AUTONOMOUS TOLL CONTROLLING OPERATION AND TAXING METHODOLOGY USING RFID

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ABSTRACT

Autonomous Controller is a paradigm that mainly focuses on the technological advances made in the field of Artificial Intelligence. Autonomous Toll Controlling Operation is basically a concept which is being introduced to make the toll taxing over the toll plaza gates done automatically. Using e-commerce & automation mechanisms, we can develop a conceptual view to simplify this automation taxing process. The result will be a user-friendly, programmer-friendly and an efficient system.

Keywords - Artificial Intelligence, Automation, Taxing, Mechanisms, Sensor Fabrication.

I. INTRODUCTION

What Is Automation?

Automation is basically a term in which a device is defined to operate under certain set of conditions as programmed, provided with thorough supervision and regular maintenance. Generally a device is being automated in order to replace the work performed by Human beings through Technology. The device developed by Technology is defined such that it can replace and operate with the same intelligence as the Human Beings are capable of doing which is known as Artificial Intelligence.

What Is Artificial Intelligence?

Artificial Intelligence is basically a term which defines intelligence of a defined device (say microcontroller) capable of operating similar to a living being with brains. In simple language, we could say that the device is designed in such a manner that it can operate just like a living being and is programmed in such a way that it can think and take decisions just as if it has brains.

Working Overview

The Autonomous Toll Controller system uses a technology which employs an electronic transponder that is placed in front of the rear view mirror.

When a vehicle enters a toll booth allocated to Toll Gate users, the tag is read, automatically identifying the account, and debiting the toll fee amount from the corresponding account. The tag is simply an identification card and all information regarding the user account is stored separately by the toll way operations company.

II. SIMULATION MODEL OF TOLL PLAZA WITH E-PASS GATE

This section describes process simulation model which have been developed, and its internal process modules for traffic jams at expressway toll plazas with E-Pass gates simulation.

(1) Simulation Model Development

Using the following 6 modules based on several software used in this study (Visual Basic, Visual Studio, Bascom Software), 6 procedures are defined for toll fee payment by vehicles at the toll plaza as follows

- **CREATE**: To generate entities (objects for simulation)
- **PROCESS**: To represent major processes in Simulation.
- **DECIDE**: To determine appropriate decision in the model.
- **ASSIGN**: To set appropriate values into system parameters such as entity properties and types.
- **RECORD**: To collect statistical values.

  DISPOSE: To represent the final point of simulation. Statistical values are recorded before the destruction of entities.

2) Module Work Assigning Concept

- **Generation of Vehicles :** CREATE module generates two types of entities, General and E-PASS. ASSIGN module defines toll collection time according to the time and type in each entity generation.
- **Lane Selection :** DECIDE module branches way towards which each entity based on arbitrary probability, entity type, traffic conditions, etc.

- **Travel on Lane:** PROCESS module gives travel time to each entity based on the traffic condition.
- **Gate Selection:** DECIDE module branches the gate to each entity based on the traffic condition.
- **Toll Collection:** Entity is captured by resources based on the predefined time for payment in PROCESS module, then the entity is released.
- **Leave Gate:** After time stamp by RECORD module, entity is destroyed by DISPOSE module.

(3) E-Pass System Processing

Processing of Information

As the information is collected and processed, the vehicle identity is registered and hereby authorized to clear the toll gate after the amount has been debited, the control gate will lift and the vehicle will be allowed to depart. This is supposed to happen within 4 to 7 seconds.

The Processing of the vehicle has being categorized under various modules which deals with the payment mechanism discussed in Taxing Technology & Schemes.

III. MATHEMATICAL ANALYSIS

The Mathematical analysis deals with the Processing flow and count balance system for proper acknowledgement of each and every vehicles so passed from the Toll Gates also keeping the exact variable process changes that could take place under the predictable cases of Overloading & Technical Failures. It also deals with the lane selection & assignment mechanism which hereby helps the processing of vehicles make even faster.

(1) Application of Queuing Theory

E-Pass System can be summarized broadly into three categories:

- Acknowledging Information
- Checking Validation
- Processing of Information

Acknowledging Information

The E-PASS system uses a technology which employs an electronic transponder that is placed in front of the rearview mirror. When the vehicle enters a toll booth allocated to E-PASS Users, the tag is read, automatically identifying the account. The tag is simply an identification card and all information regarding the user account is stored separately by the toll way operations company.

