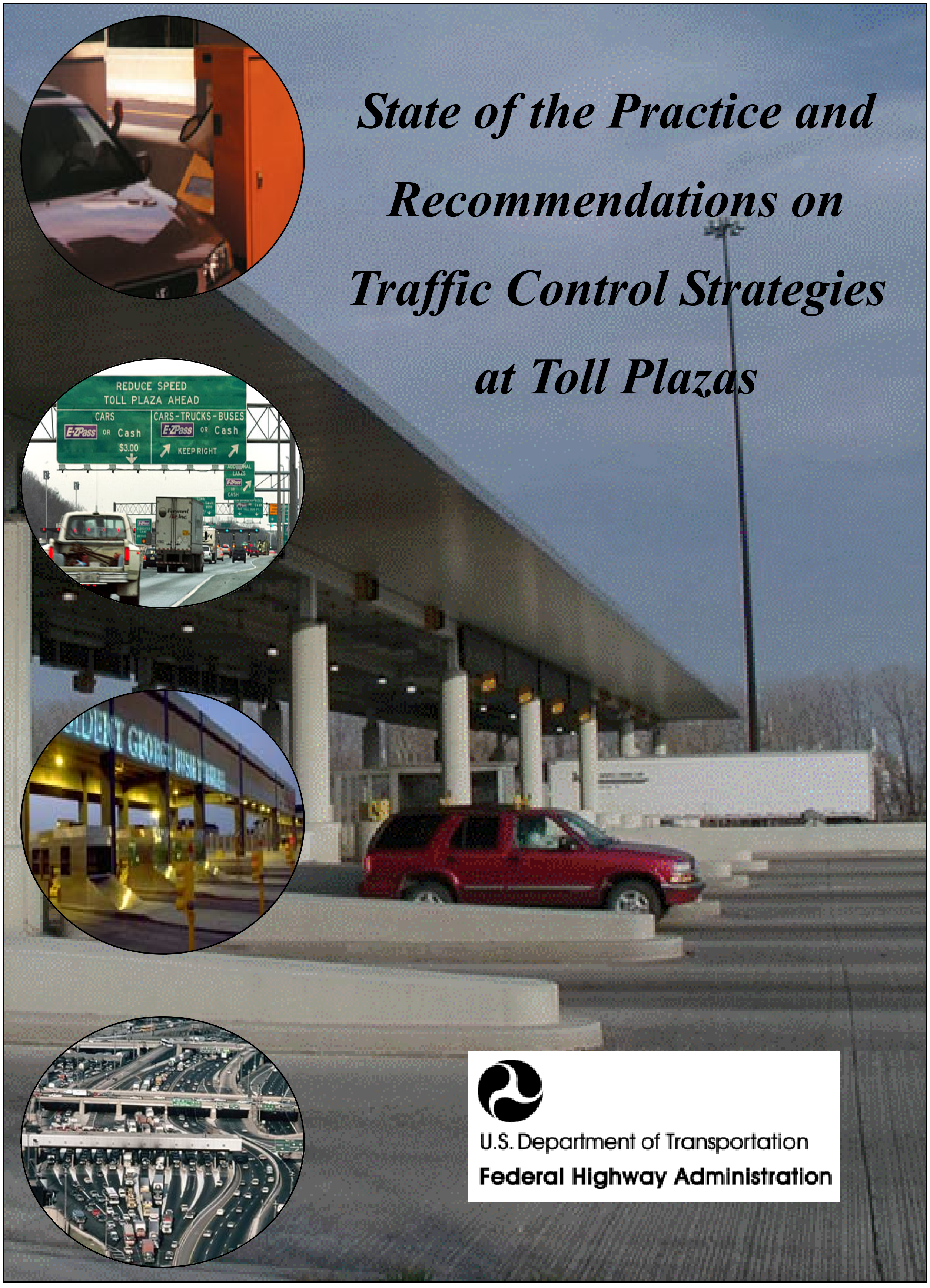

State of the Practice and Recommendations on Traffic Control Strategies at Toll Plazas

U.S. Department of Transportation
Federal Highway Administration

State of the Practice and Traffic Control Strategies at Toll Plazas: Best Practices

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CHAPTER 1

INTRODUCTION

This report has been prepared under a project initiative by the Federal Highway Administration (FHWA) to identify the 'state-of-the-practice' for traffic control strategies at toll plazas, and to develop recommended guidelines for agencies and departments that operate or plan to design and build such facilities.

The report contents begin with this introductory chapter. This chapter includes sections that outlines the purpose of this Project, provides a problem statement, articulating the focus of the project efforts, lists the study objectives, describes the methodology used to achieve the objectives, and concludes with the intended use of this report.

The introduction is followed by four chapters that include the state-of-the-practice and recommended guidelines for the following technical areas encompassing the development of traffic control strategies at toll plazas: 'Plaza Operations/Lane Configuration', 'Signing, Markings and Channelization', 'Geometric and Safety Design', and 'Toll Collection Equipment Technology'. The aggregation of these chapters provides useful historical information and a comprehensive analysis of when and where to apply various traffic control strategies.

The final chapter concludes this Report by identifying further research needs, which require more rigorous study including field verification of performance. This chapter also lists all of the recommended guidelines presented in the preceding chapters. A glossary of terms, definitions and diagrams to assist the reader's understanding of the topic material follows along with Appendix A Summary of Survey Results, Appendix B Expert Panel Workshop Summary, and Appendix C Literature Search.

1.1 PURPOSE

The purpose and focus of this report is to develop guidelines for designing and implementing traffic control strategies and devices at toll plazas that, for example, inform drivers which lanes to use for specific methods of payment, reduce speed variance, discourage lane changing and properly install equipment and devices. This was accomplished after researching related studies and reports, surveying current practices, and learning from the experience of experts within the toll collection industry. The goal is to achieve a consistent strategy for handling potential points of conflict, controlling flow of various vehicle types and conveying information at toll plazas so that safety and operations are enhanced, better efficiency and economy of design are achieved, and motorist recognition and comprehension are improved. This must be accomplished in consideration of the fact that each toll facility may desire its own unique identity.

This report addresses toll plazas built on mainline highway sections, access ramps, and approaches to bridges and tunnels. Different types of toll collection processes are addressed, including: automated cash/card/ticket, manual cash/card/ticket, and electronic toll collection (ETC). While this report covers plazas on roadway mainlines, interchange and access ramps, and approaches to bridges, and tunnels, the scope of the survey contained in Appendix A is limited to mainline plazas and approaches to bridges and tunnels. Therefore, design considerations and elements unique to ramp plazas may not be addressed in this report.

1.2 PROBLEM STATEMENT

Many decision points exist while approaching the plaza, at the plaza, and on departure from the plaza. The decision points can lead to vehicle merging, weaving, queuing, diverging and differential speeds. Diverging and weaving occurs on the approach to the plaza as electronic toll collection (ETC) users separate from cash paying customers, who then further diverge based on selected cash payment lane type, shortest traffic queue, and lane status (i.e., open or closed). Multiple collection methods can increase the potential for side swipe and rear-end collisions if the lane groupings are not clear to users who are making choices of which lane to use for payment. Potential safety hazards particularly exist when approaching and departing ETC dedicated lanes. When an driver unfamiliar with the toll plaza realizes their vehicle is in the wrong payment lane and suddenly stops, a following high-speed, ETC–equipped vehicle can easily collide with the stopped vehicle. Consequently, speed variance is another important factor to be considered at mixed use toll facilities. Similarly, merging and weaving occurs on the departure side of the plaza as the number of toll lanes tapers down to the width of the continuing mainline.

Various studies and reports have presented summaries of the state-of-the-practice within the industry, primarily related to specific design elements or practices of toll agencies. The present environment is seeing significant increases in new toll highway miles, resulting in more toll plazas, most of which include high speed express lanes for ETC users only. Further trends show toll roads facing greater commuter and recreational demands, resulting in cash paying and ETC users familiar with the toll road mixed with unfamiliar cash paying users. Without the use of good design practice, including effective deployment of various traffic control devices, this mix can result in unsafe and inefficient operations. ETC users now expect non-stop, high speed travel through toll plazas without incurring any delays. Development of national guidelines that address the implications of electronic toll collection on plaza operations has therefore become much more critical.

Toll plazas have been designed and constructed in the United States without the benefit of national toll plaza design guidelines and standards, often resulting in driver unfamiliarity and inefficient vehicle throughput. Without national guidelines and standards, designs have evolved placing undue focus on monetary constraints, deploying signs with too little or too much information, inefficiently configuring toll lanes and embodying design features with greater emphasis on establishing a unique identity than on plaza safety and operations. As a result, toll plaza design elements and practices vary from agency to agency, and are often dictated by either legacy toll plaza design practices or variations to historical designs that retains a distinctive appearance while incorporating enhancements to correct deficiencies. Plaza modifications made to add electronic toll collection (ETC) to existing plaza facilities also vary by agency. In further complicating operations and adding driver confusion, some agencies have enacted variable pricing schemes to reduce plaza delays by shifting travel demand.

Improvements and modifications to existing plazas are impacted by right-of-way constraints, requirements for maintenance of traffic and revenue, provisions for future improvements and budget considerations. Few agencies can afford to construct entirely new toll plazas that incorporate design features to maximize safety and efficient plaza operations. Incremental changes, however, may lack sufficient design analyses and incorporate minimum design elements needed for safe and efficient operations. Increases in plaza collisions and operational performance deficiencies often result from these incremental changes.

In contrast to traditional public highway departments and agencies when considering the application of traffic control devices, a toll agency has to follow a different business-customer philosophy. In addition to the various legacy provisions and constraints described earlier, the agency must consider their customer base, and how they can equitably serve the various customer groups (i.e. short-trip/long-trip, commuter/recreational, etc). With the use of electronic toll collection technology, the manner that the toll agency markets and serves their customer base through its business rules and ETC fulfillment procedures will affect toll plaza operations. The degree of success in implementing this business-customer philosophy along with good engineering judgment will dictate the best application of various traffic control strategies and devices.

1.3 STUDY OBJECTIVES

For the purposes of this report, the following description of traffic control devices will be used based on the MUTCD:

"Traffic control devices shall be defined as all signs, signals, markings, and other devices used to regulate, warn, or guide traffic; placed on, over, or adjacent to the highway, bridge or tunnel by the authority having jurisdiction."

Below are the Project study objectives:

- Enhance safety (customer, employees and visitors),
- Improve efficiency,
- Increase uniformity in traffic control devices to breed recognition and familiarity,
- Build consensus (amongst toll agencies and departments).

The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users at points of conflict and where control and information are needed to achieve these purposes. Traffic control devices inform road users of regulations and provide warning and guidance needed for the safe, uniform, and efficient operation of all vehicles comprising the traffic stream. Uniformity and consistency of the meaning, location, and operation of traffic control devices is vital to their effectiveness. Uniformity of devices helps road users because control devices are vital to their effectiveness. Uniformity of devices helps road users because it aids in recognition and understanding, thereby reducing perception/ reaction time. Uniformity assists road users, law enforcement officers, and traffic courts by removing ambiguities and misunderstandings of the proper interpretation. Uniformity assists tollway and public highway officials through efficiency in procurement, installation, maintenance, and administration. To achieve uniformity and consistency in the application and location of traffic control devices for toll plazas, a consensus amongst toll agencies must be built.

1.4 METHODOLOGY

The following sections describe the work tasks for this Project:

1.4.1 Literature Review

The project team researched, collected and compiled available literature related to toll plaza design, safety and operations and used this information to validate design elements and practices having a high frequency of use by agencies and state DOTs. Concurrent with the literature review, existing plaza design standards and guidelines were obtained through contacts with representatives of a cross section of toll agencies based on selected ranges of daily transactions.

A summary of these findings are included in Appendix C.

1.4.2 Agency State-of-the-Practice Surveys

An extensive Web-based survey requesting predominately simple responses to questions on multiple categories of toll plaza design elements and practices was prepared using JAVA scripts. Toll agencies identified through the International Bridge, Tunnel and Turnpike Association (IBTTA) member roster and the Project team's contacts were notified by email of the need for their cooperation in completing the survey to establish a coherent state-of-the-practice for traffic control strategies at toll plazas. The Web site address, along with user access instructions, were included in the notification email. The purpose and focus of the Project survey was publicized in IBTTA newsletters in the hope of improving agency participation in the survey.

In the interest of reducing the time required for toll agencies and departments to complete the survey, a multiple choice format was used for the design, safety and operational performance-related questions intended to solicit information on design elements and practices deployed on the responder's toll facility. The results of the survey were compiled to assess current practices, and the variation that exists in the toll industry.

A survey result summary is included in Appendix A.

1.4.3 Expert Panel Workshop

An expert panel was organized and assembled for a workshop on August 17th and 18th, 2004 in Lisle, Illinois. The Expert Panel consisted of seven panel members, four Project Team members, and observers from FHWA and the International Bridge, Tunnel and Turnpike Association (IBTTA). Panel members were selected to represent a wide range of toll facility, traffic engineering and toll technology experience.

A program agenda was prepared that disaggregated the Project study into four distinct categories for discussion purposes. The survey results and summaries of selected design elements were provided at the workshop. These materials, together with a brief program overview, were the basis for the Expert Panel workshop discussions. A presentation on toll plaza signing, hardware and equipment was used to illustrate the variety of usage and generate discussion.

Discussions and recommendations from the Expert Panel workshop are summarized in an Appendix B.

1.4.4 Developing Design Guidelines

Experts on the project team were tasked to develop design guidelines based upon the literature review, state-of-the-practice surveys and expert panel consensus building, starting with a workshop and concluding with incorporation or resolution of operating agency comments on a draft of this Report after completion of an internal review . Guidelines are presented in the subsequent chapters of this report along with the reasoning, methodology, and/or analysis used in the derivation of the guidelines. A draft report was distributed to all key operating agencies of toll plazas and other interested FHWA partner organizations. This Best Practice Report incorporates comments received from agencies, departments and partners.

1.5 USE OF DOCUMENTATION

This report contains two primary components, a review of the state-of-the-practice and a derivation of proposed guidelines primarily based on the design elements surveyed for this Project and researched from related literature. The guidelines presented in this report are a synthesis of this information by the authors. While the accuracy of the information gathered and presented in this report has survived a reasonableness test by the author's peers, the accuracy of the information presented has not been field verified. This report does not constitute a standard, specification, or regulation.

Operating agencies of toll plaza facilities must consider the suitability of the guidelines to their facility and fully assess the implications if an implementation follows one or more guideline(s). Changes to existing plazas may result in user confusion, depending on the nature of the change. Consequently, it is important to consider any changes in the context of the overall System if an agency operates more than one toll plaza, to maintain uniformity throughout the entire network.

The following chapters address the subject topics for mainline, ramp, bridge and tunnel toll plazas even though the survey focused on mainline plazas for roadways, bridges and tunnels. "Qualifiers" are used when appropriate, as non-mainline plazas have more unique factors to address. Plazas on ramps or interchanges vary greatly in size, depending on the facility. Though ramps usually have lower design speeds than mainline sections, curved sections and other geometric challenges are common. Toll plazas for bridges and tunnels are typically situated at the extremities of these facilities, sometimes only on one side and in one direction. Bridges and tunnels often have limited right-of-way and constrained space overall to accommodate toll plazas. In addition, the feeder routes into some bridges and tunnels are not high-speed roadways.

It should be noted that visibility, design speeds and geometric constraints may greatly affect any recommended guidelines, and engineering judgment should always be used in the application of traffic control strategies and deployment of devices.

CHAPTER 2
PLAZA OPERATIONS
AND TOLL LANE CONFIGURATION

2.1 PLAZA LOCATION

Toll plazas were originally designed to provide a venue for vehicles to stop and pay a toll with some protection from precipitation. The specific venue was and still is guided by the facility's toll operations concept, or toll system. This, in turn, is guided by the facility's business rules and requirements that are established based on traffic characteristics, revenue requirements, maintenance considerations, and site opportunities and constraints.

Two general types of toll collection systems are in use today. One is the "closed entry-exit system", or “ticket system,” so named because motorists are issued tickets at the entry points, and they surrender those tickets on exit. The ticket identifies the length of the trip, which is used to determine the fare in conjunction with the vehicle classification. Ticket systems are generally “closed,” meaning no free movements are permitted on the system.

The second collection system is the “barrier system,” which collects a set toll at a specific location along a toll facility based only on vehicle classification. Barrier systems may be “open” or “closed”. Closed barrier systems have adequate mainline and ramp toll plaza locations so no free movements are allowed anywhere on the toll facility. Open barrier systems allow some free movements between interchanges.

Once the specific type of toll collection is selected, plaza location is selected based on right of way availability, proximity to interchanges, geometrics, stopping sight distance, ease of utility access, environmental impacts, and proximity to residential neighborhoods.

2.1.1 State of the Practice - Ticket System

Deployment

States having major ticket-system toll operations in the US include Florida, Indiana, Kansas, Massachusetts, New Jersey, New York, Ohio, Oklahoma, and Pennsylvania. These toll facilities were all built as ticket-system roads between the 1940s and 1960s. However, because of traffic and operations challenges, no new toll roads in the US have been built with a ticket system since then. Most operators have converted some portions of their facilities from the ticket-system to the barrier system. Toll road sections with lower traffic volumes and large distances between interchanges still function acceptably well as ticket-system operations. The only US roads still operating ticket-system toll collection in major metropolitan areas are the New Jersey and Pennsylvania Turnpikes.

All toll collection points on ticket system toll roads are either at the system end-points, or at every interchange between those endpoints. Every vehicular movement on the system must pass through an entry toll lane and an exit toll lane. Trumpet interchange configurations (Exhibit 2-1) were used in order to bring all interchange traffic to a single point to minimize plaza and building construction, and minimize the cost and complexity of cash-handling operations. Entry lanes can be operated in either an attended or an unattended fashion using ticket-issuing machines. Because the toll amount varies with each vehicle, automation of cash collection was not possible, and all "exit" lanes were built as attended lanes.

As a result of all exit lanes being attended, and the toll amount varying from vehicle to vehicle, ticket-system exit lanes with substantial commercial vehicles process traffic at a very slow rate, often in the range of 180 to 240 vehicles per hour (vph). Ticket system entry lanes, whether attended or unattended, process vehicles more quickly and have similar performance to barrier plazas, with throughputs in car-only lanes around 600 vph.

Location Requirements for Personnel Support

Ticket system exit lanes must be staffed, so all plazas on a ticket-system road require buildings and infrastructure to support attended operations, such as personnel support, parking, cash handling security features, material and equipment storage, utilities, break and restrooms, back-up emergency generators, and other support features. Therefore, all the ticket-system access points provide positive access control, and the attendant ability to close off or meter access when desired, such as during dangerous weather conditions. The building, infrastructure, storage, and parking all limit the space available for plaza pavement, particularly with respect to sight distances, acceleration/deceleration lengths, room for weaving, etc.

Plaza Locations and Geometric Limitations

Trumpet interchange ramps provide short tangent sections on which to locate and construct a toll plaza. Traffic approaching the plaza is merging from at least two ramps, and traffic leaving the plaza is diverging into at least two directions. There is limited space for vehicle storage in queues before lane access becomes blocked. There is little time for drivers to make decisions on toll lane selection or direction of travel. As a result, ticket system interchange plazas are characterized by slow vehicular movement and weaving through the interchange; relatively low throughput capacity; and a limited capacity of queue storage before impacting merging or diverging traffic. Operations can break down quickly in peak periods. Consider an example of a typical ticket plaza with three entry lanes and five exit lanes, such as the Pennsylvania Turnpike Irwin interchange. The total storage area for the exit lanes after both eastbound and westbound traffic merge might be 100 passenger cars or a smaller number of vehicles if there is a commercial vehicle mix. The five exit lanes can process 180 to 220 vph each or 900 to 1,100 vph collectively. If peak hour traffic to a major intersecting route reached 2,000 vph, the theoretical capacity of a single exit ramp lane, a substantial queue would quickly develop.

Plaza Locations and Growth Limitations

Because of the geometric constraints of the trumpet interchange, it is often difficult or impossible to widen these plazas beyond a relatively small number of lanes. To fit in additional lanes, designers must use substandard taper rates, storage lengths, roadway grades and cross slopes.

The addition of multiple lane types and non-stop electronic toll collection (ETC) lanes in ticket-system interchange plazas is difficult. Limited sight distances, the need for quick driver decision making, and little room for weaving and merging (often only 300 to 500 feet) are characteristics of ticket system interchange plazas.

2.1.2 State of the Practice - Barrier System

Deployment

The barrier system concept of toll operations has been used almost universally on all new US toll facilities built since the 1960s. In the early 1990's the conventional barrier plaza was supplemented by non-stop express lanes employing ETC as the single method of payment, complemented by a license plate capture system for violators.

Location Rationale

All toll collection points on the barrier system charge a flat fee to authorize use of a fixed length of a toll facility by a particular vehicle type. In the cases of bridges or tunnels and shorter toll roads, this single toll represents the fee to use the entire facility. Plaza location is a matter of economics and opportunity (i.e., where developable right of way exists and can be reasonably acquired across the mainline roadway section). In the cases of bridges and tunnels, unconventional location solutions, such as suspending the administration/ plaza building from the underside of the bridge and abutting the plaza/administration building to the toll lanes, as is the case for the Tobin Bridge and Lincoln Tunnel, respectively, are sometimes necessary.

A barrier system will typically have one or more mainline plazas (or one pair for both directions of traffic) that charge the toll for a specific segment of the system. This segment would typically range from 10 to 30 miles. For example, a toll road financed on a 10¢ per passenger car mile basis and is 30 miles long could have two mainline barrier plazas which each charge $1.50.

Some barrier systems allow free movements on specific short segments between the barrier plazas. Most barriers systems, however, are "closed" in that they prevent free movements through the strategic location of interchange ramp toll plazas. Not all interchanges and ramp movements need to be tolled to meet this requirement. Plaza locations will typically be selected so that freeway facilities owned by state departments of transportation (DOTs) and high volume and speed interchanges may be constructed without ramp toll plazas. For example, it is often desirable to avoid locating conventional toll plazas at an interstate-to-interstate interchange with multiple high-speed directional ramps. The Illinois Tollway designed the new I-355 / I-55 interchange (Exhibit 2-3) in this manner (i.e., I-355 has two barrier plazas at each end and the centrally located I-55 interchange does not have ramp toll plazas).

Location Requirements for Personnel Support

Mainline barrier plazas have traditionally been attended facilities, with various improvements for personnel assigned to work on the site including offices, parking, cash handling security, utilities, emergency generators, material, and equipment storage, and other personnel support features. Barrier system ramp plazas often operate unattended. These plazas still require some infrastructure and utility support (e.g., power and communications), but the scale of site improvements is substantially reduced, and therefore allow more flexibility in location than attended facilities.

Plaza Locations and Geometric Limitations

Because mainline plazas restrain or meter passage on high-speed routes, locations are generally selected where the required right of way can be reasonably acquired, adequate stopping sight distance exists, profile grade is relatively flat, and a sufficient length of roadway is on a tangent section. Geometric limitations are less than those encountered when locating ramp plazas, although constraints on design may be imposed by portal or approach features at tunnel or bridge crossings, as well as economic development along plaza rights of way.

Trumpet interchanges do not accommodate barrier system ramp plazas easily, primarily because two of the four typical movements through the trumpet interchange are not tolled, and so free lanes must be segregated from the toll lanes. Barrier system ramp plazas typically follow the interchange design, with the exception that individual ramps need to be several hundred feet longer and comply with stopping sight distance standards in advance of a small two- or three-lane ramp plaza.

Vehicle processing speeds are faster than in ticket-system exit lanes, and implementing a non-stop ETC lane requires less transaction processing. Nonetheless, interchange ramp designs must often be altered to provide additional tangent length and transverse space for locating a small toll plaza with some expansion capability.

Plaza Sizing and Growth Limitations

When the policy is to require vehicles to stop to pay the toll, plaza design must account for the required number of lanes based on a composite vehicle throughput, and the amount of approach pavement required for safe vehicle storage. Alternative plaza locations may need to be considered if the available plaza width is inadequate.

The addition of non-stop lanes adds new considerations. Dedicated lane design requires the provision for signing and pavement markings to keep dedicated lane approaches open, particularly when the cash lanes have long vehicle queues. Express lane design requires the physical separation between vehicles moving at high speed and vehicles either at rest waiting to pay the toll or decelerating while approaching the plaza. For plazas combining express lanes and a conventional plaza, the approach and departure length requirements become paramount. These plazas should be located at least one mile from the nearest interchange.

