ISSN 0974-763X
UGC-CARE Listed Journal

SOUTH ASIAN JOURNAL OF MANAGEMENT RESEARCH (SAJMR)

Volume 15, Issue No.1 January, 2025

CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, MAHARASHTRA, INDIA

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Chhatrapati Shahu Institute of Business Education and Research (CSIBER)

South Asian Journal of Management Research (SAJMR)

Volume 15, Issue No. 1, January, 2025

Editor: Dr. Pooja M. Patil

Publisher

CSIBER Press

Central Library

Chhatrapati Shahu Institute of
Business Education & Research (CSIBER)
University Road, Kolhapur – 416004, Maharashtra, India.
Phone: 91-231-2535706/07, Fax: 91-231-2535708,
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Address:
CSIBER Press
Central Library Building
Chhatrapati Shahu Institute of Business Education and Research (CSIBER),
University Road Kolhapur, Maharashtra - 416004, India.

ISSN: 0974-763X

Price: INR ₹ 1,200/-

Editor: Dr. Pooja M. Patil

Distributed By

CSIBER Press

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Digital Transformation in Road Toll Systems: Analyzing User Perceptions of NETC Fastag in Kerala

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Abstract

According to the Global Innovation Index (2020), India ranks 48th globally in innovation and is among the top 15 countries for information and communication technology (ICT) and R&D-intensive global firms. This dynamic technological environment has enabled India to rapidly move ahead in its digital evolution, with one of the largest and fastest-growing digital consumer populations around the world. The present study looks at the technological developments within the toll collection system of India, which have seen great change from traditional manual techniques to automated and electronic systems. The Radio Frequency Identification (RFID) technology-based electronic toll collection systems, such as FASTag, have recently been launched by the National Payments Corporation of India (NPCI) in collaboration with financial institutions to address the limitations inherent in traditional modes of collecting tolls. The study provides a comprehensive overview of the toll system in India, highlighting the transition to more sophisticated technologies aimed at enhancing efficiency and user satisfaction. Data was collected from 400 users of FASTag within the Palakkad district of Kerala, enabling a detailed analysis of user perceptions regarding this contemporary tolling method. With the help of factor analysis, the study identified four key factors that affect the perception of users about National Electronic Toll Collection (NETC) FASTag. The results indicate that the efficiency, time-saving attributes, and overall convenience related to the usage of FASTag greatly improve user satisfaction. Nonetheless, the study also identifies areas that need improvement, primarily concerning technical issues experienced by users. Additionally, service accessibility plays a crucial role in shaping user perceptions, encompassing aspects such as recharging options, customer support, and the cost-effectiveness of using FASTag. Although these factors are significant, it seems that their impact on the perception of users is low as compared to the core benefits of efficiency and convenience. Therefore, these results indicate that there is a need for continuous improvement in the FASTag system so that there is smooth and user-centric tolling experience. As India advances towards adopting more digital technologies, it must work around all these barriers to facilitate further adoption across the country.

Keywords: *Toll Collection, NETC FASTag, RFID Technology, Digital, User Perceptions*
JEL Code: *L91, O32, O33, R41, R42*

Introduction

Today, technological advancements are indispensable for societal growth and adaptation. As "Necessity is the mother of invention", every technology has been built in order to meet societal demands, and as a result, it is inextricably related to the culture and behaviour of the people who inhabit the civilization. India is making notable strides in the realm of technology, positioning itself as a key player in global technological development. Despite uneven business adoption, India currently has one of the biggest and rapidly expanding digitized consumer marketplaces. An advanced knowledge economy requires a digitally empowered society. India's story of digital transformation is one of empowerment and inclusion, built on technology that is accessible, inclusive, and continuously evolving. Technology to transform a connected nation: Digital India, a report from the McKinsey Global Institute, emphasises the nation's hasty adoption of electronic technologies and their potential economic worth by 2025. If the public and commercial sectors collaborate to establish new digital ecosystems, these technologies could significantly impact the Indian economy. As part of India's Digital Transformation, the government also promotes the adoption of new technologies or upgrades while offering high-speed broadband connectivity to every nook and cranny of the nation.

