Users perception based service quality analysis at toll plazas using structural equation modeling

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ABSTRACT

Service quality is one of the main performance indicators to assess the quality of traffic operations and facilities provided at the toll plaza. Present study proposes a methodology to evaluate the service quality for toll plazas in India. This study identifies various determinants such as infrastructural and traffic characteristics, drivers' behaviour, operators' behaviour at tollbooths and trip characteristics associated with service quality at toll plazas. Thus the effect of five latent variables and sixteen indicators are determined and nine hypotheses are formulated based on the existing literature review on the above subject. A total of 1427 users at four different toll plazas located in northern and western parts of the country were interviewed and their responses were collected through predetermined structured questionnaires to derive structural equation models. After removing missing data and outliers using Mahalanobis D-square, finally, 1325 samples are used to develop the model. The five latent factors and their indicators are confirmed through confirmatory factor analysis (CFA) and hypotheses are tested through path analysis. SEM models derived in this study reveal that driver's behaviour, infrastructural and traffic characteristics, trip characteristics and tollbooth operators' behaviour positively influence service quality at toll plaza based on users' perception. Hence, it is essential that these latent factors should be given proper attention during the planning and designing of toll plaza aimed at enhancing service quality of toll plazas and safety.

1. Introduction

Road users' satisfaction is the prime responsibility of the management committee of any facility. The facilities should be focused to improve service quality fullfilling the users' perspective. The transportation infrastructure is the backbone of any nation and hence, India being a developing nation also focused on the same. Due to unavailability of funds, many road projects were undertaken through public–private-partnership (PPP) to speed up capacity augmentation and safety of the existing roads from last decade. In PPP, the private partner finances and constructs the facilities as per the contract with the government and recovers the total capital outlay by collecting toll tax from road users' for the agreed redemption period. Road users get better facilities such as well-maintained roads, less journey time and safer commuting environs for the toll paid by them. Various toll collection methods such as Manual Toll Collection (MTC), Automated Coin

Machine (ACM) and Electronic Toll Collection (ETC) are in vogue. Out of these, the most widely used form of toll collection is MTC on Indian roads, wherein toll collection is done manually by the attendants or collectors at the toll plaza (Bari et al., 2021; Navandar et al., 2021). Toll plazas have various lanes, which are divided based on the vehicle category. Each of the vehicle types should ideally follow the lane based on its type, pay toll through cash/e-card and then leave the toll plaza for further journey. But due to various factors such as traffic composition, lane changes required, etc., drivers choose the lane causing the minimum delay, causing mixed traffic conditions in a particular dedicated lane (Bari et al., 2022a–d, 2023a). It may be observed from Fig. 1 that the different vehicle classes are present in each toll lane, causing different leader–follower pairs in a single lane. For the MTC system, the toll collector has to dispense change while doing the above manual transactions after entering the vehicle details in the computer and finally issuing a receipt to the users. Thus, due to the intervention of manual

operation and the mixed traffic conditions, the service time observed in the field varies with the vehicle class (Bari et al., 2019), and the average value crosses the value of 10 s (s) per road user. However, the code of practice in India, i.e., Indian Roads Congress (IRC) SP:84 (2014) suggested the maximum limit of 10 s irrespective of payment method and vehicle type. Hence, it can be seen that use of MTC system eventually results in a reduction of tollbooth capacity of passing vehicles per hour and subsequently increases users' waiting time in queue (Bari et al., 2022d,b).

The travel time experienced at the toll plazas influences the users' perceived service quality. As such, service quality is a measure that describes operational conditions of traffic flow for any traffic infrastructural facility and their perception by road users'. In fact, several factors, such as the mixed nature of traffic, drivers and toll collectors' human behavior, design and infrastructure of toll plaza etc., influence the travel time and, eventually service quality of toll plaza. Arguably, human (drivers' and toll collectors') behavior also a sensitive factor for toll plaza management.

As of now, there is no standard procedure for evaluating service quality at toll plazas given by standard codes of practice such as Highway Capacity Manual (HCM, 2016), IRC SP:84 (2014), and Indian Highway Capacity Manual (Indo-HCM) (2017) and hence many researchers tried to develop their own thresholds. Researchers used the empirical datasets as well as the users' perceived data for developing service quality thresholds at toll plazas along with the different measures of effectiveness (MOEs), as shown in Fig. 2.

There are many studies (Bari et al., 2021; Gulewicz and Danko, 1995; Klodzinski and Al-Deek, 2002; Lin and Su, 1994; Liu et al., 2018; Navandar et al., 2019b; Osborne, 2012; Woo and Hoel, 1991) available on the determination of service quality thresholds at toll plaza using empirical data. Further, few studies have been carried out in the recent past for service quality estimation based on users' perception data. However, past studies used the ordered probit model for evaluating service quality, which generally has limitations in interpreting the coefficients, along with the assumption of the same error variance for all cases (Fenella, 2016; Williams, 2008). Further, many a time, the independent variable of one model equation can be the dependent variable in another model (Gunzler et al., 2013). Such cases are difficult to handle in such modelling techniques and hence there is a need to revisit the variables and their effects on service quality. In this connection, this study aims to focus on factors affecting the service quality at toll plaza and explore the complex relationships and cause-effect analysis amongst them. For this study, the structural equation modelling (SEM) approach is used which is powerful multivariate technique handling the complex relationship between the endogenous (dependent variable) and exogenous variables (independent variable) (Gunzler et al., 2013). Therefore, in this study, the following objectives are set- (1) to identify factors affecting users perceived service quality at the toll plaza, (2) to formulate the hypothesis based on literature review and construct a measurement model, and (3) to develop a path model.

2. Literature review

In this section, existing studies on the service quality of toll plazas are reviewed to find out the tangible and intangible factors related to toll plaza management. In the context of the operational efficiency of the toll plaza, the IRC: SP:84 (2014) and HCM (2016) do not include any methodology for estimating service quality at the toll plaza. Due to the absence of a standardized method to evaluate service quality at toll plazas, some researchers have attempted to estimate the service quality of toll plazas using different MOEs. MOEs such as waiting time in a queue (Wanisubut, 1989), volume-capacity ratio and density(Woo and Hoel, 1991), mean queue length (Burris and Hildebrand, 1996; Lin and Su, 1994), mean waiting time (Polus, 1996), queue length (Chakroborty et al., 2016), delay (Chakroborty et al., 2016; Klodzinski and Al-Deek, 2002) and percentage of trucks in traffic flow (Obelheiro et al., 2011) considered by different researchers in previous studies.

The above mentioned all studies were performed based on empirical data, simulation, and qualitative analysis. These studies considered different performance indicators to show the users' discomfort and inconvenience at toll plazas, excluding users' perception. Moreover, many studies (Klodzinski and Al-Deek, 2002; Lin and Su, 1994; Woo and Hoel, 1991) followed methodologies of HCM and compared with a delay at signalized intersections. However, considering the unique characteristics of the toll plaza and operational conditions, a comparison between the service quality of toll plazas and signalized intersections has not any stand. Table 1 summarizes the different literature for the toll plaza studies based on users' perception study.