2.1.3 State of the Practice - Future Systems

From 1989 until 2004, the percentage of tolls collected by electronic toll collection has increased from 0% to 40% or more at almost all US toll facilities. Cash-paying toll traffic constitutes the minority traffic component for many toll facilities. ETC usage is even greater during peak hour periods. In the case of the Orlando-Orange County Expressway Authority (OOCEA) and the Illinois Tollway, if the 24-hour ADT percentage of ETC participation is, for example, 50%, the peak hour penetration typically exceeds the ADT figure by 5% to 10%. This can be attributed to the appeal of ETC in improving traffic flow and reducing delays during congested, peak periods.

New toll agencies or projects begun after 1990, such as E-470 in Denver, Colorado, TCA in Orange County, California, and Delaware have designed their facilities so cash toll collection could be removed by simply closing the cash lanes. New toll facilities overseas, and some US facilities are now in operation without provisions for cash toll collection (i.e., no conventional plazas). These existing toll facilities include the following:

Toll Facility Name	Toll Facility Type	Location
SR-91	Managed Toll Lanes	Orange County, California
407 ETR	Toll Road	Toronto, Canada
City Link	Toll Road	Melbourne, Australia
Westpark Tollway	Toll Road	Houston, Texas
I-394	High Occupancy Toll (HOT) Lanes	Minneapolis, Minnesota
I-15	High Occupancy Toll (HOT) Lanes	San Diego, California
I-10	High Occupancy Toll (HOT) Lanes	Houston, Texas

Much research and writing has focused on the fact that cash toll collection requires users to stop their vehicle to pay a toll, and is not popular with the toll road customer base. As ETC becomes more popular and ubiquitous in the future, existing toll road operators will need to make as many accommodations as possible to provide what their customers are demanding.

The implication here is that a toll agency should not focus on a particular "design" or future percentage of ETC transactions resulting in a required cash toll collection capability to handle the remaining transactions. Rather, all new facilities should be designed to support no more than today's quantity of cash transactions, and be easily converted to all electronic operations involving ETC supplemented by some form of video tolling or temporary electronic passes to accommodate users without a transponder.

2.1.4 Examples

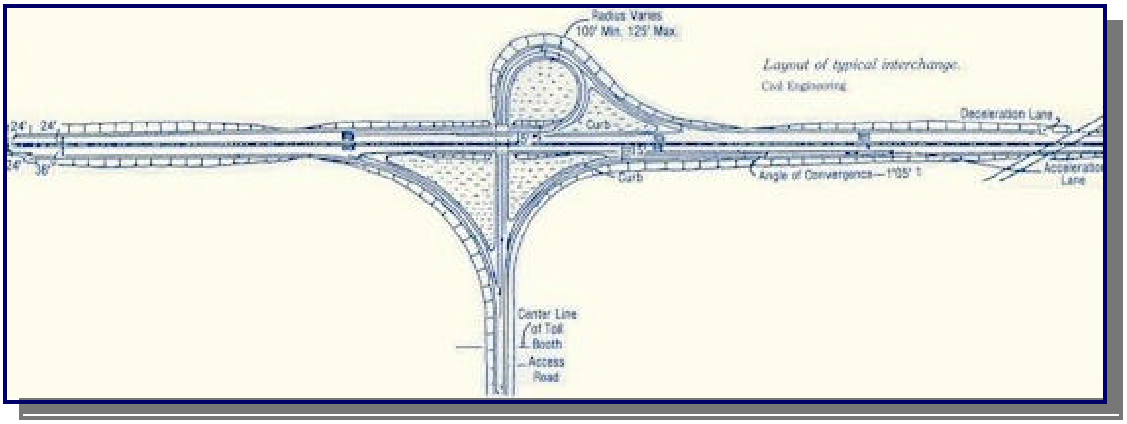


Exhibit 2-1 – Original Pennsylvania Turnpike Typical Trumpet Interchange from the 1940 Construction.

Exhibit 2-2 Small Ticket-System Toll Plaza on Florida's Turnpike at Yeehaw Junction (2004)

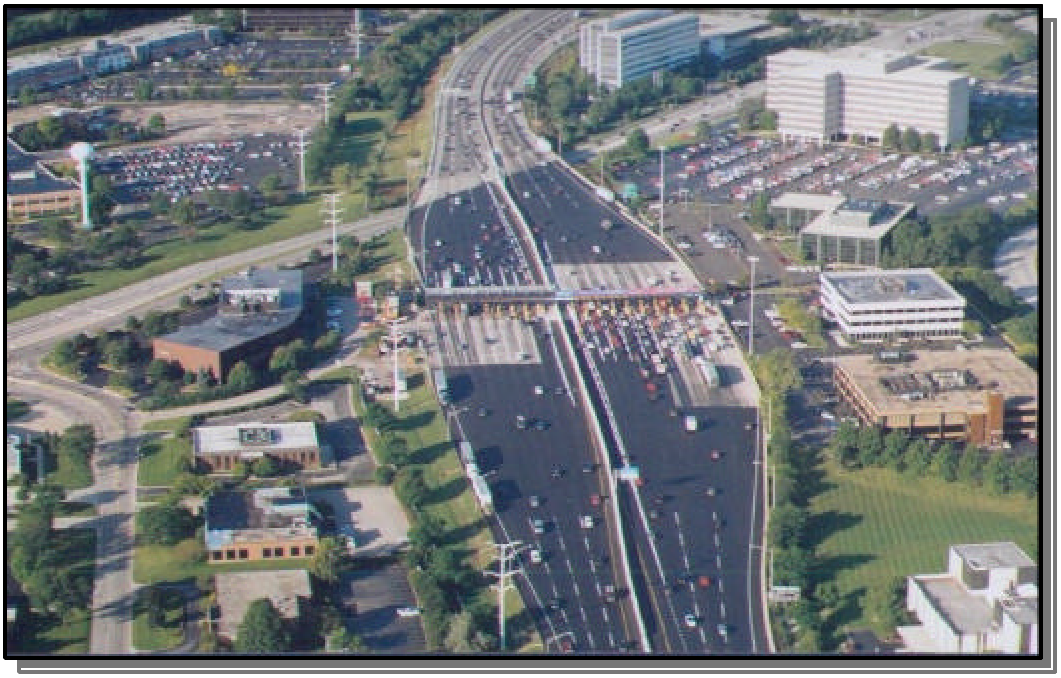


Exhibit 2-3 Mainline Barrier Plaza on the Illinois Tollway, I-88 York Road Plaza (1998)

Exhibit 2-4 Tunnel Barrier Plaza on the New Jersey Side of the Lincoln Tunnel

Exhibit 2-5 Express Lane Barrier Plaza on the Orlando, FL Orange County

2.1.5 Recommended Guidelines

Plaza Location and Collection Design Issues

As toll collection moves increasingly from cash-based to account-based, the need for traffic to stop to transact a toll decreases. In 1988, no tolls were collected electronically using radio frequency identification (RFID) technology. By the end of 2004, many US operators collected at least half of their tolls via electronic toll collection using RFID technology. Toll operators at the Florida's Turnpike and Illinois Tollway have publicly stated they target 75% market penetration of their electronic toll collection programs.

Several new toll facilities have been built without cash toll collection, and several more are in development at the time of this writing. Necessity such as lack of right of way and partially completed "freeway grade" structures supported use of an all-electronic design for SR-91 in California and 407 ETR in Toronto, respectively. Florida's Turnpike is preparing to completely remove the existing plazas from the 23-mile Sawgrass Expressway, and convert this facility to all-electronic toll collection.

The precedent set by the operation of non-stop toll facilities around the country is expected to result in toll customers increasingly not wanting to stop in a toll plaza environment, thereby limiting the life of conventional plazas, certainly less than the expected life of the underlying tolled highways, bridges or tunnels.

Proposed plaza construction and modifications should be designed with anticipation of increasing ETC utilization, and eventual removal of conventional plazas, at least for the purpose of toll collection (bridge and tunnel operators may wish to retain plazas for inspection and security reasons). Plaza locations should be selected, whenever possible, to accommodate high-speed operations and roadways for possibly obtaining a temporary pass to use the facility. Inherent in this approach, particularly for conversions, is the likelihood ETC will need to be supplemented by video tolling, temporary electronic passes, or some other means of high speed, non-stop collection to accommodate users without a transponder.

Plaza Location and Collection Guideline Development

Some design measures that would aide the owner in preparing for future growth in ETC usage are the following:

a. Provision for adequate ETC lanes to the extent that almost 100% of the approach roadway volume has an express lane or ETC dedicated lane to use. This suggests a 1:1 design relationship between ETC lanes and the approach or departure roadway lanes.

b. Simplification of the offered plaza lanes to only two types of toll collection. This greatly enables quick decision-making, which is increasingly the environment in which toll operations are conducted.

c. Economical conventional plaza design and construction is desirable where there is no existing regional use of ETC, cash collection metering affectively improves facility operations, and relatively low commuter traffic volumes are forecasted.

The expectation based on recent toll facility projects is new mainline toll plaza requirements will include non-stop ETC express lanes, and new ramp plaza requirements will include non-stop ETC dedicated lanes. In these cases, the driver approaching a plaza will have to make a choice between the non-stop lanes and the conventional plaza lanes or adjacent cash lane(s).

Plaza Location Guidelines

Guideline	Plaza Locations Guideline 1
Title	Plaza and Interchange Intervals
Text	The 2001 AASHTO *A Policy on Geometric Design of Highways and Streets* (the "Green Book") recommends separation of 1 mile (urban sections) or 3 miles (rural sections) between interchanges. This criteria should be used as a guideline for selection of new mainline toll plaza sites (i.e., the interstate standards require 1 mile to the nearest interchange in urban areas and 3 miles in rural areas).
Commentary	Although it may not be possible to meet this design guideline at bridge and tunnel crossings, the interval spacing minimums should remain a goal.

Guideline	Plaza Locations Guideline 2
Title	Site Selection and Sight Distance
Text	New toll plazas should be sited such that motorists will be able to see the plaza, while driving at posted speeds with adequate stopping sight distance before the queue zone. The plaza site should be on a tangent pavement section.
Commentary	None.

Guideline	Plaza Locations Guideline 3
Title	Ramp Plaza Movements
Text	New toll plazas should not have merging or diverging movements within the plaza approach and departure zones. New plaza construction should not occur within trumpet interchange areas, if possible.
Commentary	Some existing toll plaza locations have merging and diverging movements within the plaza approach and departure zones. Other appropriate treatment options could be applied to improve their operations.

2.2 DEDICATED LANES

The first non-stop electronic toll collection lanes in the U.S. were "dedicated lanes". Since Then current implementations have been developed under a variety of opportunities and constraints. Some agencies (New York, Illinois, Pennsylvania, OOCEA and the Florida's Turnpike Enterprise, among others) converted existing cash lanes to create dedicated lanes while others, such as the Delaware River and Bay Authority, have built new plazas incorporating dedicated lanes. In many cases conversions began with single lanes and then were expanded, incorporating specific traffic control design features along with other performance and safety enhancing changes at various stages of the conversion. As a result, there are quite a wide variety of dedicated lane implementations.

2.2.1 State of the Practice

The following are general characteristics of an ETC dedicated lane. While it is recognized there are exceptions to every rule regarding dedicated lanes, these items are deemed to be representative of common practice.

Non-stop ETC lanes meeting all of the following requirements are typically described as ETC dedicated lanes:

a. Located within a conventional plaza and sharing the same approach and departure zone pavement;

b. Located in the center or to the left of the conventional plaza and similar in appearance to the other conventional plaza lanes;

c. Single toll lanes of traffic with minimal or no shoulders;

d. Separated by either toll plaza islands of the same width as the cash collection lanes or barrier if the lanes do not need to be crossed by plaza staff.

Dedicated lanes result in mixing non-stop traffic into an often congested area designed for vehicles waiting in queues to pay the designated toll. Dedicated lanes within a conventional plaza should be designed to avoid giving a user the impression high-speed travel is allowed in these lanes.

Some operators (e.g., HCTRA in the Houston metropolitan area) built plazas with multiple lanes without islands between them. Even though the other criteria enumerated above would be met, multiple adjacent lanes should be treated as express lanes, because of the appearance as a higher grade of non-stop toll operations.

2.2.2 Survey Results

Although the survey results come from a relatively limited group of responses from toll highway and bridge operators, observation of other toll facilities indicate consistent support for the most popular practices.

Dedicated Lane Plaza Orientation

Almost 90% of responding toll road operators have ETC dedicated lanes, most with multiple dedicated lanes per direction. Most operators and all bridge operators group dedicated lanes together within the conventional plaza. The dedicated lanes are typically located to the left of the manual lanes.

Although not captured by the survey results, ramp plazas are often configured differently because of shorter approach zones, a curved roadway alignments, and proximity to other merges or directional splits. Two agencies in Florida, and the Illinois Tollway, among others, locate some or all ramp plaza dedicated lanes to the right, for operational and service reasons. Plazas located on trumpet interchange ramps may group ETC dedicated in the middle of the plaza to equally service traffic entering the plaza from multiple directions.

Dedicated Lane Separation – Same Direction of Traffic

Toll plazas often use extended raised pavement markers within the queue area to augment signing on the plaza canopy and along the approach, as well as extended solid white pavement markings. While this does not provide physical separation, it does help the driver to quickly identify dedicated lanes, and segregate vehicles that are preparing to a stop from those slowing down as needed to navigate a dedicated lane. Raised pavement markings, delineators and solid white markings are also used in the recovery zone.

Dedicated Lane Separation – Opposing Direction of Traffic

Most survey respondents operate plazas with contiguous opposing directions of traffic, but only six of the thirteen physically separate the directions of traffic with a permanent barrier.

Dedicated Lane Utilization

Of fifteen respondents with multiple dedicated lanes, only two operate lanes restricted to cars. Only one agency had installed dedicated lanes restricted to trucks (not captured by the survey since the dedicated lanes were in the process of being converted to mixed use). The majority of toll road facilities operate dedicated lanes without restriction of vehicles classes. Vehicle type, size or height restrictions may be used at tunnel and bridge toll plazas out of necessity due to structural limitations and safety considerations.

Dedicated Lane Width

The average lane width reported was over 11 feet (3.4m), and 12 feet (3.6m) was the most common response. One bridge responded, with a 14-foot (4.3m) lane width. As expected, newer facilities have wider toll lanes than older plaza facilities.

Dedicated Lane Island Widths

These responses varied between only two feet (0.6m) and 16 feet (4.9m). Six to seven feet (1.8m to 2.1m) was the most common survey response.

Island widths for dedicated lanes are often established well before the introduction of ETC into a conventional plaza and subsequent conversion of cash lanes to dedicated lanes. Island widths can be reduced to gain lane width when toll lanes are converted to dedicated lanes, although this increases construction costs and time. Many agencies have adopted standards for toll plaza design. These standards and design practices reflect operating policies and operational and safety requirements, such as the spacing of stairwells for tunnel access, height of the toll island, equipment. and toll booth horizontal clearances and restrictions on the use of exposed conduit.

Dedicated Lane Posted Speeds
The reported posted speeds ranged from 5 mph to 45 mph (8 kph to 70 kph) with an average of about 26 mph (42 kph). Typical bridge dedicated lane speeds were lower.

Excessive speed through dedicated lanes presents a challenge that all toll facilities incorporating ETC dedicated lanes must face with varying severity. The 85th percentile operating speeds tend to exceed posted speeds, sometimes by substantial margins. Operators implement a variety of measures to encourage or mandate speed compliance.

2.2.3 Examples

Exhibit 2-6 – New York State Thruway Plaza with Multiple ETC Dedicated Lanes Located to Left (ca. 2002)

Exhibit 2-7 – Hilton Head Island Toll Plaza with a Dedicated Lane Located in the Middle (ca. 2002

Exhibit 2-8 – Orlando Orange County Expressway Authority Ramp Toll Plaza with ETC Dedicated Lane Located to the Right (2004)

2.2.4 Recommended Guidelines

Dedicated Lane Design Issues

Existing design standards have provided little guidance on the subject of dedicated lane design, except for some work by the Institute of Transportation Engineers. Current AASHTO or MUTCD guidelines do not offer guidance in the design of dedicated lanes.

Some important facts regarding the evolution of ETC dedicated lanes are the following:

a. Developed on a trial-and-error basis by pioneering toll agencies;

b. Made significant contributions to improved traffic capacity at toll plazas;

c. Demonstrated throughput capacities of 1,200 vph to 1,500 vph, on the low end.

Non-stop lanes make the drivers' use of a toll plaza more difficult, in that more decisions are required to navigate the plaza. In the case of many survey respondents, ETC dedicated lanes represent a third type of toll lane, which may be further complicated by other restrictions, such as cars or trucks only. Consequently, the driver's attention is often drawn to canopy signs, lane use signals and pavement markings, and much less to nearby vehicles. The case study by Mohamed, Abdel-Aty and Klodzinksi reviews how conflicts in lane selection can lead to increased accidents.[1]

Differential speeds resulting from differences in non-stop and stop-and-go traffic flow corresponding to dedicated lane and cash lane usage, respectively, needs to be minimized within the approach and departure zones.

Dedicated Lane Guideline Development

Good design of a toll plaza with dedicated lanes should not only consider applicability of the individual guidelines from each section, but should view the guidelines collectively to derive symbiotic benefits that exceed the benefits derived when the guidelines are individually adopted (i.e., the whole exceeds the sum of the parts).

With ETC dedicated lanes now able to process the majority of traffic in peak traffic periods, the sometimes marginal benefit-cost ratio associated with automatic coin machines (ACM) justifies consideration of converting ACM lanes to ETC dedicated lanes. Coin machine lanes were developed long before development of ETC technology, and were intended to increase vehicle processing without incurring a continuous operations labor cost. Now, ETC dedicated lanes far exceed the original objectives of coin machines. The elimination of coin machine lanes, when feasible, reduces the number of lane types a driver can select during the approach to the toll plaza. Consequently, drivers can spend more time viewing their surroundings and be better prepared to take defensive measures to avoid potential incidents.

1) "Safety Considerations in Designing Electronic Toll Plaza: Case Study," ITE Journal, March 2001, Mohamed, Abdel-Aty and Klodzinski.

Some operational constraints at bridge and tunnel crossings require unusual measures, such as partial facility closures or contra-flow traffic operations during maintenance periods such as tunnel cleaning or bridge deck repairs. During these periods, existing pavement markings and signing may not apply, resulting in sometimes complex traffic control and guidance that may not be anticipated by drivers intending to use a particular bridge or tunnel crossing. In addition, at facilities with limited plaza space and prone to bottlenecks, a case could made for implementing only mixed-use toll lanes that include both ETC and cash operations.

Pavement markings can be used to separate dedicated lanes from cash lanes for a length of approximately one half of the queue zone. This not only follows the intent of the AASHTO recommended lane separation, but also helps to identify a boundary to avoid straying into by vehicles waiting in queues.

Dedicated Lane Guidelines

Based on the survey results, observation of existing practices, and published research literature,[2] the following dedicated lane guidelines are formulated to remedy this missing guidance:

Guideline	**ETC Dedicated Lane Guideline 1**
Title	ETC Dedicated Lane Count
Text	For new construction, where express lanes are not feasible, the number of dedicated lanes should at least equal the number of approach roadway lanes or the total roadway design volume divided by 1,500.
Commentary	This provision is intended to assure a given toll plaza will not require future modifications or lane conversions to meet customer demand for non-stop lanes. In theory, it may be appropriate to defer implementation of dedicated lanes for new toll plaza construction, and rely on mixed-use lanes until ETC participation increases to fully support the use dedicated lanes. In practice, new toll roads rely heavily on non-stop ETC to garner public support and acceptance.

2) Contribution to the Development of Guidelines for Toll Plaza design," Journal of Transportation Engineering, May/June 2001, McDonald and Stammer.

Guideline	ETC Dedicated Lane Guideline 2
Title	ETC Dedicated Lane Orientation – Mainline Toll Plazas
Text	Where possible, lanes accepting the same payment types should be clustered. On mainline plazas, dedicated lanes should be clustered to the left as vehicles approach the plaza.
Commentary	Exceptions may be warranted when approach or departure zones are located on interchange ramps, or high volumes of commercial traffic are present. Under these conditions, a supplemental dedicated lane towards the right of the plaza to support traffic entering or exiting the system in multiple directions, or to isolate ETC commercial vehicles away from heavy commuter traffic in the left dedicated lanes, may be warranted.

Guideline	ETC Dedicated Lane Guideline 3
Title	ETC Dedicated Lane Orientation – Ramp Toll Plazas
Text	Assignment of ETC dedicated lanes is dependent on ramp geometry and proximate merges and splits. Consistent locations should be used to enable quick recognition and simplify the plaza approach for repeat drivers.
Commentary	The conversion of cash toll collection lanes into dedicated lanes at ramp plazas has been challenging, particularly for ticket system operators which have plazas located close to at least two merges and splits in trumpet interchanges. Dedicated lane selection must be made based on traffic characteristics of the individual toll operator. The New York Thruway, for example, often uses center lanes in these plazas for dedicated lanes, as this allows a single dedicated lane to serve traffic departing the plaza area to the left or the right without weaving.

Guideline	ETC Dedicated Lane Guideline 4
Title	Directional Separation of Traffic – Mainline Toll Plazas
Text	As mainline plazas are upgraded with ETC dedicated lanes, opposing directions of traffic should be separated by permanent barrier, (or moveable barrier for reversible lanes) that is capable of absorbing the impact of a vehicle with limited movement and deflection, except where the separation between opposing directions equals or exceeds the AASHTO guidelines on highway clear zone standards.
Commentary	As ETC participation climbs above 50%, the need for reversible toll lanes lessens in most locations other than those with reversible mainline lanes. Permanent barrier is expected to assist the driver in navigating the plaza. Also, the task of moving cones to shift plaza centerlines is a dangerous field assignment, and with increasing driver speeds is becoming more dangerous. Notwithstanding the use of rigidly followed safety procedures when visibility is good, this practice should be discontinued as soon as it is feasible. For major bridge and tunnel crossings, where significant reversible lane or contra-flow traffic operations are used, the use of moveable concrete barrier could be considered if the expense is warranted. When available, a clear zone between opposing traffic directions provides an open area (i.e., no obstacles present) considered sufficient for a driver to regain control of the vehicle and avoid a collision.

Guideline	ETC Dedicated Lane Guideline 5
Title	ETC Dedicated Lane Widths
Text	Twelve feet (3.6m) is the recommended width for dedicated lanes that allow commercial vehicles (CV). For dedicated lanes that only allow passenger cars, 11 feet (3.4m) is the recommended minimum width.
Commentary	Retrofits of existing plazas may deviate from these guidelines, but the designer needs to consider expected operating speed and protection of adjacent obstacles.

Guideline	ETC Dedicated Lane Guideline 6
Title	ETC Dedicated Lane Island Widths
Text	In the absence of any other site conditions or safety requirements, dedicated lane islands should replicate the dimensions of other conventional plaza islands, in accordance with any agency or adopted design standards.
Commentary	For new or reconstructed facilities, island width should be dictated by the more controlling toll booth width plus lane clearance or lane clearance plus safe access to toll island equipment.

Guideline	**ETC Dedicated Lane Guideline 7**
Title	ETC Dedicated Lane Posted Speeds
Text	Given compliance with other dedicated lane guidelines, a maximum-posted speed of 25 - 30 mph (40 – 48 kph) is recommended. In locations with many curves, merges and diverges within several hundred feet (i.e., one hundred meters) of the plaza, lower maximum-posted speeds are recommended.
Commentary	Maximum-posted speeds lower than 25 mph may apply for ramp plazas located within trumpet interchanges.

Guideline	**ETC Dedicated Lane Guideline 8**
Title	ETC Dedicated Lane Speed Differential Mitigation
Text	Barrier or pavement markings are recommended to separate dedicated lanes from cash lanes for a length of approximately one half of the queue zone.
Commentary	Pavement markings should be continuous double solid white lines complying with MUTCD. Raised pavement markings spaced in accordance with MUTCD should also be considered.

2.3 EXPRESS LANES

2.3.1 State of the Practice

The first high-speed non-stop electronic toll collection lanes in the US were "express lanes" built with new construction on Oklahoma's Kilpatrick Turnpike, and Denver's E-470 in 1991. Others followed shortly in Georgia, Texas and California. The Illinois Tollway constructed the first plaza conversion to provide express lanes in 1999. Current practice has been developed under a variety of design guidelines, but the implementations are more consistent than in the case of dedicated lanes.

Non-stop ETC lanes meeting all the following requirements are typically described as ETC Express Lanes:

- The approach and departure zone is partially or completely separated from the approach and departure zone of the conventional plaza.
- Consist of either a single toll lane with shoulders, or multiple traffic lanes with or without shoulders designated by pavement markings.
- Lane width is equal to the mainline lane width.
- Lanes abut with no toll island separation for multi-lane sections.
- Roadside barrier is used where obstacles such as gantry supports are located within the clear zone.