The abundance of opportunities that have emerged in the world of payments over the past few years has been mostly driven by technology and digitization. The digital revolution has reshaped media, retail, and transportation industries. A new technology has been implemented in India's toll collection system with support from banks. It has been made mandatory for passengers to use that technology to cross the toll booths. A toll,

also called a toll tax, is a levy motorists must pay while navigating certain tunnels, bridges, and national and state roads. The National Highway Authority of India (NHAI) is in charge of maintaining these toll roads. By virtue of their presence, they create obstructions to the efficient flow of traffic; this inherent ineffectiveness must be reduced (Chakroborty, Gill & Chakraborty, 2016). The presence of mixed traffic conditions in a single toll lane at toll plazas, coupled with the use of manual toll collection (MTC), results in significant congestion and subsequent delays at these locations (Bari et al., 2021). Traffic congestion rises in most regions as travel demand outperforms infrastructural and managerial advancements (Gupta & Kalmanje 2006). The transportation sector generates around one-seventh of global pollution, necessitating reduction efforts (Aktar et al., 2021). To save costs and wait times, electronic toll collection technology is widely used to collect tolls; it automatically connects to toll payers' bank accounts to charge cars by debiting those accounts. The Electronic Toll Collection (ETC) system is now widely adopted across the globe. Countries such as Canada, Poland, Japan, Italy, and Singapore are among the many that have implemented ETC systems, streamlining toll collection processes and improving efficiency in transportation networks (Joshi et al., 2017).

Toll System in India

Toll Tax

The Indian Government levies taxes on every highway in India, whether state or national, to raise money for maintenance. Toll tax is collected to recoup the whole capital outlay, which covers the cost of construction, maintenance, repairs, toll operation charges, and interest on the outlay. Most highway projects in India are awarded based on a public-private partnership. In this scenario, a private company finances and builds the facility and then collects capital from customers in the form of toll taxes. A suitable amount of time is allowed for this tax to be collected before the facility is made accessible to the general public. To reduce traffic congestion and pollution in metropolitan areas, tolls are now being imposed for parking vehicles in high-traffic zones, a concept known as congestion pricing. Furthermore, safety on these highways is crucial due to the high rate of highway robberies in several regions of India. Road tax, in turn, aids in maintaining the expense of maintaining road security and safety. Based on variables including engine power, seating capacity, unladen weight, and cost, the road tax is computed. However, there will be differences in the laws and standards that apply to taxes in each state. Toll roads face criticism for the time required to stop and pay, as well as the operational costs of toll plaza management, which can account for up to one-third of the revenue in some cases. Automated toll collection systems help mitigate both of these issues, improving efficiency and reducing costs.

Types of Toll Collection

Two different kinds of toll collection systems are:

i. Open Toll System

In this system, tolls are not applied to every customer. The toll plaza is generally located at the edge of the urban area, where most long-distance drivers are committed to the facility, with a low possibility of moving to the parallel free route. Customers are categorized, and each category is assigned a specific toll rate. Local traffic around the plaza can use a service lane or receive a rebate.

ii. Closed Toll System

Customers pay the toll in a closed toll system according to their vehicle's type and the distance they travel to the facility. Free rides are not permitted. A closed toll system has plazas at every point of entry and exit, and users are given tickets as they enter the system. When leaving, the customer surrenders the ticket to the collector, who then charges them the appropriate amount based on the type of vehicle and the distance travelled. Unlike an open system, which allows for multiple stops, it only has two stops for automobiles. However, it costs more to build a closed system than an open system.

Methods of Toll Collection

The three different kinds of toll collection in India are,

Manual Toll Collection

In India, the most common toll collection method is manual toll collection. There must be an attendant or toll collector. The cash toll is paid to the collector based on the categorization of the vehicle. In addition to providing change, the collector can receive and sell cash, tickets, and coupons. They also enter the customer's vehicle into the system and give them a receipt. Processing takes the longest due to manual involvement.