Obelheiro et al. (2011) considered the users' perception and conducted a qualitative analysis to estimate service quality at the toll plaza. The authors mentioned that delays, infrastructural facility, and informative signs might also influence the service quality at the toll plaza. However, they considered mean queue length, number of tollbooths provided and percentage of trucks in traffic flow as indicators and concluded that queue length at tollbooth strongly influences the users' perceived service quality at the toll plaza. Navandar et al. (2019c) evaluated the service quality of the manual toll plazas operating under mixed traffic conditions using an ordered probit model. They found that the service quality perception varies with the vehicle classes. Additionally, they found the humps at the tollbooth as an important
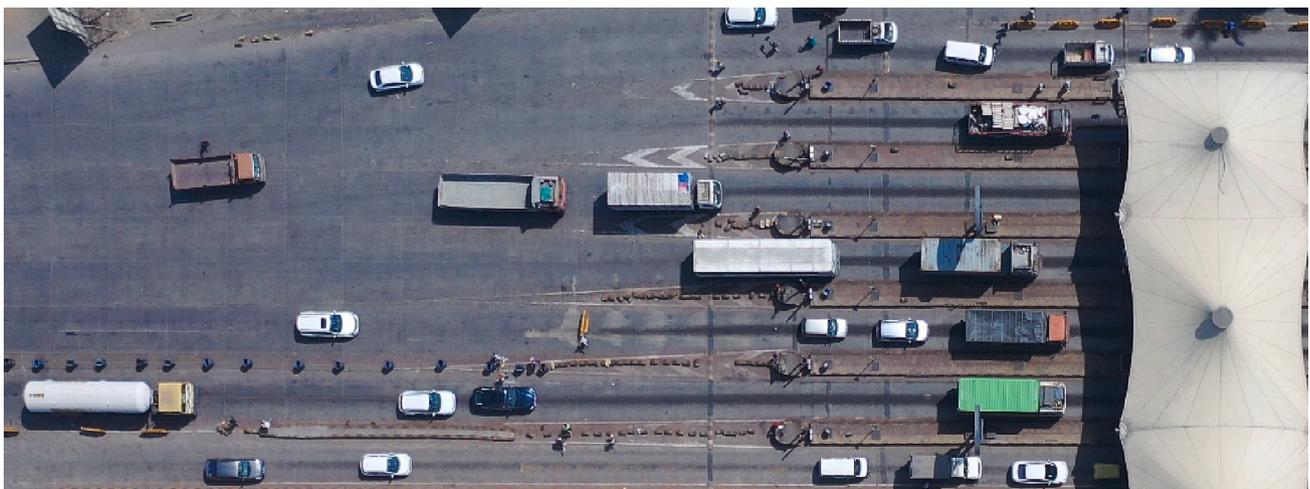

Fig. 1. Presence of different vehicle classes in dedicated lanes at toll plazas.
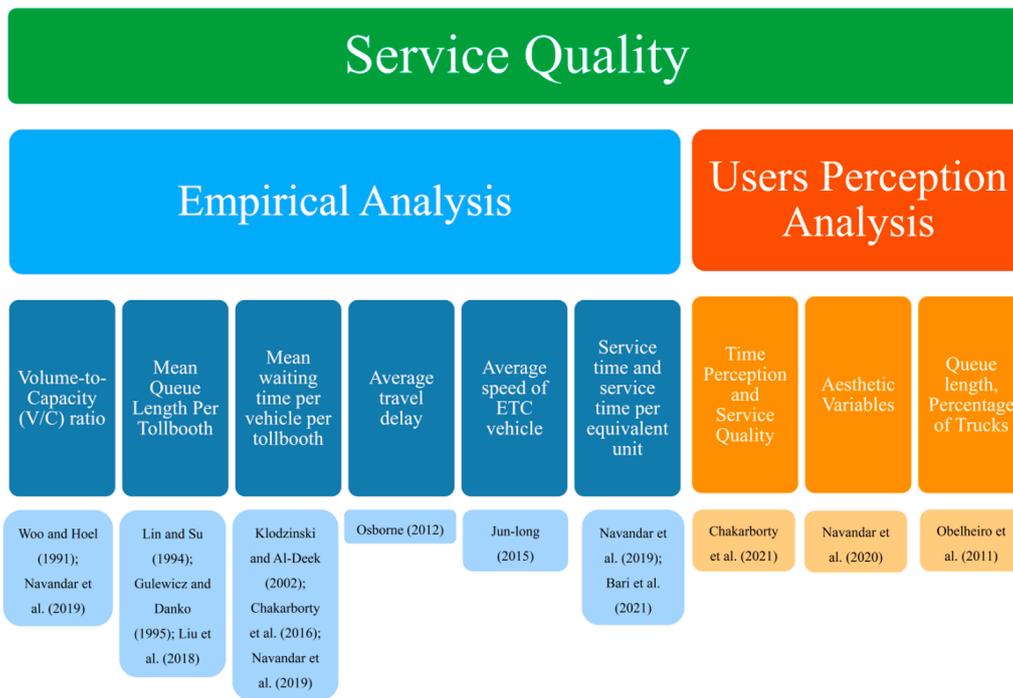
Fig. 2. Methods and MOEs considered in the literature for developing service quality at toll plazas.

Table 1
Summary of user's perceived service quality studies.

Reference	Country	Number of Samples	Interview Method	Method Used	Factors	Vehicle class considered	Findings
(Obelheiro et al. 2011)	Brazil	582	Online	Scores	Queue length and Percentage of Trucks	Car, Light truck, and Heavy truck	• Queue length has a stronger influence on the quality of service
(Navandar et al. 2019a)	India	1150	Face to face	Ordered Probit Model	Socioeconomic factors, percentage of trucks, payment method, aesthetic, humps at tollbooths	Car, Bus and Truck	• Dedicated lane followed by vehicle is found to be a significant parameter for Car user. • Driving experience and the number of tollbooths provided are important for truck users.
(Navandar et al. 2019c)	India	1431	Face to Face	Ordered Probit Model	Socioeconomic factors, percentage of trucks, payment method, aesthetic, humps at tollbooths, speed of payment method, presence of informative sign	Cars and heavy vehicle	• Age, perceived waiting time, dedicated lane follows, and humps at tollbooths are found to be positively correlated to service quality. • Drivers Experience, frequency of use, presence of heavy vehicle, informative sign about fare value, payment method and aesthetics' are negatively correlated to service quality.
(Chakroborty et al., 2021)	India	1508	Face to Face	Physiological Order Response Model	Perceived waiting time	Cars	• A function to represent bias is given in the present study. • Given that the service level depends upon the facility.

parameter for evaluating service quality. Chakroborty et al. (2021) used the physiological order response model to evaluate service quality.

Based on the review of existing literature, some factors affecting the service quality at toll plazas are summarized in Table 2.

In the above-discussed literature, the ways of perceiving service quality by users at manually operated toll plazas under mixed traffic conditions are not sufficiently addressed. Service quality is highly related to drivers' perceptions and influenced by various factors such as infrastructure and traffic characteristics, drivers' human behavior, tollbooth operators' behavior, trip characteristics and, users' feelings towards service quality. Therefore, the present study examines users'

perception of perceived service quality at toll plazas using cause-effect analysis.

Based on the exhaustive review of the literature, nine null hypotheses are formulated and listed as below:

• H1: Infrastructure and traffic characteristics (IFTC) influence the service quality of toll plaza.
• H2: Drivers' human behavior (DB) affects the service quality of toll plaza.
• H3: Tollbooth operators' behavior (TOB) affects the service quality of toll plaza.

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Table 2
Factors related to toll plaza operation in literature.

Factors	Indicators	Explanation	References
Infrastructural and Traffic Characteristics (IFTC)	Number of Tollbooth Provided (IFTC1) Informative Sign about Fare Values (IFTC2) Waiting Time in Queue (IFTC3) Dedicated Lane Followed by Vehicle (IFTC4) Presence of Heavy Vehicle (IFTC5)	Infrastructural and traffic characteristics include number of tollbooths provided, marking of sign and fare values, waiting time in queue, dedicated lane followed by vehicle and presence of heavy vehicle affects user's perception about service quality at toll plaza	(Aycin, 2006; Klodzinski and Al-Deek, 2002; Lin and Su, 1994; Obelheiro et al., 2011; Polus, 1996; Wanisubut, 1989)
Drivers' Human Behavior (DB)	Education of Driver (DB1) Age of Driver (DB2) Experience of Driver (DB3)	Drivers' human behavior includes perception about delay and reaction time. Drivers' behavior depends upon their age, education and experience.	(Al-Deek et al., 1998; Klodzinski and Al-Deek, 2002; Rong-Chang, and Yi-Wen, 2013)
Trip Characteristics (TRP)	Driver Through Toll Plaza (TRP1) Purpose of Trip (TRP2) Payment Method (TRP3)	Frequency, trip purpose and type of payment method selected influence the users' perception of service quality at toll plaza.	(Al-Deek et al., 1998; Klodzinski and Al-Deek, 2002; Rong-Chang and Yi-Wen, 2013)
Tollbooth Operators' Behavior (TOB)	Experienced Service Time at Tollbooth (TOB1) Courtesy (TOB2) Speed of Payment Method (TOB3)	TOB is highly influenced by the behavior of drivers', and their cooperation in a toll payment.	(Gordon and Newell, 1967; Klodzinski and Al-Deek, 2002; Navandar et al., 2019a; Russo et al., 2010)
Service Quality (SQ)	Experienced Waiting Time in Queue (SQ1) Overall Rating (SQ2)	It reflects the perception of road users' about the value of services offered at toll plaza against payment of toll.	(Chakroborty et al., 2016; Klodzinski and Al-Deek, 2002; Lin and Su, 1994; Obelheiro et al., 2011; Woo and Hoel, 1991)