Express lanes are physically separated from the adjacent conventional plaza toll lanes. Some facilities have "express lanes" that generally meet the design criteria given above, but still require vehicles to slow down below the posted highway operating speeds and to make merge and diverge movements in navigating the toll site. Passenger cars, buses, and trucks should be allowed to use the express lanes given the current capability of automatic vehicle classification equipment and devices. The only exception would be for a single express lane, in which case consideration should be given to banning trucks because of delays caused by these slower moving vehicles. For this reason, and because of problems caused by stalls and other lane blockages, a single express lane design should be avoided under mixed traffic flow conditions.

Since the advent of zero-cash toll collection, the term "Open Road Tolling," or "ORT," has come into use. ORT was originally used to refer to "all-electronic" facilities, such as SR-91, Toronto 407 ETR, Melbourne CityLink and the Cross-Israel Highway. Usage of this term has evolved to also refer to non-stop lanes in which the express lane cross section exactly matches the upstream mainline toll road cross-section. For example, a road with 10' right shoulder, three 12' lanes, and an 11' left shoulder on the mainline would have the same express lane cross section through the tolling zone or point. Access to the adjacent conventional toll plaza lanes would be designed the same as an interchange.

2.3.2 Survey Results

Express Lane Plaza Orientation – The majority of responding toll road operators, and the only bridge operator, have express lanes configured as a continuation of the mainline.

Express Lane Separation – Concrete barrier is most often used to separate traffic and avoid obstacles.

Express Lane Utilization - All express lanes operators allow all classes or types of vehicles to use the express lanes.

Express Lane Width
The vast majority of express lanes are twelve feet (3.6m) wide.

Express Lane Posted Speeds
Express lanes are posted at speeds greater than or equal to 55 mph (90 kph).

2.3.3 Examples

Exhibit 2-9 – E-470 Public Highway Authority Express Lane Plaza Approach (2000)

Exhibit 2-11 – Harris County Expressway Express Lane Plaza (2004)

Exhibit 2-10 – Illinois State Toll Highway Authority Express Lane

This facility was the first US toll plaza to be converted from all-cash operations to express lane operations. Note that the approach pavement is contiguous and physically shared with the cash lanes, but the express lane alignment is tangent.

2.3.4 Recommended Guidelines

Express Lane Design Issues and Guideline Development

When a toll road operator cannot meet the AASHTO Green Book freeway lane guidelines at a site due to geometric constraints such as immovable natural features or interchanges closer than one mile, the design should consider dedicated lanes for the conventional plaza, subject to accommodating design provisions for future conversion to ORT. The AASHTO Green Book is predominately adopted by toll agencies and DOTs, either directly or through incorporation into their design standards for mainline roadway design.

Express Lane Guidelines

Based on the survey results above, the AASHTO "Green Book" and ITE guidelines, recommended express lane guidelines are the following:

Guideline	**ETC Express Lane Guideline 1**
Title	ETC Express Lane Count
Text	New ORT plazas should include the same number of express lanes equal to the number of approach roadway lanes. A minimum of two express lanes in each direction should be provided when an ORT plaza may not be feasible, including provisions for future mainline and plaza widening.
Commentary	An ORT implementation assures that a given toll plaza will never require future modifications or lane conversions to meet customer demand for non-stop lanes. This design guideline is important for several reasons: 1) The appearance of a wide-open path "through the plaza" is a very effective marketing tool 2) Once constructed, future plaza changes will not be required to accommodate higher ETC demand at the toll facilities, assuming the mainline is not widened. This eliminates additional express lane design and construction along with the risk of reduced revenue resulting from delays caused by reconstruction and high traffic control costs to assure user safety during reconstruction. This guideline applies to new construction of ORT and express lane plazas or re-construction of existing plazas to include express lanes.

Guideline	ETC Express Lane Guideline 2
Title	ETC Express Lane Orientation
Text	Express lanes should be oriented to the left, as a continuation of the mainline approach pavement.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline through the tolling zone or point, not requiring any change in driving pattern.

Guideline	ETC Express Lane Guideline 3
Title	ETC Express Lane Separation of Traffic
Text	Express lanes should be protected and separated from conventional plaza traffic according to the expressway design criteria applied on the approach and departure roadways.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline lanes, not requiring any change in driving pattern.

Guideline	ETC Express Lane Guideline 4
Title	ETC Express Lane Utilization Restrictions
Text	Express lanes should not restrict usage by particular vehicle types, such as “cars only,” or “trucks only,” beyond those restrictions in force on the approach and departure roadway or the roadway facility in general.
Commentary	Express Lanes should appear to the driver as a simple continuation of the toll facility, not requiring any change in driving pattern. An exception is a single lane express lane, which should prohibit truck usage because the operational performance of trucks tends to cause delays and safety concerns when mixed in the same lane with passenger cars

Guideline	ETC Express Lane Guideline 5
Title	ETC Express Lane Roadway Geometry
Text	Express lanes should be designed meeting the same geometric requirements for grades, cross-slopes, clearances and clear zones, stopping sight distance and horizontal and vertical curvature, as is applied to the proximate approach and departure roadways.
Commentary	Express Lanes should appear to the driver as a simple continuation of the toll facility, not requiring any change in driving pattern.

Guideline	ETC Express Lane Guideline 6
Title	ETC Express Lane Posted Speeds
Text	Express lane posted speed should not deviate from the posted speed on the interconnecting mainline.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline, not requiring any change in driving pattern.

2.4 LANE ASSIGNMENTS / CONFIGURATION

2.4.1 State of the Practice

Until the mid-1990s, many toll plazas interspersed various lane payment types, but based on survey responses most agencies now group their lanes by payment type. Although there is variation in implementation details used by agencies, predominant practice is to locate dedicated lanes to the left and manual lanes to the right of conventional plazas.

In many urban plazas, there are often ramp plazas located within approach or departure zones, as well as queue zones. In some extreme cases, these are on the left as well as the right, particularly with older facilities in New York and New Jersey. These facilities often mix payment types across the plaza, so that the driver can find a lane close to his or her intended direction of travel. This configuration is increasingly difficult to support with the increased use of electronic toll collection and the concomitant differential speeds that degrade safe operations.

2.4.2 Survey Results

<u>Lane Assignment of Attended ("Manual") Lanes</u>
Most responding agencies group their attended lanes together. All allow oversized permit vehicles to use the facility, typically in the far right lane where the toll lane or passageway is wider.

<u>Lane Assignment of Unattended Lanes (Automatic Coin Machines (ACM) / Automatic Ticket-Issuing Machines (ATIM))</u>
Most responding agencies group unattended lanes to the left of attended lanes, although a responding bridge toll agency locates their ACM lanes to the right of the attended lanes. This may reflect an intent to place the higher demand lanes in the center of the plaza, consistent with a bell shaped distribution often observed for multiple lane queues with equal service rates.

<u>Lane Assignment of ETC Dedicated Lanes</u>
As noted in the ETC dedicated lanes discussion, most operators report they group their dedicated lanes to the left of the attended lanes. Also previously noted, these lanes may be located in the center of the plaza when the approach zone and or departure zone receive and or feed, respectively, multiple directions of travel.

2.4.3 Examples

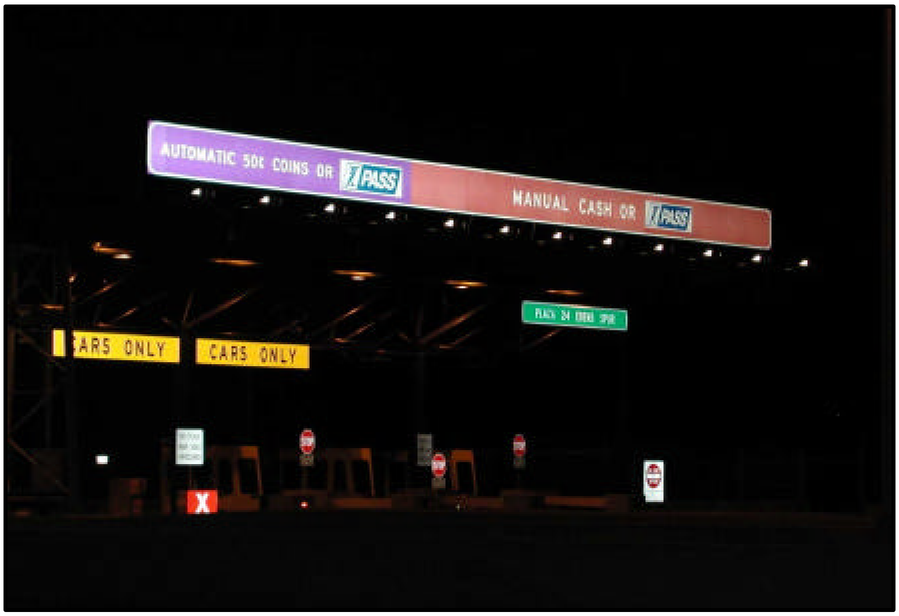


Exhibit 2-12 – Illinois State Toll Highway Authority Conventional Plaza

Exhibit 2-13 – North Texas Turnpike Authority Plaza with Lane Assignments

Exhibit 2-14 – Florida Turnpike Enterprise Lane Assignments in Orlando

2.4.4 Recommended Guidelines

Lane Assignment/Configuration Design Issues

A number of toll road operators configure one or more lanes to operate in multiple modes (i.e., some combination of attended, unattended and ETC dedicated lanes). The New York Thruway and the Orlando Orange County Expressway Authority are examples of operators who operate multiple mode lanes. These lanes allow operators to re-configure plazas for times of varying ETC demand. For example, during peak tourist periods when traffic is heavy but ETC participation rates are low the lane would operate as attended and ETC. Lane convertibility does not necessarily involve wholesale changes in modes of operation, but rather changes in the count of capability for each lane type.

As average ETC penetration rates increase and dedicated lanes are added to serve the demand, previous throughput capacity challenges wane and the need to vary lane types to maximize vehicular throughput also diminishes. As average speeds through toll plazas increase, the need to simplify and minimize lane selection increases. This in turn results in the need to group payment types and limit the number of lane payment types.

Lane Assignment/Configuration Guideline Development

Practically, there are two configurations for ACM/ATIM lanes, depending on the need for reversible lanes and the location of ETC lanes. Illinois and OOCEA, for example, locate their cars-only ETC lanes to the far left; with ACM lanes operated in between the ETC and attended dedicated lanes. Other agencies have located the ACM lanes to the left, with ETC lanes in the center. This configuration attempts to concentrate commercial vehicles within the plaza by grouping the lane types (i.e., ETC dedicated lanes and attended lanes) that these vehicles are allowed to use. This also results in the lower operational cost ACM lanes being located in the center of a bidirectional conventional plaza, where reversible operation can be easily implemented. For all cases of low truck volumes and physically separated directional plazas, as the volume of ETC traffic increases, and the volume of ACM traffic decreases, ETC dedicated lanes should be located to the left of the plaza, and the ACM lanes should be located in the center. This arrangement supports conversion of ACM lanes to ETC dedicated lanes instead of conversion of attended lanes, a process that is likely to cost significantly less.

Existing agency design standards, and the current AASHTO or MUTCD guidelines and standards, have provided little guidance on the subject of toll plaza lane assignments and configurations.

Lane Assignment/Configuration Guidelines

Based on the survey results above, current trends in the industry and results of literature research on the subject matter, the following Lane Assignment Guidelines are provided:

Guideline	Lane Assignment Guideline 1
Title	Lane Clustering.
Text	All payment type lanes should be grouped together or clustered, particularly during peak traffic periods in the case of multi-mode capability. This enables advance plaza configuration signing to enable early decision-making on lane selection.
Commentary	This provision is intended to enable driver decision making to be done in stages, first to select the payment type, then selecting a particular lane offering the selected payment type based on queue length and its vehicle composition.

Guideline	Lane Assignment Guideline 2
Title	Permit or Over-Size Vehicles
Text	The far right lane should be sized to accept permit or oversized vehicles.
Commentary	This is consistent with common practice, and allows the slowest vehicles to stay to the right. Note that if ETC dedicated lanes are oriented to the right of the plaza, this requires permit-vehicles to pay with ETC. Provisions for oversized vehicles may not be possible at constrained plazas and the underlying facility (e.g., size, structural capacity and safety considerations), particularly for bridges and tunnels.

Guideline	Lane Assignment Guideline 3
Title	Attended Lanes
Text	Attended lanes are slower processing lanes because of truck transactions, receipt processing and informational assistance, and should be located to the right side of the conventional plaza.
Commentary	Ramp plaza lanes may need attended lanes on both the left and right sides to more safely accommodate traffic arriving from and or departing to multiple directions.

Guideline	Lane Assignment Guideline 4
Title	ACM/ATIM Lanes
Text	ACM/ATIM lanes are capable of processing vehicles at a higher rate than attended lanes and should be located to the left of the attended lanes.
Commentary	None.

Guideline	Lane Assignment Guideline 5
Title	ETC Dedicated Lanes or ETC Express Lanes
Text	ETC dedicated lanes should be grouped or clustered and located to the left of the conventional plaza. Consideration should be given to locating dedicated lanes in the center of a ramp plaza if the plaza approach or departure receives or feeds, respectively, multiple directions of travel. Mixed use express lanes, by definition, must abut, be physically separated from the conventional plaza, and consist of at least two lanes.
Commentary	The intent is to breed familiarity by users when traveling multiple facilities.

2.5 BRANCH LANES AND SATELLITE PLAZAS

2.5.1 State of the Practice

A practice that was common with toll roads over thirty years old was to build small branch or satellite plazas to increase throughput capacity. The concept was to allow vehicles to either pass through an un-tolled plaza lane similar to an ETC dedicated lane, and then stop at a small plaza further downstream or enter a branch lane within the approach zone that leads to a small plaza upstream of the main conventional plaza. The objective was to add approximately one to three additional toll processing lanes to the existing capacity.

2.5.2 Survey Results

Branch Plazas

Only one of twenty-four agencies still uses branch plaza lanes. Vehicles pass through the supplemental plaza lane at an average of 37.26 mph, which is very similar to an ETC dedicated lane.

2.5.3 Examples

Exhibit 2-15 – Satellite Plaza

2.5.4 Recommended Guidelines

<u>Branch Lane and Satellite Plaza Design Issues and Guideline Development</u>

Branch lanes and satellite plazas are difficult to sign, create a confusing environment for the user to drive, and are deficient from a toll operations perspective. The location of the satellite plazas makes safe access by collection and maintenance staff very difficult. Also, physical separation of the branch lanes using barrier results in deficient approach and departure tapers, adversely affecting efficient use of the plaza lanes.

<u>Branch Lane and Satellite Plaza Guidelines</u>

Guideline	Toll Plaza Branch and Satellite Plazas Guideline 1
Title	Use of Branch and Satellite Plazas
Text	New toll plaza design should not include branch lanes and satellite plazas. Existing plazas containing these lanes should develop a plan for removal of these lanes by transitioning to ETC dedicated lanes that eventually provide throughput capacity equivalent to the satellite plaza capacity.
Commentary	As ETC participation grows after implementation, the overall plaza capacity increases and eliminates the need for branch and satellite plaza lanes.

2.6 REVERSIBLE LANES

2.6.1 State of the Practice

Reversible toll plaza lanes, in the center of bi-directional plazas, enable the operators to augment the plaza with additional toll lanes for directional A.M. or P.M. peak hour travel.

Toll operators retain reversible lanes after upgrading their System to include ETC dedicated lanes in one of two manners: 1) separate the ETC dedicated lanes from the lanes configured as reversible lanes, preferably resulting in the ETC dedicated lanes being located in the approximate center of a directional conventional plaza, or; 2) ETC dedicated lanes configured as reversible lanes.

At mainline plazas with dedicated lane speeds above 30 mph (50 kph), operation of cash lanes to the left of the dedicated lanes has proven unsatisfactory from an operations point of view because of the difficulty cash traffic, particularly trucks, has to merge to and diverge from the left. However, non-stop, reversible, dedicated lanes are potentially more hazardous for staff to move temporary traffic control devices than reversible conventional plaza cash lanes. Consequently, if the passenger car toll is less than a dollar, automatic lanes (i.e., ACM, ATIM) with automatic barrier gates are potentially the safest lane type to operate as reversible lanes.

At ramp plazas, particularly trumpet interchange plazas, reversible lanes have been a necessity due to limited lanes and capacity constraints where traffic is highly directional. This is true even in relatively high ETC participation areas such as the New York Thruway.

2.6.2 Survey Results

Reversible Lanes – approximately half of the respondent agencies use reversible lanes.

2.6.3 Examples

Exibit 2—16 Indiana Toll Road Reversible Lanes

2.6.4 Recommended Guidelines

Reversible Lane Design Issues and Guideline Development

Reversible lanes present a potentially hazardous condition, in that cones or other moveable delineators/pylons must be moved in the center of a bidirectional conventional toll plaza when changing the direction of the reversible lanes. In addition, if ETC dedicated lanes are located to the left, the added utility of reversible dedicated lanes is questionable, because a single approach lane normally only requires the use of a just slightly more than a single ETC dedicated lane. As plazas are reconstructed with express lanes to the left of the conventional plaza, provisions for implementing reversible lanes are affectively eliminated.

In the absence of reversible lanes such as HOV lanes, managed lanes or contra-flow lanes, new plaza construction on new facilities should not include reversible lanes.

Reversible Lane Guidelines

Guideline	**Reversible Toll Lane Guideline 1**
Title	Use of Reversible Toll Lanes on Standard Expressway Cross-Sections
Text	Reversible toll lanes should be avoided where possible and excluded from the design of new toll facilities.
Commentary	For existing barrier system plazas, it is recommended that the use of reversible lanes be discontinued as soon as possible for operations and safety reasons, as soon as ETC participation rates allow. At existing ticket-system plazas, it may be practically impossible to eliminate the use of reversible lanes, as overall operations are slow in these plazas, and additional capacity is often needed regardless of ETC participation.

2.7 ADMINISTRATION BUILDING AND ACCESSWAY LOCATION

2.7.1 State of the Practice

All attended toll plazas and most unattended plazas have a roadside building structure to provide the operations staff cash-handling, restroom, break room and locker facilities as well as protection of computer and communications equipment. A single plaza building is often located on the right side of one of the two directional conventional plazas. This building has also been located in the center of the plaza between the two directional conventional plazas. In both of these cases, a tunnel or overhead walkway is commonly used to provide safe access to the operations staff when walking to their assigned toll booth. In cases of limited right of way, overhead buildings have been built, such as New Jersey Exit 1, which provides safe and convenient access for the operations and maintenance staff. Agencies such as TCA in Orange County, California, have constructed plaza buildings on both sides of the overall plaza (i.e., right side of each directional conventional plaza). This approach eliminates the need for a tunnel or overhead walkway if safety procedures are strictly followed by the attendants. Furthermore, these buildings can be designed for easy demolition in conjunction with future conversion to an ORT facility once ETC participation reaches a pre-established threshold.

Vehicle access to the administration building requires a paved access way that intersects with the departure zone pavement.

Operations staff walk from the administration building to their assigned toll booth either by walking across the toll islands and lanes, or through a tunnel (traditional approach) or overhead walkway (more recent approach).

The survey results indicated most toll operators provide grade-separated crossings for operations staff. These crossings are located either over or under retrofitted ETC dedicated lanes. Plaza observations indicate ETC customers rarely stop as they drive through any toll lane with ETC capability, particularly if they know their account will only be charged the toll amount if the transponder is not read in the lane, pursuant to the agency's business rules for handling ETC customer violations when traveling in a vehicle that is listed with their profile information. Multi-mode lane capability can provide an agency limited control in the way the plaza lanes are configured.

2.7.2 Survey Results

<u>Administration Building Configuration and Access way</u>
Majority of toll plazas are configured such that the buildings and access way(s) are located downstream and to the right of a directional plaza.

<u>Toll Personnel Access Across ETC Dedicated Lanes</u>
About three quarters of the survey toll road responders do not require toll collectors to walk across ETC dedicated lanes, but most bridge operators do require this.

2.7.3 Examples

Exhibit 2-17 Illinois State Toll Highway Authority Access Way to Plaza Administration Building

Exhibit 2-18 – Florida Turnpike Enterprise Stairwell to Tunnel for Toll Collection.

2.7.4 Recommended Guidelines

Administration Building and Access way Location Design Issues and Guideline Development-The location of an administration building depends on the implementation of express lanes, the location of ETC dedicated lanes, and existence or plans for a tunnel or overhead walkway. If express lanes are part of initial construction or planned for the future, either a single or dual administration building should be located beyond the far outside pavement on either one or both sides. If a tunnel or overhead walkway is not designed nor planned, two buildings are required and any ETC dedicated lanes must be located to the far left of the conventional plaza. If a tunnel or overhead walkway is designed or planned, there are no restrictions on lane placement within the conventional plaza.

The vehicle access way to the building should always be located downstream of the conventional plaza to avoid blockages by the adjacent lane queues and disrupting traffic flow. The metering affect of a manual lane provides the gaps needed for right-in and right-out movements. Making provisions for vehicle access to an administration building located in the center of a plaza precludes the placement of ETC dedicated lanes to the far left because of safety considerations. Consequently, any ETC dedicated lanes must be placed in the center of the directional conventional plaza, and either automatic or manual lanes must be placed on the left. Again, the access way must be located within the departure zone, downstream of the plaza. The intersection is a left-in and left-out movement.

Safe staff access to the building parking area, and then to the toll booths, is an important design element feature. Specifically, operations staff should never need to cross an ETC dedicated lane to reach their assigned toll booth. Unless the ETC dedicated lanes are located to the far left of a conventional plaza, a tunnel or overhead walkway is required for toll booth access by the operations staff. Preferably, tunnel or overhead walkway access is provided even when ETC is implemented in the conventional plaza to only supplement manual and automatic collection (i.e., no ETC dedicated lanes). If the operations staff is allowed to cross multi-mode lanes with ETC capability, the toll island should include lane passage constraints to highlight staff to a hazardous condition. This is a significant departure from the days when all toll collection was stop-and-go, resulting in considerably less risk to the toll collector when crossing toll lanes. Furthermore, for new conventional plaza construction, toll island access to either an overhead walkway or tunnel should be spaced to require crossing only one toll lane (i.e., access every third toll island).

Administration Building and Access way Location Guidelines

Guideline	**Administration Building Configuration and Access Guideline 1**
Title	Accessway
Text	Toll plaza administration building access way should be located downstream from the toll collection point, on the side where the administration building is planned, which is normally the right side.
Commentary	An exception would be at ramp plazas or one-way roadways where the slower, cash toll lanes are located to the left. In these cases, the building accessway should be located on the left. Design should be prepared following AASHTO design guidelines applicable in the departure area, where speeds are still slow.

Guideline	**Administration Building Configuration and Access Guideline 2**
Title	Personnel Lane Access
Text	For all new plaza construction with ETC dedicated lanes or express lanes and one administration building, provide a tunnel or overhead walkway.
Commentary	Toll island access to the tunnel or overhead walkway should be spaced so that toll collectors should not have to cross more than one live toll lane (i.e., access on every third toll island).

CHAPTER 3

SIGNING, MARKINGS AND CHANNELIZATION

The growth in electronic toll collection (ETC) transactions at toll plazas in this country has resulted in an increase of speed differentials within the plaza approach and departure areas. In addition, since the operational characteristics of ETC technology are vastly different than traditional cash collection (e.g., manual and automatic) the toll road operator must configure the plaza to maximize safety and efficiency so the user can quickly unravel the added complexities. This complexity breeds increased driver confusion and erratic maneuvers within a plaza. These conditions combine to result in a reduction in safety with a coincident effect on operational performance.

Historically, toll plazas have been prone to sudden stops and lane changes as well as unsafe approach and departure speeds, particularly in an environment of merging, diverging and queuing vehicles that effectively increases the probability of a collision. With just two methods of collection, manual and exact change automatic coin machines (ACM), problems still pervade toll plazas with incorrect lane selection and the resulting unsafe stops and maneuvers to change lanes. The addition of ETC in manual and ACM lanes tends to increase this confusion. When ETC dedicated lanes are deployed in conjunction with these conventional lane types, differential speed and driver expectations for high speed, non-stop performance compounds the problems encountered in manual and automatic lane plazas.