Checking Validation

As soon as the Electronic Card / Tag is checked, the information within the Tag / Sensor is being processed. As the information is being checked, the validation process continues to process the required information from the vehicle. After the validation, the vehicle is given the clearance of pass and the toll gate allows the vehicle to clear.

The toll plaza problem involves multiple user types and multiple server types. The service rate depends on combination of server type and user type. For example, due to the different driver heights for cars and trucks, the service time can be longer for the more inaccessible one. Although at present there are several other service types for tollbooths, such as the Mixed E-PASS/Manual, the lane allocations will be simplified and a combination service of E-PASS and Manual will no longer be made available.

Then the total Manual lane users is just the Total minus that of the E-PASS lanes, and then total Manual users were equally distributed among the Manual lanes. Furthermore, the total number of E-PASS using vehicles was allocated equally among the E-PASS lanes, and the total number of vehicles using Manual collection lanes divided equally among Manual collection booths. In actuality, the distribution of vehicles among the available toll lanes may be more complicated than uniform distribution, due to factors such as layout, distance of target lanes from the oncoming vehicles, visibility, driver preparedness, length of queues and other factor.

Using the volumes allocated to each service type, the total time spent in the system (which includes time in queue plus time being served) using the following equation:

$$E(v) = \frac{\rho}{1-\rho} \cdot \frac{1}{\lambda} \qquad \text{(Eqn. 1)}$$

Where E(v) = average time spent in the system (toll plaza)

$$\rho = \frac{\lambda}{\mu} \qquad \text{(Eqn.2)}$$

Where ρ = utilization factor
λ = average arrival rate (vehicles / hour)
μ = average service rate (vehicles / hour)

$$E(s) = \frac{1}{\mu} \qquad \text{(Eqn. 3)}$$

Where E(s) = the service time (hours/vehicle)

Thus waiting time E(w), is just:

$$E(w) = E(v) - E(s) \qquad \text{(Eqn. 4)}$$

These are then calculated for each lane type using the allocated volumes under the various scenarios.

(2) Process Simulation Model

Number of incoming vehicles per hour is defined as Equation (1) for non E-Pass vehicles and Equation

(2) [given below] for E-Pass vehicles, respectively. E-Pass mixing ration in overall vehicles is defined as Equation (3).

$$t_g = \frac{3600}{x_g} \quad (1)$$

$$t_e = \frac{3600}{x_e} \quad (2)$$

$$p = \frac{x_e}{x_g + x_e} \quad (3)$$

where

t_g : time interval for incoming non- E-Pass vehicles [sec]

x_g : incoming hourly volume of non- E-Pass vehicles [no/hr] t_e : time interval for incoming E-Pass vehicles [sec]

x_e : incoming hourly volume of E-Pass vehicles [no/hr] p : E-Pass ratio in all vehicles [%]

Entity moves from point A to point C on the queue lines [shown at Procedure of Process Simulation] at a certain time interval as defined in Equation (4).

$$T_d = [\, L - (q_i + q_j)\, l - L_s \,] S_c + L_s S_s \quad (4)$$

where

T_d : time delay for move [sec]

L : distance between start and goal (A-C) [m] qi : number of vehicles in Queue.i

qj : number of vehicles in Queue.j

l : average distance between two vehicles in queue [m] Ls : distance from speed-down and halt points [m]

Sc : average time for unit distance [sec/m]

Ss : average time for unit distance at speed-down [sec/m]

T_g and T_e represent required time from the queue end to toll gate for non- E-Pass and E-Pass vehicles, respectively as shown in Equations (5) and (6).

$$T_g = \frac{q_{ig}\, t_{pg}}{m} + q_j\, t_{pg} \quad (5)$$

$$T_e = \frac{q_{ig}\, t_{pg}}{m} + q_j\, t_{pe} \quad (6)$$

where

Tg : time from queue-end to toll gate (non- E-Pass) [sec] q_{ig} : total number of non- E-Pass in Queue-i (i=1,2..)

