Traffic Congestion at Toll Plaza: A Case Study of Khed-Shivapur, Pune

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Abstract - *Khed-Shivapur toll plaza is one of the four toll plazas on National Highway 4 in Maharashtra state, which also happens to be the busiest amongst all. This study analyses current reasons for congestion and provides solutions for the same. The delay and queue is mainly due to two different charging methods namely known as 'Manual Toll Collection (MTC)' and 'Electronic Toll Collection (ETC)'. At this toll plaza, all the lanes are having mixed lane system that is both MTC and ETC vehicles pass through the same lane. Furthermore, with the help of data collected and visual on-site survey, some additional causes for the traffic congestion were noticed. Considering all of these causes, this paper suggests various solutions to these problems. It was found out from the traffic volumes that the toll booth capacity and type of toll service have influence on traffic operation and the efficiency of the toll plaza. Based on the flaws which were observed on the Khed-Shivapur Toll Site, some recommended configurations for different traffic conditions and setup for toll plaza is proposed. This research provides a useful reference for management and decision making.*

Key Words: Electronic toll collection (ETC), Radio-Frequency Identification System (RFID), Traffic congestion, FASTag, Khed-Shivapur toll plaza, National Highway 4

1. INTRODUCTION

Urban Transportation in India with large scale and high speed development has entered a new century. Rapid urbanization and motor vehicle numbers is forcing urban traffic to face new challenges and the road traffic safety problem becomes prominent. Hence it is considered to be important content of the urban traffic safety management which include the scientific and rational planning of the traffic congestion, accidents and fuel consumption, etc. and to improve the urban road traffic safety levels. Electronic tolling system is an automated system in which toll charge is collected from user's bank account, when he passes through the toll gate. Electronic tolling collection (ETC) was introduced in India in year 2014 for the golden quadrilateral project at Ahmedabad. The purpose of electronic tolling is to avoid congestion and provide cashless pass through for vehicles. Major objectives of ETC are making toll collection hassle free and with less man power. There are four types of toll lane which are Manual toll lane, electronic toll lane, express electronic lane and mixed lane (both manual and electronic toll cars are allowed in this lane).

Intelligent transportation system is the modern adaption of traffic managing software and wireless technology. India is one of the fastest developing nations in the world today. Road transportation has been a primary choice nowadays. The number of vehicles in last 21 years has grown rapidly massive. Most toll plazas in India are manually operated. The average waiting time in this manually operated toll plaza is more than 10 minutes [urban mobility information (2015)] which costs a lot of fuel and time wastage. The improvement of the manual toll collection system becomes necessary. Radio Frequency Identification is unique Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information that charges user electronically. RFID tags are installed on the front glass of every vehicle according to the height of vehicle. A frequency identifying camera is placed over the toll lane. When a vehicle with RFID tag passes, the scanner scans the bar code which is unique for every user leads to automated deduction of toll amount. The sensors and cameras provided on the lanes scans the RFID and deducts the amount directly from an account, such as a credit card or debit card, whichever is connected to our electronic pass.

1.1 Literature Review

"Automatic Toll E-Ticketing System For Transportation Systems (2015) by Sana Said Al-Ghawi Lecturer Middle East College Knowledge oasis Muscat, Sultanate of Oman et. Al.", now a days most of the highway toll plazas are manually operated, where an operator collects cash from the driver and provides a receipt. This paper provides a low cost and efficient method called Electronic Toll Collection (ETC) using RFID modules that collects the toll electronically from the vehicles when they pass through the toll plaza. Owner has a prepaid account through which the toll is deducted automatically. If the owner does not have balance in the account or if the vehicle is not equipped with a RF system, the toll gate remains closed. In such a case vehicle owner will have to pay the toll in cash. The owner receives a message on his mobile about the details of the payment and there is no need to stop the vehicle. How many vehicles passing through the toll gate is stored in a database. A software program is designed on computer retrieves vehicle details from its vehicle database. Based on