Toll plazas with express lanes typically separate ETC customers from the conventional plaza upstream of the plaza, and either use the continuation of the mainline lanes or channelize the ETC customers into non-stop express lanes that diverge from the mainline lanes using an AASHTO compliant alignment. Dedicated ETC lane plazas (where a non-stop dedicated ETC lane is provided in the conventional plaza) present special challenges due to the mixing of non-stop vehicles and cash customers who are required to stop to pay tolls at the plaza. The diverging, weaving and merging both upstream and downstream of conventional toll plaza can be minimized significantly through the use of advance signing, provided lanes serving each payment type are grouped together. Conventional plazas with ETC dedicated lanes that vary the location (grouped to the far left, far right, and center, or alternated ETC dedicated and cash lanes) among plazas are inherently difficult to sign as well as engender a "user familiarity" in advance of the plaza.

The following sections deal individually with the following issues:

- The spacing of advance signing for express lanes and conventional plazas;
- Advance signing message/sign content for express lanes and conventional plazas;
- Canopy signing for conventional plazas;
- Toll lane signing;
- Speed control/mitigation through conventional plaza lanes;

- Lane use control signals;
- Pavement markings;
- Channelization;
- Crash block/attenuator delineation; and
- Warning lights/flashing beacons

3.1 SPACING AND FREQUENCY OF ADVANCE TOLL PLAZA SIGNING

3.1.1 State-of-the Practice

The MUTCD recommends that advance guide signing for major/intermediate freeway interchanges be provided at distances of 2, 1 and ½ mile from the interchange. The advance sign at the 2-mile distance is optional, but recommended. For minor interchanges, the MUTCD requires advance signs at 1 and ½ mile distances from the interchange. In addition, the MUTCD recommends placing signs overhead when three or more mainline lanes exist in one direction, or at complex interchanges.

The MUTCD (Section 2C.06) also provides guidance for the placement of warning signs in advance of an obstacle or required maneuver by the driver. Table 3.1, (excerpted from the MUTCD), provides advance sign placement distances based on the posted/operating speed of the roadway, and the speed reduction (or stop condition) that the vehicle is required to attain. The guidance (minimum advance sign placement distance) provided in this section is based on the time required for sign information processing, driver recognition, present speed and to allow a lane change maneuver. This guidance may be applied to determine the following: the minimum advance placement distance of signs for the divergence of the conventional toll plaza from the express lanes that typically follow the roadway mainline alignment; and, the minimum advance placement distance of the last advance sign before the toll plaza. The advance sign placement distances should, however, be recalculated using higher Perception-Interpretation-Emotion-Volition (PIEV) times to account for possible complex weaving and lane changing maneuvers inherent to toll plazas. In addition, the location of the last advance sign should be selected to ensure canopy signing and lane control signals are not obstructed.

Table 3.1 MUTCD Warning Sign Advance Placement Distances

Posted Speed (mph)	Advance Placement Distance (feet): Reduce Speed & Change Lanes (1)	Slow To (2): 30 mph	Slow To (2): 10 mph	Stop (3)
45	750	Site Conditions	125	175
50	850	100	200	250
55	950	175	275	325
60	1100	250	350	400
65	1200	350	425	475
70	1250	425	525	550

(1) Legibility distance = 175 ft, PIEV = 14.0 to 14.5 sec

(2) Legibility distance = 250 ft, PIEV = 2.5 sec, Deceleration = 10 ft/s^2

(3) Legibility distance = 175 ft, PIEV = 2.5 sec, Deceleration = 11.2 ft/s^2

3.1.2 Survey Results

Tables 3.2 and 3.3 summarize the spacing of advance signing for express lanes and conventional plazas. Information on the survey methodology used to obtain the results presented below can be found in Subsection 1.4.2. As shown in the tables pertaining to toll roads, the distance of the first (furthest) sign in advance of the toll plaza varies from ½ to 2 miles for plazas with express lanes, while the first sign for conventional plazas is placed approximately 3/8" to 1 ¼ miles from the plaza. Of the nine Toll Road agencies, all provided a minimum of 2 advance signs for plazas with express lanes, while six agencies provided 3 advance signs. Only one toll bridge agency provided express lanes, with the first sign being placed approximately 1,000 feet (0.2 miles) in advance of the plaza.

Table 3.2 Express ETC Toll Lanes

Distance to Advance Sign (Miles)			
Toll Roads			
	Min	**Max**	**Average**
Furthest Sign	0.50	2.00	0.95
Second Sign	0.25	1.00	0.50
Third Sign	0.01	0.50	0.21
Toll Bridges			
	Min	**Max**	**Average**
Furthest Sign	0.20	0.20	0.20
Second Sign	0.00	0.00	0.00
Third Sign	0.00	0.00	0.00

Table 3.3 Conventional Toll Plazas

Distance to Advance Sign (Miles)			
Toll Roads			
	Min	**Max**	**Average**
Furthest Sign	0.31	1.25	0.88
Second Sign	0.25	0.62	0.47
Third Sign	0.02	0.50	0.21
Toll Bridges			
	Min	**Max**	**Average**
Furthest Sign	0.50	1.90	0.97
Second Sign	0.50	0.57	0.54
Third Sign	0.38	0.38	0.38

Of seven responding toll bridge agencies, four agencies installed 3 advance signs for conventional toll plazas with ETC dedicated lanes, while two agencies installed 2 advance signs. Only one of the toll bridge agencies installed only one sign in advance of the dedicated ETC toll plaza.

3.1.3 Expert Panel Workshop Recommendations

Express Lanes

The Expert Panel recommended providing toll plaza advance signs at distances of approximately 2, 1 and ½ mile from the point at which the mainline lanes diverge resulting in express lanes and conventional plaza lanes, typically located to the right of the express lanes. Although Tables 3.4 and 3.5 require advance sign placement at approximately 2 miles upstream from the reference point, after further analysis this sign placement was deemed optional because of implementation difficulty, particularly for ramp, tunnel and bridge plazas. This sign is commonly used to provide advance notice of a toll plaza the driver is approaching, such as "Toll Plaza Ahead 2 Miles".

The panel recommended the advance sign located 2 miles from the divergence point be placed overhead. However, this sign could be installed as a roadside ground-mounted sign. The 1 and ½ mile signs were also recommended to be placed overhead. The distances of 2, 1 and ½ mile were chosen as desirable locations, although local conditions would dictate the specific placement distance of these signs from the divergence point. In addition, the panel recommended provisions for toll rate information on the 2, 1 and ½ mile signs be considered optional.

At the gore (i.e. the divergence point of express and conventional plaza lanes), it was recommended that overhead signs be installed. These signs would indicate the payment methods accepted and vehicle restriction information in the express lanes and conventional plaza lanes.

It should be noted that the expert panel recommendations are specific to mainline plazas. Out of necessity advance signing for ramp plazas may involve less discrete advance signing locations because of limited ramp length. Signs providing notification of an approaching exit plaza for a closed ticket system are the sign types that can be eliminated with little or no expected impact on operational performance.

Conventional Plazas

For the conventional plaza, the Expert Panel recommended providing toll plaza advance signs at distances of approximately 2, 1 and ½ mile from the plaza. On the 2 mile sign, the panel recommended including messages warning of the toll plaza ahead, with optional toll rate information. To minimize confusion, the lanes in conventional plaza should be grouped by accepted payment type, e.g. "Automatic Lanes", "Manual Lanes", "Exact Change Cars Only", "Changes Receipts All Vehicles") for display on signs at the divergence points. Overhead sign placement was preferred, although ground-mounted roadside signs could be used instead. The plaza centerline was considered the baseline for measuring distances for sign placement at the conventional plaza while the survey used the front edge of the canopy because it represented the closest possible placement for an overhead sign to be visible to approaching traffic and is independent of the canopy dimensions.

The recommended placement of the 1 and 1/2 mile signs is overhead, with sign content composed of messages warning of a toll plaza ahead, the payment methods accepted, vehicle restrictions, and toll rate information as an option.

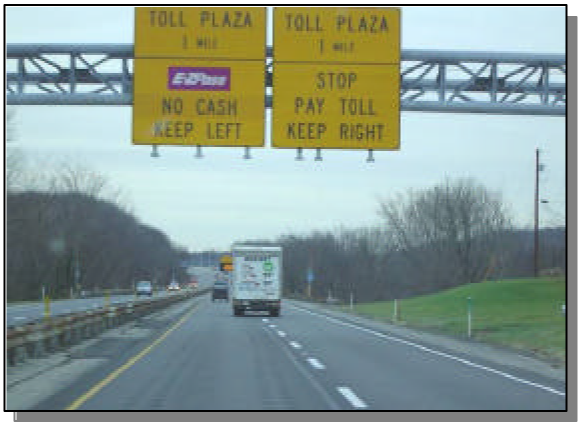
The panel recommended a sign be placed a minimum of 800 feet from the canopy that provides information on payment methods accepted at the plaza lanes. This distance was selected to ensure that the sign did not obstruct plaza canopy signing and lane use signals.

An optional sign was also proposed at a distance of ¼ mile from the plaza canopy that provides payment method/lane type information, and lane-speed restrictions. Payment methods/lane type and lane-speed restrictions messages are optional.

Detailed toll rate information was recommended to be provided only on a toll schedule sign, placed close to the plaza. The optional toll rate information on the 2, 1 and ½ mile signs should only be provided as brief messages for the highest volume vehicle type, with detailed toll rate information provided on a separate toll schedule sign.

3.1.4 Examples

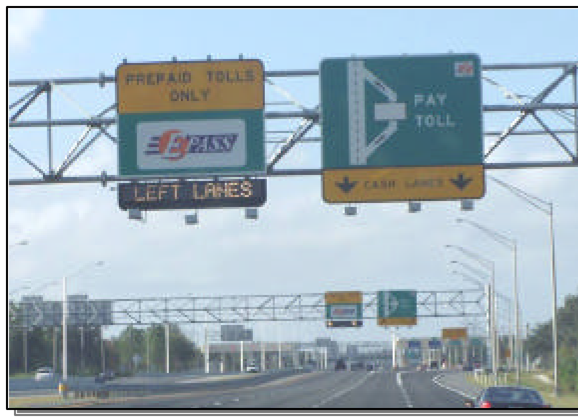
Illinois Tollway Advance Toll Plaza Signing



New York Thruway Advance Toll Plaza Signing

Exhibit 3-1 Advance Toll Plaza Signing

Oklahoma Turnpike Advance Toll Plaza Signing



Orlando- Orange County Expressway Advance Toll Plaza Signing

E-470 Advance Toll Plaza Signing

Exhibit 3-2 Advance Toll Plaza Signing

New York Thruway Advance Toll Plaza Signing

Exhibit 3-3 Advance Toll Plaza Signing

3.1.5 Recommended Guidelines

Tables 3.4 and 3.5 summarize the recommended guidelines for advance toll plaza signing for Express lanes and conventional toll plazas. These tables summarize the spacing of advance signs, recommended placement (overhead where indicated) and the message/sign content.

Table 3.4
EXPRESS ETC LANE TOLL PLAZA
RECOMMENDED SIGNING SCHEME

Sign Location	Message/Sign Content					
Distance From Gore	Toll Plaza Ahead	Payment/Lane Type	Toll Rate	Vehicle Restrictions	Lane-Use	Speed Limits/Restrictions
2 Miles	X Overhead placement preferred.		Optional			
1 Mile	X Overhead		Optional			
1/2 Mile	X Overhead		Optional			
Gore		X		X	X	
At least 800 ft from Canopy		Optional				Optional
Canopy (Over Cash lanes)		X		X	X	X
Toll Schedule (typically 100-200 feet from plaza)			X			

Table 3.5
CONVENTIONAL TOLL PLAZA
RECOMMENDED SIGNING SCHEME

Sign Location	Message/Sign Content					
Distance From Plaza	Toll Plaza Ahead	Payment/Lane Type	Toll Rate	Vehicle Restrictions	Lane-Use	Speed Limits/Restrictions
2 Miles	X Overhead placement preferred.		Optional			
1 Mile	X Overhead	X	Optional	X		
1/2 Mile	X Overhead	X	Optional	X		
1/4 Mile (Optional sign - depends on distance from the plaza)		Optional			X Overhead	Optional
Canopy		X	Option - Place on Booth	X	X	X
Toll Schedule (typically 100-200 feet from plaza)			X			

Advance Toll Plaza Signing Guidelines

The following guidelines are provided based on the preceding discussion.

Guideline	Advance Toll Plaza Signing Guideline 1
Title	Sign Spacing and Location – Express lanes
Text	Provide advance signs at approximately 1 and ½ miles in advance of the divergence of mainline express lanes (or some subset of the mainline lanes) from the conventional plaza lanes similar to interchange guide sign spacing. Where the conventional plaza offers multiple payment types, an overhead sign should be installed approximately 800 feet from the canopy to provide guidance on the payment types available in the toll lanes ahead.
Commentary	It may not be possible to meet this guideline due to geometric constraints, but a minimum of two signs at 1 and ½ mile from the conventional plaza lane divergence should be provided. After further analysis, an advance sign at approximately 2 miles from the stated reference point is considered optional, contrary to Table 3.4. The location of these signs should be determined based on field conditions to maximize their contribution to plaza operational performance and safety.

Guideline	Advance Toll Plaza Signing Guideline 2
Title	Sign Spacing and Location – Express lanes
Text	Provide a bridge structure with a sign array at the divergence of conventional plaza from the express lanes that continue on the roadway mainline alignment to display allowed payment types, vehicle restrictions and lane-use guidance.
Commentary	None

Guideline	Advance Toll Plaza Signing Guideline 3
Title	Lettering and letter-spacing
Text	Standard letter heights and letter-spacing in the FHWA's MUTCD and *Standard Highway Signs* Book should be used in designing toll plaza sign messages at a minimum, with increased letter height desired to increase sign legibility in the vicinity of toll plazas.
Commentary	Complex driver maneuvers in the vicinity of toll plazas require increased sign legibility to enhance sign comprehension.

3.2 CANOPY TOLL SIGNING

Toll plaza canopy signing is primarily used to indicate which payment type(s) are accepted in the lanes. In addition, the front fascia panel or underside of the canopy is often used to mount a lane use signal consisting of a red "X" or a green downward pointing arrow to indicate the operational status of the lane (i.e., open or closed). Subsection 3.5 provides more detailed information on lane use signals. For agencies using a fixed, static sign panel above automatic lanes, the canopy signing may include the toll rate for two axle vehicles in addition to payment methods accepted. Both fixed panel static signs and changeable message signs (CMS) are used to display the payment methods supported by the toll lane. The capability of changing the payment methods available (e.g., "Exact Change – ETC", "Exact Change Only") in a particular lane requires the deployment of a CMS.

3.2.1 State-of-the-Practice

Fixed panel static signs are in predominant use, although several agencies have used changeable message signs when the lane is multi-mode or equipped for multiple payment types (e.g., "Change – Receipts", "Exact Change" and "E-ZPass Only"), thereby allowing lane operation changes based on traffic demand and equipment operational status. A changeable message sign can also be used to display the current operation state of the lane, using both text ("Lane Closed") and a symbol (red "X"). Flashing beacons or warning lights are often installed on both sides above or below the canopy sign to distinguish non-stop ETC dedicated lanes within the conventional toll plaza. The flashing lights are visible well before the canopy signs become legible so the ETC user has more time to maneuver to get into the correct lane. In addition, some agencies as part of their ETC retrofit have installed small, separate sign panels displaying the agency's ETC logo above the manual and automatic lanes to indicate the lane is equipped to support ETC. Where lane payment types are not changed and toll lanes supporting the same payment types are grouped together, the use of fixed, static sign panels with a unique background color have proved to be very effective in improving operational efficiency for toll roads such as the New York State Thruway and the Harris County Expressway (See Exhibits 3-4 and 3-5).

Exhibit 3-4 – New York State Thruway Conventional Plaza Lanes

Exhibit 3-5 – Harris County Expressway Express Lanes and Conventional Plaza Lanes

3.2.2 Survey Results

Table 3.6 Dedicated ETC Lane Canopy Signing

Toll Roads		
Sign mounted above each dedicated ETC lane?		
	No.	**%**
Yes	14	88%
No	2	13%
Total	16	
The sign is:		
	No.	**%**
Fixed panel	10	71.4%
Changeable	2	14.3%
Other	2	14.3%
Total	14	

Toll Bridges		
Sign mounted above each dedicated ETC lane?		
	No.	**%**
Yes	6	86%
No	1	14%
Total	7	
The sign is:		
	No.	**%**
Fixed panel	3	42.9%
Changeable	2	28.6%
Other	2	28.6%
Total	7	

Toll Roads

Sign mounted above each lane?

	ACM/ATIM	Manual
Yes	3	10
No	2	6
Total	5	16

The sign is:

	ACM/ATIM	Manual
Fixed panel	3	8
Changeable	1	2
Other	0	0
Total	4	10

Toll Bridges

Sign mounted above each lane?

	ACM/ATIM	Manual
Yes	2	7
No	0	2
Total	2	9

The sign is:

	ACM/ATIM	Manual
Fixed panel	1	3
Changeable	1	2
Other	0	2
Total	2	7

3.2.3 Expert Panel Workshop Recommendations

Information recommended for display on canopy signing included the following: payment types accepted and services offered (e.g., ETC, exact change only, tokens, change and receipts,), vehicle restrictions (e.g., cars only, cars and trucks, trucks only), lane status (i.e., open and closed), and lane-speed restrictions.

3.2.4 Examples

Exhibit 3-6 Chicago Skyway Bridge Canopy Signing

Exhibit 3-7 FTE Orlando Canopy Signing

Recommended Guidelines

3.2.4 Canopy Signing Design Issues and Guideline Development

For conventional plaza lanes capable of multiple methods of collection (e.g., ETC, manual and automatic), deployment of a CMS can result in user confusion if the available collection modes are not consistently applied over extended time periods. Driver expectancy resulting from a consistent schedule of signing messages should preclude a reduction in safety and operational efficiency when using a CMS to change the collection mode(s) available in a toll lane.

To maintain safety and operational efficiency as well as reduce weaving, the location of permanent ETC dedicated lanes within a conventional plaza should be uniquely distinguished to approaching customers in advance of the queue zone. This can be accomplished by using flashing beacons mounted adjacent to the sides of the signs or below the sign. This is particularly relevant to non-barrier protected dedicated lanes within a conventional toll plaza. Past experience of the New York State Thruway indicates mounting the flashing beacons at the bottom of the sign is more effective in distinguishing the ETC dedicated lanes to customers positioned at a wider range of distances from the canopy. Flashing beacons can be used as a hazard warning device to notify users where the higher speed, non-stop ETC dedicated lanes are located when approaching a conventional toll plaza. This is considered consistent with the general intent of the MUTCD.

Canopy Signing Guidelines

Guideline	Canopy Signing Design Guideline 1
Title	Canopy Signs
Text	Plazas offering lanes with multiple payment types and services should include canopy signing centered above each lane to indicate the payment type and service supported. Lanes supporting the same payment type(s) should be grouped together and use the same background color for the fixed, static sign panel. Lane use signals should be installed above each conventional plaza lane to display the operating status (i.e., open or closed) of each toll lane that is visible from the start of the queue zone, as a minimum.
Commentary	Information to be provided on canopy signing may include payment types accepted (i.e., ETC, exact change/tokens, or change & receipts), and vehicle restrictions (e.g., cars only, trucks only, cars and trucks). A CMS is required to provide the flexibility of changing the payment type (s) supported by the lane and the lane status, thereby eliminating the need for a separate lane use signal.

3.3 TOLL LANE SIGNING

Toll lane signing is used to guide and direct traffic through a toll lane from approximately the beginning of the impact attenuator or front edge of the toll island to the far end of the toll island. A variety of different signs have been adopted by toll agencies to accomplish this objective, including changeable message and blankout signs, in addition to the standard fixed panel, static signs, both with and without a variable display module. Changeable message signs or combination fixed and variable display module signs are predominately used to control speed through the lane by providing feedback on the user's speed approaching the toll collection point. When considering the deployment of various toll lane signs, the desire to improve operational flow and safety along with discouraging violations needs to be tempered with user overload and toll island clutter resulting in user confusion.

3.3.1 State-of-the-Practice

Over the years there has been a noticeable trend in conventional plaza lanes of less toll lane signing with the likely intent to reduce user confusion. A sign that can be found in the majority of conventional toll plaza cash lanes is the stop sign. The survey data indicates that 51% of the agencies responding have deployed stop signs in cash lanes. The expert panel discussed the use of stop signs, particularly the modified versions that have been installed in manual and automatic (i.e., exact change) toll lanes. Examples of modified stop signs, defined as those containing supplemental messages such as "Pay Toll" and "Take Ticket", were reviewed. Some panelists reasoned the limited space to install visible signing on the islands had necessitated placing supplemental messages on the Stop signs. No consensus recommendation was reached on the use of the modified stop signs along the toll lanes. However, the panel did see merit in a new section of the MUTCD specifying a modified stop sign that included supplemental messages such as "Pay Toll" or "Take Ticket". This new sign would be restricted for use only at toll plazas. Alternatively and in the interest of preserving the integrity of the stop sign, a plaque could be mounted beneath the standard stop sign to provide supplemental information. The panel also discussed one agency's practice of using a rectangular sign with the message "Stop Pay Toll" using black letters on a white background. This application was viewed as being contrary to uniformity and familiarity engendered by the MUTCD and was rejected.

With the proliferation of electronic toll collection (ETC) in all toll lanes, the installation of speed limit signs in the conventional plaza lanes, specifically the permanent ETC dedicated lanes, has become more prevalent. After adjusting for outliers, the survey data finds a considerable range in posted speeds through a dedicated lane, ranging from 5 mph to 45 mph. While it is understandable for agencies to be concerned with the safety of their staff and customers, posting a speed significantly below the average 85% percentile speed without a rigorous enforcement regimen will result in little compliance based on field observations conducted on the Illinois Tollway in conjunction with testing the effectiveness of speed display signs. In a 1998 study, speed display boards installed along local streets and arterials were found to be effective. The study also revealed that all speed control devices produced more significant results on speeds of 10 mph or more over the 25-mph speed limit.[1] Consequently, speed display signs can only be viewed as one element of a group of factors designed to both control and minimize the consequences of higher speeds in the dedicated lanes. For the manual lanes, the survey data indicates that only 23% of the responding agencies have installed speed limit signs. While use of a speed limit sign in a multi-payment type lane that also has a "stop pay toll" sign is likely to cause confusion and should be avoided, the ETC user cannot always be expected to stop if the traffic signal turns green prior to passing the tollbooth door or ACM/ATIM.

This becomes more complicated for multi-payment type lanes that are operated as ETC dedicated lanes, commonly when commuter traffic is heavy. In these lanes a speed limit sign without a "stop pay toll" sign should be deployed to provide some measure of attendant protection in crossing the lane, but needs to be supplemented with other measures. To this end, as described above, some agencies have implemented speed display signs on the approach end of the toll island to show the user's speed, typically measured by radar sensors, in conjunction with the posted speed limit. Either MUTCD compliant signs commonly installed along local streets and arterials or LED signs similar to displays deployed at roadway construction sites are used to show the driver's speed. The survey data indicates agencies are more likely to deploy these signs in the ETC dedicated lanes than in the cash lanes, suggesting the dedicated lanes are experiencing more problems with excessive speeds. However, the lanes the attendant must cross should be afforded the highest priority when considering the use of these signs.

Other signs that have been used in conventional toll plazas include "No Stopping" (Do Not Stop) in the ETC dedicated lanes, "Stay in Vehicle" in the ACM/ATIM lanes, "Enforcement by Video" or a related camera based enforcement message in lanes deploying violation enforcement system (VES) equipment, and "Wait for Green" attached to the island traffic signal pole in the cash lanes. The toll island location of some of these signs is shown on the toll plaza diagram below and in the Glossary.

3.3.2 Survey Results

Q0236 Does the manual lane toll island include a stop sign?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	18	51%
No	17	49%

1) The numbers game, R. Knaras, Transportation Management & Engineering (TME), Volume 10/No. 2, April 2005.

Q0237 If yes, what is the distance from the centerline of the of the toll booth door to the stop sign (in feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
0	1	8.3%
+3	1	8.3%
+4	1	8.3%
+5	1	8.3%
+10	2	16.7%
+16	1	8.3%
+19.7	2	16.7%
+20	1	8.3%
+43	1	8.3%
-12	1	8.3%

Q0172 If yes, what is the distance from the centerline of the ACM/ATIM to the stop sign (in feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
0	1	25%
+15	1	25%
+22	1	25%
-8	1	25%

Q0084 What is the posted speed limit in the dedicated ETC lanes?		
Choices	**Number of Responses**	**Percentage of all Responses**
5	2	14.3%
10	1	7.1%
15	1	7.1%
25	3	21.4%
30	2	14.3%
35	1	7.1%
45	1	7.1%
55	1	7.1%
65	1	7.1%
70	1	7.1%

Q0085 Where is the speed limit sign located relative to the centerline of the ETC antenna ((+) X' ahead or (-) X' behind)?		
Choices	**Number of Responses**	**Percentage of all Responses**
+24.6	1	11%
-2640	1	11%
+15	1	11%
+20	1	11%
+2	1	11%
+ 2400	1	11%
+150	1	11%
0	1	11%
+1320	1	11%

Q0213 Is there a speed limit sign posted on the toll island (manual lanes)?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	6	23%
No	20	77%

Q0214 If yes, where is the speed limit sign located relative to the centerline of the toll booth ((+) X' ahead or (-) X' behind)?