- H4: Trip characteristics (TRP) impact the service quality of toll plaza.
- H5: Infrastructural and traffic characteristics (IFTC) affect the tollbooth operators' behavior.
- H6: Trip characteristics (TRP) influence the infrastructure and traffic characteristics (IFTC).
- H7: Trip characteristics (TRP) bear on drivers' behavior (DB).
- H8: Drivers' human behavior (DB) influences tollbooth operators' behavior (TOB).
- H9: Drivers' human behavior (DB) depends upon infrastructure and traffic characteristics (IFTC).

Referring to the factors mentioned in Table 2, IFTC, DB, TRP, TOB, and service quality are found as latent factors which are not easily quantifiable. Formulated hypotheses show cause-and-effect relationships among these constitutes as latent variables. Therefore, SEM, a multivariate technique, is appropriate to develop the measurement and path model to test the above hypotheses and discussed in detail in subsequent sections.

3. Structural equation modeling (SEM)

SEM is a suitable method for examining complex multiple relationships, analyzing a series of hypotheses in an entire model, and combining regression and factor analysis (Najaf et al., 2018). SEM deals with both independent and dependent variables. This is useful for defining relationships among the unobserved (latent) and observed variables (Deutsch et al., 2013). SEM with unobserved variables is composed of three sets of equations, which (1) a measurement model for the dependent variable, (2) a measurement for the independent variable, and (3) a structural model is simultaneously estimated. Further, it evaluates the relationship from exploratory analysis to confirmatory analysis. It tests initial theory-driven relationships considering latent variables as well as observed variables. This type of analysis is not possible by regression analysis and ordered probability models. More, SEM evaluates direct and indirect effects on the latent variable(s), whereas it is not possible in regression and ordered probit models to determine indirect effects. This distinction in SEM, as compared to other techniques, allows testing a variety of hypotheses about the measurement of constructs and their relationships. So, for the cause-effect analysis among the selected latent variables and user's perceived service quality at toll plaza, SEM is a more appropriate research method for this study.

SEM has gained popularity over time due to the availability of a host of software packages incorporating features like analysis of moment structures (AMOS) (Arbuckle, 2017) and linear structural relations (LISREL) (Joreskog and Sorbom, 1989). The availability of these packages has encouraged researchers to use this technique in many fields such as psychology, biology, economy and statistics (Jayakumar and Sulthan, 2013; Saxena and Khanna, 2013), construction management (Patel and Jha, 2016) as well as in the field of transportation (Das et al., 2017; Deutsch et al., 2013; Dong et al., 2021; Eboli and Mazzulla, 2012; Tavares et al., 2021). Narayanan (2012) advocates to the use of AMOS due to its user-friendly graphical interface, well-ordered and easily accessible output format, and a number of options for bootstrapping as compared to other commercially available software. Hence in this study too, AMOS 24 has been employed.

4. Research methodology

The present study follows the six steps suggested by Hair et al. (2014) to develop the SEM model for users' perceived service quality at the toll plaza as depicted in Fig. 3.

The first four steps belong to confirmatory factor analysis (CFA), which is employed for validating the measurement model, while the remaining two steps belong to path analysis to study the structure model (Fig. 3) (Anderson and Gerbing, 1988). The development of the SEM model is briefly presented stepwise as below.

4.1. Step 1: To define an individual construct

This step involves the listing of the latent variables which will be included in the measurement model. As discussed previously, variables for users' perceived service quality at toll plaza such as IFTC, DB, TOB and TRP with their indicators are considered for this model, as shown in Table 2. These measurable indicators of latent factors have been decided based on the existing literature review, content validity, and interaction with toll plaza managers.

4.2. Step 2: To develop the overall measurement model

The maximum number of indicators may present a more reliable result, and a minimum of three indicators per latent variable are enough to present a good result (Hair et al., 2014). However, in previous studies, many researchers selected two to six indicators for each latent variable (Patel and Jha, 2016) based on different study objectives and latent
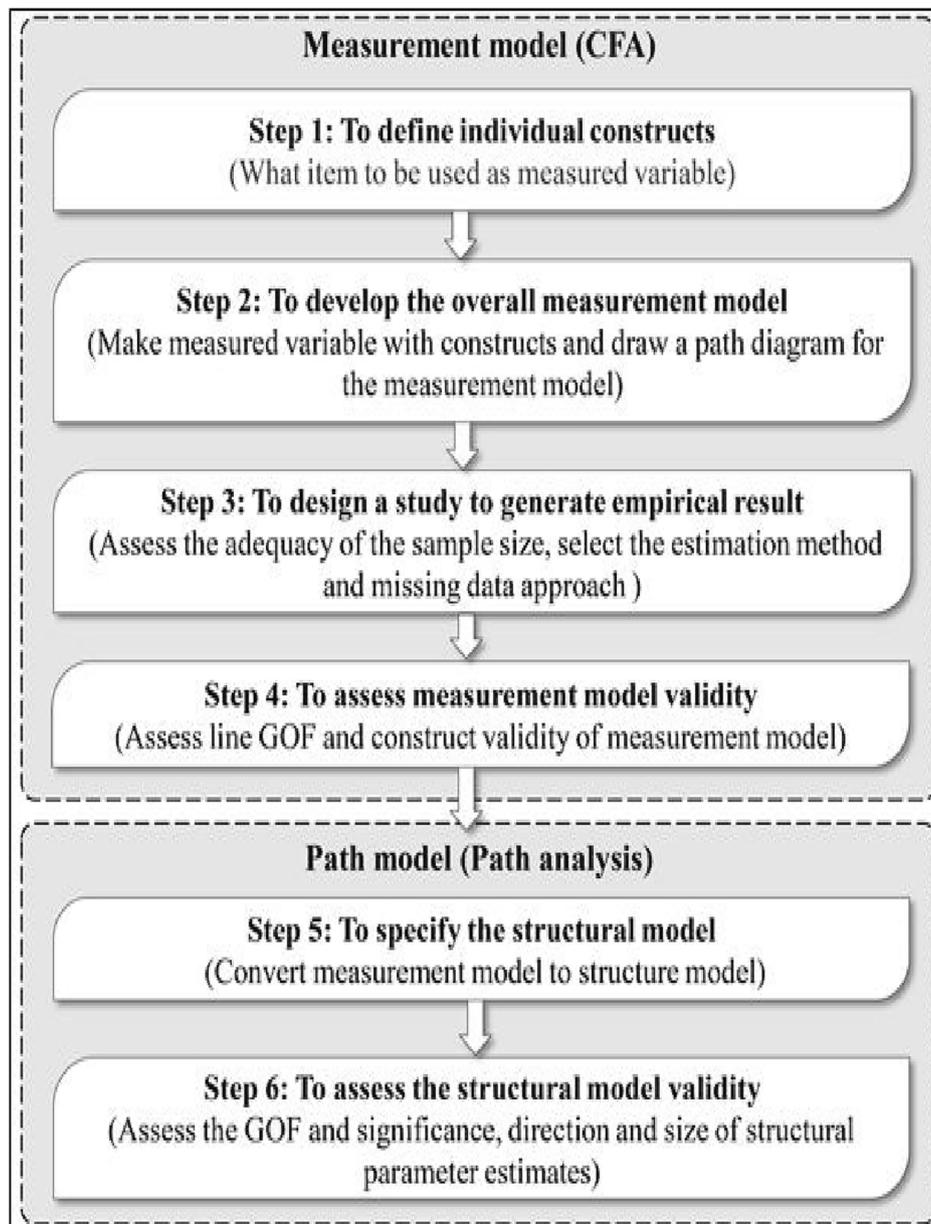
Fig. 3. Steps for SEM (Patel and Jha, 2016).

variables. Hence, in the present study, a minimum of two and a maximum of five indicators are considered for different latent variables. Five unobserved factors and 16 associated indicators have been considered to formulate the hypothetical and measurement model. These indicators should be easily measurable. The hypothetical structure of SEM formulated is shown in Fig. 5 with the help of factors mentioned in Table 2. The oval shape shows the latent variable, whereas the rectangle shows their indicators. The magnitude of the arrow is the factor loading which illustrates the intensity of the relationship between the unobserved variable and the indicator or any other unobserved variable.

