Toll Plaza & its Impact on Road User & Environment

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Abstract - *The present study intends to study and make a comparison between the manual & electronic systems of toll collection, by analyzing the wastage of fuel due to both systems.It also intends to study the effects of toll system on road user & environment.*

A case study at the 'KACHKOOT TOLL PLAZA' , J&K on NH 44 to analyse the objectives of the project including ,technology in use , time & fuel lost in delay at toll plaza, effect of toll plaza on road users & environment and suggestions and improvements needed .

Key Words: (Toll Plaza, ETC, FASTag, PCU, Fuel Wastage, Pollution, Passenger Car Unit, Cruising Speed)

1.INTRODUCTION

Highway toll plazas consist of a structure positioned on the highway, which forces drivers to reduce their velocity or completely stop to carry out a payment for the service provided by the plaza operator The toll road system has been historically accounted for the bulk of the financing of highway network. By building a toll roadway, it is possible to provide a number of improved services to the road users, which can be measured in order to ensure that they deliver the outcomes that are envisaged. Toll roads have been gaining popularity for more than a decade in India. A few years after the tollway projects are put into operational mode, they are expected see a lot of traffic every day comprising a variety of vehicles ranging from personal vehicles, light and heavy commercial to multi axle trucks and so on. As per the prescribed Government policy guidelines, toll fares are levied on most of the vehicles using toll road facility. It is important to provide good quality road infrastructure as well as other required amenities to the road users, with focus on enhancing the safety measures.The toll plazas are set up by the private developers for collecting toll from the vehicles passing through the toll road as part of the toll road contract agreement made with the Government.

As the owner, mostly the NHAI, is not conducting customer satisfaction surveys across all the toll stretches rigorously, these kinds of studies can help the authorities to take appropriate actions. It also enables the citizens to provide feedback about the poor condition of the road system and penalize the developers for not maintaining consistence performance.

Today, due to the increase in the number of vehicles with increasing population, there is a lot of gathering of the traffic at the toll booths. The main reason for this traffic at the toll booths is due to the manual working of the toll tax collection at the booths. Each vehicle on an average needs to stop at the tool booth for about a minute for the payment of the toll tax. In order to decrease this traffic, we decided to work on the construction of a project which reduces the manual work and hence increases the vehicle speed passing by the toll booth.

Toll plaza operations in India are entirely different from that of the United States (US) and European countries. The majority of tollbooths in India now are electronically operated, as earlier they were manually operated where all the vehicles arriving at the toll plaza have to stop at tollbooth to pay the toll. During this process, a vehicle first decelerates, joins the queue and pays the toll at tollbooths. Afterwards, the vehicle accelerates and regains the stream speed. The overall process causes delay to each approaching vehicle due to deceleration, waiting time in the queue, service time at the tollbooth and finally due to acceleration. Hence, the present study aims to quantify the overall delay that includes system delay (service time and waiting time),acceleration and deceleration delays at toll plazas under mixed traffic conditions under ETC & Manual mode of toll collection.

The toll plaza under our case study is 'KACHKOOT TOLL PLAZA' located on NH44 Srinagar –Jammu National highway. The Highway is only source of road connectivity of the area with the rest of the country India.

1.1 METHODOLOGY

Before The present era is experiencing a fast degradation of non-renewable resources in terms of fossil fuel.As the primary energy source, the continuous use of fossil-based fuels not only led the world to a severe condition of fuel crisis but also offers another primary concern of environmental degradation. The continued exhaustion of fossil-based fuel also resulted in a subsequent upsurge of exhaust gasses and emerged as a major factor for global warming .

Researchers are putting effort all over the globe to save any potential wastage of fossil based fuels. This study presents an assessment of fuel wastage due to vehicle idling at road toll that can aid in finding solutions for restricting the fuel wastage.

In the present study for analysis of fuel wastage,various assumptions were made as;

1) All the vehicles were considered to be of similar types of passenger vehicles & converted into passenger car units (PCU).

2) The fuel efficiency of the vehicles (fe) was assumed as constant 16 km/L.

3) The average vehicular cruising speed in non-idling conditions (vs) was assumed as 60 km/h) The vehicle engine assumed to be remained on during idling conditions throughout the waiting time.