Choices	Number of Responses	Percentage of all Responses
+2	1	20%
+4	1	20%
+10	1	20%
+15	1	20%
+75	1	20%

Q0103 Does the dedicated ETC lane include a travel speed display sign?

Choices	Number of Responses	Percentage of all Responses
Yes	2	9%
No	21	91%

Q0104 If yes, what distance in front of the ETC antenna is the speed display sign (in feet)?

Choices	Number of Responses	Percentage of all Responses
20	1	50%
50	1	50%

Q0105 If yes, what technology is used for the speed display sign?

Choices	Number of Responses	Percentage of all Responses
Fluorescent flip disk	0	0%
LED	2	100%
Fiber optic flip disk	0	0%
Other	0	0%

Q0240 Does the manual lane include a travel speed display sign?

Choices	Number of Responses	Percentage of all Responses
Yes	1	4%
No	22	96%

3.3.3 Example Installations

Exhibit 3-8 E-470 Mainline Toll Plaza Lanes

3.3.4 Applicability to MUTCD

The MUTCD provides the framework for toll lane signing, upon which agencies have made modifications to better relate the toll collection aspects with guidance and control of traffic flow through the lane. The stop sign used in a toll plaza environment often attempts to combine the MUTCD regulatory function with the legal obligation to pay the indicated toll or to take a ticket representing an official record of entry into the System.

3.3.5 Recommended Guidelines

<u>Toll Lane Signing Design Issues</u>

- While the implementation of ETC in cash (i.e., manual and automatic) lanes has not diminished the desires of the agencies to have all traffic stop at either the tollbooth or ACM, a user with a transponder is more likely to focus on the island traffic signal than the stop sign with the expectation of a successful read. Consequently, a problem with the transponder or ETC account unbeknownst to the user is likely to result in the vehicle being beyond the stopping location for paying the attendant or depositing coins in the ACM. If the traffic signal remains red, the user may make an ill-advised and unsafe decision to back-up their vehicle to pay the toll.

- The location of the toll lane signing must be selected to assure visibility to approaching passenger car and truck traffic, spaced along the toll island to avoid overloading the user with information, and installed adjacent to any equipment to which the sign specifically relates. The location of toll lane signing is constrained by physical features of the toll island, such as the size of tollbooth and columns supporting the canopy as well as the length of the toll island.

- Adequate horizontal clearance from the vertical face of the toll island or raised barrier must be provided to avoid damage from passing vehicles.

- The less frequent or new user of an agency's toll facilities can benefit from some of the following signs that have been deployed: "No Stopping" ("Do Not Stop") in the ETC dedicated lanes, "Stay in Vehicle" in the ACM/ATIM lanes, "Enforcement by Video" or a related camera based enforcement message in lanes deploying VES equipment, and "Wait for Green" attached to the island traffic signal pole in the cash lanes. The problem each of these signs is attempting to address varies from region to region, and the severity may not warrant deployment of these particular signs.

<u>Toll Lane Signing Guideline Development:</u>

- Although use of the toll industry standard modified stop sign stating "Stop Pay Toll" may not be afforded the same level of compliance among ETC accountholders, deployment of this sign in the cash lanes should continue to reinforce the user's statutory responsibility to pay the indicated toll. This applies equally to the "Stop Take Ticket" sign commonly deployed in the ATIM lanes of a closed ticket system. Users of a ticket system, including those without a valid transponder or ETC account, are given reasonable notice to initiate a toll transaction at their entry location by taking a ticket to avoid payment of a toll based on the furthest entry point from their exit location.

- The location of toll lane signing on the toll island must be selected to result in the user consistently responding at the intended location along the lane. Speed limit signs need to be installed at the approach end to the toll island with the expectation that the user will adjust their speed to comply with the speed limit when traveling through the lane. If speed display signing is deployed, it should be located in conjunction with a speed limit sign to elicit a quicker response from the user to comply by reducing the vehicle's speed as needed when traveling through the lane. The modified stop sign commonly used by the agencies should be installed at the approach end of the tollbooth in the manual lanes. For the automatic lanes, the modified stop sign should be installed on the toll island prior to the ACM or ATIM, mounted to a canopy column or other physical feature, if available. For multi-payment type lanes that are operated in an ETC only mode, a speed limit sign should be installed in the lane, particularly when a collector must cross these lanes to access their assigned tollbooth. In this case, an ETC user complying with the "Stop Pay Toll" sign may be inclined to quickly accelerate from the booth or machine when exiting, which is where the collector typically crosses the lanes. Signing related to equipment installed on the toll island should be attached to or installed adjacent to that equipment. Any "No Stopping" signs should be installed in an ETC dedicated lane prior to where the user recognizes there are no provisions for cash payment in the lane. The "Stay in Vehicle" sign should be installed above the ACM or ATIM. The selected location of these signs must assure visibility to all passenger car and trucks allowed to use the particular lane. The diagram at the end of this section shows the location of some of the signs described above.

- With an assumed window of 6-18 inches representing a conservative range for horizontal clearance from the travelway used within the toll industry, 12 inches provides an appropriate minimum clearance for protecting toll lane signing from extended mirrors and objects or materials extending beyond the side of a vehicle. The AASHTO "Green Book" guidelines specify 18 inch clearance to an obstacle on an urban arterial with curbs where speeds are expected to be higher and lanes are not physically separated.

- Before adding toll lane signing such as "No Stopping" in the ETC dedicated lanes, "Stay in Vehicle" in the ACM/ATIM lanes, "Enforcement by Video" or a related camera based enforcement message in lanes deploying VES equipment, and "Wait for Green", the agency should make an assessment of the magnitude of the problem the particular sign is intended to address along with the particular user benefit derived from the sign.

Toll Lane Signing Guidelines

Guideline	**Toll Lane Signing Guideline 1**
Title	Stop Signs
Text	Stop signs should be deployed in cash toll lanes to require all users to stop to either pay a toll or take a ticket. A standard stop sign above a plaque containing supplemental information (e.g., pay toll, take ticket) or a modified stop sign stating "Stop Pay Toll" should be installed in the manual and ACM lanes and "Stop Take Ticket" should be installed in the ATIM lanes.
Commentary	A compliant ETC user in a multi-payment type lane is not expected to be inconvenienced by stopping in the cash lanes, even though the island traffic signal may display a green state when observed by the user.

Guideline	Toll Lane Signing Guideline 2
Title	Speed Limit Signs
Text	Speed limit signs should be installed at the approach end to the toll island for all ETC dedicated lanes.
Commentary	Although deployment of speed limit signs in conjunction with stop signs should be avoided, where speed display signs are deployed in particular cash lanes because of excessive toll lane entry speeds, a speed limit sign should be installed in conjunction with the speed display sign.

Guideline	Toll Lane Signing Guideline 3
Title	Miscellaneous Signs
Text	Deployment of miscellaneous signs should be based on an assessment of the particular problem the sign is intended to address or the value of the benefit derived by the user from the information the sign provides.
Commentary	None.

Guideline	Toll Lane Signing Guideline 4
Title	Sign Horizontal Clearance
Text	A horizontal clearance of 12 inches should be used from the face of the toll island or raised barrier to the nearest edge of the sign or display.
Commentary	None.

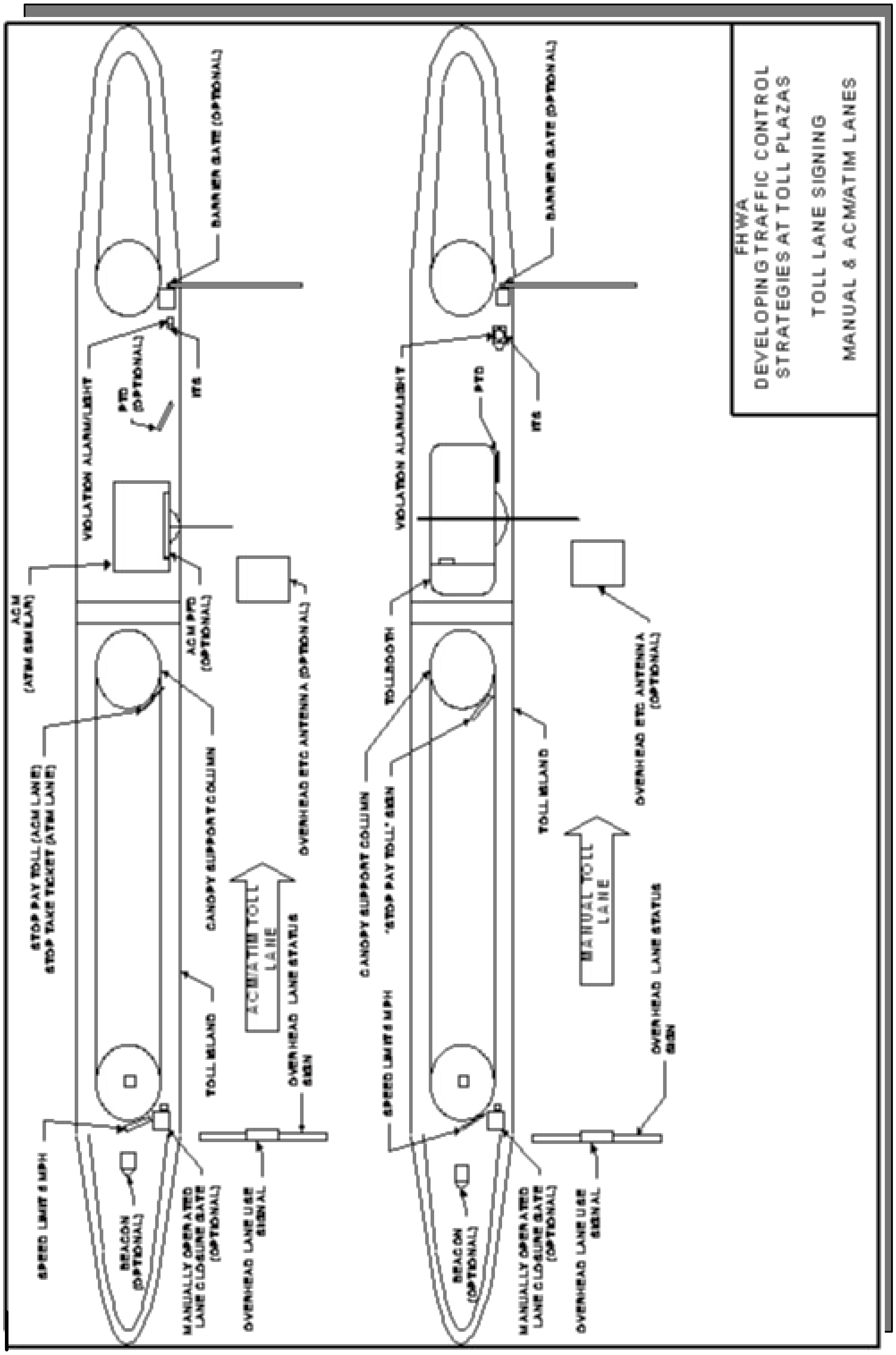


Exhibit 3-9 Toll Lane Signing

3.4 SPEED CONTROL/MITIGATION

Speed reduction of all traffic approaching a conventional plaza after divergence with any express lanes has been a prime concern for toll agencies. With the increasing use of ETC technologies within the conventional plaza, particularly ETC dedicated lanes, there is greater concern for vehicles approaching and departing at excessive speeds resulting in speed differentials with adjacent users that stop to pay the indicated toll or to take a ticket. Although there is less maneuvering on the departure side than the approach side of a conventional plaza, variation in the acceleration performance of different vehicles and types/classes of vehicles complicates the merging of vehicles as lanes reduce to the available continuous mainline lanes. The speed attained after leaving the plaza should match the prevailing mainline travel speed when merging, which may be prevented when following slower moving trucks.

3.4.1 State-of-the-Practice

To reduce vehicle speed approaching a toll plaza, agencies have used a varied application of advance speed warning signs, pavement markings, channelization devices, raised pavement markers (e.g., turtles) and speed bumps, in addition to posting speed limit signs. For express and ETC dedicated lanes, speed enforcement by the state patrol or other authorized law enforcement personnel is deployed to varying degrees amongst toll agencies. This strategy requires sufficiently wide shoulders or a widened pull-off area downstream or upstream of the tolling point. For the departure side of the conventional plaza, the strategy used by the majority of agencies is to use signs to request trucks and possibly buses and RVs stay in the right lane to minimize the affect on other traffic in attaining the mainline prevailing speed. The randomness of the toll transaction time in the cash lanes provides an inherent metering affect that tends to relieve merging conflicts.

3.4.2 Survey Results

Dedicated Lane Speed Limit (mph)

Toll Roads

Max	Min	Mode	Average
70	5	24	33.0

Location of speed limit sign relative to the centerline of the ETC antenna ((+)X' ahead or (-)X' behind)?

+24.6
-2640
+15
+20
+2
+ 2400
+150
0
+1320

U.S. Department of Transportation
Federal Highway Administration

Toll Bridges

Max	Min	Mode	Average
31	5	5	14.2

Location of speed limit sign relative to the centerline of the ETC antenna ((+)X' ahead or (-)X' behind)?

+12
Ahead
On the canopy
+ 7
0

Dedicated Lane Speed

Toll Roads

Is speed measured through the dedicated ETC lane(s)?

	No.	%
Yes	10	67%
No	5	33%
Total	15	

If yes, what device is used to measure speed?

	No.	%	
Loop detector	6	60%	
Light curtain	1	10%	
Overhead laser sensor	1	10%	
Radar device	1	10%	
Other	1	10%	Treadle
Total	10		

Toll Bridges

Is speed measured through the dedicated ETC lane(s)?

	No.	%
Yes	2	40%
No	3	60%
Total	5	

If yes, what device is used to measure speed?

	No.	%	
Loop detector	0	0%	
Light curtain	1	50%	
Overhead laser sensor	0	0%	
Radar device	0	0%	
Other	1	50%	loop detector and overhead laser sensor
Total	2		

Speed Display Sign

Toll Roads

Does the dedicated ETC lane include a travel speed display sign?

	No.	%
Yes	2	13%
No	14	88%
Total	16	

If yes, what distance in front of the ETC antenna is the speed display sign (in feet)?

20 feet, only mixed use lanes

If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	2	
Fiberoptic flip disk	0	
Other	0	

Toll Bridges

Does the dedicated ETC lane include a travel speed display sign?

	No.	%
Yes	0	0%
No	7	100%
Total	7	

If yes, what distance in front of the ETC antenna is the speed display sign (in feet)?

If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	0	

3.4.3 Recommended Guidelines

Speed Control/Mitigation Design Issues and Guideline Development

- In addition to providing time savings and better safety performance, toll roads must distinguish themselves from freeways by providing customer service. The use of raised pavement materials to reduce speed is uncomfortable to the vehicle passengers and may cause damage to the vehicle. For this reason, the use of in-pavement materials to reduce speed when approaching a conventional plaza lane should be avoided and alternatives should be investigated for plazas that currently use this method of speed control.

- The acceleration performance of trucks is clearly less than passenger cars, with some rare exceptions. Given manual lanes are normally located on the right side of the conventional plaza, the use of signs to require trucks and possibly buses and RVs to use the right lanes and stay to the right when departing the plaza provides a strategy with an expected high benefit/cost ratio. The effectiveness of this strategy is dependent on the cooperation of the truck or bus drivers, who may believe the value of their time allows them to use any lane or path when departing the plaza. However, this attitude is expected to be in the minority.

3.4.4 Speed Control/Mitigation Guidelines

Guideline	**Speed Control/Mitigation Guideline 1**
Title	Approach Speed Reduction
Text	Speed bumps, turtles or other raised in-pavement materials should not be used to reduce vehicle speed before entering a conventional plaza toll lane.
Commentary	This recommendation is not intended to preclude or discourage the use of rumble strips (slotted or raised thermoplastic) used to warn drivers veering out of a travel lane.

Guideline	**Speed Control/Mitigation Guideline 2**
Title	Departure Speed Control
Text	Signs should be placed to require trucks using cash lanes located to the right of the conventional plaza to use the right lane/ stay to the right when departing the plaza.
Commentary	This strategy may not be feasible when the length of the approach zone and queue zone is inadequate for trucks to safely merge to the right. Furthermore, manual lanes may not be located to the far right of the plaza, which primarily applies to ramp toll plazas being fed traffic from two directions.

3.5 LANE-USE SIGNALS

Lane-use signals are devices commonly mounted to the fascia or front edge of the canopy, centered over a toll lane, and used to indicate an open or closed lane operating status. One of the two types of signals most commonly installed in toll plazas use a red "X" for closed and green "?" for open. These symbols are primarily formed from LEDs and fabricated as part of a rectangular environmental enclosure or part of a multi-line changeable message sign that is also used to display methods of payment supported by the installed lane equipment. The other commonly used signal is horizontally aligned red and green traffic signal heads.

3.5.1 State-of-the-Practice

Lane-use signals within the tolling industry are not as standardized in appearance and function as other equipment and devices used along or within the toll lane, such as the ITS, ACM, and loop detector. However, the simplicity and clarity of the message these devices are intended to display allows variation in design that is expected to result in minimal user confusion.

Conventional lane-use signals are specially fabricated overhead displays/signals that permit or prohibit the use of specific lanes. The two types of lane-use signals used most often by toll agencies are distinguished by their shapes and symbols. The rectangular fabricated signs typically display either an arrow or an 'X', using green and red colors, respectively. A variation to this scheme is shown in Exhibit 3.6, where a third state, flashing concentric yellow circles, is used when the lane is operated as a dedicated ETC lane. The other type of lane-use signal deployed above conventional plaza lanes is the traditional signal heads similar to those used at signalized intersections on arterials, with the signal heads positioned in a horizontal alignment.

From the survey responses, approximately 60% of toll agencies use lane-use signals consisting of traditional signal heads positioned horizontally. Sizes of the two primary lane use signals deployed today vary, with lane-use signal display panels ranging between 14 and 42 inches high, and signal heads ranging from 8 to 12 inch diameter are predominantly used. Although square display panel configurations are most common, rectangular displays are also being used by some agencies.

3.5.2 Survey Results

Q0047 Is a lane-use signal installed above each toll road Express lane?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	3	27%
No	8	73%

Q0106 Is a lane use signal installed above each dedicated toll road ETC Lane?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	12	75%
No	4	25%

Q0178 Is a lane use signal installed above each toll road ACM/ATIM Lane?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	4	80%
No	1	20%

Q0243 Is a lane use signal installed above each toll road manual Lane?

Choices	Number of Responses	Percentage of all Responses
Yes	7	100%
No	0	0%

Q0244 If yes, does the lane use signal consist of a red "X" and a green arrow? (includes all lane types for both road and bridge facilities)

Choices	Number of Responses	Percentage of all Responses
Yes	20	34%
No	38	66%

Q0109 If no, does the lane use signal consist of red and green traffic signal heads? (includes all lane types for both road and bridge facilities)

Choices	Number of Responses	Percentage of all Responses
Yes	31	76%
No	10	24%

Q0182 If yes, what is the diameter of each signal head (in inches)? (includes all lane types for both road and bridge facilities)

Choices	Number of Responses	Percentage of all Responses
15”	2	7%
12”	19	63%
10’	1	3.5
8”	7	23%
6”	1	3.5

3.5.3 Applicability to MUTCD

The MUTCD 2003 only mention of toll collection applications related to lane-use signals, states that: “Lane-use signals may be used for reversible-lane operations at toll booths. They may also be used if there is no intent or need to reverse lanes”.

3.5.4 Recommended Guidelines

Lane-use Signal Design Issues

Location of the lane-use signal above the respective toll lanes must be selected to be clearly visible to approaching traffic well in advance of the toll lane and complement the lane status sign providing information on payment types supported in the lane.

- Vertical clearance and uniformity of signal location for each plaza must be maintained.
- Consistency with existing standard practices for roadway, bridge and tunnel designs, particularly for symbol type and display colors.
- Selection of conventional signal heads in lieu of arrow and “X” symbols needs to be considered from a user familiarity prospective that may have already been established from lane-use signal deployments on other facilities (both tolled and freeway) within a metropolitan statistical area or other defined region.
- From a safety perspective, color blind users will be considerably more likely to correctly interpret the arrow and “X” display than the traffic signal.
- Expended man-hours and lane closures to maintain each of the two signal types must be considered when selecting between traffic signal heads and customized displays.
- Spares and parts inventory must be assessed to avoid full unit replacement before the device reaches its useful life.

Lane-use Signal Guideline Development

- Location and mounting of lane-use signals should be centered above each conventional plaza toll lane and attached to the canopy fascia below the lane status sign or supported from the underside of canopy, respectively. Alternatively, lane use signals can be mounted to a gantry or bridge structure located immediately in front of the canopy. A minimum vertical clearance of seventeen feet (17’) should be maintained based on national interstate bridge guidelines (AASHTO *A Policy on Geometric Design of Highways and Streets*). To the maximum extent possible, the mounting needs to accommodate easy access to the power and communication interconnections and provide clearance for accessing internal components.

- The lane-use signal should be designed as a larger version of the lane use signals specified by the MUTCD that are mounted overhead to gantries and bridge structures and centered above roadway, bridge and tunnel travel lanes. Provisions for consistency with these installations supports the recommended placement of the lane-use signal below the canopy sign. A red "X" should be displayed to indicate a closed state and a downward pointing green arrow should be displayed to indicate an open state. Lane –use signals should be visible from at least 600' to allow users to make a timely decision on which lane to use for their transaction.

- If lane-use signals are currently in use within the metropolitan statistical area or other defined region encompassing the toll facility, either adoption of this lane-use signal or coordination with the agency deploying the existing signals to consider adopting a new signal should be pursued. Uniformity on a regional basis will assure user familiarity, which is expected to result in improved traffic flow.

- Maintenance considerations of the two types of lane-use signals (i.e., horizontally aligned signal heads or combined arrow and "X" display panels) result in the recommended use of LED technology for both designs. Use of incandescent light for the signal heads would require more frequent maintenance requiring capacity reducing lane closures, and thereby longer vehicle queues.

- Spares and parts must be procured to assure continuous operation of the lane-use signals that displays critical information to the user in making a timely determination of lanes available for their desired transaction type. This is expected to result in improved traffic flow.

Guideline	**Lane-use Control Signals Design Guideline 1**
Title	Signal Design
Text	Recommend use of MUTCD standard green arrow and red "X" design for lane-use signals in lieu of traditional signal heads.
Commentary	Use of traditional signal head may cause confusion, as the green and red signal head indications generally mean "go" and "stop", not "open" and "closed". Color blindness of an expected small percentage of the users justifies the display from a safety perspective.

Guideline	**Lane-use Control Signals Design Guideline 2**
Title	Lane-Use Signal Specifications
Text	Lane-use signal faces shall provide a minimum nominal height of 450mm (18 in.) or 12" diameter, be visible from a minimum distance of 600', provide readily accessible power and communication interconnections, be comprised of long life, high intensity LEDs, and be installed with a minimum vertical clearance of 17'.
Commentary	These requirements are considered general and are not intended for procurement purposes.

3.6 CHANGEABLE MESSAGE SIGNING

Changeable message signs (CMS) at conventional plazas are primarily used for providing lane collection mode information, allowing the agency the ability to change a particular lane, such as from attended to unattended in either a combined ETC and ACM mode, or just one of these two collection modes. Conversely, an ACM collection mode can be converted to an ETC dedicated lane during times of high ETC demand. Flexibility in changing the collection mode of the lane allows better management of vehicle throughput and operational costs, although based on the survey data about half of the agencies are not taking advantage of this flexibility. This lane type flexibility presumes the lanes are properly equipped and the physical features of the lane are conducive to safe travel in any of the selected collection modes. Facilities that charge or are contemplating charging time of day pricing typically use variable display modules combined with fixed static sign panels to show the current toll for passenger cars and possibly other vehicle classifications. Notwithstanding the above, CMS should only be deployed when multiple sign messages are required because of the significantly higher capital and operating costs incurred relative to a fixed static sign.