4.2.1. Questionnaire design and data collection

Pertaining to the service quality study of toll plazas based on users' perception, different toll plazas are considered to capture the variability in the responses and, thus the behavior of an individual. Four candidate toll plazas located in the northern and western parts of geographical India are considered. Face-to-face interviews were carried out near toll plazas at locations such as petrol pumps and hotels in March and

November 2017. The survey was carried out for the whole day in said months so that the response of users passing in peak and off-peak hours from the toll plaza could be captured. The data near four toll plazas are carried on the given date as shown in Table 3.

For obtaining the proper insights into the service quality, the questionnaire design should be proper to sustain all the variables that may have an effect on the response. Hence, in the present study, more focus was carried out on questionnaire design. For the present study, the questionnaire is oriented towards two important aspects (a) socioeconomic and demographic parameters and (b) trip and perception-based parameters. The socioeconomic information includes age, gender, and experience in the first part. In the second part, trip and perception related information include the frequency, trip purpose, etc.

From the literature review, five latent factors and their sixteen factors that potentially affect the users' perception of service quality of toll plazas were identified and included in a questionnaire to evaluate them by respondents. This questionnaire is close-ended, and more general terms were used in a questionnaire so respondents can easily understand them and respond properly. For example, 'waiting time in queue' was
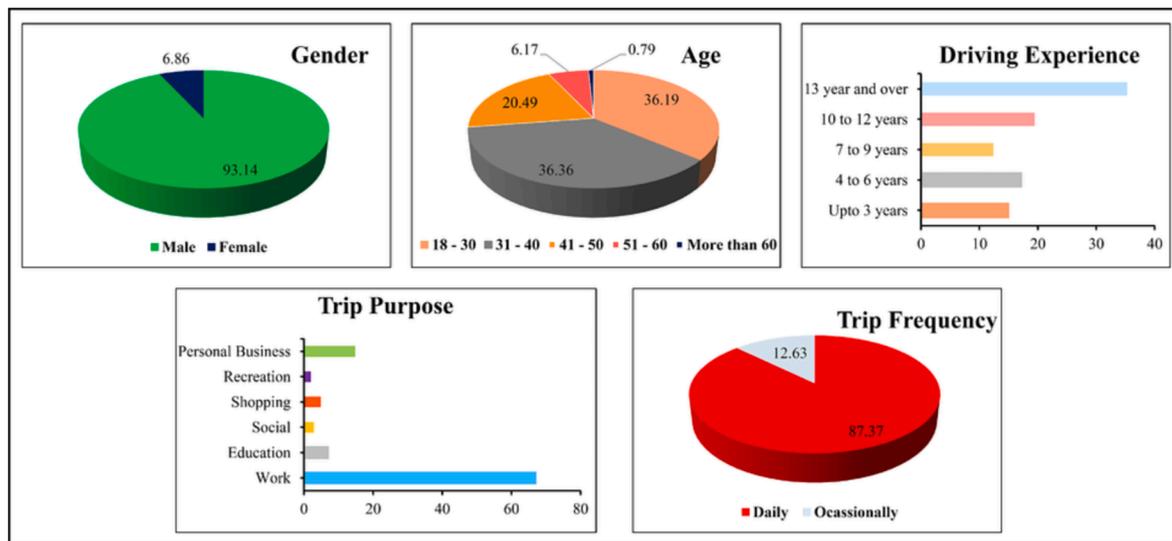
Fig. 4. Users socioeconomic and travel-related characteristics.

used instead of 'delay'. As seen from Table 2, factors such as Number of Tollbooth Provided, Informative Waiting Time in Queue, Dedicated Lane Followed by Vehicle, Presence of Heavy Vehicle, Purpose of Trip, etc., are the variables that are asked to the users for their rating (For more details see Appendix). The assessment of service quality at toll plazas by each user is subjective and each user may generally have a different state of mind about their perception and experience. Hence, the present study utilized a five-point Likert scale to measure the importance of each factor by users. Respondents evaluated the factors according to their importance in influencing the quality rating of a toll plaza on '1' to '5' scale in the questionnaire, with 1 being very less influencing and 5 being very high influencing. The 2, 3, and 5 are in between these two representing very less, moderate, and high influence, respectively. Additionally, the same factors were enquired for linguistic terms such as poor, moderate, or good, to know the user's level of satisfaction for the candidate toll plaza. Further, the pictorial images for the different service quality at the candidate toll plaza were shown to know the perceived service quality. The supplementary toll plaza service quality view helped the users to answer properly about the service quality as they are not technocrats. This also adds knowledge to the users about the different service quality categories based on the supplemented information to them.

4.2.2. Analysis of survey data

A total of 1427 samples were collected through the users' response survey. Out of these, 93 forms were found incomplete and contained some missing information and hence finally, about 1334 samples were considered for further analysis. As the socioeconomic and travel characteristics are shown in Fig. 4. 93.13% of respondents were male. In the present study, the maximum proportion of drivers are male. Authors want to convey that very few females drive vehicles in India. The same can be verified by the driving license data of India. For instance, please check the report given by Times of India (TNN, 2014). They have also suggested the drivers in India are mostly male. Hence, the developed SEM model can totally be applicable for the Indian conditions and hence the results. Age is categorized into five groups- 18–30, 31–40, 41–50, 51–60, and more than 60. From the data, it can be observed that 60% of the respondents were up to 40 years of age. Very few (0.79%) of the users were old age people (more than 60 years). A wide variation in data is observed for driving experiences, and the maximum users had an experience of more than 13 years (35.46 percent). For the survey, different trip purposes such as work, education, social and shopping, etc., were enquired and as the survey was for toll roads, most of the users

were making trips for their work (67.23 percent). Related with trip purpose, trip frequency is also an important variable to study, and it was found that 85% of the respondents were daily commuters.

Cronbach's Alfa reliability test is performed to check the suitability of the grouping of constructs of users perceived service quality at toll plazas and the reliability of the data. An alpha value between 0.60 and 0.70 is considered appropriate, and more than 0.70 is considered more reliable (Hair et al., 2014).

4.3. Step 3: To design a study to produce empirical results

The present study prefers to covariance matrices rather than correlation matrices (Hair et al., 2014; Schumacker and Lomax, 2004) as the prime objective of this study is to test and confirm the theory (Hair et al., 2011). Moreover, main criteria, multivariate normality, sample size, outlier, missing data, communality, and estimation method are to be checked before developing a model. In the collected responses, nine outliers were identified using the Mahalanobis D^2 equation and were neglected for further analysis. These 9 outliers show discrepancies in given responses from users. Users have given quality ratings for all variables as positive, whereas overall service quality is ranked as "E" (Poor) or "F" (Very Poor) or vice versa. Hence, statistically, these samples were also identified as an outlier in the present study.

The Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity values are 0.77 and 0.00 respectively. These values confirm to sampling adequacy and multivariate normality.