4) Several observations were made at toll booth, and their mean values were considered for calculating the average waiting time for a vehicle in a queue at toll

5) (qµ), and length of the queue in meter which was considered from the point when vehicles start retarding on approaching side of toll plaza to the point where vehicles gain normal cruising speed (qL), in toll booth.

The approximate total number of vehicles passing per day at the tolls (Tv) was retrieved from the National Highways Authority of India (Toll Information system, 2017).

For estimations of fuel consumption with vehicle idling at tolls and savings of fuel when no tolls were present, average fuel consumed per hour by passenger vehicle in an idling condition (ct) was calculated which was used to determine the fuel consumption of each of the vehicle while idling in the queues at toll (cq), and fuel consumption of each vehicle if there was no toll (cn).

If no tolls are present, average fuel saved per vehicle(sv), total fuel saved per day (sd), and total fuel saving per year (sy), were assessed. It was assumed that fuel efficiency (fe) was16 km per liter, and average vehicular cruising speed (vs) was 60 km per hour, so average fuel consumption for a vehicle per hour, considering vehicle was running at assumed speed throughout the hour became 3.75 liters per hour. According to Tong *et al.* (2000), in their defined conditions, for a passenger vehicle, the fuel consumption rate while cruising the vehicle is 39.10 gram per km, and at idling, the condition is 18.11 gram per km. It can be deduced from the results of Tong *et al.* (2000) that idling condition fuel consumption is 46.32 percent of the fuel consumption in the cruising conditions.

If not considering the fuel consumption rates at accelerating and decelerating conditions of vehicles, the average fuel consumption for a passenger vehicle at idling condition (ct) will be 46.32 % of the cruising speed condition making ct equals to 1.737 liters per hour. With the provided assumptions, fuel consumed per vehicle while the vehicle is in the queue at the toll (cq) was calculated in liter as the product of the average waiting time of the vehicle and average fuel consumption for a vehicle per hour in idling condition using Eq. 1.

$$cq = q\mu \times ct \quad \ldots\ldots \quad (1)$$

Total fuel consumed per vehicle in litre if no tolls were present (cn) was calculated as the ratio of the length of the road where the queue was there to fuel efficiency of the vehicle using Eq. 2.

$$cn = qL \,/\, fe \quad \ldots\ldots \quad (2)$$

Through, Eqs. 1 and 2, the total fuel saved per vehicle (sv) in litre was calculated as the difference of the fuel consumed while a vehicle has to go in the queue if the toll was present to the fuel consumed by the vehicle if no toll was present, using Eq. 3.

$$sv = cq - cn \quad \ldots\ldots \ (3)$$

Through Eq. 3, total fuel that can be saved in litre at each of the tolls was calculated as the product of total fuel saved per vehicle and the total number of

vehicles passing through each of the tolls per day, using Eq. 4. The outcome was multiplied with 365 to get the total fuel that can be saved over the toll booths in a year, using Eqs. 5.

$$sd = sv \times Tv \quad \ldots\ldots \ (4)$$

$$sy = sd \times 365 \quad \ldots\ldots (5)$$

Using the equations (4) and (5), total fuel costs that can be saved per day and per year, if no toll was present, can be calculated by multiplying **sd** and **sy** with the fuel price per liter, respectively.

For designing any major highway project all the vehicles are considedred to be of similar types of passenger vehicles also called passenger car unit (pcu).

2. Manual Toll Collection

Manual toll collection was most widely used collection method in India. It requires a toll collector or attendant. Based on the vehicle classification, cash toll is received by the collector. The collector, who also dispenses change, may accept and sell scrip, tickets, coupons, making an entry of the vehicle in the system and issuing receipt to the patron . Due to manual intervention, the processing time is highest.