this information, appropriate toll tax is deducted from the pre-paid account of the vehicle's owners. The improvement can be done to develop a multi vehicle amount deduction and send SMS to all vehicles.
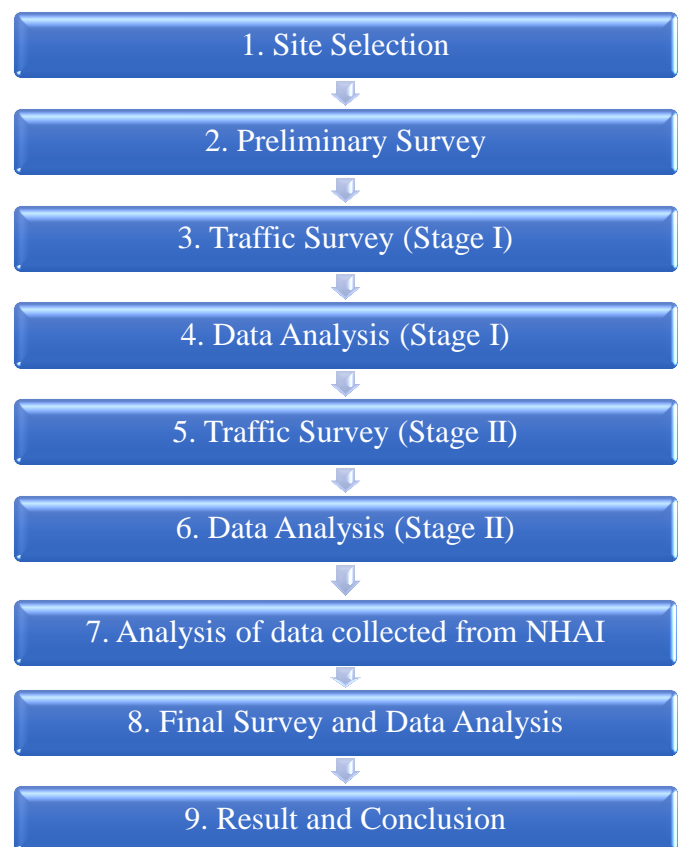
"Subhankar Chattoraj - Department of Electronics and Communication Engineering Techno India University Kolkata, India et. Al - Design and Implementation of Low Cost Electronic Toll Collection System in India (2016)", Manual toll systems in India are present everywhere nowadays. This paper gives a new approach illustrating an electronic toll collection (ETC) system which will accomplish the goal of electronic toll payment. This technique makes use of Radio frequency identification (RFID) based smart card which is used for self-payment services. The Optical Character Recognition system plays a key role in helping the enforcement department for vehicle licence plate identification. The ETC system is a unique system which is totally automated and cost effective. The use of RFID based smart card decreases the overall cost of this system. On implementation of this system the revenue generated will be higher than the manually operated system as it does not require hiring labours for toll collection. This will also be helpful in rapid decrease in traffic congestion.

"Operational benefits of electronic toll collection by H. M. Al-Deek, A. A. Mohamed and A. E. Radwan (2010)", Traffic congestion is experienced every day by many travellers on urban and suburban highways in the United States. The technological revolution called intelligent transportation systems (ITS) is a method that can overcome this problem. Within ITS, the electronic toll collection (ETC) system which utilizes automatic vehicle identification (AVI) technology to improve efficiency of toll collection. The AVI technology has the ability to identify vehicles as they move through toll lanes. AVI works with the help of wireless communications between a tag (transponder) on a vehicle and an (sensor) located at the lane side. The sensor transmits short pulsed signals repeatedly to the transponder and receives back a modified signal carrying the vehicle's identification. The toll plaza lanes were classified as one of the following lane types: manual toll lane, mixed AVI lane, where AVI is installed on a manual lane, an automatic lane, or both, dedicated AVI lane that permits AVI patrons only. Express AVI lane permits free-flow speed up to 88 km/h. The increase in throughput in the E-PASS lane could not be attributed to normal growth in traffic demand at the plaza, but was caused by introducing the dedicated AVI lanes and traffic shifting to these E-PASS lanes from the mixed lanes.

"Freeway Traffic State Estimation and Prediction Based on ETC-Based Path Identification Toll System (2017) by Wenliang Zhang, Xinkai Ji, Jian Zhang and Shanglu He. Traffic data collection is very important in the field of traffic engineering research, and related research achievements cannot meet the traffic management. There

are disadvantages like high cost of input and usage, difficult installations, and low coverage for special traffic detectors. Electronic toll collection systems are useful on freeway toll, and also it provides a new resource for the extraction of freeway traffic state. In this paper, a method of estimating traffic volume of road sections and the average travel time is proposed by processing the path information and toll data in the system. Author has used ETC data in Tianjin to compare freeway traffic flow characteristics between holidays, weekends, and working days. Author has proposed a theoretical method to obtain traffic flow parameters of a certain time and certain section by using toll data, and verified this method by the flow-speed model. As a result, the prediction result calculation showed that the average percentage error was 9.2%. It was also taken into consideration that the accuracy of this estimation and prediction method is related to the layout density of the identification stations. The higher the density is, higher accuracy will be. If the proportion of ETC vehicles to all vehicles is higher, the accuracy also will be higher.

1.2 METHODOLOGY

1. Site Selection
2. Preliminary Survey
3. Traffic Survey (Stage I)
4. Data Analysis (Stage I)
5. Traffic Survey (Stage II)
6. Data Analysis (Stage II)
7. Analysis of data collected from NHAI
8. Final Survey and Data Analysis
9. Result and Conclusion

1.2.1. Site selection

The site was selected by collecting information of two of the toll plazas i)Khed-Shivapur Toll Plaza ii)Mumbai-Pune Bypass Highway Toll Plaza. The traffic characteristic variation of the two plazas was very different, the traffic congestion problem at Mumbai-Pune bypass highway toll

plaza was little less concerning as compared to the traffic congestion problem at Khed-Shivapur.

