Behavioral Study of Traffic Composition Vehicle Classifications for Toll Plaza Design: A Study Reviews

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***Abstract*: Toll plazas are a crucial component of transportation operations nationwide. They help supply funding for growth and help control demand. Each phase of the process is depicted as a queuing mechanism. Recommendations for further study include the examination of traffic flow and safety in connection with toll plaza traffic flow, says the study. The traffic simulation model was used to simulate multiple parking lot exit plaza designs that took into consideration the various channel arrivals. The study concludes that toll plaza services have advantages and drawbacks, despite the user's belief to the contrary.**

***Keywords*: Toll Plaza Design, Vehicle Enforcement System, Vehicle Classifications & Traffic composition**

I. INTRODUCTION

Historically, building long-distance highways has necessitated toll revenue. Greeks recognized toll roads in Asia centuries before they were established. The opening of the first turnpikes in the Midwest in the early 1800s established the Great Plains for colonization. Toll roads laid the framework for the interstate system that Americans enjoy today. Emerging nations such as China are increasingly creating their own superhighways and charging tolls for vehicles. While tolling continues to help pay road upgrades in Singapore and London, it is also employed to restrain the number of vehicles in the metropolitan area, resulting to greater transit use and easing the crowded streets.

A fundamental drawback remains: tolls annoy drivers and construction companies alike. When traffic is backed up, cars queue up to pay their tolls and when they are finished, they impede the flow of traffic, which causes a time loss when the multiple lanes departing the toll plaza rejoin the flow of traffic. All around the world, it's considered a problem. NJIT has shown that toll removal might save motorists an average of 10% of their travel time on a 14-mile section of the Garden State Parkway. Unlike conventional toll plazas, contemporary toll facilities enforce all toll payments using electronic transponders, so that cars are not delayed while completing payments. Increasing toll traffic makes adopting electronic toll collecting impossible for older tollways. In plain terms, to keep consumers from waiting in long lines, supply as many tollbooths as feasible. We will use tollbooths to determine how many to use to get the best mix of efficiency and convenience.

To comprehensively identify the issue, we must undertake a qualitative research in which we identify the elements we should concentrate on, those we should dismiss, and rules that the system components are required to obey. Finally, we must devise a gauge for roadway performance. When we know the traffic flow level, the number of tollbooths, and the number of beginning lanes, we can use certain conclusions from queuing theory to establish a toll plaza performance calculation method. Simulation efforts have traditionally focused on toll plazas. The trend is event-discrete models in toll plaza modelling. These models accurately depict the user-server process, but they fail to capture the traffic-related and facility-related behavioral interactions. Moving into the most convenient lane area, where weaving and right-of-way regulations apply, and the exit (priority rules). It all relies on these elements of traffic. Most recent simulation models that encompass both the user/server interface and the traffic operations employ a stochastic model for the whole system.

1.1 General Toll Plaza Operation and Configuration

By means of an introduction to the topic being proposed within this thesis, it is important to first have a basic understanding of general toll plaza operation and configuration. The general operation and configuration of a toll plaza is based upon basic elements that may differ across various plazas, including the following:

• Plaza type;

• Lane types;

• Electronic tolling technology hardware; and,

• Electronic tolling technology software.

Hardware

Electronic Tolling systems use a series of interconnected wireless and wire line communication devices to facilitate automatic vehicle identification (AVI). Transponders or tags are Radio-Frequency Identification (RFID) units that serve as the basis for modern electronic tolling. These devices communicate using Dedicated Short Range Communication (DSRC) to the toll reader system which registers identification and completes toll transactions.

Antennas

Emitters or antennas are the medium through which DSRC functions and exchanges identification from the passing vehicle to the stationary toll system. Antennas are connected to a lane controller to prevent transaction duplication. Additionally, the lane controller coordinates operations with the axle counter and vehicle enforcement system. Computer servers located on site function as a database and processing unit that connects and records transactions with the turnpike authority and financial institutions. Due to this important role, multiple redundancies are typically employed in nearly every function, (fiber optics, transmitters, and power supplies) at the local and regional level.

