Traffic Decongestion in Toll Plaza using Electronic Toll Collection

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ABSTRACT

The focus of this paper is to disclose some of the proposals to minimize the traffic congestion encountered in the toll plazas by optimizing the toll collection method using technological advancements. A mobile application is used as a user interactive tool for toll payment and also lets user to predict the traffic situation at the toll plaza. Collection of toll fee manually involves more of human labour and very slow. It also affects the toll gate revenue. The prime objective being to minimize the waiting time of the user and also help evade fare dodging to a higher level. The proposed system will have a mobile application as a feature to reserve toll tickets. The number plate recognition mechanism uses high sensitive cameras to capture number plate images and retrieve the vehicle number information and sends to a server. This data will be used to allow the vehicle enter the toll plaza. The collected data may be maintained in the server so that it can be used to trace vehicles when needed.

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INTRODUCTION

Toll way or Toll road is a roadway maintained either by public or private firms, for which a fees is levied to pass through it. The fee is collected to recover the total cost outlay which is spent for construction, maintenance, toll operation and for the repair works carried out. The toll gate is an entrance for the toll roads. The toll roads reduce the travel time and also increase the level of service. Most of the highway projects are given on PPP basis, i.e. Public Private Partnership. The toll is collected for a certain period of time after which the facility is surrendered to the public. Usually, toll fee is being charged for vehicle parking in the urban centers so as to decongest the streets without traffic and reduce the pollution levels. This methodology is known as Congestion Pricing (Haresh, G., et al., 2013). Toll collection is done either manually or automatically. In some cases Electronic toll collection is also done.

Manual toll collection is most widely used method which involves toll collector to collect toll fee. A ticket or slip may be issued in exchange to the fee collected. Due to manual processing the time taken is highest. In automated method, automated kiosks are being placed to dispense the ticket. This method of toll collection takes relatively less time than the previous method. Electronic Toll Collection (ETC) is a system that automatically identifies a vehicle outfitted with a valid encoded data tag or transponder as it moves through a toll lane or checkpoint. The ETC system then posts a deduction or charge to a user’s account, without the user having to stop to pay the fee in toll plaza. ETC increases the track throughput because vehicles need not stop to pay the toll.

The implementation of toll plaza normally has to consider many factors. Few of the factors that have to be considered are: (a) Throughput: It is the number of vehicles passing through the toll plaza over a short period of time, usually 1 hour (Richter Opoku – Boahen, et al., 2013). (b) Demand: It is the sum of throughput and the number of vehicles queued up at the toll plaza during 1 hour. (c) Processing Time: It is the difference among the moment a vehicle leaves and the instance when it enters the toll plaza. The entry time is taken from the moment a vehicle leaves in the queue. (d) Queuing Area: It is the area of the toll plaza where the number of lanes of arriving vehicles increases from the number of traffic lanes on highway to the number of tollbooths. The vehicles line up in this area to make the toll disbursement. (e) Merging Area: It is the spot of the toll plaza where the total number of tracks of retiring vehicles shrinks to the number of number of lanes on main road. The vehicles have to merge with other vehicles in this...
Insight into Existing System:

In manual toll collection method, toll collection rate depends upon the toll collector’s efficiency. This introduces considerable waiting time to the user. When there are multiple toll booths between starting and target location, waiting at every toll plaza further increases the journey time. There might be huge crowd expected during festive time and a novel method have to be adopted to tackle traffic congestion. The existing system does not have any special provision or dedicated lane for emergency vehicles like ambulance. This problem is to be addressed with utmost care so that human values are preserved. Almost all of the existing toll system does not have a provision to intimate the users about the traffic situation in advance. In such case the user might plan his traffic accordingly to evade traffic congestion.

After careful study of all insight into the existing system a system is suggested to redress most of the problems. Optimizing the toll plaza electronically may provide a better solution to cater all the problems to the most extent.