Automatic Toll Collection

The usage of Automated Coin Machines (ACM) is the basis of automatic toll collection. These accept operating agency-issued tokens as well as coins. Depending on the toll rate, using automated coin

or token collection as opposed to manual collection cuts down on both operating costs and transaction and processing times.

Electronic Toll Collection System

A vehicle equipped with a properly encoded data tag or transponder is automatically recognised by an Electronic Toll Collection (ETC) system as it passes through a toll lane or checkpoint. Without the user needing to stop and pay the toll, the ETC system subsequently records a debit or charge to the user's account. ETC speeds up traffic, as there is no need to stop and pay the toll (Shahrier & Huq, 2021).

NETC FASTag: Insights into Implementation and Operation

FASTag, an Electronic Toll Collection (ETC) system in India operates and manages by the National Highway Authority of India, through its subsidiary Indian Highway Management Co. Ltd. (IHMCL). The National Payments Corporation of India (NPCI) oversees FASTag transactions within its extensive digital payment framework, facilitating instantaneous toll payments straight from the user's associated bank account or digital wallet. NPCI is a comprehensive entity that manages most retail payment systems in India. In 2014, FASTags were first installed as a demonstration project at the Golden Quadrilateral between Ahmedabad and Mumbai (Joshi et al. 2017). By 2017, 370 toll plazas under NHAI's jurisdiction had a FASTag lane installed. The government mandated the use of FASTag for all new vehicles sold in India that year. Later, the NHAI mandated the use of FASTags beginning on February 15, 2021. FASTag enables direct toll payments on National Highways through Radio Frequency Identification (RFID) technology, which uses radio waves to identify tagged objects linked to prepaid or savings accounts. With a FASTag card affixed to the vehicle's windshield and a scanner positioned at highway toll booths, vehicles can pass through toll plazas without human interaction (The Statesman, 2020). Using RFID technology, the card on the vehicle communicates with the scanner at the toll booth. Once the vehicle reaches the toll plaza, the necessary toll amount is promptly debited from a prepaid wallet or bank account connected to the FASTag. The FASTag owner receives an SMS notification whenever money is deducted from their account or wallet. There is no expiration date for the balance amount on a FASTag; it remains valid as long as the tag is intact and can be read at toll booths. If a vehicle does not have a FASTag or if the tag's balance is insufficient, the driver must pay double the toll amount in cash to pass through the toll booth. Additionally, vehicle owners are liable to pay double the toll even if the FASTag is malfunctioning due to card damage. Waiting times, fuel costs, and vehicle running expenses will be minimized with the aid of FASTag. It will prevent accelerating, idling, and emitting hazardous vehicle emissions. It helps to lessen the congestion, pollution, and usage of paper. Using centralised user accounts avoids cash handling, which improves audit control. It will promote digital payments and enhanced information and data gathering to track traffic and revise the toll policy of government. In comparison to conventional toll collection, FASTag offers numerous benefits to the society, government, general public etc.

FASTags are issued by 37 certified banks via a variety of channels, including point-of-sale (POS) terminals at some bank branches and National Highway toll plazas. They are also offered on mobile wallets like Paytm and e-commerce sites like Amazon. State Bank of India, Axis Bank, HDFC Bank, IDFC Bank, ICICI Bank, Punjab National Bank, Federal Bank, Kotak Mahindra Bank, IndusInd Bank, Syndicate Bank, Yes Bank, Union Bank, etc and payments banks like Fino Payment Bank and PayTm are some of the leading banks in issuing FASTags. The technology was successfully adopted by offering its services through banks. By utilizing technical advancements to upgrade payment systems and develop new payment methods, banks have created strategies and policies to promote growth through innovative electronic payment methods. Electronic technologies that are tailored to the digital economy are being introduced alongside other communication channels as part of a policy to make services more accessible to the client (Walid 2020).