As a large sample size reflects more reliable results, the minimum sample size considered is at least 150 in the SEM if there are seven or fewer constructs, with modest communalities (0.50) and no under-identified constructs (Hair et al., 2014). The maximum likelihood (ML) approach is unbiased and more efficient when the assumption of multivariate normality is met even in 50 number of samples (Hair et al., 2014; Kline, 2015). However, after removing nine outliers out of 1334, the final samples were obtained as 1325 for the present study. These samples are sufficient to apply the ML approach as it is one of the proven methods per the literature. The order and rank conditions are considered to avoid identification problems (Patel and Jha, 2016). The degree of freedom (DOF) for a measurement model should be more than zero. This is an order condition and shows the under-identified model. Similarly, the rank conditions are satisfied by avoiding cross-loading between different unobserved variables in the model.
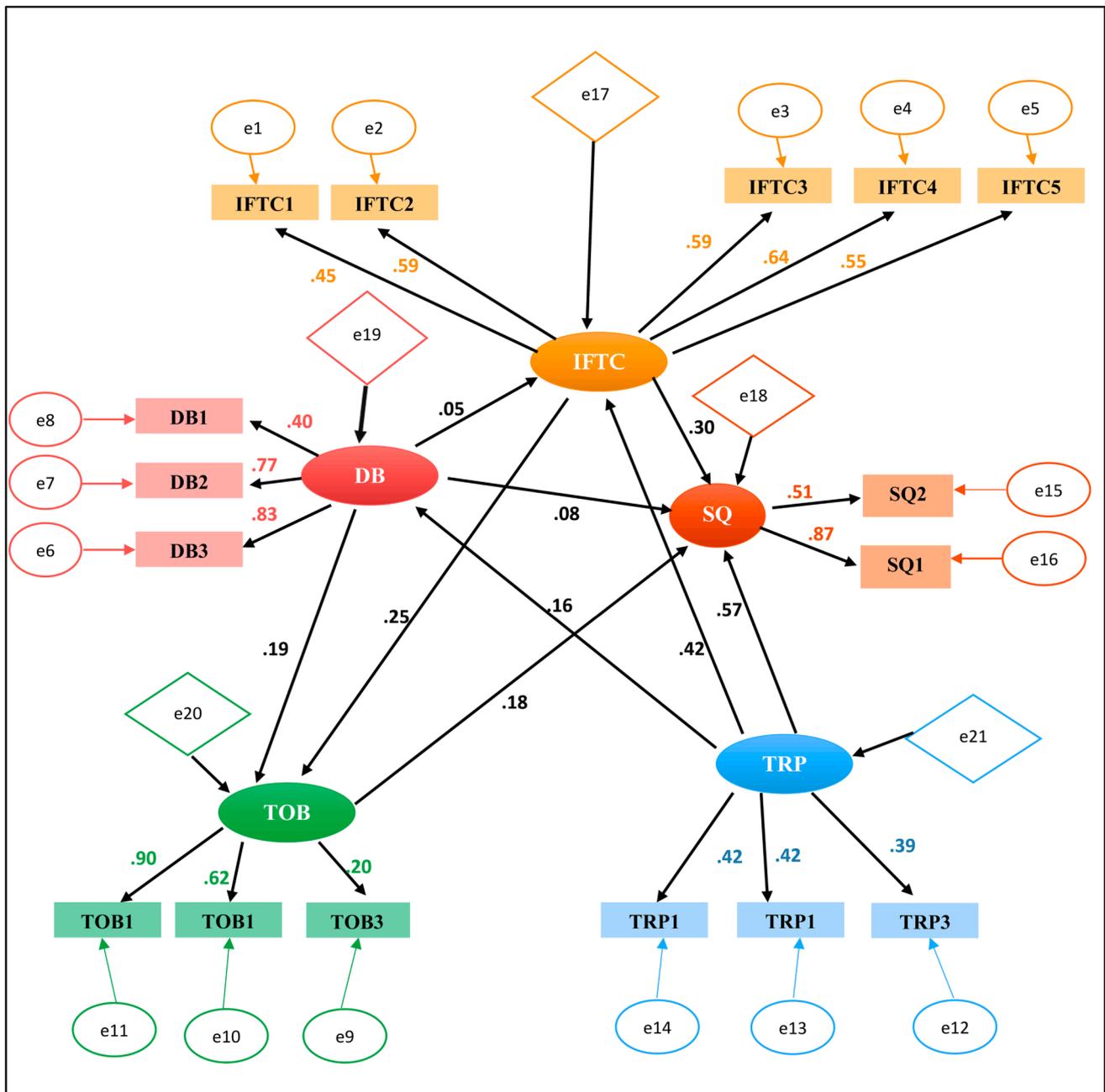
Fig. 5. Hypothetical model.

4.4. Step 4: To assess measurement model validity

Measurement model validity depends upon the goodness-of-fit, validity, and reliability of constructs. So, specific measurement models, selected estimation techniques, consistency of a measure, and validity need to be checked. A brief explanation of the reliability and validity of measures with their permissible limits is presented in Table 4.

4.5. Step 5: To specify the structural model

SEM building involves finding the desired relationships among identified variables in the structural model. As per the proposed theoretical model, nine relationships were built up among all constructs based on hypotheses, as shown in Fig. 5. TRP is the exogenous construct, whereas IFTC, DB, TOB, and SQ1 are the endogenous constructs. In this stage, the parameter is specified to be free or fixed. Fixed parameters are

not calculated from observed samples and are likely to be non-zero. The measurement model is validated with different measures of goodness-of-fit indices such as absolute (normed chi-squared, the goodness of fit (GFI), root mean square error of approximation (RMSEA), root mean square residual (RMR)), incremental (normed fit index (NFI), Tucker-Lewis index (TLI), comparative fit index (CFI)), and parsimony (adjusted goodness of fit (AGFI), parsimony normed fit index (PNFI)) are indices. The details about all these measures of goodness-of-fit indices are explained by Hair et al. (2014). Once the overall fit for the measurement model is achieved, it is tested for reliability and validity.

4.6. Step 6: To assess the structural model validity

This is the last stage of the decision process in which the validity of the structural model is checked by comparing structural model fit with CFA model fit. According to Hair et al. (2014), the minimum value of the

Table 3
Data Collection.

Sr. No.	Name of Toll Plaza	City and NH	State & Region	No. of Response Collected	Date
1	Boriach Toll Plaza (BTP)	Navsari (NH-8)	Gujarat (Western Region)	308	03/3/2017 to 05/3/2017 (Friday to Sunday)
2	Kerki Toll Plaza (KTP)	NCR (NH-8)	Delhi (Northern Region)	337	9/3/2017 to 12/3/2017 (Thursday to Sunday)
3	Ghoti Toll Plaza (GTP)	Nasik (NH-3)	Maharashtra (Western Region)	408	15/3/2017 to 19/3/2017 (Wednesday to Sunday) and 10/10/2017 to 12/10/2017 (Friday to Sunday)
4	Baswant Toll Plaza (PBTP)	Nasik (NH-3)	Maharashtra (Western Region)	374	22/3/2017 to 25/3/2017 (Wednesday to Saturday)and 15/10/2017 to 18/10/2017 (Wednesday to Saturday)

goodness-of-fit index from each of the absolute and incremental indices and the model's normed chi-squared value falls within its permissible range to satisfy the SEM validity. In the present work, SEM is tested for its validity, as depicted in Fig. 5. Then, it is checked whether the structural relationships are consistent with theoretical or hypothetical expectations.

In Fig. 5, e1 to e16 are the error terms for each indicator while e17-e21 are the error terms for each latent variable.

5. Data analysis and model validation

SEM includes CFA and path analysis to examine the relations between latent and hypothesized factors. The CFA and path analysis are presented in the following sections.