Electronic toll collection (ETC) aims to remove the delay on toll roads by collecting fees electronically. ETC determines whether the vehicles fleeting are registered in the program, alerts enforcers for those that are not, and electronically debits the accounts of registered vehicles so that owners need not stop to pay the toll fee. The main endeavor is to minimize the traffic congestion in toll gate. Also a means to provide solution for emergency/special users is been suggested.

For travelers who use NH, it is essential for them to use the toll plaza for safe and quick journey. When many users are approaching the toll plaza at the same instant, it leads to huge traffic at toll plaza which increases traveling time. Furthermore, heavy traffic at Toll Plaza makes it difficult to provide special/emergency services to the users.

PESTEL Analysis:

A PESTEL examination is a scaffold or tool used by marketers to evaluate and observe the macro-environmental (outdoor promotion environment) factors that have an impact on an organization. PESTEL stands for (Guo Chao Alex Peng, Miguel Baptista Nunes, 2007) P – Political, E – Economical, S – Social, T – Technological, E – Environmental and L – Legal.

Political factors in optimizing Toll plaza depends mainly in Government policy making. Almost all Toll Plaza in India are maintained by Private firms in BOT (Build Operate and Transfer) basis. So a clear government policy plays major role in upgrading toll plaza. Economical factors include cost incurred for installing surveillance cameras and sensors which are required to modernize toll plazas. Also the cost for installing Servers to back up large amount of data is considered. Digital display systems are also necessary. The social factors associated with the toll plaza are to be analyzed carefully. Employment opportunity to the local people and other social factors are to be considered.

The Legal aspects involve getting approval from the National Highways Authority of India (NHAI) and other legal issues in setting up a Toll Plaza. Applying for ISO standards are also the legal factors. While designing a product it has to be considered how the device works in different environmental conditions. A sensor performance may get affected due to several reasons like mist, fog, low light conditions, temperature and so on. Selecting a sensor to withstand all conditions is an environmental factor. When a wireless application is used, the connectivity may get affected due to different weather conditions which are also another environmental factor which is to be considered. The display devices used has different behavior in different lighting conditions and the type of power used and measures to be taken in case of unforeseen weather conditions has to be clearly reviewed and
actions should be sought accordingly. The new product developed should comply with existing technological advancements and also the existing product should be very flexible to incorporate new technical advancements.

**Fig. 2: Project Development Life Cycle**

**Requirement Engineering:**
Requirements study, also called requirements engineering, is the process of shaping user expectations for a fresh or modified artifact. These features, called requirements, must be proven, significant and thorough. Therefore in software engineering, such necessities are often called functional specifications. It refers to the method of defining, documenting and maintains the necessities to the sub-fields of systems engineering and software engineering concerned with this practice. The various requirements that a product should fulfill are (Harleen, K., et al., 2014) (i) Functional Requirement: The functional requirement for toll plaza is to minimize the traffic congestion and to achieve this task existing infrastructure should not be altered much. Toll collection should be made simple. There should be a special lane provided for emergency care vehicles. Efforts should be made to tell the user about the traffic situation before the arrival of user to the toll gate. (ii) Performance Requirement: The time taken for toll collection should be as minimum as possible. The waiting time for the emergency care vehicles should almost be zero. (iii) Physical Requirement: It includes usage of less number of sensitive devices, reducing the power consumption of devices and so on. (iv) Regulatory Requirements includes getting approval from NHAI, making the system to pass ISO standards, providing Patrol vehicles to monitor traffic. (v) Economical Requirements includes cost incurred by sensors, cameras and other installed devices. The maintenance cost also adds to this requirement. (vi) Technical Requirements includes all hardware and software required and server computers required to store the data. (vii) Behavioral Requirement narrates how the system behaves in unforeseen conditions and tells how to bring in coordination among the devices. (viii) Environmental Requirement narrates environmental hurdles that a product should pass. For instance, minimizing the usage of paper, rain water harvesting, using renewable power are few examples. (ix) Stake holder Requirements tell how the system benefits the end user and other stake holders.