3.6.1 State-of-the-Practice

Agencies use changeable message signs over ETC dedicated, automatic (i.e., ACM and ATIM) and manual lanes. The survey data indicates the percentage usage of CMS in each of these lane types as follows:

Lane Type	CMS Percentage Usage
ETC Dedicated Lanes	24%
Automatic Lanes	33.3%
Manual Lanes	26.7%

The level of sophistication of the CMS installed at conventional plazas varies considerably. Signs capable of from 1 to 3 lines of text are being used to display a lane's collection mode. The majority of CMS implementations use a character height of 10 or 12 inches, making the signs visible from a distance of at least 500 feet. The results of the survey data indicates that only half of the agencies are changing the lane collection mode messages displayed above the toll lane. This may be partly attributable to the physical characteristics of the toll lane or a consistent user demand throughout the day for a particular collection mode.

Some agencies have combined variable display modules with fixed, static signs to provide the capability to change a very limited portion of the complete sign message. This approach is typically used by agencies that have implemented or are contemplating the implementation of time of day pricing, whereby the variable toll amount for a passenger car and possibly other vehicle classifications shown on the fixed, static portion of the sign is displayed. With many regions of the country experiencing high traffic congestion, toll agencies and state departments of transportation are responding to the congestion and, in the case of existing toll facilities, the associated conventional plaza delays by planning and implementing variable priced express lanes for their facilities. To expand participation in the ETC Program, various discounts and incentives such as time of day pricing may be offered only to ETC users. Depending on the method an agency chooses to convey pricing information, fixed static signs with variable display modules may be needed to display the current toll in effect to the ETC customers.

3.6.2 Survey Results

Q0111 Is a sign mounted above each dedicated ETC lane? "and" Q0112 If yes, is the sign:		
Choices	**Number of Responses**	**Percentage of all Responses**
Fixed panel	13	62%
Changeable (CMS, VMS, DMS)	5	24%
Other	3	14%

Q0113 If changeable, what is the maximum number of lines supported?		
Choices	**Number of Responses**	**Percentage of all Responses**
2	4	57%
3	3	43%

Q0114 What is the height of each character?		
Choices	**Number of Responses**	**Percentage of all Responses**
10	4	57%
12	3	43%

Q0115 For a CMS/VMS, is more than one message displayed above the dedicated ETC lane?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	4	50%
No	4	50%

Q0183 Is a sign mounted above each ACM/ATIM lane? "and" **Q0184 If yes, is the sign:**		
Choices	Number of Responses	Percentage of all Responses
Fixed panel	4	66.7%
Changeable (CMS, VMS, DMS)	2	33.3%
Other	0	0.0%

Q0185 If changeable, what is the maximum number of lines supported?		
Choices	**Number of Responses**	**Percentage of all Responses**
No Lines	2	50%
2	1	25%
3	1	25%

Q0186 What is the height of each character?		
Choices	**Number of Responses**	**Percentage of all Responses**
10"	4	100%

Q0187 For CMS, is more than one message displayed above the ACM/ATIM lane?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	2	50%
No	2	50%

Q0248 Is a sign mounted above each manual lane? "and" Q0249 If yes, is the sign:		
Choices	**Number of Responses**	**Percentage of all Responses**
Fixed panel	11	73.3%
Changeable (CMS, VMS, DMS)	4	26.7%
Other	0	0.0%

Q0250 If changeable, what is the maximum number of lines supported?		
Choices	**Number of Responses**	**Percentage of all Responses**
No Lines	1	25%
1	1	25%
2	1	25%
3	1	25%

Q0251 What is the height of each character?		
Choices	**Number of Responses**	**Percentage of all Responses**
10	4	50%
12	3	37.5%
13.65	1	12.5%

Q0252 For CMS, is more than one message displayed above the manual lane		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	4	50%
No	4	50%

3.6.3 Examples

Exhibit 3-10 Delaware Memorial Bridge Toll Plaza

Lane Use Signal & Changeable Lane Status Signs

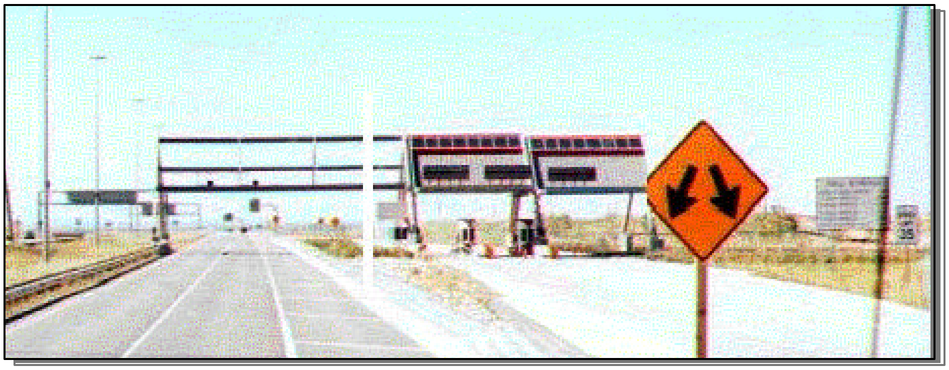


Exhibit 3-11 E_470 Changeable Lane Status Message Signs

3.6.4 Applicability to MUTCD

The *MUTCD* provides standards and guidance for the design of guide signs, from which a framework for multi-collection mode signing can be derived. Toll agencies have used this framework to make modifications to better relate toll collection aspects with guidance and control of traffic flow through a lane. MUTCD committees have been active in setting guidelines and standards for the use of CMS along freeways, which have applicability to toll facilities. Their efforts have resulted in proposed amendments to Chapter 2J addressing Changeable Message Signs.

3.6.5 Recommended Guidelines

<u>CMS Design Issues</u>

- After years of evaluating the performance of CMS using fiber optic technology versus LED technology, LED has evolved as the preferred technology, largely because of the rapid advancement in LEDs that are used to comprise the sign messages. Fiber optic signs typically use a halogen light source that needs frequent replacement, even with recent technology advancements. A catwalk should be installed in conjunction with the CMS to accommodate access for maintenance without the need for lane closures. Alternatively, a bucket truck or lift platform can be used for CMS maintenance after closing the lane below.

- Visibility under all ambient lighting and weather conditions supports the use a light based technology such as LED and fiber optic over a mechanical technology such as prism and flip disk.

- Light based technology signs have significantly higher capital and operating expenses relative to mechanical technology signs.

- To achieve maximum visibility for approaching traffic, the CMS must be tilted toward the plaza pavement at the angle and height recommended by the manufacturer. The CMS can be manufactured with the front face at the recommended angle and having a vertical backplane to reduce installation complexity. The color of the characters should be selected to comply with the MUTCD, while achieving maximum visibility. The height of the characters must be selected to be visible at a distance at least equal to the length of the queue zone. The CMS needs to be centered over the toll lane.

- CMS employing a light based technology should be capable of multiple brightness levels that are selected based on data inputs from multiple photocells attached to the top of the CMS.

- The canopy structure must be structurally sound to support the weight of the CMS, catwalk and two maintenance technicians.

<u>CMS Guideline Development:</u>

- The advantages of CMS using a light based LED technology are now significant and should be deployed for all new installations. Design of the catwalk for maintenance service must assure sign visibility is not diminished by the presence of the catwalk as the user approaches the toll lane. The finish on the CMS cabinet (i.e., sides and back) needs to minimize the absorption of heat to reduce the cooling load on the CMS ventilation system and to prevent the cabinet surface temperature from exceeding a safe threshold for performing maintenance. The catwalk should be fabricated from low maintenance, non-corrosive materials. Grounding and lightning protection needs to be provided for the housing cabinet and copper power and communication lines.

- If the manufacturer's recommended tilt is not fabricated into the design of the cabinet, CMS support brackets must be securely attached to the canopy framing to achieve the recommended angle. The CMS should be visible for a distance at least equal to the depth of the queue zone plus an additional 40 - 50% approach factor. The minimum height of the CMS letters when the speed limit is less than 55 mph should be 10.6 inches, and where the speed limit is 55 mph or greater, the minimum letter height should be 18 inches.

- CMS employing a light based technology should be capable of a minimum of three levels of brightness that are based on data inputs from a minimum of three photocells.

CMS Guidelines

Guideline	CMS Guideline 1
Title	CMS Technology
Text	CMS using a LED technology should be used for all new installations.
Commentary	When budget is a significant consideration and if visibility concerns can be adequately addressed for a particular installation, a CMS using a mechanical technology should be considered to satisfy a message variability requirement.

Guideline	CMS Guideline 2
Title	CMS Visibility
Text	The CMS should be visible for a distance at least equal to the depth of the queue zone plus an additional 40 - 50% approach factor. The minimum letter height should be 10.6 inches. Word messages for a conventional plaza canopy CMS should be created using all Upper Case letters.
Commentary	None.

Guideline	CMS Guideline 3
Title	CMS Brightness
Text	CMS using a light based technology should be capable of a minimum of three levels of brightness that are based on data inputs from a minimum of three photocells.
Commentary	Fog conditions may severely impact visibility regardless of the brightness level.

3.7 PAVEMENT MARKINGS/CHANNELIZATION/IMPACT ATTENUATORS

Several types of pavement markings can be found at toll plazas. Pavement markings such as lane lines, gore striping, and transverse and diagonal lines are used by most agencies within their conventional plazas. Specific applications vary, but are generally used for plaza zone definition, channelization and virtual plaza island extensions. Pavement markings have also been used for lane guidance, indicating a particular primary collection mode (e.g., exact change, full service, attended, E-ZPass Only) within a lane channelized by pavement markings extending to an impact attenuator or chevron pavement markings immediately in front of the toll island.

Lane channelization is used to direct vehicles in a particular direction. It occurs before and after conventional plaza toll lanes, in both the queue and recovery zones, respectively. Express and ETC dedicated lanes require special lane striping and channelization techniques to minimize lane changes through the plaza.

Pavement markings extending upstream from the front of a toll island require a quicker response by the user in selecting a lane to complete their transaction, but reduce the space available for unsafe maneuvering within the queue zone. Pavement markings extending downstream from the rear of the toll island allow users more time to accelerate before merging with other customers prior to entering the mainline lanes.

LED-illuminated in-pavement markers can provide direction and information to the driver directly from the road surface. A vendor supplied controller for these LED in-pavement markers can be integrated with a lane controller similar to lane status signals to provide lane guidance to approaching and departing traffic resulting in a more efficient and safe operation.

Channelizing devices (i.e., delineators/pylons) extending a limited distance upstream from the front edge of the toll island or impact attenuator are used to separate plaza approach lanes. Delineators/pylons provide the same channelization function as pavement markings described above. Polycarbonate delineators/pylons are most commonly used, although traffic cones have also been used to delineate plaza approach lanes. Traffic cones are predominately used to indicate a closed lane, particularly when the lane does not include a lane closure gate at the approach end of the toll island.

Impact attenuators are installed in front of toll islands and the approach end of concrete barrier to absorb the energy of a colliding vehicle by collapsing upon its framework. Although various vendor designs are available, results of performance tests on their products reduces the number of potential selections. A recommended list of approved vendors is often available from the state department of transportation. References should also be checked to assess the experience of existing installations and to compare actual performance to claimed performance.

3.7.1 State-of-the-Practice

Based on the survey results, for agencies using pavement markings in advance of the toll lanes within a conventional plaza, the tapered chevron and gore taper pattern are most commonly used. Pavement markings provide the agencies with a means of effectively extending the toll lanes to require a more timely lane selection by the user while reducing the incident of maneuvering and lane changes within the plaza queue zone. As stated above, pavement markings are also used by some agencies to indicate the collection mode in the toll lane at the end of the approach lane channelized by pavement markings. Pavement marking materials most frequently used, listed in the order of durability and highest cost are: preformed tape, thermoplastic coating, epoxy paint and reflective paint. Pavement marking colors other than white and yellow have been used to distinguish lanes, particularly ETC dedicated lanes. For example, the ETC dedicated lanes on the New Jersey Turnpike use purple and white colored pavement markings to delineate the ETC express lanes. As an example of lane guidance, TCA distinguishes ETC and cash lanes with pavement markings primarily for use when fog significantly reduces visibility of overhead signs.

Impact attenuators have been installed by the many toll road agencies and to a lesser extent by toll bridge agencies at the front of the conventional plaza toll islands and barriers. While an impact attenuator provides protection to the user when approaching any of the conventional plaza toll lanes, the manual toll island impact attenuators also provides critical protection for the attendant operating the tollbooth collection equipment. Even with mass concrete protection commonly constructed in conjunction with the island in front of the toll booth, a properly designed energy absorbing device offers additional protection, particularly in the case of errant trucks. The design length of the impact attenuator is based on the size and speed of vehicles the impact attenuator could encounter during its design life. The majority of impact attenuators installed are retractable, multi-sectional guardrails that increase resistance as the front sections of the attenuator collapse and move toward the island, usually on a track anchored to the pavement. Other similar attenuator designs and associated materials have been used based on the same theory of operation. Chapter 4 of the Roadside Design Guide should be referenced for additional information on this topic.

3.7.2 Survey Results

Toll Road:

Q0086 Are impact attenuators installed in advance of the dedicated ETC lane?			
	No.	**%**	
Yes	10	59%	
No	7	41%	
Total	17		

Q0088 If yes, what pattern of pavement markings is installed in advance of the attenatuators (check all that apply):			
	No.	**%**	
Tapered Chevron	3	25%	
Gore Taper	7	58%	
None	1	8%	
Other	1	8%	Object marker
Total	12		

Q0149 Are impact attenuators installed in advance of the ACM/ATIM island?		
	No.	**%**
Yes	4	100%
No	0	0%
Total	4	

Q0150 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):		
	No.	**%**
Tapered Chevron	2	50%
Gore Taper	1	25%
None	0	0%
Other	1	25%
Total	4	

Q0151 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):		
	No.	**%**
Tapered Chevron	0	0%
Gore Taper	1	33%
None	2	67%
Other	0	0%
Total	3	

Toll Road Manual Lanes:

Q0215 Are impact attenuators installed in advance of the toll booth island?

		No.	%
Yes		14	88%
No		2	13%
	Total	16	

Q0216 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		5	36%
Gore Taper		8	57%
None		1	7%
Other		0	0%
	Total	14	

Q0217 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		1	20%
Gore Taper		0	0%
None		3	60%
Other		1	20%
	Total	5	

Q0086 Are impact attenuators installed in advance of the dedicated ETC lane?

		No.	%
Yes		3	43%
No		4	57%
	Total	7	

Q0088 If yes, what pattern of pavement markings is installed in advance of the attenatuators (check all that apply):

		No.	%
Tapered Chevron		1	33%
Gore Taper		2	67%
None		0	0%
Other		0	0%
	Total	3	

Q0149 Are impact attenuators installed in advance of the ACM/ATIM island?

		No.	%
Yes		1	100%
No		0	0%
	Total	1	

Q0150 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		1	100%
Gore Taper		0	0%
None		0	0%
Other		0	0%
	Total	1	

Q0151 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		0	0%
Gore Taper		0	0%
None		1	100%
Other		0	0%
	Total	1	

Toll Bridge Manual:

Q0215 Are impact attenuators installed in advance of the toll booth island?

		No.	%
Yes		4	40%
No		6	60%
	Total	10	

Q0216 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		2	50%
Gore Taper		2	50%
None		0	0%
Other		0	0%
	Total	4	

Q0217 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		0	0%
Gore Taper		2	40%
None		3	60%
Other		0	0%
	Total	5	

3.7.3 Expert Panel Workshop Recommendations

The panel only discussed pavement striping and channelization with respect to guiding drivers into the toll lanes and preventing last-minute lane changing. The panel recommended the use of pavement striping and channelizing devices only for non-stop lanes. This recommendation did not consider the benefits and appropriateness of "gore area" pavement markings used by many agencies to highlight toll islands and direct vehicles to both the left and right, as applicable.

3.7.4 Recommended Guidelines

<u>Pavement Markings/Channelization/Impact Attenuators Design Issues and Guideline Development</u>

- The use of pavement markings to indicate the collection mode in the upstream toll lane can be covered over by a vehicle during a considerable portion of the peak hour periods. Attempts by the customers to read partially concealed pavement markings may result in increased plaza delays. Lane guidance overhead signing can be supplemented by placing pavement markings near the divergence of express lanes and conventional plaza, where a higher rate of interpretation is expected. However, accumulated snow and ice can render the markings unreadable. Depending on the type of pavement marking material used, extensive use of pavement markings within a plaza will effectively raise the annual plaza maintenance budget. Pavement markings may also reduce surface friction when the pavement is wet, thereby increasing the potential hazards of vehicles maneuvering to find the shortest queue.

- While pavement markings used to delineate lanes within the queue zone effectively reduce the space available for customers to maneuver their vehicles in search of the shortest queue length, a significant portion of these customers are expected to ignore the markings. However, pavement markings used to distinguish reversible lanes should be used in conjunction with lane use signals to assure vehicles do not enter a reversible lane open to vehicle traveling in the opposite direction.

- Pavement markings used to extend the physical separation of dedicated lanes from cash lanes should be double, 8 inch, white lines. This is consistent with MUTCD's recommendation for installing wide white lines where crossing is prohibited but without giving a specific width.

- Only tall reflective traffic cones with a minimum height of 28 inches and a fluorescent collar should be used to close lanes to assure maximum visibility. The nose of the impact attenuator must also be highly visible to approaching traffic for all lighting and weather conditions. As a minimum, cones used in closing a lane should be placed across the lane at the front edge of the impact attenuator or the toll island when there is no impact attenuator.

<u>Pavement Markings/Channelization/Impact Attenuators Guidelines</u>

Guideline	**Pavement Marking/Channelization/Impact Attenuator Guideline 1**
Title	Toll Island/Attenuator Pavement Markings
Text	Gore or chevron pavement markings should be installed immediately in front of the impact attenuator, as applicable, or the toll island.
Commentary	While winter visibility and maintenance expenses are important considerations, the safety and operational benefits of reducing space for unsafe lane changes and maneuvering within the plaza and highlighting the areas of the plaza queue zone that do not lead to a toll lane justify the recommended pavement markings

Guideline	**Pavement Marking/Channelization/Impact Attenuator Guideline 2**
Title	Lane Separation using Pavement Marking
Text	Extension of physical separation of ETC dedicated lanes and cash lanes should be accomplished using double 8 inch wide pavement markings.
Commentary	Except for standard edge markings, use of pavement markings within the queue and recovery zones should be evaluated based on such factors as traffic patterns, weather conditions, delays caused by maintenance, and improvements to operational performance.

Guideline	**Pavement Marking/Channelization/Impact Attenuator Guideline 3**
Title	Dedicated Lane Channelization
Text	Dedicated lanes within a conventional plaza should use both barrier and pavement markings that extend upstream to approximately the point where approaching vehicle speed to the cash lanes drops below 30 mph during off peak hours.
Commentary	The 30 mph threshold is deemed to be a reasonable maximum speed through an ETC dedicated lane. Channelization is intended to prevent or discourage vehicles from attempting to enter a dedicated lane by unsafely crossing the cash lanes when the driver inadvertently failed to get into the proper lane when approaching the plaza.

Guideline	**Pavement Marking/Channelization/Impact Attenuator Guideline 4**
Title	Toll Island/Impact Attenuator
Text	Impact attenuators/crash cushions should be installed at the approach end of all mainline plaza toll islands whenever the approach speed of vehicles can exceed 25 mph.
Commentary	For agencies to assure approach speeds do not exceed 25 mph, continuous rigorous enforcement using both enforcement personnel and speed detection devices in conjunction with a license plate capture system to issue high fines should be deployed. Exhibit 3-8 shows the condition of a 1999 Volkswagen Passat after a front end collision with a stationary object when traveling at 35 miles per hour. The damage shown should not be considered indicative of the damage sustained by other types of vehicles, which may be considerably more severe and therefore supports use of a lower threshold speed for deploying an attenuator.

Guideline	**Pavement Marking/Channelization/Impact Attenuator Guideline 5**
Title	Toll Island/Impact Attenuator
Text	Impact Attenuator/crash cushions for cash lanes should be designed for selected percent above the posted approach zone speed limit, plus 5 mph. For existing plazas, this percentage should be determined from field studies. Each impact attenuator/crash cushion type has specific requirements relative to cross slopes, grades, curbs, etc. Consequently, profile grades and cross slopes for new construction should be designed per the specification of the impact attenuator/crash cushion.
Commentary	Pavement markings offering warning to approaching motorists should be considered for placement immediately in front of the impact attenuator/crash cushions, in the form of a gore taper with diagonal striping or tapered chevrons.

Exhibit 3-12 1999 Volkswagen Passat Crash Test

3.8 DELINEATION

Delineators/pylons are retro-reflective devices typically mounted above the roadway surface and at continuous intervals along the side of the roadway to indicate alignment of the roadway. Variants to the MUTCD defined delineators/pylons are commonly used in conventional plazas to channelize vehicles into a toll lane and prevent crossing into or out of a channelized lane or access way. The more commonly used delineators/pylons installed to separate vehicles are tubular flexible stanchions that are anchored to the pavement using adhesives and or hardware. Pop-up delineators/pylons are also available and should be considered for use at plazas with reversible lanes. Delineators/pylons used to define plaza alignment are commonly rigid and are anchored below the ground surface outside the shoulder.

3.8.1 State-of-the Practice

Delineators/pylons are primarily used at reversible plazas to separate vehicles traveling in opposite directions, to separate higher speed dedicated lanes from the lower speed cash lanes and along the plaza approach and departure zones to assist merging and diverging traffic as it approaches and departs the plaza, respectively. Delineators/pylons have also been used within the shoulder at the tolling point of express lanes and ETC dedicated lanes to prevent vehicles from eluding capture by the violation enforcement system cameras.

3.8.2 Survey Results

No survey questions regarding delineation were offered.

3.8.3 Expert Panel Workshop Recommendations

The panel recommended the use of delineators/pylons only for non-stop toll lanes.

3.8.4 Recommended Guidelines

Delineation Design Issues and Guideline Development

Significant shortcomings with delineators/pylons are a relatively high maintenance cost and potential damage and loss of function from snow removal operations. Pop-up delineators/pylons require more extensive maintenance service to ensure the delineator's retraction and release mechanism is fully operational at all times. Delineators/pylons do not provide the physical separation needed to prevent an errant vehicle from crossing into an adjacent lane. The advantage of delineators/pylons is the low cost to remove and replace these devices to accommodate reconfiguration of the plaza. Also, for drivers that lose control of their vehicles but avoid colliding with another vehicle or a rigid structure, can avoid injury and incurring significant property damage by striking delineators/pylons before regaining control. Design considerations for these devices are presented in section 4.5.

Delineation Guideline

Guideline	Delineation Guideline 1
Title	Plaza Delineation
Text	Flexible delineators/pylons for lane separation should not be installed within a conventional plaza unless a quantitative and qualitative benefit-cost analysis supports the use of these devices.
Commentary	High maintenance cost and a lack of true physical separation are expected to eventually lead to more durable and reliable alternatives for separating vehicles. For reversible lanes, the expected high maintenance costs of pop-up delineators/pylons may be less than the equipment, labor and materials costs and the possible delay cost imposed when relocating the barrier that are associated with moveable barrier, the primary physical separation alternative.

3.9 FLASHING BEACONS/WARNING LIGHTS

A flashing beacon is a highway traffic signal with one or more signal sections that operates in a flashing mode. It is used for warning applications at toll collection facilities, generally for providing a supplemental warning emphasis.

3.9.1 State-of-the-Practice

Flashing or warning beacons are positioned by some agencies next to lane-use signals, centered over the toll collection lanes. Other overhead applications include at the left and right sides of the overhead lane signs mounted on the toll plaza canopies. Besides overhead locations, beacons are sometimes installed on crash blocks or ramparts on the toll island to draw attention to the location of the toll island as users approach the plaza, particularly under adverse weather and poor lighting conditions.

The survey of toll agencies found that use of flashing beacons for ETC dedicated lanes is common, although the most common use is mounting flashing beacons on toll island concrete, at a height of 1.6 to 4 feet. The beacons are normally flashing, though some use steady burns. The beacons are either 8 or 12 inches in diameter and yellow or amber in color.

The MUTCD 2003 provides guidelines for general design and operations of flashing beacons. The standard design should follow the provisions for traffic control signal features, with a flashing rate between 50 and 60 times per minute.