Transponders

Transponders operate on the 915 MHz radio frequency with an operating range of 32.5 feet. Transponders communicate with antennas using DSRC in a cycle of exchanging ID information and confirmation that lasts sixteen milliseconds. The device attempts to “handshake” ten times before the device is ignored.

Axle Counters

Axle counters are electronic circuits shaped in a loop located under the roadway used in violation enforcement and vehicle classification. The counter detects number of axles which is used to adjust vehicle classification and fares accordingly. In its violation enforcement role, the loop triggers cameras used to capture license plate photos used to process transponder misreads or violators.

Vehicle Enforcement System

Cameras take still photographs from the front and rear of each vehicle upon loop trigger. The redundancy of photographs prevents non-paying vehicles with only one license plate or those tailgating to escape through the lane unaccounted. The system takes pictures and reads RFIDs simultaneously regardless of traffic density, and speed. In mixed-mode or exclusive ramp lane setups, one antenna is used per lane. In express or open road tolling (ORT) lanes, multiple antennas will be mounted to capture shoulder and mid lane transactions. In open road tolling, antenna systems are more sophisticated to detect cars that may pass under in multiple lanes (6).

II. LITERATURE REVIEW

The toll plaza environment is in many regards one of more complex and demanding places to drive in terms of safety and motorist involvement. Vehicles approach at high speeds and decelerate at various speeds while merging and scanning for signage and toll lanes. In order to understand the intricacies of toll plaza operations, a review of current and past literature was compiled. Studies highlight driver decision making, signage, lighting give light to the vast amounts of sensory information and methods of payment. Simulation efforts with ETC equipped toll environments have revealed the theoretical performance and introduced behavior models to hopes to replicate and predict real world events. The following background is by no means an all-encompassing review electronic tolling safety and simulation but should provide a backdrop for the research proposed herein.

2.1 RECENT LITERATURE

Contrastingly, a 2007 report of the New York State Thruway Authority crash records showed an increase in ETC related crashes as ETC penetration increased from 1992 to 1998. Crashes on an Orlando Florida expressway doubled after installing dedicated ETC lanes. The crash rates involving dedicated ETC lanes and/or ETC vehicles rose from 3.375 crashes per month to 7.5 crashes per month. At the same toll facility, rear-end crashes increased as a result of a adding a dedicated ETC lane. Not even a year later a second adjacent ETC lane was installed, and again rear-end crash frequency increased. Speed was the leading cause of conflict and the culprit in raised accident rates. Prior to toll plaza renovations speed variance was low, but after construction velocities noticeably escalated. These results provide strong support to the idea that decision making spurred by ETC lanes may spark conflicts at toll plazas that are leading to additional accident. Another model, TPSIM, built by Correa et al. (2004) was able to reproduce typical toll plaza operations with lane decision based on queue length.

The deterministic toll plaza software SHAKER created by Florida Department of Transportation out puted most efficient plaza configurations by assigning approaching traffic to shortest queue lanes (15). TOLLSIM toll plaza model, developed by Wilbur Smith, now CDM Smith, estimates traffic characteristics such as delay and queues at a plaza (14).

Few studies have developed toll plaza micro simulations with widely available traffic simulation programs (AIMSUN, VISSIM, Paramics, CORSIM). The model produced by Mudigonda et al. (2008) revolves around maximizing user utility based on three parameters for ramp plazas was programmed into an API by Nezamuddin. The model validated mainline plazas on Orlando Orange County Expressway Authority (OOCEA) toll facilities. The study found success in modeling field observations with correlating lane assignments on the order of 0.98 (3). Fuller et al. worked with CORSIM developers to add a toll plaza module to CORSIM version 6.3. CORSIM models in the past had used Stop and Yield Signs to emulate cash and manual payments. Previous attempts at modeling were deterministic and used shortest queue for lane determination. VISSIM toll plaza simulation was configured using OOCEA mainline plazas with substantial success. Russo (2008) created a deterministic model that used stop signs as cash lanes and reduced speed zones for dedicated ETC lanes. A laboratory driving simulator study in Illinois compared seven experimental open road tolling signs. The simulation collected driver reaction and comprehension time for a series of proposed signs. Participants were assigned a role as a cash or ETC customer and drove through a toll gantry with the freedom to change lanes without repercussions. Conflicting results did not clearly pinpoint an optimal sign layout but eliminated options for the subsequent field study. The driving simulator proved to be a cost-effective method of trial and error. The initial research task, which was introduced at the onset of the research development, was a thorough review of the literature related to this topic. The systematic review of pertinent background research articles began with journal and database keyword searches. More specifically, studies on lane configuration, simulation and driver decision making were the focus of the literature review. Several databases were examined based on relevance to human factors and transportation peer-reviewed journal research. The National Transportation Library, a branch of the Research and Innovative Technology Administration (RITA) and Transportation Research International Documentation, and Transportation Research Board's database were selected as primary search engines. Other journal catalogs used were Engineering Village, Web of Knowledge, LexisNexis Academic, SciVerse, and Ebscohost.