5.1. Measurement model

Nine hypotheses were formulated and tested using SEM. The CFA was carried out for five latent variables and their 16 indicators. The Cronbach's alpha value of more than 0.60 for all unobserved variables (Table 4) shows that the internal consistency and reliability of the hypothetical model are sufficient. The communalities of all indicators are greater than 0.35 except IFTC1, IFTC5, DB1, TRP1, TRP2, TRP3, TOB3, and SQ1. The measurement indicators having communality <0.50 represent that their respective factor loadings are <0.50. The measurement model is capable of reflecting the average variation between the observed variables and item reliability in order (Hair et al., 2014). Based on the standardized factor loading between each indicator and latent variable, variance, AVE, communality, and CR can be calculated (Hair et al., 2014). The AVE and CR of each latent variable are estimated and found within the permissible range except only for TRP. Table 5 depicts the measures of each unobserved variable joining or sharing a high proportion of variance in common.

Rank and order conditions are fulfilled by considering a minimum of two measures per latent variable. As shown in Table 5, AVE and communality values confirm the discriminant validity check for the developed model (Patel and Jha, 2016). Discussion with experts and existing literature confirm the content validity. A discussion with toll plaza managers and tollbooth operators has confirmed face and nomological

Table 4
Explanation on reliability and validity.

Checks	Parameters	Explanation	Permissible limit
Consistency of a measure (Reliability)	**Construct reliability (CR)**	It is a measure of the degree to which a set of observed variables of a latent variable are internally consistent and how observed variables are interrelated to each other.	CR value of 0.60 to 0.70 may be acceptable (Hair et al., 2014).
	Item reliability	It refers to the amount of variance in an item attributed to the underlying unobserved variable rather than error. It is obtained by squaring the factor loading.	It should be greater than x0.50 (Hair et al., 2014).
Validity (extent to which research is accurate)	**Convergent validity**	The indicators of a specific latent variable should converge or share a high proportion of variance in common. The factor loading, communality and average variance extracted (AVE) are used to check convergent validity.	The minimum value of factor loading, communality and AVE should be 0.70, 0.50 and 0.50 respectively (Patel and Jha, 2016).
	Discriminant Validity	Discriminant validity is the extent to which an unobserved variable is truly different from other unobserved variables.	The AVE of each construct should be higher than the squared correlations between the construct and all other constructs in the model (Patel and Jha, 2016).
	Face validity	It denotes the understanding of each item's meaning or content.	Based on existing literature.
	Nomological validity	It is tested by studying whether the correlations among the unobserved variables in a measurement model make sense.	Based on existing literature.

validity. After satisfying all reliability and validity checks, the given measurement model is ready to be tested for its theory contribution by comparing the developed model.

The output from AMOS-24 for fit indices is briefly presented in Table 6. The chi-square value of the overall model is found to be 646.95 with 94 DOF and a p-value of 0.000. The ratio of chi-square to DOF, 6.88, is slightly more than the permissible limit (2 to 5). Therefore, it needs to check that other indices reflect the nature of the model's overall fit. The GFI (0.94), RMSEA (0.066), PNFI (0.65), and PGFI (0.65) values are observed within the acceptable range. The model needs no improvement as the standardized residuals are found to be less than five. Further, no largest modification indices (MIs) are observed in the model. Hence, this model does not require any modification in any relationship among constructs. With this, all steps of CFA are completed.

5.2. Path analysis

The hypothesized theory is presented as the structural model in the path diagram visually based on the nine hypotheses as shown in Fig. 6. Again, AMOS-24 software was used to evaluate the hypothetical model,

Table 5
Estimation of parameter for CFA.

Latent Factors	Indicators	Cronbach's Alpha	Factor Loading	Unique Variance	Communality	AVE	CR
Infrastructural and Traffic Characteristics	IFTC1	0.70	0.45	0.80	0.20	0.33	0.70
	IFTC2		0.59	0.65	0.35		
	IFTC3		0.59	0.65	0.35		
	IFTC4		0.64	0.59	0.41		
	IFTC5		0.55	0.70	0.30		
Drivers' Human Behavior	DB1	0.71	0.40	0.84	0.16	0.48	0.73
	DB2		0.77	0.41	0.59		
	DB3		0.83	0.31	0.69		
Trip Characteristics	TRP1	0.63	0.42	0.82	0.18	0.15	0.33
	TRP2		0.42	0.82	0.18		
	TRP3		0.27	0.93	0.07		
Tollbooth Operators' Behavior	TOB1	0.68	0.90	0.19	0.81	0.42	0.63
	TOB2		0.62	0.62	0.38		
	TOB3		0.20	0.96	0.04		
Service Quality	SQ1	0.61	0.51	0.74	0.26	0.51	0.67
	SQ2		0.87	0.24	0.76		

Table 6
Estimation of the model parameter.

Goodness-of-fit and Indices	Parameter	Permissible range	CFA	Hypothetical model	Revised model
Goodness-of-fit index	Chi-square	As low as possible	646.95	658.82	388.55
	DOF	As high as possible	94	95	68
	Normed chi-square (chi-square/ DOF)	Between 2 and 5	6.88	6.93	5.71
	p value	<0.05 or 0.01	0.000	0.000	0.000
Absolute fit indices	GFI	0–1	0.94	0.94	0.96
	Adjusted GFI	>0.80	0.91	0.91	0.93
	RMSEA	<0.08	0.066	0.067	0.059
	90% confidence interval for RMSEA	N.A.*	0.062;0.071	0.062;0.072	0.054;0.065
	SRMR	<0.08 or 0.05	0.07	0.07	0.06
Incremental fit indices	NFI	>0.90 or 0.95	0.84	0.83	0.89
	TLI or NNFI	>0.90 or 0.95	0.82	0.81	0.88
	CFI	>0.90 or 0.95	0.86	0.85	0.91
	Relative non centrally index (RNI) 0r RFI	>0.90 or 0.95	0.80	0.79	0.86
	IFI	>0.90 or 0.96	0.86	0.85	0.91
Parsimony fit index	PNFI	>0.50	0.65	0.66	0.66
	PGFI	>0.50	0.65	0.65	0.62

and its values of different goodness-of-fit indices are found within the permissible limit as shown in Table 6. While comparing CFA with a hypothetical model, the chi-square value and DOF are observed increment of 12 and one (1), respectively, in the hypothetical model. This, in turn, has resulted in significant improvement in the hypothetical model as compared to CFA.

In the hypothetical model, all hypotheses are found to be significant except only DB to SQ, DB to IFTC and TRP to DB. However, in the hypothetical model, the correlation coefficient between TOB to TOB3 and TRP to TRP3 are 0.20 and 0.27, respectively (Fig. 5). These are the lowest values in this hypothetical model. So, the hypothetical model could be improved by removing insignificant variables such as TRP3 (payment method) and TOB3 (speed of payment method). Payment method and speed of payment seem insignificant as in India, more than 85% of users pay tolls by manual method (Annual Report, 2019). Hence, there is not much variation found in these indicators, resulting in lower factor loading. Therefore, to seek a better model, the TRP3 and TOB3 have been deleted in the hypothetical model. All values of goodness-of-fit indices of this revised model are presented in Table 6. Comparing the hypothetical model with a revised model, the chi-square value and DOF in the revised model are decreased by 270 and 27, respectively. Similarly, the normed chi-square value for the revised model is reduced to 5.71 from the 6.93 observed in the hypothetical model. The chi-square value of the revised model is close to the range of 2 to 5 suggested in the literature. Values of goodness-of-fit indices imply that the revised model is better than the hypothetical model. Further modifications in the revised model do not show any improvement in its goodness-of-fit indices. So the revised model shown in Fig. 6 is fixed for this study.

The revised estimate is found to be 0.11 (P < 0.001) between DB and SQ and 0.36 (P < 0.001) between IFTC and SQ. Thus, improvements are observed in both of these values. The absolute, incremental, and parsimony fit indices have improved slightly, and all values fall within the permissible limit. The loading of some paths has improved slightly in the revised model as compared to the hypothetical model, as would be expected. All the relationships are found significant except only DB to IFTC (Fig. 6). The path between DB and IFTC was found insignificant, but the sign of the coefficient is observed to be positive, which is in line with the hypothesis.

6. Findings and discussions

Table 7 shows the summary of hypotheses as per revised model. It can be seen that only one null hypothesis (IFTC < DB) is rejected while others are accepted.