3.9.2 Examples

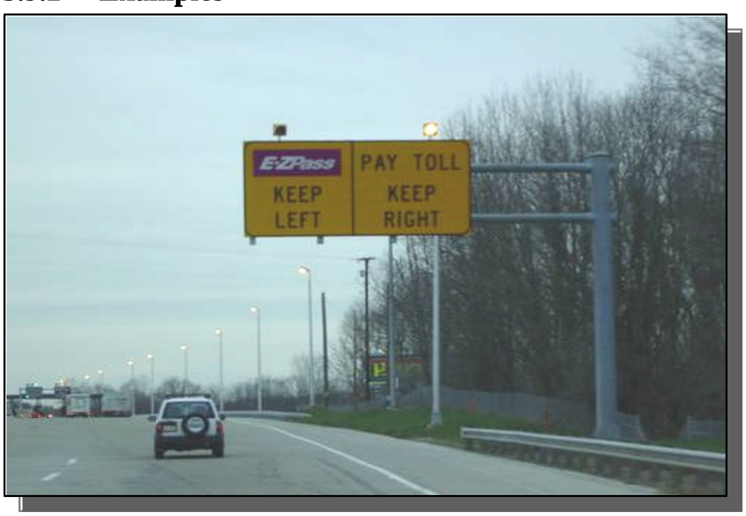


Exhibit 3-13 New York Thruway Advance Toll Plaza Signing - Flashing Beacon /Warning Devices

3.9.3 Recommended Guidelines

Flashing Beacon Design Issues and Guideline Development

Some of the significant issues to consider in using flashing beacons/warning lights are the following:

- Avoiding confusion by approaching users with the installation of a flashing beacon next to a lane-use signal centered over a toll lane;
- Selecting a location to mount a flashing beacon on both sides of the canopy lane status sign that results in maximum effectiveness in distinguishing a dedicated ETC lane both at a distance and within the queue zone of the conventional plaza;
- Selecting a location to install a flashing beacon on either an impact attenuator backup blocks or toll island crash block/rampart that will be most effective in avoiding single vehicle collisions with the toll island protection materials;
- The flashing beacon design and installation should be in full compliance with the MUTCD.

Flashing Beacon Guidelines

Guideline	Flashing Beacons/Warning Lights Design Guideline 1
Title	Supplement to Lane-use Signals
Text	Flashing beacons should not be installed together with lane-use signals, as it provides contradictory information to drivers.
Commentary	Use with lane-use signals presents contradiction to MUTCD.

Guideline	Flashing Beacons/Warning Lights Design Guideline 2
Title	Supplemental to Canopy Signs
Text	Flashing beacons may be used as warning devices with canopy lane status signs for ETC dedicated lanes only, with the intended purpose of indicating the location of the dedicated ETC lane (s) when approaching the conventional plaza lanes.
Commentary	Installation of the flashing beacon at the bottom of the lane status sign has been shown to be effective in highlighting the location of the ETC dedicated lanes when maneuvering within the queue zone to find the toll lane with the shortest vehicle queue.

Guideline	**Flashing Beacons/Warning Lights Design Guideline 3**
Title	Overall use of Flashing Beacons
Text	Flashing beacons may be used on impact attenuators, backup blocks or toll island crash blocks/ramparts at toll plazas.
Commentary	Use should be limited as much as possible to minimize distractions to drivers. Only the yellow color application should be considered. An automatic dimming device may be used to reduce the brilliance during night operation. The flashing beacons mounted on the island should be at an appropriate height above the ground for viewing.

CHAPTER 4

GEOMETRIC AND SAFETY DESIGN

The design of a toll plaza is primarily performed based on quantifiable factors: travel demand, traffic mix, type of toll system (i.e.. barrier or closed ticket), methods of toll collection that account for plaza configurations suited for initial and future toll rates (e.g., high rates preclude automatic (ACM) lanes), existing water, power and communication infrastructure, right-of-way availability at proposed plaza location, potential sources of radio frequency (RF) interference, and roadway, bridge or tunnel mainline approach and departure geometrics. Additionally, some important toll plaza planning issues include: initial and ultimate right-of-way needs, environmental mitigation issues including wetlands, historic preservation, air, noise and light pollution, arrangements for on-site violation enforcement patrols, staffing needs, provisions for staff safety, cash handling security options, budget, and accessibility (i.e., Americans with Disabilities Act (ADA) provisions). These factors are unique and vary considerably across all toll plazas. Some of these factors are identified in Chapter 2.

While the primary objective of this report is to addresses traffic control strategies and applications, it is recognized that roadway geometrics and safety design of toll plazas play a complementary role in the implementation of these strategies. As the MUTCD is the national standard for traffic control devices and measures, the AASHTO *A Policy on Geometric Design of Highways and Streets,* 5th edition, 2004 (i.e., Green Book) provides relevant standards for all NHS highways on geometrics and safety design and is used extensively for reference purposes in this section. Many toll agencies refer to either their own independently published manuals or the respective state DOT's roadway and bridge design manual for guidance.

Recognizing that many factors greatly influence the toll plaza design, the following sections address specific design issues, identifying the state-of-the-practice and offering recommended guidelines wherever appropriate.

4.1 APPROACH ZONES

The approach zone of a conventional plaza design is the area in advance of the toll plaza. It includes a transition area where the pavement widens at a specified taper rate from either the mainline roadway section to the width of the conventional plaza toll lanes, plus a queue zone with no taper prior to the front edge of the toll islands (see Figure 3 in the Glossary). If the toll plaza has express lanes, the approach transition zone extends from the start of the gore area where the conventional plaza lanes diverge from the express lanes.

4.1.1 State-of-the-Practice

Approach queue zones from the project survey results range from 100 feet to over 1300 feet, with an average of 528.7 feet. Lengths may be attributed to an inadequate number of toll plaza lanes or the longer lengths could include the transition areas. Taper rates on toll roads were found to range from approximately 4 to 40, with an average of 9. On toll bridges, this range was from 2 to 17, with an average of 5. As expected, tapers for bridges and tunnels tend to be shorter, presumably the result of a shorter overall approach zone.

Table 4.1
Conventional Plaza Approach Taper Rates

Taper Rates		
Min	**Max**	**Average**
1:40	1:3.73	1:8.82

The MUTCD 2003 and AASHTO "Green Book" provide diverging taper rates for lane additions and drops. However, neither of these sources provides taper rates specifically for the approach zones of conventional plazas. The AASHTO "Green Book's" policy of interdependence of taper rates and speed should be considered in the design to assure a safe transition.

4.1.2 Recommended Guidelines

<u>Approach Zone Design Issues</u>

Some significant issues to consider in designing approach zones include the following:

- available right-of-way or space,
- greater ETC penetration and future addition of express lanes or conversion to open road tolling,
- proximity to upstream interchange on-ramps,
- express lane alignment and separation from conventional plaza lanes,
- profile grade and cross slopes for low maintenance drainage,
- pavement materials to minimize frequency of rehabilitation and reconstruction,
- queue zone pavement materials providing best foundation support for impact attenuators,
- number of roadway (e.g., mainline, ramp) lanes feeding the toll plaza,
- number of conventional plaza toll lanes, both current and future, including ETC dedicated and cash lanes,
- queue zone requirements based on an analysis of throughput capacity of proposed configuration during peak periods,
- provisions for oversized trucks to turn around or perform another safe maneuver to exit a plaza area, particularly before entering or crossing a bridge or tunnel, respectively, unless provided in the departure zone.

Approach Zone Guideline Development

The design development work performed in 1999 by McDonald[1] and in 2001 by McDonald and Stammer[2] should be used as the basis for the layout of approach zones. For agencies with existing design standards, the stated reference should function as a supplement.

The number of toll lanes needed to accommodate the forecasted design year traffic volumes can be determined manually by the use of queue theory models and calculations or through the use of plaza simulation techniques. Some examples of simulation packages are the following:

TOLLSIM, is a simulation model developed by Wilbur Smith Associates to analyze the toll operation at the approach to the toll plaza. It requires traffic data and lane type configuration, ramp approaches and the storage length of each lane. The model produces simulation analysis results in graphic and number format, listing a number of measures of effectiveness such as delay per lane, delay overall, and queue length. No analysis of traffic operation downstream from the toll plaza can be performed.

VISSIM, is a general simulation model that can be tailored for toll plaza performance analysis. It requires the same input data listed above under TOLLSIM. In addition, calibration is required to match existing toll operations in the field. The advantage of VISSIM is that the user can analyze the highway leading to the plaza, downstream from the plaza and at the plaza. The interactions between these locations are seamless in this model.

CORSIM, is also a simulation model commonly used for highway corridors. It can be used in conjunction with TOLLSIM to analyze the traffic operations on the ramps and local roadway system downstream from the toll plaza. Although it can theoretically simulate operations at a toll plaza, this is not a straightforward modeling effort, requiring resolution of some inherent complications.

1) McDonald, D.R., Jr. (1999). "Development of Toll Plaza Design Guidelines and Creation of a Toll Plaza Design Model." PhD thesis, Vanderbilt University, Nashville, Tenn., Publication No. AAT 9944570. Bell & Howell Publishers.

2) McDonald, D.R., Jr. and Stammer, R.E., Jr. (2001) "Contribution to the Development of Guidelines For Toll Plaza Design", Journal of Transportation Engineering, Vol. 127, No. 33, May/June 2001.

Approach Zones Design Guidelines

Guideline	Approach Zones Design Guideline 1
Title	Queue Zone Lengths
Text	The length of queuing zone should be based on estimated or actual peak hour queue lengths, determined by an analysis, plus an added safety factor, with a minimum of 200 feet. Design year traffic volumes should be used.
Commentary	For plaza reconstruction and expansion, design should make use of a simulation model to calibrate existing plaza operations and to estimate plaza queuing and toll lane usage, or use professionally acceptable manual calculation methods (note: vehicle mix, daily/weekend/ holiday profiles, and unusual demand generators). The analysis must account for increased usage of express lanes and ETC dedicated lanes which is expected to reduce conventional plaza queuing in the future.

Guideline	Approach Zones Design Guideline 2
Title	Transition Zone Tapers
Text	Transition zone tapers approaching the conventional plaza should use the minimum taper rates presented in the McDonald 1999 and McDonald and Stammer 2001 reports. The diverge tapers from the latter publication for speeds of 40 mph or less is specified as L=WS/105 and for speeds 45 mph or more and L=3/8 WS for speeds 45 mph or more, where L= minimum length (ft.), S= posted approach speed in mph, and W= offset distance in feet. Use of a smaller taper for wide plazas and a minimum taper of 10:1 for speeds less than 30 mph was recommended.
Commentary	Reference the ITE Freeway and Interchange Geometric Design Handbook – Chapter 13 for further design information on taper rates.

Guideline	Approach Zones Design Guideline 3
Title	Proximity to On-ramp
Text	If the distance to safely change lanes to access the express lanes after entering the mainline from an upstream interchange on-ramp is not sufficient, this movement should be physically prevented through the use of barrier or delineator/pylons separated auxiliary lane extensions.
Commentary	Existence of an ETC dedicated lane or provisions to add one within the conventional plaza should minimize any inconvenience to the ETC customer.

Guideline	Approach Zones Design Guideline 4
Title	Express Lanes
Text	The approach transition zone begins at the start of the gore where the conventional plaza and express lanes split.
Commentary	For tunnel and bridge plaza approach zones, sensors and physical constraints should be deployed to prevent oversized trucks from entering a toll lane. Provisions for safely maneuvering the vehicle out of the plaza area are required.

4.2 DEPARTURE ZONES

The departure zone of a conventional plaza is the area encountered by a driver upon exiting a toll lane. It includes the recovery zone, which is a non-tapered extension of the toll lanes downstream of the toll islands used for driver re-orientation and acceleration, followed by a departure transition area downstream of the recovery zone where the pavement narrows at a specified taper rate from the conventional plaza width to the total width of the mainline or ramp (see the Glossary). This can be more complicated with separate express toll lanes and often results in either no taper or a minimal taper on the side adjacent to the express lane and requires the transition pavement width to merge with the express lanes (typically on the mainline alignment) consistent with interchange design standards.

4.2.1 State-of-the-Practice

Departure recovery zones from the project survey results range from 100 feet to over 1300 feet, with an average of 500.7 feet. Although it is uncertain whether the longer lengths include the transition areas, this is likely the case. As shown in Table 4.2, departure zone taper rates on toll roads were found to range from approximately 3 to 40, with an average of 9. For toll bridges, this range was from 4 to 11, with an average of 6. As expected, tapers for bridges and tunnels tend to be shorter, presumably the result of a shorter overall departure zone.

Table 4.2
Conventional Plaza Departure Taper Rates

Taper Rates		
Min	Max	Average
1:40	1:3	1:9

The MUTCD 2003 and AASHTO "Green Book" provide taper rates for lane additions and drops. However, neither of these sources provides taper rates specifically for departure zones of conventional plazas. The AASHTO "Green Book" policy of interdependence of taper rates and speed should be considered in the design to assure a safe transition.

4.2.2 Recommended Guidelines

<u>Departure Zone Design Issues</u>

Some of the significant issues to consider in establishing departure zones include the following:

- available right-of-way or space,
- current or future merge with express lanes,
- proximity to downstream interchange exit,
- number of continuing roadway or ramp lanes after departing conventional plaza,
- number of conventional plaza toll lanes, both current and future, including ETC dedicated and cash lanes,
- relative acceleration rates and speed of vehicles in the recovery zone,
- provisions for oversized trucks to turn around or other safe maneuver to exit a plaza area, particularly before crossing or entering a bridge and tunnel, respectively,
- profile grade and cross slopes for low maintenance drainage,
- pavement materials to minimize frequency of rehabilitation and reconstruction,
- provisions for buses and RV traffic to pull-off onto a widened shoulder or other area not affecting the flow of traffic when assistance is needed.

Departure Zone Guideline Development

The design development work performed in 1999 by McDonald and in 2001 by McDonald and Stammer should be used as the basis for the layout of departure zones. For agencies with existing design standards, the stated reference should function as a supplement.

Departure Zones Design Guidelines

Guideline	**Departure Zones Design Guideline 1**
Title	Recovery Zone Lengths
Text	The departure recovery zone should be equal to at least 200 feet and preferably 300 feet, a length expected to allow sufficient driver re-orientation, acceleration, and initial merge distance after exiting the plaza.
Commentary	For tunnel and bridge toll plazas, a longer recovery zone may be warranted for oversized vehicles to safely maneuver out of the plaza area if sensors and physical constraints are not available or deployed to detect an oversized vehicle prior to entering a toll lane, thereby precluding any maneuver to exit the plaza on or before the plaza approach.

Guideline	Departure Zones Design Guideline 2
Title	Transition Zone Tapers
Text	Transition zone tapers departing the toll plaza should use the minimum taper rates presented in the McDonald 1999 and McDonald and Stammer 2001 reports. The diverge tapers from the latter publication for speeds of 40 mph or less is specified as L=WS/105 and for speeds 45 mph or more and L=3/8 WS for speeds 45 mph or more, where L= minimum length (ft.), S= posted approach speed in mph, and W= offset distance in feet. Use of a smaller taper for wide plazas and a minimum taper of 10:1 for speeds less than 30 mph was recommended.
Commentary	Reference the ITE Freeway and Interchange Geometric Design Handbook – Chapter 13 for further design information on taper rates.

Guideline	Departure Zones Design Guideline 3
Title	Proximity to Off-ramp
Text	If the distance to safely change lanes to reach the exit lane of a nearby downstream interchange from an express lane is not sufficient, this movement should be physically prevented by a downstream extension of the raised median or barrier separating express lanes and merging conventional plaza lanes.
Commentary	New construction should avoid potential information overload related to informing ETC users to exit the facility through the conventional plaza lanes in lieu of the express lanes by locating the plaza a sufficient distance from entry and exit ramps. For existing facilities, advance signing should be used to direct traffic that will be exiting at an interchange ramp just downstream of the plaza to use the conventional toll plaza lanes in lieu of the express lanes. Existence of an ETC dedicated lane or provisions to add one within the conventional plaza should minimize any inconvenience to ETC customers. The number of ETC dedicated lanes required should be calculated by estimating the percentage of ETC users exiting at a nearby downstream interchange ramp after traveling through a conventional plaza and or the percentage of ETC users entering the conventional plaza from a nearby upstream interchange on ramp. These percentages are then converted to volumes of dedicated lane ETC traffic and combined with an estimated residual of ETC traffic that elects to use the dedicated lane in lieu of the express lanes or all ETC mainline traffic if there are no express lanes.

Guideline	Departure Zones Design Guideline 4
Title	Express Lane Departure
Text	The departure recovery and transition zones should be fully completed prior to the merge with continuing express lanes. (i.e. merged lanes should equal the number of lanes on the typical roadway section downstream of the plaza area), subject to provisions for merging with any express lanes.
Commentary	An auxiliary lane may be used to temporarily increase the number of lanes merging with the continuing roadway lanes after exiting the conventional plaza.

Guideline	Departure Zones Design Guideline 5
Title	Recovery Zone Dedicated Lane Design
Text	Placement of physical separation devices for dedicated lane traffic should be extended beyond the toll islands until traffic in the adjacent lanes that had stopped to pay the toll has accelerated to 50% of the operating speed. As a minimum, solid white striping should continue until the accelerating traffic has reached a point of approximately two-thirds (66%) of the operating speed based on the average acceleration rate of a mid-size vehicle.
Commentary	Although specific locations are provided, the intent is to minimize the potential hazards of differential speeds when exiting a toll plaza.

4.3 EXPRESS LANES

There are many real and potential safety concerns at toll plazas, with particular regard to multiple payment methods that include ETC technology. Inclusion of this technology at toll plazas introduces another payment option for users that may add to their confusion on lane choice. ETC technology eliminates the need for drivers to stop for toll payment. As such, it creates speed differentials in the overall flow of traffic. In an effort to minimize conflicts and adverse conditions associated with these speed differentials, the higher speed ETC lanes are physically separated from the conventional plaza lanes where cash payment requires the vehicle to stop.

The ETC dedicated lane within a conventional plaza is only equipped to collect tolls electronically, thereby limiting use of the lane to vehicles having a valid transponder. Dedicated lanes usually do not require the driver to stop their vehicle, however, due to physical constraints, collection staff safety, and speed differential concerns, the allowable travel speed is usually much less than the posted speed limit on the approach to the toll plaza. Express lanes ideally are effectively equivalent in design to the approach and departure roadway sections. Typically the number of express lanes are less than the approach roadway lanes. Barrier are installed to prevent access to the express lanes from the conventional plaza. Express lanes are capable of supporting a much higher throughput of traffic and result in the least amount of delay relative to all plaza lane types. Because a single express lane prevents a user from passing a slower moving vehicle and requires wide shoulders to assure continued vehicle passage if lane blockage occurs, two express lanes are often considered a practical minimum.

To minimize conflicts, locating express lanes to the far left of a directional toll plaza is generally recommended, since faster drivers typically stay to the left and the approach roadway alignment is easier to maintain through the express lanes. To separate high speed, non-stop vehicles from the conventional plaza that supports both lower speed ETC dedicated lanes and cash lanes, a barrier, or raised median providing an adequate clear zone, or a combination of both is normally used commensurate with the speed of the approach roadway. This configuration also discourages drivers from making lane changes close to the toll plaza.

4.3.1 State-of-the-Practice

The tables below present the project survey results related to express lanes configuration, and the type of barriers used on either side of these lanes. Note that almost all agencies have express lanes that are a continuation of the mainline or ramp roadway, rather than tapering to one side or the other. One variation to this configuration is the tapering of the express lanes to their ultimate location within the median, the location where all future widening is planned to occur that will ultimately align the future “inside” mainline lanes with the initially constructed express lanes. This approach avoids the need for future expansion to the outside and the attendant changes to interchange ramp connections. Based on the survey results provided below, most agencies use concrete barriers on each side of the express lanes.

4.3.2 Survey Results

Q0033 Relative to the mainline through lanes, express lanes:		
	No.	**%**
Are a continuation	10	91%
Taper to the left	1	9%
Taper to the right	0	0%

Q0031 The barrier type installed on the left is (check all that apply)?		
	No.	**%**
Concrete	8	73%
Guard rail	2	18%
None	0	0%
Other (Earth Berm)	1	9%

Q0032 The barrier type installed on the right is (check all that apply)?		
	No	**%**
Concrete	7	64 %
Guard rail	3	27 %
None	1	9%
Other	0	0%

Placing higher speed lanes on the left, consistent with highway travel is most common. However, some agencies have constructed their express ETC lanes on the right side of the plaza to accommodate reversible lanes or to provide staff access to and egress from a median facility (i.e. administration building and parking lot). There are added challenges with this approach, including requiring higher speed traffic to veer to the right, followed by a merge with slower conventional plaza traffic.

4.3.3 Recommended Guidelines

Express ETC Lane Design Issues and Guideline Development

Some of the significant issues to consider in establishing express lanes include the following:

- potential solution for alleviating speed differentials in the conventional plaza that includes ETC dedicated lanes and cash lanes,
- location of the express lanes under both the initial and ultimate builds,
- minimizing abrupt lane changes at the tolling point and license plate image capture zone,
- safe and operationally efficient divergence of traffic into the express lanes and conventional plaza lane when approaching a plaza,
- safe and operationally efficient merge of express lanes and conventional plaza traffic downstream of the toll plaza,
- provisions for maintaining existing reversible lane operations in the conventional plaza after verifying the need to continue the operation of these lanes,
- maintaining the existing location of the administration building and parking within the roadway median,
- weave length from upstream on-ramp gore to express lane - conventional plaza approach gore,
- weave length from express lane - conventional plaza departure gore to downstream off-ramp gore,
- allocation of available right-of-way to the express lanes, conventional plaza lanes, administration building(s) and any plaza bypass lanes.

Express Lane Design Guidelines

Guideline	Express Lane Design Guideline 1
Title	Lane Placement
Text	To avoid or minimize potential conflicts, express lanes should be located to the far left of the plaza.
Commentary	This is consistent with general highway travel, therefore, meets the expectations of the drivers. This effectively prohibits any reversible lane operation. Facilities where staff must access tollbooths or toll equipment from a facility located in the median, a tunnel or overhead walkway is needed to accommodate express lanes located to the far left. See Chapter 2 for more information on toll plaza configuration.

Guideline	Express Lane Design Guideline 2
Title	Express Lane Design
Text	Design of express lanes should preferably be a continuation of the normal mainline lanes with similar features (i.e. design speed, lane widths, and shoulder widths). The split between the express lanes and the conventional plaza lanes should occur prior to approach transition zone for the adjacent conventional plaza, and the merge downstream of the toll plaza should occur after the departure transition zone. (see Figure-3 and subsections 4.1 and 4.2)
Commentary	A barrier wall, guardrail, delineators/pylons and/or other types of physical separation should be considered between the express lanes and the conventional toll plaza lanes when highway standard clear zone separation is available to prevent confused and deviant drivers from trying to access the conventional plaza.

Guideline	Express Lane Design Guideline 3
Title	Diverging and Merging Express Lane and Conventional Plaza Lane Traffic
Text	Design of the conventional plaza approach and departure zones from and to the roadway mainline should comply with pertinent elements of interchange design, whereby the express lanes "should function" the same as the mainline through lanes.
Commentary	The design must account for the available right-of-way and the ultimate number of express and conventional plaza lanes, shoulder widths, and median. The ultimate express lane width should be equal to the ultimate mainline cross section.

4.4 LANE AND SHOULDER WIDTHS

Historically, the width of conventional plaza toll lanes, particularly automatic lanes, tend to be narrower than the adopted width for freeway lanes. This is done to encourage the driver to slow their vehicle through the toll plaza lanes, thereby minimizing the potential for vehicle and equipment damage and to more quickly maneuver the vehicle into position to complete a transaction. However, express lanes must be designed for travel at higher speeds. Furthermore, shoulders for express lanes need to be designed similar to a freeway typical section, for safety and refuge purposes, as well as to minimize capacity loss due to lane blockage.

4.4.1 State-of-the-Practice

Tables below present the project survey findings for lane widths of different modes of toll collection for toll roads and toll bridges (i.e., manual, automatic coin machine/automatic ticket issuing machine (ACM/ATIM), dedicated ETC, and express ETC).

Q0199 What is the width of the manual lanes (feet)?			
Max	**Min**	**Mode**	**Average**
15	9.8	10	10.68

Q0133 What is the width of the ACM/ATIM lane (feet)?			
Max	**Min**	**Mode**	**Average**
14	10	10	11.00

Q0072 What is the width of each dedicated lane (feet)?			
Max	**Min**	**Mode**	**Average**
12	9.5	12	11.1

Q0027 What is the width of each Express lane (feet)?			
Min	**Max**	**Mode**	**Average**
9.5	14	12.0	12.0

Q0029 What is the express lane width of left shoulder (feet)?			
Min	**Max**	**Mode**	**Average**
1	12	4.0	6.36

Q0030 What is the express lane width of right shoulder (feet)?			
Min	**Max**	**Mode**	**Average**
0	12	12.0	10.83

4.4.3 Examples

New York State Thruway Toll Plaza Lane Sharing

4.4.3 Recommended Guidelines

Lane and Shoulder Width Design Issues and Guideline Development

The AASHTO "Green Book" does not specifically mention anything related to toll lane widths. Consequently, the AASHTO recommended 12 foot width should be adopted for express lanes. As described above, conventional plaza lanes have historically been less than 12 feet, although this is not necessarily applicable to newer conventional plaza designs. Twelve (12) foot wide toll lanes can comfortably accommodate larger vehicles and elderly drivers than in narrower lanes where they may come in contact with toll island equipment. Oversized loads (up to 14 feet wide) need to be accommodated in at least one lane, subject to state/local permit requirements. Oversized vehicles are usually handled in the far right lane where a shoulder can be used to provide additional lane width.