1.2.2. Preliminary survey

The daily traffic flow of the Khed-Shivapur Toll plaza was obtained by the discussion with the authority in charge at the site and National Highway Authority of India (NHAI) official website. The geographic location of the toll plaza was obtained with the help of google maps.

1.2.3. Traffic survey (stage I)

This survey was an initial step in total observations recorded. In this, the traffic survey was done with the help of different resources. Various official websites such as website of Ministry of Transportation, Government of India and National Highway Authorities of India posted annual traffic details. These records were taken into consideration for stage l survey.

1.2.4. Data Analysis (stage I)

Data collected from stage I traffic survey was analysed for initial traffic congestion causes. Information on various websites was vast and useful data was extracted from the whole information.

1.2.5. Traffic survey (stage II)

This survey was more detailed than stage I survey. For this survey, time was recorded on site. In this, time taken by a vehicle to move from its spot as its preceding vehicle moves to barrier opening again. It is called as saturation headway. Vehicles were classified according to their type such as cars, HCVs, Multi-Axel trucks etc.

1.2.6. Data Analysis (Stage II)

Time recorded in the stage II survey was tabulated and was analysed. According to the type and length of vehicle, results are compared to various standards and regulations. Primary causes were highlighted through this survey.

1.2.7. Analysis of data collected from NHAI

National Highway Authorities of India (NHAI) is a government approved body for control of construction and maintenance of highways in India. Data received from NHAI was fairly detailed and was of duration of one month. Data was collected everyday throughout the month. This data was analysed to increase the accuracy of primary causes of congestion and to find more causes.

1.2.8. Final survey and data analysis

Final traffic survey will be conducted for a week starting from Monday morning till Sunday night. Vehicular traffic load for various lanes for various durations of day will be recorded. This data will be analysed for patterns and

common defects observed in all surveys and to come up with plausible solutions.

1.3 DATA COLLECTION AND ANALYSIS

Following data was collected during stage I traffic survey, in which survey was done on three days of the week (Monday, Wednesday, Saturday) out of which the traffic congestion problem was most severe during the week. So data of that day was considered for the analysis. Table I shows the average saturation headway (Minimum time interval for vehicle to pass similar segment) for Saturday from 08:00 AM to 08:00 PM.

Table -1: Average Saturation Headway

Lane No.	Time	Cars	LCVs	HCVs
Lane 1	07:00 to 07:30 AM	20.02	29.67	28.67
	07:30 to 08:00 AM	19.89	31.43	38.50
	08:00 to 08:30 AM	26.59	22.33	31.50
	08:30 to 09:00 AM	28.83	00.00	25.00
Lane 2	09:00 to 09:30 AM	24.21	24.89	34.67
	09:30 to 10:00 AM	21.14	27.00	38.25
	10:00 to 10:30 AM	22.93	26.00	29.57
	10:30 to 11:00 AM	20.21	33.33	35.80
Lane 3	12:00 to 12:30 PM	27.41	25.50	39.11
	12:30 to 01:00 PM	20.76	27.88	36.83
	01:00 to 01:30 PM	23.09	30.57	34.33
	01:30 to 02:00 PM	34.29	24.50	35.47
Lane 4	02:00 to 02:30 PM	28.19	18.58	38.00
	02:30 to 03:00 PM	20.26	28.33	43.37
	03:00 to 03:30 PM	24.00	27.08	24.49
	03:30 to 04:00 PM	28.63	20.9	28.82
Lane 5	05:00 to 05:30 PM	29.36	29.13	40.28
	05:30 to 06:00 PM	31.57	32.63	41.45
	06:00 to 06:30 PM	26.42	28.53	28.86
	06:30 to 07:00 PM	25.35	26.00	30.54
Lane 6	07:00 to 07:30 PM	30.32	30.40	37.00
	07:30 to 08:00 PM	30.89	32.64	40.35
	08:00 to 08:30 PM	27.71	31.64	30.35
	08:30 to 09:00 PM	30.58	28.50	35.94

From the above analysis, it has been observed that FASTag vehicles which were promised for faster passage through the toll lanes which is not followed currently resulting in delay for the owners. Even though lanes are distributed according to the type of vehicles, it has been observed that the passengers don't follow the lane disciplines which results in traffic congestion during peak hours. The Saturation Headway of HCVs (Heavy Commercial Vehicle) is more as compared to cars and LCVs. They should be

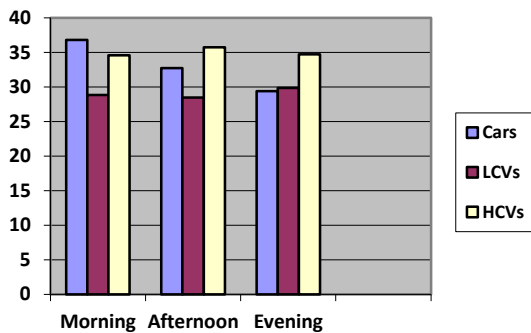provided with more exclusive lanes than others and provisions should be improved.