**Fig. 2: Project Development Life Cycle**
4. Proposed Work:
In almost all existing systems Radio Frequency Identification (RFID) tag is used as a prepaid or recharge card from which the toll fee is debited. This feature needs hardware (RFID tag) to be installed prior to the usage of toll plaza. (Ayoub Khan, M., et al., 2009) RFID tags have to be authenticated by the toll plaza officials before it is stuck to the windshield of the vehicle. Since the RFID (Khadijah Kamarulazizi) tags are easily removable higher levels of fare dodging is inevitable in toll collection. The user may easily remove the tag and place it in next coming vehicle without many complications (A.usha kiran). The proposed method carefully observed the insights of the problem and came out with a solution. The prime objective being to minimize the waiting time of the user and also help evade fare dodging to a higher level. The proposed system will have a mobile application as a feature to reserve toll tickets. At the time of ticket reservation, the registration number of the vehicle is received and sent to the server to authenticate the vehicle to pass through the toll gate. The time of journey is to be mentioned during reservation; however the token is valid for one day. The application also intimates the reserved users about the traffic situation a couple of hours based on the situation. The user may reschedule his journey for few hours based on the situation.

**Fig. 3:** Automated toll plaza using RFID

The proposed method identifies the registered user’s vehicle based on the registered number plate. The system will have two cameras of high resolution and infra-red illumination system. The camera is placed one to capture number plate at the front end and another placed to capture the number plate at the rear end. The captured image is processed and the information of register number is extracted. The extracted registration number is then compared with the number available in the server and if both number matches, the vehicle is allowed to pass through the toll gate. The information retrieval speed of the server should be very high so as to minimize the waiting time of the user. The registered user is allowed to pass through automated lane. (Bhupendra Moharil, et al., 2012) Unregistered users may be allowed by collecting toll manually in a separate lane. Also a dedicated lane is provided for emergency care vehicles. The users can also register tickets with the help of SMS service if mobile application is not installed in his phone.

**Fig. 4:** Data Flow Diagram
As the vehicle approaches the toll area, and starts the cycle by stepping over a magnetic loop detector [6] (which is the most popular vehicle sensor), Priyanka Chhoriya, et al., 2013. The loop detector will sense the vehicle and its presence is informed to the sensing unit. Swiftly sensing unit switches the infra-red illumination system and takes pictures of either front or rear plates from the camera. The images of the vehicle include the plate and the pixel information is read by the image processing hardware.

The sensing unit examines the illustration with different image processing software algorithms, Yu-fai Fung, Homan Lee, and M. Fikret Ercan, 2006. The smart camera at the reserved entry enhances the illustration, detects the plate arrangement (Raja Vikramdeep Singh, Navneet Randhawa, 2014) and identifies the fonts using unique artificial intelligence methods. (Kannan Subramanian, 2013) The sensing unit checks if the vehicle appears on a predefined list of approved vehicles, and if found - it signals to unfasten the gate by activating its relay (Amol. A. Chapate, D.D. Nawgaje, 2015). The unit can also toggle on a green “proceed” light or red “halt” light. The approved vehicle enters into the secured vicinity. After fleeting the tollgate its detector closes the toll gate. Now the system waits for the subsequent vehicle to loom the sensing region.

**Fig. 5:** The smart camera at the reserved entry

**Conclusion:**

In this paper a detailed survey is conducted and based on the outcome a mobile application is developed with user friendly graphical user interface (GUI). The mobile application is one of the features to decongest toll traffic. The traffic prediction enables the user to plan their journey so that waiting time is minimized. The unique number plate recognition mechanism helps prevent fare dodging thereby increasing the efficiency of toll collection. The system is also designed to be flexible to incorporate all future technological advancements. This paper provides a solution to achieve prime objective of minimizing the waiting time of the user and also help evade fare dodging to a higher level. Future works include implementing the system in ARM processor. The image processing algorithms will be reviewed to make it highly accurate and sensors will be selected to work in all weather conditions.

**REFERENCES**


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