Based on the above outcomes of analysis, H1 (infrastructure and traffic characteristics influence the service quality of toll plaza) was found to be significant with an estimate of 0.36 (P < 0.001). Obelheiro et al. (2011) concluded that the 'number of tollbooths' is an insignificant parameter for users' perceived service quality at the toll plaza in Brazil. On the contrary, the present study shows that this is a significant parameter. In fact, a correlation between indicators of IFTC and service quality at toll plazas is supported in many studies, such as 'the number of tollbooths provided' (IFTC1) influences toll plaza operation (Aycin, 2006; Lin and Su, 1994; Russo et al., 2010), 'informative sign and fare values' (IFTC2) (Obelheiro et al., 2011), 'waiting time in the queue' (IFTC3) (Klodzinski and Al-Deek, 2002; Obelheiro et al., 2011; Polus,
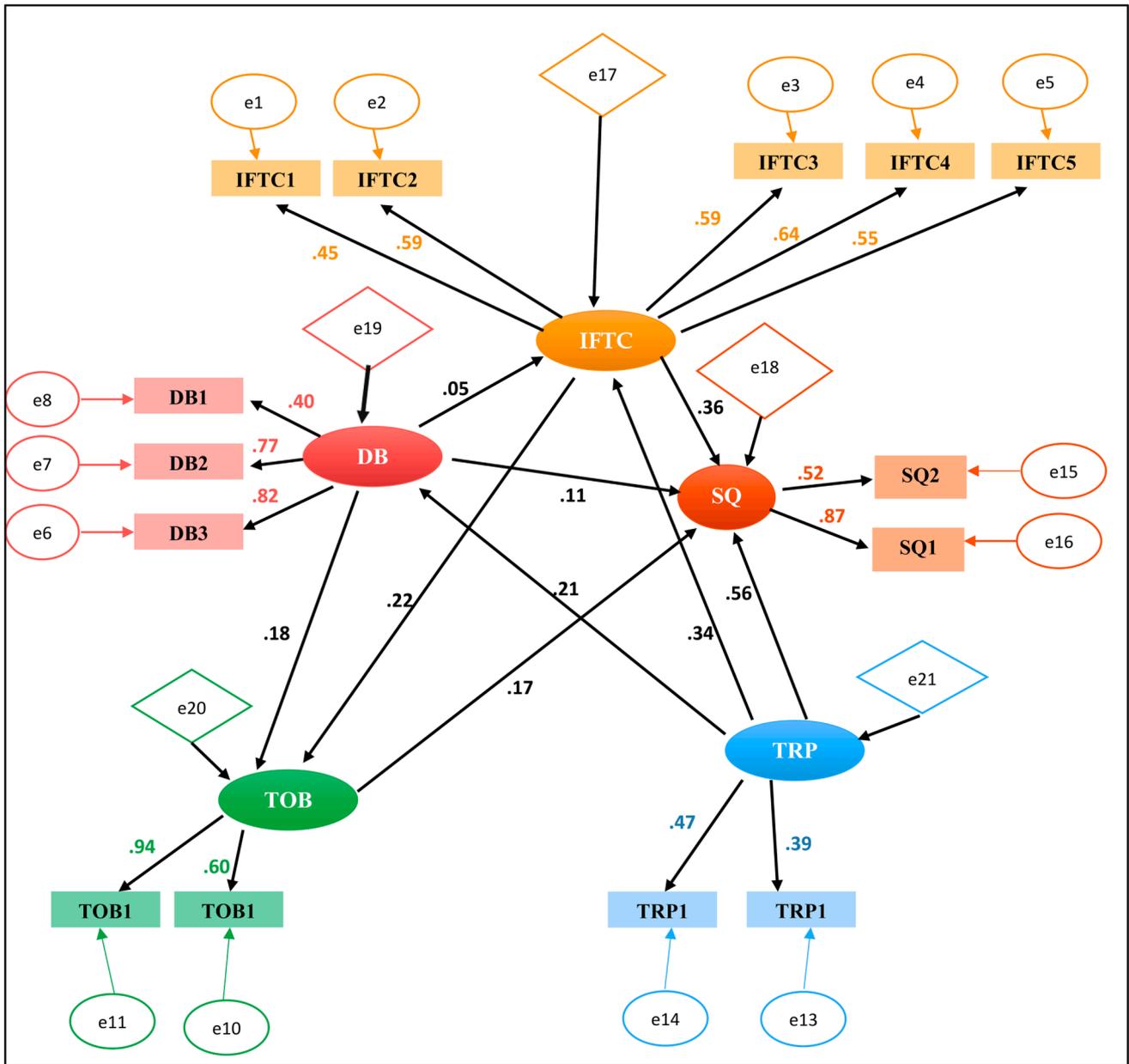
Fig. 6. Revised model.

1996; Wanisubut, 1989), 'dedicated lane follow by vehicle' (IFTC4) and 'presence of heavy vehicle' (IFTC5) (Bains et al., 2017; Obelheiro et al., 2011; Russo et al., 2010; Wanisubut, 1989) shows that these factors influence toll plaza operations. Crossing and paying the toll, the drivers on most Indian highways exhibit the unique tendency to do lane violations in this quest to join the tollbooth, which has the shortest queue to save time (Bari et al., 2022d). In doing so, they sometimes approach the ETC queue dedicated to the radio frequency identification (RFID) tagged vehicles and thus increasing the waiting time of the RFID-tagged vehicles also (Bari et al., 2022a; b; c). This is because the RFID-tagged vehicles are presently found to be less than fifteen percent, and thereby the ETC lanes are encroached upon by other vehicles. To address these issues, toll plaza management should consider the above factors while designing a toll plaza to improved users' perceived service quality. Management authority should strictly enforce users to follow a dedicated lane. At appropriate locations, fare values and informative signs should be displayed so that users can easily understand well in advance and be prepared to pay the toll. It is recommended that before one

kilometer of the toll plaza, the lanes should be marked by color codes to make separation of vehicles for fast tag lanes from mixed traffic based on their dedicated lane type. If users' waiting time in the queue' (IFTC3) increases at the toll plaza due to mixed traffic conditions and manual payment method, users start to feel discomfort and inconvenience, and this may effect on users' level of satisfaction for paying the toll. Hence, the provision of audio and integrating the same with social messages at toll plazas may relax drivers and thus make them feel at ease while waiting in the queues for manual payment.

H2 (driver's human behavior affects the service quality of toll plaza) was found to be significant in the revised model with an estimate of 0.11 ($P < 0.001$). Rong-Chang and Yi-Wen (2013) also reiterated that drivers' human behavior, such as education, age, and experience, influence the users perceived service quality at a signalized intersection. From the results, it is deduced that 'experience' (DB3) and 'age' (DB2) show higher correlations (0.82 and 0.77 respectively) with 'drivers' human behavior' (DB) as compared to 'education level' (DB1) (0.40).

H3 (tollbooth operators' behavior affects the service quality of toll

Table 7
Summary of Hypotheses as per revised SEM model.

Path	Standardized Estimate	Standard Error	C.R. (t-value)	Hypothesis Accepted/Rejected
LOS < IFTC	0.36	0.02	6.04	Accepted
LOS < DB	0.11	0.01	2.56	Accepted
LOS < TOB	0.17	0.01	4.48	Accepted
LOS < TRP	0.56	0.17	5.03	Accepted
IFTC < DB	0.05	0.02	1.14	Rejected
IFTC < TRP	0.34	0.27	4.38	Accepted
TOB < IFTC	0.22	0.05	6.41	Accepted
TOB < DB	0.18	0.03	5.60	Accepted
DB < TRP	−0.21	0.33	−3.40	Accepted

plaza) reveals a significant path with an estimate of 0.17 ($P < 0.001$), and these results are also in line with the study concluded by Obelheiro et al. (2011). 'Experienced service time' (TOB1) shows higher factor loading among all other indicators and their latent variables. Service time is the most influencing variable for toll plaza operations (Gordon and Newell, 1967; Klodzinski and Al-Deek, 2002; Russo et al., 2010), as the performance of tollbooths depends upon the service time. 'Courtesy' (TOB2) means how the tollbooth operator treats drivers while collecting the toll. 'Speed of payment method' (TOB3) may improve the capacity of tollbooths and reduce drivers' delay time (Al-Deek et al., 1998; Bains et al., 2017; Klodzinski and Al-Deek, 2002). Tollbooth operators' behavior is positively correlated with users' perceived service quality at the toll plaza. Therefore, toll plaza management should focus on improving tollbooth operators' behavior and skill to expedite the toll collection process from drivers (Bari et al. 2022e).