t_{pg} : time to pay at toll gate (non- E-Pass) [sec]

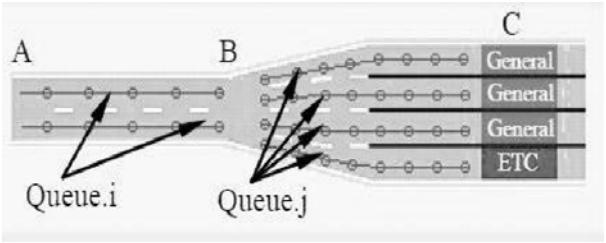
T_e : time from queue-end to toll gate (E-Pass) [sec] t_{pe} : time to pay at the toll gate (E-Pass [sec]

m : number of gates for non- E-Pass vehicles.

(3) Internal Procedure of Process Simulation

Figure below shows a sample of process simulation model for toll plaza with E-Pass [ETC] gate with 3 gates for general vehicles and 1 gate for ETC vehicles, which represents a typical toll plaza of expressway in Gurgaon, India.

Letter A represents generation point for entity, letter B represents expansion point of drive lane, letter C represents gate point. Queue.i is defined as waiting queue between A-B points, and Queue.j is defined as waiting queue between B-C points.



IV. ANALYTICAL SCENARIOS

The main parameters for defining the analytical scenarios are in terms of

- The total number of booths in a plaza/checkpoint.
- The manner allocation of the different service types among the booths.
- The percentage of E-PASS enabled users.
- Total vehicle volumes at the toll plaza/checkpoint.

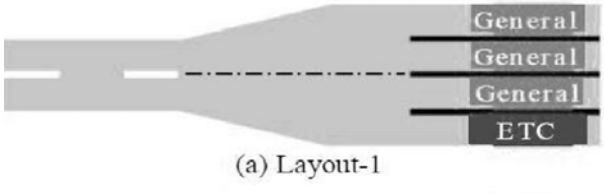
Using these assumed parameters, the following were calculated:

- Average delay per lane.
- Total average delay (average delay weighted by the volumes allocated to each lane with corresponding service type).
- At specific volume and service type allocation regimes, the total plaza volume at which at least one lane type will be saturated and thus be unable to serve with the volume within the hour. This is used as an indicator of the regime capacity.

PROCESS SIMULATION MODEL FOR VERIFICATION BASED ON MATHEMATICAL DATA

In order to analyze traffic jams at toll plaza with E-Pass / ETC gates, some comparative simulation was conducted using the process simulation model. Feasibility of the model is also studied using layout design consideration around the toll gate plaza. In each simulation, entity generation is started at 500m before

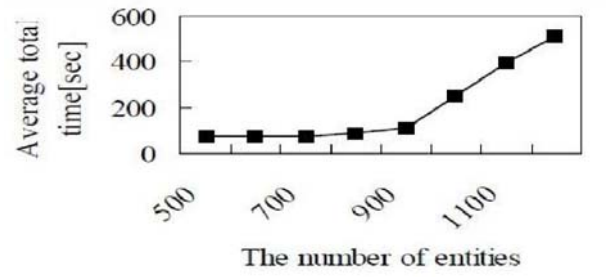
the toll gate with 2 driving lanes in Queue.i, with 8 entities in each Queue.j towards 4 gates to drive through.



(a) Layout-1

Toll Distribution of Vehicles into Lanes

Figure below shows the required time to pass the toll gate (drive-through time) according to the hourly traffic volume ranging from 500 to 1200 vehicles per hour. The time stays around 100 seconds up to 900 vehicles, but it drastically increases when the number of incoming vehicles exceeds over 1000, which means that the capacity of toll gates in this simulation is about 900 vehicles per hour.



Gate-through Time in each traffic volume

Introduction of E-Pass system can hereby also provide a solution to solve the problem of traffic jam at toll gates.

IV. STATISTICAL ANALYSIS

There are a number of important research issues in the toll plaza design problem. Some of these are

- How many of each type of booth should we have?
- How should we layout the mechanism and what should be the relative positions of the different types of toll payment methods.
- What is the traffic delay as a function of the numbers of different types of toll booths and layouts?
- What other traffic control methods should be used to ease the traffic congestion.

