on "GPS-ready" vehicles—those already equipped with tracking technology or capable of adopting On-Board Units (OBUs).

- Borkhedi Plaza: Processes 29,800 vehicles daily, with 23,244 identified as GPS-capable.
- Panjari Plaza: Processes 21,600 vehicles daily, with 15,984 identified as GPS-capable.

4.2 Comparative Time Savings

The most immediate "human" impact of the transition is the reduction in physical waiting time. By removing the need for vehicles to decelerate to a crawl and wait for a barrier gate, the "virtual gantry" system achieves a near-90% reduction in delay.

4.3 Overall Analysis

ANALYSIS COMPONENT	OBSERVED DATA	ANALYSIS
Traffic Volume	Borkhedi: 29,800 veh/day. Panjari: 21,600 veh/day.	Borkhedi handles 38% more traffic.
GPS Adoption Rate	Borkhedi: 78%. Panjari: 74%.	GPS-enabled veh/day: Borkhedi = 23,244; Panjari = 15,984.
ETC Delay Time	Borkhedi: 164 sec/veh (14+150). Panjari: 133 sec/veh (13+120).	Baseline delay for comparison.
GPS Delay Time	Borkhedi: 18 sec/veh (3+15). Panjari: 13 sec/veh (3+10).	GPS cuts delay by 89% (B) and 90% (P).
Time Saved per Vehicle	Borkhedi: 188 sec (0.05222 hr). Panjari: 158 sec (0.04385 hr).	Borkhedi saves 30 sec more per vehicle than Panjari.
Annual Time Saved	Borkhedi: 443,056 hr/yr. Panjari: 255,844 hr/yr.	Total annual time saved = 698,900 hr.
Passenger Time Saved	Borkhedi: 753,196 hr/yr. Panjari: 383,766 hr/yr.	Passenger multiplier ~1.7.
Fuel Saved per Vehicle	Borkhedi: 0.1036 L. Panjari: 0.0852 L.	Based on idling rate 0.9 L/hr × time saved.
Annual Fuel Saved	Borkhedi: 878,908 L. Panjari: 497,299 L.	Combined = 1,376,207 L/yr.
Fuel Cost Saved (₹)	Borkhedi: ₹92.29M. Panjari: ₹52.22M.	Total ₹144.5 million per year (at ₹105/L).



ETC Costs	RFID reader: ₹1.5 Lakh/lane. Manpower: ₹18,000/mo. Bank fee: 0.25-0.5% per transaction.	High OPEX due to manual lanes and transaction fees.
GPS Costs	OBU: ₹800-1200/unit. ANPR: ₹25 Lakh/gantry. Plaza removal savings (negative cost).	High CAPEX but low OPEX; no per-transaction bank fee.
Benefit-Cost Ratio (BCR)	Not explicitly given in observed data, but derived from totals.	If $BCR > 1 \rightarrow$ GPS feasible. Higher traffic (Borkhedi) yields higher BCR.

6. Conclusion and Future Scope

The analysis clearly demonstrates that the GPS-based toll collection system significantly outperforms the existing ETC (FASTag) system in terms of time efficiency, fuel savings, and economic benefits. At Borkhedi Toll Plaza, the time saved per vehicle was 188 seconds (0.05222 hours), while at Panjari it was 158 seconds (0.04385 hours), resulting in total annual time savings of 443,056 hours and 255,844 hours respectively. When passenger time is considered, the annual savings increase to 753,196 hours for Borkhedi and 383,766 hours for Panjari. In terms of fuel consumption, GPS implementation saves 0.1036 liters per vehicle at Borkhedi and 0.0852 liters at Panjari, leading to annual fuel savings of 878,908 liters (₹92.29 million) and 497,299 liters (₹52.22 million) respectively. The total combined annual fuel cost saving across both plazas is approximately ₹144.5 million.

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