H4 (trip characteristics impact the service quality of toll plaza) is also significant, with an estimate of 0.57 ($P < 0.001$). Trip characteristics (TRP) show a higher correlation with service quality among all latent variables. Previous studies also illustrate that a correlation between trip characteristics such as frequency and purpose affects users' perceived service quality at the signalized intersection (Rong-Chang et al., 2013). 'Frequency of trips' (TRP1), 'purpose of trip' (TRP2), and 'type of payment method' (TRP3) are the indicators of trip characteristics in the present study. Among these indicators, 'type of payment' (TRP3) is found as an insignificant indicator, and so it has been removed in the revised model. Arguably it may happen due to the maximum number of users (more than 85%) using the manual method, and there is no variation obtained from drivers for this question.

Similarly, H5 (infrastructure and traffic characteristics affect tollbooth operator's behavior), H6 (trip characteristics influence the infrastructural and traffic characteristics), and H8 (driver's behavior influences tollbooth operator's behavior) are significant with estimates 0.22, 0.42 and 0.19 ($P < 0.001$) respectively. The causal relationship between TRP and IFTC depends on users' traveling frequency, trip purpose, and infrastructural and traffic characteristics present at the toll plaza. Further, 'drivers' human behavior' shows a positive relationship with tollbooth operators' behavior. 'Drivers' human behavior' depends upon age, education, and experience. For example, when comparing younger drivers (18 to 30 years) with older age drivers (above 50 years), younger drivers are found to be more aggressive and impatient (Rong-Chang and Yi-Wen, 2013). Generally, users with more years of experience have higher expectations about the quality of service provided at facilities Rong-Chang et al. (2013). While organizing exams for driving licenses, the driving license authority should emphasize on examining

and improving the driver's attitude towards the quality of services and their cooperation in toll plaza management.

H7 (trip characteristic bear on driver's human behavior) shows a significant path with a negative sign for an estimate (−0.21). The result shows 'trip characteristics' (TRP) negatively affect 'drivers behavior' (DB). About 85% of respondents are daily commuters having a higher expectation about facilities provided at toll plazas. Also, more than 73% of respondents' age is found to be below 40 years. Thus as mentioned in the literature, these younger users are normally more aggressive and impatient, so it delays tollbooth operation. Therefore, the causal relationship between TRP and DB may be negative. Toll plaza authorities should frequently conduct feedback surveys and consider the users' expectations to improve toll plaza operations. H9 (driver's human behavior has a direct effect on infrastructural and traffic characteristics) is rejected with estimates 0.05 ($P > 0.001$). However, a sign of coefficient between 'drivers human behavior' and 'infrastructural and traffic characteristics' is positive, which is the same as in the formulated hypothesis.

7. Conclusions

Gaining a better understanding of users' perception-based service quality at toll plazas will be useful in developing strategies for improving their service quality. Limited studies have attempted to estimate service quality at toll plazas based on users' perceptions under mixed traffic conditions. Thus, this study has attempted to analyze the users' perception about the service quality at manually operated toll plazas under mixed traffic conditions in India using SEM. From users' point of view, four interdisciplinary determinants of service quality, 'infrastructural and traffic characteristics' (IFTC), 'drivers' behavior' (DB), 'tollbooth operators' behavior' (TOB), and 'trip characteristics' (TRP) were selected to study interrelationships existing among these determinants and their impact on service quality. Out of these, 'drivers' behavior' (DB) and 'tollbooth operators' behavior' (TOB) are related to behavior science. Based on the literature review, a total of nine hypotheses were formulated among four determinants and service quality and thus, the measurement model was developed and examined by CFA. The outcomes of the final SEM model show that 'trip characteristics' (TRP) with a standardized regression weight of 0.56 influence service quality more than other remaining determinants. Moreover, it confirms that the 'drivers' behavior (DB)', 'infrastructural and traffic characteristics (IFTC)', 'trip characteristics (TRP)' and 'tollbooth operators' behavior (TOB)' positively influence service quality at toll plaza based on users' perception. Thus, these latent factors are examined and found to be significant for planning and designing toll plazas, especially for enhancing service quality at toll plazas. Therefore, the outcome of the present study provided new insights for toll plaza management and planners to understand and improve the users' perception of service quality at the toll plaza.

8. Implication of the present study

The literature points out that users' perceived service quality at toll plazas is a complex, multidimensional construct. Though various previous studies used different MOEs for estimating service quality at the toll plaza, there are limited studies on users' perception of service quality under mixed traffic conditions. Considering this aspect, an attempt has been made to analyze the users' perception of service quality at manually operated toll plazas under mixed traffic conditions in India. The results show that there is a multitude of factors such as 'infrastructural and traffic characteristics' (IFTC), 'drivers behavior' (DB), 'tollbooth operators behavior' (TOB), and 'trip characteristics' (TRP) have a positive impact on users perceived service quality at the toll plaza. Therefore, the outcome of the present study provided new insights for toll plaza management and planners to understand and improve the users' perception of service quality at the toll plaza.

Based on the results derived in the present study, it is obvious that infrastructural facilities and traffic characteristics (number of tollbooths, informative signs about fare values, dedicated lane followed by vehicles, and presence of heavy vehicles) directly affect the efficiency and service quality of the toll plaza. Hence, the outcome of this study should be considered and transformed for application at the toll plaza in the form of improvement in lane marking, display of toll rate at appropriate places before the toll plaza, and imposing penalties for the vehicles intruding on the FASTag lanes. Governments should promote automated payment methods at toll plazas or thus make it mandatory to fix RFID system on vehicles by automobile manufacturers or dealers. Concessionaires may offer concessions in toll payment and be aware of the users about benefits of RFID. RFID tags should easily be made available to users' through various public modes such as toll plazas, banks, post offices and online portals etc. Implementing this intelligent transport system will increase the throughput from the tollbooth and improve the operation efficiency of tollbooths. Drivers' personal characteristics (age, gender and experience) and tollbooth operators' behavior also impact users' perceived service quality. Therefore, management authority should improve the tollbooth operators' behavior and psychology by providing training to them at regular intervals. Tollbooths should have sufficient space for toll collectors with the comfortable arrangement of the computer system, printer, cash, fan, etc. While designing the cabins of toll collectors, a systematic ergonomic process should be considered to prevent musculoskeletal injuries and to improve human behavior, performance, and productivity of toll collection. It will reflect in operators working efficiency and be useful to improve service quality at the toll plaza.

Due to the increase in vehicle growth rate and highway infrastructural development, service quality is an essential property for performance evaluation of toll plazas, including functionality, recovery time, recovery cost, and redundancy. Functionality depends on the facilities provided by toll plaza management, such as 'number of tollbooths provided' (IFTC1), 'informative sign about fare values' (IFTC3), 'dedicated lane followed by vehicle' (IFTC4), 'payment method' (TRP3), 'experienced service time at tollbooth' (TOB1) and 'speed of payment method' (TOB3). Toll plaza planners may be assigned some reversible lanes during peak hours in each direction based on traffic demand will help improve redundancy (IFTC1) and users' perceived service quality.

9. Research limitation

In the future study, similar to users' perception, tollbooth operators' and management's perception should be studied to improve service quality at toll plazas. In fact, this study is limited to four toll plazas located in urban and rural areas in India. Researchers may accommodate more toll plazas so a better model can be developed in future studies. However, this present study paved a new way, yielding valuable insights into the relationships among IFTC, DB, TRP, TOB, and service quality to improve the performance of toll plazas.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cstp.2023.101053.

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