2. Electronic Toll Collection

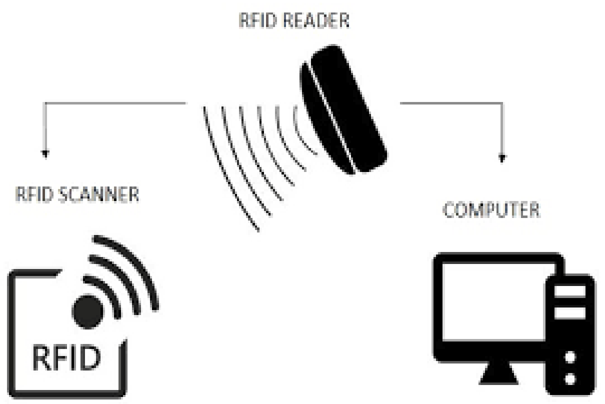
Electronic Toll Collection (ETC) is a system that automatically identifies a vehicle equipped with a valid encoded data tag or transponder as it moves through a toll lane or checkpoint. The ETC system then posts a debit or charge to a patron's account, without the patron having to stop to pay the toll. ETC increases the lane throughput because vehicles need not stop to pay the toll.

2.1. Electronic Toll Collection by using FASTag

FASTag is a simple reloadable tag which allows for automatic deduction of toll charges without having to stop at the toll plazas for making the payments. This tag is affixed on the vehicle's windscreen and works on the Radiofrequency Identification (RFID) technology.

Initially set up as a pilot project on the stretch of the Golden 26 Quadrilateral between Ahmedabad and Mumbai in 2014, the system was implemented on the Delhi-Mumbai arm of the Quadrilateral on 4 November 2014(Joshi, 2017).

At present, FASTag is operational at 240+ toll plazas across National Highways. The customer must visit any of the Point of Sale (POS) locations at Toll Plazas / Issuer Agency to get his FASTag account created by paying a onetime fee of ₹ 200. FASTag account is procured by making a payment through cheque or online through Credit Card/ Debit Card/ NEFT/ RTGS or through Net Banking. FASTag account can be recharged upto Rs. 1,00,000.00 (Rupees One Lac only). Users can drive their vehicles through the FASTag lanes at the toll plaza's after recharging their FASTag accounts and the toll amount will be automatically deducted from their account.



3. Calculations

From the data collected from NHAI from april 11, 2021 to april 20, 2021.It was calculated that an average of 19043 pessenger car units passed the toll plaza daily by taking some assumptions in order to simplify calculations.

At the site of toll plaza we took a refernce point at nearly 50 m from the toll both on each side.At this point the vehicles start to decelrate when approaching toll plaza to diverge into the different queues of toll plaza i.e, the point where queuing starts.

When the vehicles cross the toll plaza there comes a point where the vehicles start gaining cruising speed and merge into two lanes of the highway the point is also at nearly 50 m distance from the toll booths.

That means we took a stretch of 100 m along the road with toll booth at its centre .This stretch of 100 m we will be assuming as queue length.

As there was no hourly data available so we had to take the average for whole day.

3.1 In Case of ETC

For the vehicles with fastag installed average time taken to cross this stretch of 100m taking the average of peak(38 s) and normal(21.5 s) traffic values came to be 29.5 seconds ~~which we will be taking as 30 seconds to cover up errors and simplify calculations

Assuming cruising speed of 60 kmph i.e, 3.7 litres per hour.

Fuel consumed per km in cruising condition = 39.10 g/km

Fuel consumed in idling condition = 18.11 g /km

Neglecting acceleration/ deceleration at toll plaza we take idling condition at toll plaza

$$Cq = Qu * Ct$$

If no toll plaza is present

$$Cn = Ql / Fc$$

$$=0.1km/16 (km\backslash h)$$

$$=0.00625$$

Fuel consumed = 6.25 ml

In the presence of toll plaza

$$Cq = Qu * Ct$$

$$Cq = 30/3600 * 1.737 = 0.014475 \text{ litres}$$

where Qu is waiting time in queue i.e 30 seconds

Hence Cq = 14 ml.

Fuel wasted per vehicle due to presence of toll

$$= Cq – Cn$$

$$= 14 – 6.25$$

$$=7.25 \text{ ml}$$

Hence 7.25 ml of fuel are wasted per vehicle due to presence of toll plaza.

Fuel wasted per day due to presence of toll plaza=

= no. Of pcu crossing toll per day * fuel lost per vehicle (with pcu value of 1)

=19043(pcu) * 7.75 ml

=147583.25 ml

=147 litres per day

Hence on an average 147 litres of fuel are wasted per day due to presence of toll plaza.