In order to answer these questions, we need to take into consideration about the present methodology of taxing and operation of toll booths. One thing which always should be acknowledged that any technologies though developed should always account for the changes to be taken place along with the main consideration of human usage and beneficial comfort it will generate for the rest after being into use.

Road Investments in India

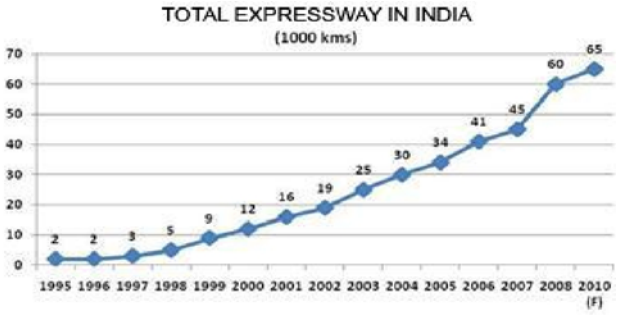
The roads in India are mainly categorized under certain parameters for up gradation and maintenance. They are **Rural Roads**, **Key Road Projects** & **Road Maintenance**. Within the last decade, it has been observed that the investment has been made focusing on the up gradation of the roads which proved to be a better way of maintenance. Also the Rural roads are being modified and developed in order to upgrade the overall road network of the country.

Now in order to make the investments incurred from the public i.e. the users of the roads, toll gates are built over the roads / highways. So in order to get the tax collected, the government body has to invest again on the toll booths by installing it, employing officials hereby adding extra cost to the user of the road. So in order to make the investment less, hereby automation of gates is the best possible solution.

In actual scenario, if the toll gates are automated, then the operational cost of the toll booths will be marginally low. This will result in the deduction of the net charges made for the road usage. Hence automation will prove to be a better option on the long run.

Expressway usage and up gradation Scheme

In India, if we consider that the expressways will be initially using the automated toll booths, then we can see that almost 42% of the roads having toll gates are expressways. This would result into the usage of toll gates on a regular basis. Now, at the present scenario, it has been seen that almost at all the toll booths, a lot of time is being wasted because of manual delays, operational faults etc. hereby leading to a lot of inconvenience for the general travellers. Also delay at the toll booths unnecessarily results into the waste of time.



In order to overcome this problem, if automation is done, then time constraint should also be focused on. In order to do so, if the Taxing Technology is being broadened, then then scope of getting clearance would be much higher as there would be parallel schemes to get the processing done.

If the Taxing scheme is to be considered, then after automation there must be alternative ways to get the billing done. So it calls for a dual scheme i.e. prepaid as well as a postpaid / e-billing scheme.

V. TAXING TECHNOLOGY & SCHEMES

Taxing Schemes

Taxing i.e. billing is the prime concern for building a toll plaza. So it must be carried out with utmost attention and every minute discrepancy must be dealt with utmost attention. In order to get the taxing done at ease, two parameters are introduced.

First, a prepaid system or tag which will provide a certain balance calculation and the amount resultant will be read and hereby processed. In prepaid module, the vehicle will be provided with Tags which will be recharged initially and also can be done at regular intervals which when processed from the toll gate will be read by the tag reader and hereby after the balance deduction; the gate will authorize to pass the vehicle.

Secondly, a postpaid system will also be interfaced along with the module comprising the tag which will allow the drivers/passers to go for e-billing in case the balance in the prepaid module goes without balance; the driver will be alarmed to acknowledge the permission of getting e-billing done. This is so because as when the prepaid module goes to be inoperable, the driver has to pay the tax which hereby leads to unnecessary stoppage of the vehicle, thus resulting into traffic jams & vehicle Queues.

Taxing Technology

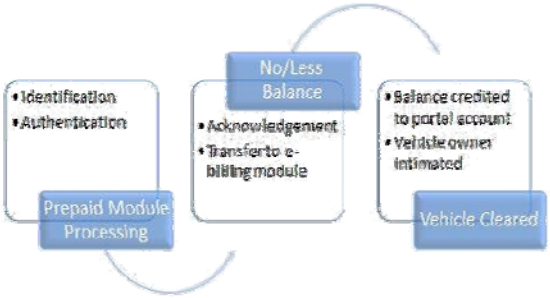
The Taxing Module can be developed by programming the tags. It can be done in two generic ways.