Search keyword logic was developed after subsequent search engine explorations. Toll plaza safety, electronic toll collection, plaza configuration and sideswipe crashes were the initial search terms. This rationality provided an exorbitant number of resources. Search terms were refined and tweaked to minimize the wealth of articles into a useful collection. Keywords were found to be too broad, and were replaced with specific terms. Using electronic tolling system names (e.g., E-ZPass, SunPass) served as an excellent filter. Changing the logic from the "OR" operator to the "AND" operator and separating the differentiating keywords provided much needed discriminating power. The key filter terms after trial and error included safety, crash, merge, sideswipe and queue. The final search revision used the following logic where articles must return one term from each column.

III. DESCRIPTION OF MODEL

Toll Plaza Design

A 2006 appeal from the National Transportation Safety Board beckoned tolling agencies to retrofit and otherwise implement improvements to reduce the widespread risk of rear-end collisions (10). These junction points on the nation's interstate systems are high crash locations and necessitate a set of guidelines to fill the regulation void (25). Agencies have produced several guides in an attempt to streamline design, but the majority of lessons learned come from the tolling agencies themselves. The lack of standardization between tolling facilities prohibits travelers from building familiarity with the tolling experience. Vehicle conflicts, such as those observed with a conflict and event study, can serve as a proxy to gauge toll plaza safety. Statistics can be used to verify if changes in a toll plaza retrofit have yielded substantial improvements. Menta hypothesized that at a toll plaza, as ETC penetration rose, safety risks would decrease or at least maintain prior levels. These proportion of ETC users were divided up by vehicle type; passenger cars, trucks and buses. The PANYNJ uses a traffic model for toll plaza design. The model for tollbooths allocates the marginal vehicle to the lane with the absolute lowest queue regardless of lane movements required to reach that toll booth. In the case where queue lengths are equitable, the algorithm routes vehicles to the right. The model is used to determine how many ETC lanes should be operated but fails to show where to locate these lanes effectively.

According to the NHRCP Toll Plaza Design guide, only 28 percent of tolling agencies have wide load lanes on the right side of toll plazas. Lane alignment is only a flexible parameter if land usage is accommodating. Geometric limitations have a large impact on toll plaza placement. Toll plazas placed on trumpet-shaped exchanges converging to one egress tangent provide very short straight sections to position queue lanes and are therefore avoided. Plaza placement is also discouraged at the intersection of major highways due to high volume and speed. Plazas should also not be located within a mile of another interchange to adhere to approach and divergence length requirements. The number of plaza lanes is a function of geometric availability and traffic demand. The Federal Highway Administration (FHWA) recommends using at least as many entering highway lanes for dedicated ETC service or the total throughput volume divided by 1500 (the hourly flow capacity in vehicles) (2). The results of converting lanes to dedicated ETC revealed that as ETC penetration increased, conflict potential subsequently fell and a "more organized" traffic flow or efficient stream of traffic developed.