Review of Literature

Electronic Toll Collection (ETC) is an automated system for toll collection that has been widely researched and implemented on highways, bridges, and tunnels worldwide. Through data exchange between RFID tags placed on vehicles and antennas installed along the roadside or on toll gates, the central control computer identifies the road user by the information stored in the tag. It then deducts the toll fee from a prepaid card or linked bank account. The key benefit of ETC is that vehicles can pass without stopping, greatly enhancing toll station efficiency and improving traffic flow on toll roads (Xiao, Guan, & Zheng, 2008). The implementation of the E-toll system has significantly reduced traffic congestion, a growing issue in major metropolitan areas. This system offers an efficient solution for managing heavy traffic by eliminating the need for travelers to wait in long queues at traditional toll booths. Conventional toll payments result in wasted fuel, time, and increased pollution, along with the inconvenience of carrying cash. In contrast, the E-toll system streamlines the payment process, reducing fuel consumption and eliminating the need for cash, offering a more convenient and eco-friendly travel experience (Algonda, Sonar, & Bhutada, 2018). (Chauhan & Chauhan, 2022) analyze the automated toll collection system aimed at deducting toll fees from moving vehicles at toll plazas in

India. The method outlined offers an efficient way to detect and recognize vehicle license plates. A dedicated database was established to evaluate the system's performance, containing details such as vehicle registration numbers, owner names, unique identification numbers, mobile contacts, and linked bank account balances. The findings highlight a significant decrease in vehicle wait times, queue lengths, fuel consumption, and pollution at toll points. In the future, this system could also be adapted for vehicle theft prevention.

Khan, (2019) examines the challenges and potential of introducing ETC in Bangladesh through a questionnaire survey and key informant interviews, with nine participants surveyed. Seventy percent of respondents were aware of ETC's launch, and most believed it would ease traffic jams caused by manual toll payment. However, challenges remain, as this is a new technology. With collective efforts, ETC could align with the vision of Digital Bangladesh and improve toll payment efficiency. In a developing country like Bangladesh, the highway traffic management system requires efficient Electronic Toll Collection (ETC) technologies (Zoy, Shahrier, & Huq, 2020). Aligning with the vision of a "Digital Bangladesh," RFID-based ETC systems offer an affordable and easily implementable short-term solution. However, for long-term benefits, more advanced technologies such as mobile phone tolling and satellite-based Electronic Road Pricing (ERP) may be optimal for both the government and the public. Karsaman et al., (2015) examined three types of Electronic Toll Collection (ETC) systems implemented on various toll roads in Surabaya, Indonesia. Although all systems are based on RFID technology, they differ in work mechanisms and equipment specifications, resulting in varying service performance. Overall, ETC is more cost-effective than traditional toll systems. Interviews with toll road users revealed general satisfaction with ETC, along with expectations for further improvements, such as multi-bank interoperability and the use of cards for multiple merchants or multipurpose applications.

Joshi et al., (2017) compares modern automatic toll collection systems with traditional methods. It examines systems like FASTag, which employs RFID (Radio-Frequency Identification) technology, and BookMyToll, an Android app-based solution that uses smart devices to detect nearby mobile devices at toll plazas. The author emphasizes that manual toll collection can be inefficient, often causing congestion at busy toll booths. To avoid long queues for cash payments, commuters increasingly rely on these electronic systems, allowing for quicker and more convenient transit through toll roads on a daily basis. Ahmed et al., (2019) discusses the RFID-based Electronic Toll Collecting System as a strategy to solve the traffic issue and preserve the transparency of the system. This developed system seeks to develop a computerised toll system that can clear gridlock on toll roads, toll tunnels, and toll bridges without using currency or needing cars to stop. The literature highlights the effectiveness of Electronic Toll Collection (ETC) systems like FASTag in reducing congestion, wait times, fuel consumption, and emissions at toll plazas.

Objectives of the Study

General Objectives

- To gain a comprehensive understanding of advancements in toll collection systems in India, with a focus on the implementation of the NETC FASTag system.

Specific Objectives

- To identify the key factors shaping user perceptions of NETC FASTag.
- To provide actionable recommendations for enhancing the overall FASTag user experience.