Chart -1: Average Duration as Per Type of Vehicle

3. CONCLUSIONS

The whole idea of this project is to identify and overcome the factors accounting for traffic congestion at the Khed-Shivapur toll plaza. Over the course of project completion, various surveys were conducted both offline and online (from authorised sources) for gathering information about saturation headway for different type of vehicle. According to analysis of visual survey following problems were observed which were mainly causing the delay and forming traffic congestion:

i. Mixed Lanes: Mixed lanes are the lanes at a toll plaza which allows both Manual tolling vehicles and automated tolling vehicles to pass through. At Khed-Shivapur toll plaza, all lanes are mixed lanes. This was the prime reasons causing delay of FASTag vehicles which increases the load on toll booths resulting in congestion. So it is essential to provide dedicated lane exclusive for FASTag vehicles.

Fig -1: Khed-Shivapur Toll Plaza Showing Mixed Lanes

ii. Lack of display boards: Vehicles which travels at high speed approaching at the toll plaza, it is not possible for a short distance to switch the lanes at that speed. National Highway 48 is a six-lane divided Highway and vehicles travel in all three lanes with a speed limit of 80 KMPH. Such huge speed causes problem to change the lane rapidly, this results in vehicles entering the wrong lane which is not allocated for them. This may look like a small issue but during peak hours it is a concerning congestion causing factor.

Fig -2: Lack of Display Boards at Khed-Shivapur Toll Plaza

iii. Manual Corrections: For manual tolling vehicles, toll staff collect the cash from vehicles, give a computer generated receipt, and allow the vehicle to pass. As one can see, the staff is a vital part in this process. During the conversation with the toll authorities it was observed that co-ordination of the staff was not effective creating chaos at the booths affecting the saturation headway. However this observation is practical and is up to individual's correction.

iv. Toll exemption IDs: Government vehicles are excluded from the toll duty for using the highway. However at Khed-Shivapur toll plaza, many of the consumers argue at the booths for a free passage by flashing their IDs and other issues. This adds the waiting time for other vehicles in same lane which also causes congestion but for a quite lesser time period.

These factors along with some minor factors cause the traffic congestion. After a brief study, most plausible solutions are recommended to these problems which will certainly reduce the load on toll plaza and traffic congestion. Solutions for the problems   mentioned   are applied to various toll plazas in various parts of the world and are checked for all the errors. Following are the solutions provided for the problems studied in detailed in final   survey:

i. Dedicated segregation of Lanes: Khed-Shivapur toll plaza has 6 lanes in the direction of Pune, all of which have a working toll booth. Problem with all the lanes is that these lanes are mixed lanes which allows all type of vehicle with all toll paying systems. Dedicated segregation of lanes is a system in which specific type of vehicle with specific toll payment system is allowed through the defined lane.

ii. Provision of Signs and boards: Provision of digital sign-boards for lanes should be done so that lanes can be switched for different purposes. For example, if number of trucks increases then a car lane or LCV lane can be shifted to truck lane which will reduce the saturation headway for trucks.

iii. Pre-tolling (online and offline): This concept of pre-tolling is pioneering. In this, owners can pay the toll before passing the toll plaza. It could be done on both online platform and offline platform. In online platform, owner can pay on website or app according to his vehicle type and design destination. In offline platform, owner can buy the toll ticket at a restaurant, food mall or petrol pumps at least 1 KM prior to toll plaza. These vehicles are allowed through the unobstructed lane which is there for local vehicles.

iv. Strict policies: Although toll plazas are provided with many rules and regulation, many of the owners don't follow it. Strict punishments and fines should be implemented so that rules will be followed.

From table No. 1, the top three maximum average saturation headway are highlighted according to the type of vehicle. It is observed that between 05:30 to 06:00 PM, the average saturation headway of all three types of vehicles is maximum and between 07:30 to 08:00 PM the average saturation headway is maximum for Cars and LCVs. This is the critical time periods in which maximum traffic congestion is observed by all types of vehicles. Hence, in order to overcome this situation at the Khed-Shivapur Toll plaza, it is recommended to allocate more number of staff between 05:30 to 06:00 PM and 07:30 to 08:00 PM time period to handle such huge traffic load, so that the problem of traffic congestion on these time period shall be reduced.

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