Fuel wasted per year =

= 147 * 365

= 53655 litres

Hence 53655 litres of fuel are wasted per year due to presence of toll plaza in case of ETC.

3.2 In Manual System

Average time taken was found 44 seconds which we will be taking 45 seconds for calculations & including various errors.

Fuel consumed per vehicle for 100 m span of toll

=45/3600 * 1.737

=21.7 ml = 22ml

Fuel lost per vehicle

=22-6.25

=15.75 ml

Fuel lost per day =

=19043 * 15.75

=300 litres

Fuel wasted per year =

=300 * 365

=109500 litres

Hence 300 litres of fuel are wasted daily in presence of toll plaza under manual collection of toll

And an average of 109500 litres are wasted yearly at toll a single toll plaza by manual method.

4. Effects on Road User & Environment

As deduced from calculations above calculations a huge quantity of fuel is wasted at a single toll plaza due to waiting time and various delays during the toll payment process. In india there are more than 1000 toll gates ,so one can imagine the loss at all these toll gates per day & yearly. According to a Times of India article fuel ,time worth 12000 crore wasted at toll plaza's yearly.

Despite loss of fuel commuters are made to pay hefty amounts for using highways. According to NHAI total collection on national highways stood at Rs 26851 crore during 2019-20.Which is said to grow 14-15 % during 2020-21.

Also due to huge amount of traffic there is a greater amount of both air pollution as well as noise pollution at the toll plaza's .Vehicular pollution contributes a major part of overall air pollution.The main pollutants emitted from automobiles are hydrocarbons,lead/benzene,carbon monoxide ,sulphur dioxide, nitrogen dioxide and particulate matter .Majority of the emission gases are harmful to humans & may cause several diseases in the personals who have prolonged exposure to them.

Among different types of vehicles, Trucks and Lorries contribute 28.8% CO_2 (70.29 Tg), 39% NO_x (0.86 Tg), 27.3% SO_2 (0.19 Tg) and 25% PM (0.03 Tg), which constitute 25% of the total vehicular emission of India.

Similarly, two-wheelers are a major source of CO (0.72 Tg; 23.7%), CH_4 (0.06 Tg; 46.4%), and HC (0.46 Tg; 64.2%) and buses are emitting NO_x (0.68 Tg; 30.7%) and PM (0.03 Tg; 20.5%). Vehicular emissions vary with type, efficiency and the type of fuel used.

Emission analysis based on the vehicle type reveals that bus and Omnibuses contribute higher CO_2 (CO_2: 96.5%, NO_x: 2.28%) compared to two-wheelers (CO_2: 86.8%, CO: 7.18%, HC: 4.6%).

Passenger light motor vehicles (CO_2: 86.8%, CO: 7.6%, NO_x: 1.9%), cars and jeeps (CO_2: 98.8%), taxi

(CO_2: 94.6%, SO_2: 4.68%), Trucks and Lorries (CO_2: 97.6%, NO_x: 1.2%), goods light motor vehicles (CO_2: 98.4%), and trailers and tractors (CO_2: 98.4%) is different (CPCB, 2010).

5. CONCLUSIONS

As deduced from the calculations that nearly 147 litres of fuel are wasted daily at the toll plaza under study in case of ETC and 300 litres are wasted daily if the mode of toll collection is manual.

Hence 53655 litres of fuel are wasted per year due to presence of toll plaza due to ETC system, and an average of 109500 litres are wasted yearly at toll a single toll booth by manual method.

Although ETC system has removed the limitations of Manual Toll Collection system to some extent but still there is a lot of work needed to be done to reduce these losses e.g, adopting GPS toll collection system which is more logical than the present systems.

Also a lot of time is wasted daily at the toll booths .The reason being that vehicles need to stop to pay the toll causing a wastage in fuel as well as pollution due to very congested condition at the toll plaza's .

Due to the emission from vehicles the concentration of harmful gases is very high at the toll plaza's which is harmful for all the people working at toll plaza as well as commuters and locality.

Hence the need of the hour is to adopt a toll collection system which does not require the vehicles to stop at a particular spot to pay the toll taxes,which will avoid various losses incurred in present system and as well as curtail to a greater extent the ill effects of them on road user and environment.

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