Methodology

This research adopts a descriptive and analytical approach. Primary data was collected from 400 FASTag users in Palakkad district, Kerala, using a structured questionnaire to identify the factors influencing their perceptions of NETC FASTag. The study employed a purposive sampling technique, focusing solely on FASTag users to ensure relevance to the research objectives. Krejcie and Morgan’s sample size determination table was used to accurately determine the minimum required sample size for the study. It indicated that at least 384 responses were required for an infinite population. A total of 400 reliable responses were gathered and finalized for analysis.

In addition to demographic questions, a five-point Likert scale with 16 statements (both positive and negative) related to user perceptions was used. Percentage analysis was applied in the initial phase, followed by factor analysis using SPSS software to identify the key influencing factors. The questionnaire was pretested with 50 respondents to identify any issues in clarity and accuracy, with adjustments made based on their feedback. Secondary data from newspapers, articles, and online sources were also incorporated to provide context on the toll collection system in India.

Results and Discussions

Table No. 1: Socio-Demographic Profile of Respondents

Sl. No.	Variable	Category	%
1.	Gender	Male	72.5
		Female	27.5
2.	Age	18 – 36 years	48
		37 – 55 years	36
		More than 55 years	16
3.	Occupation	Employee	63
		Business	23
		Profession	12
		Others	2

Source-Computed data, N=400

The demographic profile of the study participants shows a higher representation of male respondents compared to females. In terms of age, the majority of users fall within the younger to middle-aged groups, with fewer participants in the older age category. Most of the respondents are employees, followed by those engaged in business, while a smaller proportion are professionals and others in varied occupations.

Table No. 2 : KMO and Bartlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.813
Bartlett's Test of Sphericity	Approx. Chi-Square	4.852E3
	df	120
	Sig.	**.000**

Source: Computed data

The KMO value indicates whether the variables in the dataset are adequately suited for factor analysis. Values above 0.80 are considered that the data is suitable for factor analysis (Kaiser, 1974). A KMO value of 0.813 suggests that the data is well-suited for factor analysis, as there is enough common variance among variables to justify the use of this technique.

Bartlett's test checks if the correlation matrix is significantly different from an identity matrix (where variables are uncorrelated). A significant result (p-value < 0.05) indicates that the variables are sufficiently correlated (Bartlett, 1950). The p-value is 0.000, which is highly significant. This result confirms that the data is appropriate for factor analysis, as the variables are not independent and have enough correlations.

Table No. 3: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.543	28.394	28.394	4.543	28.394	28.394	4.478	27.986	27.986
2	3.183	19.894	48.288	3.183	19.894	48.288	3.210	20.061	48.046
3	2.776	17.351	65.639	2.776	17.351	65.639	2.686	16.787	64.833
4	2.245	14.033	79.671	2.245	14.033	79.671	2.374	14.839	79.671
5	.484	3.025	82.697						
6	.419	2.621	85.318						
7	.365	2.279	87.597						
8	.347	2.168	89.765						
9	.338	2.115	91.880						
10	.286	1.786	93.666						
11	.232	1.448	95.114						
12	.217	1.359	96.473						
13	.171	1.071	97.544						
14	.139	.868	98.412						
15	.133	.830	99.242						
16	.121	.758	100.000						
Extraction Method: Principal Component Analysis.									

Source: Computed data

The first four factors have eigenvalues greater than 1, indicating they are significant contributors to the variance. The cumulative variance of 79.67% by these four factors signifies that together they explain a

significant amount of variability in user perceptions. After extraction, the values in this instance remain the same because all components with eigenvalues greater than 1 were retained. The extraction method used here is Principal Component Analysis (PCA), which retains the most significant factors. After applying rotation, the variance explained by the individual factors is redistributed more evenly. The first factor explains 27.99%, the second explains 20.06%, the third explains 16.79%, and the fourth explains 14.84%. These four factors explain 79.67% of the total variance in the data, which is quite high. This indicates that the underlying structure of the data can be effectively captured by these four factors.