Prepaid Scheme

The taxing software interface can be programmed in VB Programming Language which will allow the tag readers to detect the tags, read the information within the tags, processes it and pass the vehicle with acknowledgement.

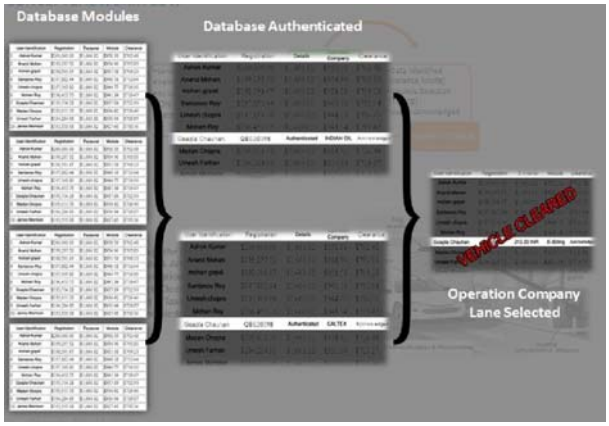
Postpaid/E-Billing Scheme

In e-billing scheme, the tags are initially scanned are after getting the response of NO BALANCE from the prepaid module, the e-billing module will acknowledge the vehicle driver about the e-billing & recharge notification which hereby the vehicle owner can pay later with his account details provided to him at the time of registering the automation module. The e-billing can be done by managing database about the vehicle, its identity, its authorization. This can be done by using DATABASE, MySQL. The client side end can be configured and modeled into a webpage with HTML, PHP.



Data Flow Analysis of Processing Scheme

Thus both the schemes will be easily carried out and hereby result into fast processing of vehicles and thus will lead into congestion free roads as vehicle clearance would be easily done.



VI. CONCLUSION

This paper overviewed the Automation of Toll Points & Taxing Technology around the world as well as in India, and pointed out some critical issues of traffic jams around expressway toll plaza in India. Simulation-based approach has been applied to various areas related to transportation system and its feasibility has been reported as described in the Introduction. The simulation-based approach can also be applied to the issues of traffic jams in this study, but its key to success is very much relied upon the quality of the model. If a high quality model is built, various kinds of simulation studies can be conducted to find / propose solutions to actual problems.

VII. REFERENCES

i. Abbas-Turki, A., O. Grunder and A. Elmoudni. 2001. "Simulation and optimization of the public transportation connection system", In Proceedings of the 13 th European Simulation Symposium, October 18-20, Marseille, France, pp.435-439.

ii. Biancadi, A., R. De Lotto and A. Ferrara. 2000. "A multimodaltransport simulation tool to solve urban location problems", Proceedings of the 12 th European Simulation Symposium, September 28-30, Humburg, Germany, pp.437-442.

iii. Fernandes, R.J. and S. Bampi. 1998. "A software environment to integrate urban traffic simulation tasks", Proceedings of the 10th European Simulation Symposium, October 26-28, Nottingham, United Kingdom, pp.371-377.

iv. Krajzewicz, D., G. Hertkorn and P. Wagner. 2002. "An example of microscopic car models validation using the open source traffic simulation SUMO", Proceedings of the 14 th European Simulation Symposium, October 23-26, Dresden, Germany, pp.318-322.

v. Process Simulation Approach to design and Evaluation of Toll Plaza with ETC Gates, Teruaki Ito, University of Tokushima, pp. 2-4.

vi. Lucjan, G. and O. Jozef. 1999. "Modeling of public transport commuters flow at urban interchange centers", Proceedings of the 11 th European Simulation Symposium, October 26-28, Erlangen, Germany, pp.217-219.

vii. Schwentke, R. 2000. "Integrated training system for traffic control", Proceedings of the 12 th European Simulation Symposium, September 28-30, Hamburg, Germany, pp.

viii. Journal of the Operations Research Society of America, Vol. 2, No. 3 (Aug., 1954), pp. 339-341

ix. Internal NHAI-I-SystemWriteUp: General Project Write Up, Effective Date: 01st March 2004