Assess Safety

To assess safety the research included an analysis of crashes at toll plazas followed by a conflict and event study. An initial crash analysis was completed to identify key toll plazas of high potential crash risk. Crashes were spatially analyzed using geographical tagging at the police collection level. The intent of the crash analysis was to identify the nature of the relationship between collision trends, toll configurations and the extent to which driver attention is diverted. A conflict and event study were supplemented by video footage taken from Exit 4 of the Massachusetts Turnpike system.

IV. Analyze Driver Decision Making

The driver decision making objective strived to understand and model how motorists chose lanes on toll plaza approach. A clear understanding of this behavior may lead to improved designs and recommendations for placement of lanes and configurations to minimize risk and improve overall traffic flow. Specifically, this study sought to identify how confusion spawned by the multitude of sensory information impacts driver decisions such as those made when approaching toll interchanges. According to some experts, electronic toll availability and how it is provided (dedicated or mixed-use) may influence this choice. Concerning weaving motions and other potentially unsafe vehicle movements, the way the lanes are set up may also be important. As upstream traffic and wait length have been shown to have a major impact on lane movements, it is widely accepted that these variables are important for movement frequency and pattern. Drivers may be exasperating their mental and sensory potential in search for the lane opportunities in turn leading to a high rate of rear-end crashes due to a loss in forward attention. Analysis from these studies aimed to discern consistent patterns of While cars approach a toll plaza, they are analyzing and responding to information that pertains to the approaching toll plaza.

Vehicle Classifications & Traffic composition

In order to differentiate different behaviors in VISSIM, four vehicle "classes" were formed. Classes allow the micro simulation programmer to specify certain behaviors, rights and restrictions to a group of vehicles. Classes can involve multiple vehicle types or just a single type. Four classes were established: cash cars, E-ZPass cars, cash heavy vehicles and E-ZPass heavy vehicles. Car classes had one vehicle type, cars, with default characteristics of width, length, acceleration. Heavy vehicles had a mixture of single unit, bus and tractor trailer units with default characteristics. The quantity and distribution levels of these classes are assigned in the traffic/vehicle composition menu and were determined by field data. The vehicle compositions and desired speeds are demonstrated.

Reduced Speed Limit Zones

It permitted the model to replicate electronic toll collecting lanes since the speed limit had been lowered in some areas. Vehicle class speed limits do not take precedence over specified reduced speed zones in VISSIM. Providing slower speed to E-ZPass consumers causes them to slow down at plazas. These car class restrictions did not impact cash customers. Distributions that were based on toll plaza speed restrictions in Massachusetts were utilized in the calculation of reduced speed restrictions. Cars were allotted 15-22 mph, while heavy trucks were allocated a speed distribution between 10 and 18 MPH. These distributions were assigned by vehicle class a 90-foot-long reduced speed zones for each lane accepting an ETC payment. Combination lanes with speed reduction only effect E-ZPass vehicle classes and customers who pay with cash will not be impacted by the speed reduction zone. Cash vehicles decelerated on arrival to virtual stop signs that provided a means to emulate manual transactions.

Stop Signs and Dwell Distributions

Toll transactions were imitated by using traffic signs that had stoplights. Based on the finding that most cars came to a full stop during a manual cash toll transaction, this VISSIM function was determined to be adequate. Designated by vehicle type, field data created the empirical stay distributions were assigned differing stop or transaction periods, each with a different distribution, on plaza arrival. A table and graph have been provided in Figure 13 that depict the car and heavy vehicle dwell distributions for this model.

V. Conclusion

Crash histories provide engineers with trends in moderate to severe safety concerns in the form of collision reports. Other incidents may be occurring that due not lead to a crash but nonetheless may be jeopardizing the safe and efficient passage of vehicles through a toll plaza. Every single toll plaza is an essential part of transportation operations throughout the country. The credit unions assist offer finance for expansion and help keep demand in check. The procedure is diagrammed to represent a queuing mechanism for each stage. In terms of more research, it is recommended that future study focus on traffic flow and traffic safety in conjunction with toll plaza traffic flow, according to the study. Several different parking lot exit plaza designs were designed using the traffic simulation model, which took into account the different arrivals that the channel may have. The research concluded that although some drivers may think toll plaza services have benefits, other drivers would be unhappy with them.

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