Table No. 4: Rotated Component Matrix

Sl. No.	Statements	Component			
		1	2	3	4
1.	FASTag has improved the efficiency of toll payments at plazas	**.828**	-.047	-.011	.042
2.	I find the process of recharging my FASTag account easy and convenient	.003	.025	**.944**	.058
3.	FASTag has significantly reduced the time I spend waiting at toll plazas	**.867**	-.019	.034	-.042
4.	The toll transaction notifications from FASTag are timely and accurate	.010	-.039	**.950**	.027
5.	Using FASTag helps me save money by reducing fuel consumption due to shorter wait times at toll plazas	-.026	-.061	.049	**.899**
6.	FASTag has made road travel more convenient compared to traditional cash payments	**.868**	.010	.047	-.006
7.	FASTags are often blacklisted automatically due to low balance without sufficient warning or notification, which causes difficulties at toll plazas	-.034	**.920**	.007	-.019
8.	There is a risk of the FASTag being lost, misplaced, or physically damaged	-.061	**.894**	-.007	-.025
9.	I have often experienced incorrect or double deductions from my FASTag account	-.043	**.862**	-.028	-.035
10.	I frequently face issues with my FASTag not being scanned properly at toll plazas	.009	**.898**	.031	.018
11.	I am satisfied with the customer service provided for resolving FASTag-related issues	.049	.016	**.935**	.023
12.	FASTag has reduced the need for carrying cash while traveling on highways	**.929**	-.019	.035	-.014
13.	The FASTag system is reliable for seamless toll payments	**.814**	-.056	-.047	-.089
14.	I find FASTag to be a cost-effective solution compared to traditional toll payment methods	-.048	.028	-.012	**.881**
15.	FASTag provides good value by streamlining toll payments and cutting unnecessary costs	-.008	-.023	.065	**.878**
16.	The FASTag system has reduced traffic congestion at toll plazas during peak hours	**.865**	-.028	.030	-.006

Source: Computed data

Factor loadings represent the correlation of each variable with a factor. After rotation, the matrix clarifies the relationships, grouping similar variables. Factor loadings above 0.6 are considered high, and variables with high loadings on a particular factor are closely associated with that factor. Principal Component Analysis under the rotation method (Varimax with Kaiser Normalization), rotation converged in 4 iterations. The following four components may be extracted:

Component 1: (Statements 1, 3, 6, 12, 13, 16) All of these items relate to the efficiency of the FASTag system in reducing toll processing time, improving the convenience of travel, and congestion, and its reliability. “FASTag has improved the efficiency of toll payments at plazas” and “FASTag has made road travel more convenient compared to traditional cash payments” highlight that users feel the system streamlines toll payments. “The FASTag system is reliable for seamless toll payments”, indicate users trust the technology for consistent performance. The mention of reducing traffic congestion during peak hours signifies a broader impact on travel efficiency.

Component 2: (Statements 7, 8, 9, 10) This represents challenges users face with FASTag, such as blacklisting without warnings, risk of loss, scanning errors, and incorrect deductions. The high loading of the statement

regarding FASTag being blacklisted indicates a significant problem faced by users, suggesting that technological reliability is a concern. Statements about loss of tag, scanning errors, along with the incorrect or double deductions, further illustrate the issues affecting user satisfaction and trust in the system. The automatic blacklisting due to low balance without adequate notification points to a significant pain point, which could lead to user frustration and dissatisfaction.

Component 3: (Statements 2, 4, 11) The statements about timely transaction notification and finding the process of recharging easy reflects the importance of user-friendly features in service adoption. Satisfaction with customer service for resolving issues points to the significance of support in enhancing the overall user experience.

Component 4: (Statements 5, 14, 15) The statement regarding savings on fuel consumption due to reduced wait times at toll plazas illustrates a direct financial advantage that users associate with using FASTag. The perception of FASTag as a cost-effective solution reinforces the idea that users see tangible financial benefits from using the system, particularly in comparison to traditional toll payment methods. Statements about providing good value by streamlining payments indicate that users appreciate the efficiency and convenience of the service, which translates into cost savings.

The rotated component matrix suggests the presence of the four interrelated factors.

Table 5: Naming of Factors

Factor No.	Name of Dimension	Item No.	Variables	Factor loading
F1	Efficiency	1	FASTag has improved the efficiency of toll payments at plazas	**.828**
		3	FASTag has significantly reduced the time I spend waiting at toll plazas	**.867**
		6	FASTag has made road travel more convenient compared to traditional cash payments	**.868**
		12	FASTag has reduced the need for carrying cash while traveling on highways	**.929**
		13	The FASTag system is reliable for seamless toll payments	**.814**
		16	The FASTag system has reduced traffic congestion at toll plazas during peak hours	**.865**
F2	User Challenges	7	FASTags are often blacklisted automatically due to low balance without sufficient warning or notification, which causes difficulties at toll plazas	**.920**
		8	There is a risk of the FASTag being lost, misplaced, or physically damaged	**.894**
		9	I have often experienced incorrect or double deductions from my FASTag account	**.862**
		10	I frequently face issues with my FASTag not being scanned properly at toll plazas	**.898**
F3	Service Accessibility	2	I find the process of recharging my FASTag account easy and convenient	**.944**
		4	The toll transaction notifications from FASTag are timely and accurate	**.950**
		11	I am satisfied with the customer service provided for resolving FASTag-related issues	**.935**
F4	Cost-effectiveness	5	Using FASTag helps me save money by reducing fuel consumption due to shorter wait times at toll plazas	**.899**
		14	I find FASTag to be a cost-effective solution compared to traditional toll payment methods	**.881**
		15	FASTag provides good value by streamlining toll payments and cutting unnecessary costs	**.878**

This table provides the names assigned to the factors based on the patterns of the loadings from the rotated component matrix:

Factor 1: Efficiency – This factor highlights the positive perception of FASTag's efficiency and the convenience it brings to road travel. This factor consistently has high loadings across multiple items, making it the most significant influence on users' perceptions. Users highly value the efficiency, time-saving benefits, and

convenience FASTag brings to their travel experience. The convenience of quick toll payments not only saves time but also enhances the overall travel experience, making it a game-changer for road users.

Factor 2: User Challenges – This factor captures the negative experiences users have with technical issues, suggesting areas for improvement. The technical difficulties experienced with FASTag, such as blacklisting and the risk of loss of tag, are a major concern for users. This factor holds the second-highest influence on perception, with multiple items having high loadings. Continuous improvement in technology and user interface can help mitigate these negative experiences, reinforcing the positive aspects of efficiency.

Factor 3: Service Accessibility – This factor highlights the accessibility, ease, and satisfaction users experience with FASTag services, particularly in areas like recharging, transaction notification, and customer service. It plays a significant role in shaping user perceptions, with notably high loadings, highlighting the importance of these accessible features in enhancing the overall user experience. This factor is crucial for maintaining user satisfaction, as it ensures that the advantages of efficiency are accessible to all users. By enhancing the support infrastructure, FASTag can further solidify its position in the market.

Factor 4: Cost-effectiveness – This focuses on the financial gains users derive from FASTag, including fuel savings and the overall perception that it is a more economical and valuable toll payment solution compared to traditional methods. While important, it ranks fourth in terms of overall significance based on the factor loadings. By highlighting the savings from fuel efficiency and the comparative value of using FASTag over traditional methods, marketing strategies can effectively communicate the long-term benefits to potential users.

In summary, while efficiency is the primary driver of positive perceptions of FASTag, addressing challenges and enhancing service accessibility will further solidify its position in users' minds. Additionally, emphasizing cost-effectiveness can attract a broader audience, making FASTag a preferred choice in toll payment solutions. Future studies could investigate how these factors influence each other and change over time, which could lead to new ways to make the user experience better.

Conclusion

The study examines technological advancements in India's toll collection system. India, recognized as the world's second-fastest-growing digital economy by McKinsey, has integrated e-services into toll collection. The shift from manual toll collection to automated systems has significantly improved the efficiency of toll management operations. FASTag is one of the most revolutionary electronic toll collection initiatives, as it uses technology for optimizing the payment procedure instead of the conventional manual toll collection practices, which are often slow and prone to human error. The benefits in terms of time-saving and convenience, coupled with its significant advantages, are the most salient feature impacting user perceptions positively. The users consider the reduction in waiting time at toll plazas as an improvement in the overall travel experience and indicate a broader shift toward digitalization in transportation services.

Although FASTag offers many significant benefits, the study also underlines the problems that the user faces, especially the technological challenges. Those challenges, including blacklisting issues, loss of tag as well as scanning errors, represent areas where focus and improvement are needed. Improvement of these technological deficits is required to increase the satisfaction level of users and build trust in the system. An improved, efficient FASTag experience has the ability to significantly raise user satisfaction and increase acceptance among the drivers. Besides efficiency and technical reliability, the research underlines the significance of service accessibility. Factors such as easy recharge of FASTag accounts and responsive customer support would be part of the users' experience. A seamless and user-friendly recharge process and efficient customer service that quickly responds to user inquiries and concerns can significantly influence user satisfaction. These factors of service accessibility enhance the overall user experience and promote increased acceptance of the FASTag system. The research also highlights the economic benefits of using FASTag, particularly in terms of fuel savings and cost-effective solution compared to traditional toll payment methods.

Banks have played a crucial role in the success of FASTag, offering comprehensive services and contributing significantly to toll collection efficiency, a role that continues to expand with emerging technologies. India's road infrastructure is undergoing a remarkable transformation, driven by advanced innovations such as FASTag, Automatic Number Plate Recognition (ANPR), and the recently launched Global Navigation Satellite System (GNSS)-based tolling system. These advancements are revolutionizing toll collection and road maintenance, showcasing India's rapid strides in technological progress (Ajith Athrady, 2022; The Economic Times, 2022; Shubham Chhabra, 2024). The introduction of GNSS with the help of the National Highways Authority of India (NHAI) and the National Payments Corporation of India (NPCI) represents a major milestone in modernizing India's road infrastructure, offering the potential for more efficient toll collection and an enhanced travel experience for millions of road users.

Limitations of the Study

The study is limited by its geographic focus, since it has been restricted to the Palakkad district, and this might impact the generalizability of the results to other areas. Further, there might be bias in the data, since participants might have had varied experiences with FASTag, which could affect the results. Data collection was indeed difficult, especially since the study population was those who use FASTag frequently; less frequent users of the service rarely agreed to participate in the survey. These factors may limit the depth of insights gathered and could influence the overall conclusions drawn from the research.

Implications for Future Developments

Implementing FASTag is an important step forward in terms of India's toll collection systems, aligning with the country's broader goals of digital transformation and efficiency in public services. The findings of the study indicate that stakeholders should focus on error resolution processes and give timely alerts or warnings to avoid blacklisting, thereby reducing user frustration. Simplifying the recharge process and enhancing customer support services to make it more user-friendly. Highlighting the savings in terms of time and fuel for using FASTag and, thereby, a larger user base. By covering these areas, stakeholders can enhance user satisfaction and promote the continued growth and acceptance of digital payment systems in India's transportation infrastructure, paving the way for a more efficient and user-centric toll collection experience.

Future Scope of the Study

The future scope of the study includes several areas for further research. Longitudinal studies could determine how users perceive FASTag over a period of time. Generalizing the geographic focus of the study beyond Palakkad district would help understand different regions' user experiences. Further study into upcoming technologies in road toll collection may establish innovative solutions with regards to improving user convenience and system efficiency. Analyzing demographic factors, such as age and tech-savviness, could reveal differences in user experiences and preferences. Future research could also explore the integration of FASTag with other transportation technologies, as well as conduct comparative analyses with other digital payment systems to identify best practices. In addition, environmental benefits of FASTag can be added to further discussions on sustainability in transportation.

Declaration of Interest Statement: There is no known conflict of interest.

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