An ITE report recommends that manual, ACM/ATM, and dedicated ETC lanes have the following minimum widths:

Lanes with less than 10% trucks	10 feet minimum
Lanes with 10-30% trucks	11 feet minimum
Lanes with over 30% trucks	12 feet minimum

Some of the significant issues to consider in establishing lane and shoulder widths include the following:

- speed reduction through the toll plaza,
- potential for damage to vehicles and toll equipment installed near the edge of the toll island as the result of contact between these mobile and stationary items, respectively,
- provisions for handling large trucks and over-sized vehicles,
- provisions for passage of maintenance vehicles,
- refuge for disabled vehicles in express lanes,
- refuge for law enforcement vehicles for on-site violation enforcement details and homeland security functions,
- provisions for emergency vehicle access to express lanes during peak-hour periods,
- in cases with insufficient median width only, possible tapered reduction to the inside express lane shoulder width to accommodate gantry supports,
- capacity loss due to partial or full lane blockage,
- available right of way and overall plaza width.

Lane and Shoulder Width Design Guidelines

Guideline	Lane and Shoulder Width Design Guideline 1
Title	Manual and ACM/ATIM Lanes
Text	Toll lane width should be a minimum of 11 feet, with 12 feet desirable to accommodate large vehicles.
Commentary	A far right manual lane width of at least 16 feet should be considered for over-sized vehicles. For existing facilities, this same objective may be achieved by a 12 foot lane and a 4 foot shoulder.

Guideline	Lane and Shoulder Width Design Guideline 2
Title	Dedicated ETC Lanes
Text	Toll lane width should be a minimum of 11feet, with 12 feet desirable to accommodate larger vehicles, if permitted.
Commentary	None

Guideline	Lane and Shoulder Width Design Guideline 3
Title	Express ETC Lanes
Text	Toll lane and shoulder widths should match the typical section design used for the approaching roadway.
Commentary	Some shoulder restriction may be needed to the inside shoulder to accommodate a bridge or gantry structure foundation used to support overhead toll and violation enforcement equipment when the median width is insufficient. This isolated shoulder restriction should be tapered and the shoulder width reduction should be limited in length to minimize the impact on an emergency vehicle using the shoulder to bypass congested traffic conditions subject to the shoulder width being sufficient for vehicle travel.

4.5 TOLL ISLAND

The toll island provides physical lane separation and protects the tollbooth, agency staff, and toll collection equipment within the conventional plaza. It provides a foundation for the canopy and tollbooth, conceals conduits and wireways, and forms a part of an access way to either a tunnel or overhead walkway. In addition, the toll island provides the foundation for equipment used in lanes operating in manual and automatic collection modes. This equipment includes an automatic coin machine, an automatic ticket issuing machine, traffic control equipment including the island traffic signal, and automatic barrier gate, and display equipment such as a patron toll display and any speed display sign. Crash protection on the island approach end of a manual lane is provided to protect the attendant, tollbooth and equipment, along with anyone using the integral stairs from either an overhead walkway or tunnel. The crash protection generally includes the following items, listed from the furthest to the closest to the tollbooth: crash cushion/impact attenuator, rampart, and crash block(s). Impact attenuators are not intended to reduce the number of accidents, but rather the severity of an accident. The rampart and crash block(s) are intended to protect the attendant, tollbooth and toll collection equipment.

4.5.1 State-of-the-Practice

The vast majority of tollbooths and toll collection equipment are installed on toll islands constructed of concrete that rises above the toll lane pavement surface. The higher surface provides the following: a solid foundation for a tollbooth, canopy, and traffic control and toll related equipment, a platform for an attendant to service trucks, aesthetics enhancement of the plaza by concealing conduit runs, and a means of diverting drainage away from a tollbooth and any openings to the tunnel below the booth. Agencies and departments use ramparts and/or crash blocks, either separately cast or monolithic with the toll island concrete, to protect the tollbooth, attendant and toll related equipment. Some agencies have combined planters with crash blocks to make the plaza more aesthetically appealing. Observation of the conventional toll plaza of many agencies and departments indicates impact attenuators are installed in front of the toll island to provide additional protection for the tollbooth and toll attendant.

If an automatic barrier gate, which blocks traffic from exiting the lane until the toll due is paid, is not deployed, agencies were found to provide protection for attendants, supervisors and maintenance staff crossing toll islands and lanes by using chains, ropes, gates or some other type of moveable barrier installed on the toll island and preventing walking into a toll lane with non-stop traffic. A majority of the agencies surveyed use a crash cushion/attenuator in front of toll islands. Additionally, pavement markings are used immediately in front of the crash cushions/attenuator to provide advance warning to drivers and to guide them into making a lane selection prior to reaching the crash cushion/attenuator.

Most agencies were found to have their own design standards for toll islands. There are no specific island design standards or recommendations found in industry guidebooks. However, the AASHTO *Roadside Design Guide* 2002 presents information on various types of crash cushions/impact attenuators. It also provides information regarding grades and curbs near crash cushions.

Some agencies and departments were found to use some form of safety related signing or pavement crosswalk markings across the lane between islands for warning drivers of agency staff who may stray into the lane. These can be pavement markings and/or simple standard stop signs, "modified or enhanced" non-standard stop signs, or some type of crossing warning sign.

4.5.2 Survey Results

Tables below present the project survey findings for toll island widths used to support different modes of toll collection (i.e., manual, automatic (ACM and ATIM), and dedicated ETC) for toll roads and toll bridges:.

Q0074 If a toll island is on one or both sides of the lane, what is the width of the island (feet)?			
Max	**Min**	**Mode**	**Average**
16	2	6	7.2

Q0074 If a toll island is on one or both sides of the lane, what is the width of the island (feet)?			
Max	**Min**	**Mode**	**Average**
16	2	6	7.2

Q0134 What is the width of the toll island on which the ACM/ATIM is mounted (feet)?			
Max	**Min**	**Mode**	**Average**
6.5	4	6	5.50

4.5.3 Recommended Guidelines

Island Design Issues and Guideline Development

Some of the significant issues to consider when designing a toll island and recommendations for resolving these issues include the following:

- The island design needs to be capable of supporting a tollbooth, a canopy whose load is transferred to the island through columns and toll collection equipment; conceal unsightly conduit runs; and provide protection for a stairwell to either an access tunnel or overhead walkway. Cast-in-place reinforced concrete provides a durable foundation that can be formed to achieve various shapes and contours around openings and conduits can easily be embedded to route wires and cable to the tollbooth and island equipment.

- The island design must provide a means of securely anchoring the tollbooth and provide a positive means of clearance from the edge of travel way. A concrete blockout allows the bottom edge of the tollbooth to be anchored below the surface of the island. This prevents the displacement of the booth into a lane if the anchor bolts are sheared as the result of a vehicle collision. A minimum one foot ledge from the tollbooth wall to the outside edge of island is recommended to protect the tollbooth from damage by passing vehicles.

- When agency staff and visitors must cross multiple lanes to get to their desired island location, provisions for an island refuge prior to a crossing lanes should be provided. It is recommended the tollbooth be installed in juxtaposition to canopy supports and toll equipment so that there is an access-way in a straight alignment across all islands in a particular direction of travel. If the access way is installed behind the tollbooth, line of sight to approaching vehicles should not be obscured by the booth when standing near the edge of the island.

- Agency staff and visitors may inadvertently walk into a dedicated or cash lane when crossing lanes coincident with a vehicle passing through the lane. Alternative solutions range from a warning sign to installing a pedestrian gate or other moveable barrier that blocks access across the lane without taking some positive action. If staff is required to cross a lane that provides ETC, crossing the lane should be blocked by a rope, chain, gate or other moveable item. An exception is when the lane has an automatic gate that is not held in an open position during peak periods. For crossing a cash lane without ETC capability, a conspicuously located warning sign is recommended to achieve a minimum level of pedestrian safety when crossing toll lanes.

- Although an impact attenuator is expected to absorb a significant portion of an errant vehicle's momentum, the island design must incorporate feature(s) to prevent all vehicles from a head-on collision with the tollbooth. The commonly used solution consisting of ramparts and crash blocks that satisfies the following criteria is recommended:

- capable of sustaining vehicular impacts,
- does not block the vision of the attendant,
- consistent with any plaza architectural theme,
- does not launch a vehicle when impacted,
- designed to be monolithic with or securely anchored to the island to prevent any displacement as a result of a vehicle collision, and
- requires minimal maintenance.

- The island design must provide appropriate clearances and accommodate the strategic placement of toll collection and traffic control equipment and devices, displays, and signs to meet functional requirements while avoiding the appearance of clutter and information overload. The dimensions of the island should be established based on the planned or existing tollbooth exterior dimensions, provisions for a stairwell for tunnel or overhead walkway access and the recommended locations of the items listed. The island width should be a minimum of six (6) feet, based on a maximum tollbooth width of four (4) feet. All plaza islands should be of the same length in a particular direction of travel even though automatic lanes usually require a smaller island than manual or attended lanes. From a safety perspective, the toll island should be a minimum height of six (6) inches, which is equivalent to municipal and state standards for arterial roadway curbs. However, added protection is warranted for the safety of the collector and protection of the agency's investment in equipment and the tollbooth installed on the toll island. This is particularly relevant with the addition of ETC capability that commonly results in higher speeds through the lane. The AASHTO "Green Book" defines a barrier curb as eight (8) inches. A height exceeding this exacerbates the difficulty of servicing low profile sports vehicles. For new facilities, the recommended height is eight (8) inches, assuming the elevation of the tollbooth floor is approximately equal to the surface of the island downstream of the booth.

- The location of the island needs to be clear to all approaching traffic under all lighting and weather conditions. To assure visibility of the toll island the design should incorporate a beacon/fog light mounted to the mass concrete protection on the approach end of the island and installed at a height that is visible to all approaching traffic. The visibility of any impact attenuator should be enhanced using reflectors and reflective tape.

Toll Island Guidelines

Guideline	Toll Island Guideline 1
Title	Island Width
Text	The island width should be a minimum of six (6) feet, subject to providing at least a minimum of one (1) foot of clearance on each side of the tollbooth or combined booth and ACM/ATIM equipment. For standalone ACM/ATIM equipment lanes, the width should be based on safe clearance for servicing (e.g., changing coin vaults, stacking tickets, maintenance servicing) the equipment, subject to the recommended minimum.
Commentary	Design must consider an acceptable clearance offsets for ACM/ATIM equipment from the curb face for customer convenience during transactions.

Guideline	Toll Island Guideline 2
Title	Toll Island Length
Text	The length of a toll island can vary based on the following: design of island access facilities (e.g., stairwell, stairway), space requirements for toll collection and traffic control equipment, and provisions for toll-booth and equipment protection. Toll island length in a conventional plaza should be uniform even though the island supporting manual collection tends to be the longest and ETC dedicated lanes tend to be the shortest. Specifically, the length of a manual island depends on the design of the tollbooth; design of any stairway for an overhead walk-way or stairwell for an access tunnel; provisions for violation enforce-ment and traffic control equipment; tollbooth protection; design of canopy supports; provisions for staff access across the islands; and aesthetic considerations.
Commentary	A possible exception to the manual lane being the control island length is when ACM/ATIM equipped lanes (i.e., automatic lanes) per-mit truck use and thereby deploy a pre-classification subsystem that requires a minimum 5-axle truck length in advance of the ACM/ATIM equipment so the correct toll or class can be displayed or printed to the ticket, respectively.

Guideline	**Toll Island Guideline 3**
Title	Rampart and Crash Blocks
Text	Tollbooth protection provided by ramparts and crash blocks should be designed to withstand anticipated loads of design vehicles. The rampart should be designed to redirect errant vehicles and not launch the vehicle. Crash blocks are constructed of reinforced concrete and can incorporate aesthetic features such as planters.
Commentary	Double crash blocks should be considered if large vehicles are permitted. Longer blocks may be considered in lieu of a rampart. Design should be performed by an experienced structural engineer. If planters are used, any planted vegetation should not block the collector's vision of approaching vehicles and a filtered drainage outlet is required.

Guideline	**Toll Island Guideline 4**
Title	Staff Access
Text	Grade separated access to toll islands should be considered so no more than a single lane must be crossed to gain access to the intended island. Design should include a means to block access into the adjacent lane by installing a pedestrian gate, moveable barrier, or a chain or rope strung between two posts at the edges of the toll island to warn and protect staff crossing lanes.
Commentary	Two alternatives for grade-separated crossing access are an access tunnel immediately below the tollbooth and an overhead walkway. In addition to stairway access to these facilities, for new construction ADA regulations may require the inclusion of elevator access subject to official job descriptions and minimum requirements to perform the work If using a pedestrian gate or moveable barrier, it should not extend into the adjacent toll lane when "open".

4.6 CROSS SLOPES

The cross slope is the percent of elevation change along the cross section of highway pavement. Cross slopes are necessary to provide adequate drainage in the vicinity of toll plazas. However, excessive rollover must be avoided. Rollover is the change in slope between two adjacent road pavements. This could occur between two adjacent travel lanes, or the travelway and shoulder.

4.6.1 State-of-the-Practice

The project survey results of cross slopes for express lanes had a range of 1.5%-3.0%, with 2% the most common.

Adequate cross slopes need to be constructed to facilitate proper pavement drainage. Providing adequate drainage is critical in the vicinity of the toll plaza, particularly during periods of low temperatures that promote the formation of ice. Express lanes should adhere to the guidelines used for the mainline highway segment.

The AASHTO *Roadside Design Guide* 2002 states that grades (profile or cross slopes) should be avoided near crash cushions, as these grades can adversely affect the errant vehicle impact angle and possibly the collapse mechanism of the impact attenuator under load. Mainline plazas constructed on roadway curve sections present special challenges in meeting this criteria because of provisions for superelevation.

4.6.2 Recommended Guidelines

<u>Cross Slope Design Issues and Guideline Development</u>

Some of the significant issues to consider when designing a toll island and recommendations for resolving these issues include the following:

- slopes that promote storm water runoff from roadway and canopy,
- location of inlets, grates, catch basins and other drainage facilities to handle runoff,
- consideration of superelevation for conventional plazas constructed on roadway curves,
- use of cross slopes and profile grades in lieu of inlets within the toll lanes to prevent ponding and assure heavy drainage flows have no affect on safety and throughput, particularly as a result of a clogged drain,
- use of minimal cross slope in lanes where treadles are installed to avoid any degradation in performance,
- rollover of adjacent lanes with differing cross slopes.

Cross Slope Design Guidelines

Guideline	Cross Slope Design Guideline 1
Title	Cross Slope Ranges
Text	Design of cross slopes should follow the methods and guidelines provided by the AASHTO "Green Book" and or the respective state DOT design manuals. Drainage design needs to address runoff from the canopy. Cross slopes will typically range from 1%-2% on tangent roadway sections and higher on curves.
Commentary	The drainage design must combine cross slopes with longitudinal grade to avoid any water ponding within the toll plaza. Canopy runoff should be directly piped into the drainage system.

Guideline	Cross Slope Design Guideline 2
Title	Rollover Ranges
Text	Design of rollover of adjacent lanes should follow the methods and guidelines provided by the AASHTO "Green Book" and or the respective state DOT design manual. Rollover should be limited to a combine grade differential of 4%.
Commentary	None

4.7 VERTICAL PROFILE GRADES

The vertical profile grade is the percent of elevation change along the centerline of the roadway. Vertical grades are necessary to assure drainage of storm water within the plaza to inlets and or outfall locations. Profile grades affectively reduce construction costs by more closely following the natural grade within the established right of way, balancing the quantity of excavation and embankment material and reducing the foundation and earthwork cost of bridges.

4.7.1 State-of-the-Practice

The survey did not request information on vertical profile grades.

4.7.2 Recommended Guidelines

Vertical Profile Grade Design Issue and Guideline Development

Construction of a toll plaza at the crest of a profile grade results in sight distance advantages and plaza operations benefit from gravitational forces in slowing vehicles approaching the toll lanes and accelerating vehicles departing the plaza. Consequently, some studies have recommended the use of a $\pm$ 3% grade for the plaza approach and departure area. Unfortunately, when the plaza's mixed flow traffic includes commercial vehicles, a 3% grade will adversely affect the performance of these vehicles, resulting in additional delays through the plaza. A vertical profile grade greater than or equal to $\pm$ 1% and less than or equal to $\pm$ 2% better accommodates the performance of commercial vehicles under the stop and go conditions normally encountered in plaza queue zones. For the toll lanes, the cross slope and the vertical profile grade should be designed concurrently to assure proper drainage. Under no circumstances should the vertical profile grade be less than $\pm$ 0.5% or exceed $\pm$ 2% in a toll lane. This avoids the undesirable need to install trench or slot drains across the toll lane entrance that may clog, causing the possible unsafe condition (to both attendant and user) of ice formation within the lane. The canopy and storm drainage system design must direct collected water away from the toll lanes.

Vertical Profile Grade Guidelines

Guideline	**Vertical Profile Grade Guideline 1**
Title	Plaza Approach and Departure Profile Grades
Text	In cases of mixed flow traffic, the vertical profile grade approaching and departing the toll plaza should be greater than or equal to ± 1% and less than or equal to ±2%.
Commentary	The upper limit on vertical profile grades may be increased to ±3 when the percentage of commercial vehicles is low and the toll plaza is located at the crest of the profile grade.

Guideline	Vertical Profile Grade Guideline 2
Title	Toll Lane Profile Grades
Text	The vertical profile grade in a toll lane should be equal to or greater than ± 0.5% and less than or equal to ±2%.
Commentary	The cross slope and profile grade should be designed in conjunction to avoid storm drainage flows across the entrance to the toll lane. The canopy and storm drainage system design should direct collected water away from the toll lanes and help reduce precipitation within the toll lane.

4.8 LIGHTING

Safety hazards prevalent to a toll plaza are compounded at night and need to be mitigated by properly designed lighting both at the plaza approach and departure, as well as the conventional plaza toll lanes. For toll plazas with express lanes, roadway divergence into a conventional toll plaza requires lighting equivalent to partial interchange lighting standards deployed at interchanges. The lighting design for the approach transition and queue zones must provide the level of luminance needed to identify open toll lanes and select the appropriate lane to transact a toll. Lighting design for manual and automatic lanes must be sufficient to see toll island signing, displays, traffic control equipment, and toll collection/ ticket issuing equipment. Lighting design for the departure recovery and transition zones must provide a smooth transition for the user departing the plaza, who must simultaneously accelerate and merge with other vehicles exiting the plaza before joining any express lane traffic on the continuing roadway lanes. Tower, high-mast, and standard pole and mast arm roadway lighting are used for the approach and departure zones as well as at the divergence of the express lanes and conventional plaza lanes. Design of the toll lane lighting must strive to eliminate glare and provide uniform lighting through the toll lane. This can be achieved using island mounted luminaries directing light upward to reflect off the underside of the canopy or overhead mounted luminaries directing light downward.

4.8.1 State-of-the-Practice

As presented in the Table below, most toll roads and toll bridges use standard pole and mast arms with a single luminaire to light approach and departure zones. However, a good percentage use high mast supports with multiple luminaires. Tower lighting is the least commonly used application.

4.8.2 Survey Results

Q0017 Plaza approach and departure lighting is provided by:		
	No.	**%**
High mast - multiple luminaries	8	35%
Tower - single or dual luminaries	2	9%
Std. pole and mast arm - single luminaire	12	52%
Other	1	4%
Total	23	

As seen in the Table below, toll lane lighting is most commonly provided by canopy mounted luminaires. Column/pole mounted luminaires are next most popular, with booth mounted luminaires least common.

Q0018 Plaza lighting is provided by (check all that apply):		
	No.	**%**
Canopy mounted luminaire	17	57%
Booth mounted luminaire	3	10%
Column/pole mounted luminaire	10	33%
Total	30	

Table below shows the type of luminaire used to light the plaza approach and departure zones. High pressure sodium is the most popular.

Q0019 Luminare used to light the plaza is (check all that apply)?		
	No.	**%**
Halogen	0	0%
High pressure sodium	16	73%
Metal halide	3	14%
Mercury vapor	1	5%
Fluorescent lights	2	9%
Total	22	

4.8.3 Recommended Guidelines

<u>Lighting Design Issues</u>

According to the AASHTO "Green Book", where there are concentrations of pedestrians and roadside intersectional interferences, fixed-source lighting tends to reduce crashes. The "Green Book" does mention that toll plazas are usually lighted. Due to the amount of activity from traffic weaving, diverging, merging and stopping in the approach and departure zones, and the presence of fixed objects mounted in front of and to the toll island(s) adjacent to the toll lane, properly designed luminaires are critical to maintaining safety and operational efficiency through the plaza.

Some of the significant issues that should be addressed when designing toll plaza lighting include the following:

- design should strive to eliminate harsh glare on approaching and departing motorists,
- reduce lighting spillover into adjacent properties, especially residential areas,
- provide a smooth transition from toll lane lighting to departure zone lighting,
- maintain uniform lighting through a toll lane,
- minimize the quantity of plaza approach and departure lights standards and poles, that effectively pose a roadway hazard,
- conceal conduit to canopy mounted luminaries,
- protect approach and departure lighting poles and foundations in accordance with AASHTO guidelines and agency design guidelines and standards,
- Support security cameras installed either inside the tollbooth or mounted to the canopy to view both the transaction and the person making the transaction.

Lighting Design Guidelines

Guideline	**Lighting Design Guideline 1**
Title	Intensity and Uniform Coverage
Text	Intensity levels and uniformity ratios should be based on adaptations from the American National Standards Institute (ANSI) and Illuminating Engineering Society (IES).
Commentary	ITE recommends an average illuminance of 1.0-4.0 foot-candles for pedestrian facilities, which is deemed insufficient for supporting a CCTV security system and providing a high level of visibility to agency staff.

Guideline	**Lighting Design Guideline 2**
Title	Minimize Lighting Spillover
Text	Use proper shielding and aiming to minimize lighting spillover into adjacent properties, especially residential communities.
Commentary	Migration of light pollution should be in accordance with approved environmental document(s).

Guideline	**Lighting Design Guideline 3**
Title	Quantity of Plaza Approach and Departure Lights
Text	High mast and tower pole designs for mounting luminaries should be used to minimize the addition of roadway hazards that must be protected by barrier if inadequate clear zone is available or is impractical.
Commentary	Tower design, and to a lesser extent high mast design (based of an internal luminaries lowering mechanism) must address the issue of accessing the luminaries for maintenance.

Guideline	**Lighting Design Guideline 4**
Title	Toll Lane Lighting
Text	Lighting intensity and uniformity should be based on adaptations from the American National Standards Institute (ANSI) and Illuminating Engineering Society (IES).
Commentary	Toll lane lighting should provide a minimum of 20 foot-candles for at least 25 feet each side of the tollbooth or automatic machine (i.e., coin, payment or ticket issuing) centerline, subject to consideration of contributions from other site-specific light sources. This level of lighting is intended to enhance plaza security including camera video and improve visibility of agency staff crossing a toll lane.

CHAPTER 5

TOLL COLLECTION EQUIPMENT TECHNOLOGY

A toll collection and revenue management system requires a variety of equipment, typically involving hardware and software components, to handle both front end and back office tasks. Front end tasks include data collection, transaction and event processing and performance monitoring while back-office tasks include processing, storing, retrieving, reporting performance monitoring. Only the equipment that the customer interfaces with or uses in some fashion is addressed below. While not all equipment can be strictly categorized as a traffic control device, each item can affect traffic flow through a toll lane if the design and/or installation are deficient. A list of this equipment is the following:

- Automatic Coin Machine (ACM),
- Automatic Ticket Issuing Machine (ATIM),
- Island Traffic Signal,
- Patron Toll Display,
- Automatic Barrier Gate,
- Tollbooth,
- Violation Enforcement System (VES) Cameras and Lights.

5.1 ACM/ATIM TOLL EQUIPMENT DESIGN

The automatic coin machine (ACM) is used in barrier plaza toll lanes where users must pay the indicated toll by dropping coins or tokens into the basket or hopper attached to the front of the ACM cabinet before exiting the lane. The ACM then automatically separates and detects the denomination of the coins, and either displays the value of the deposited coins or tokens and/or displays a fare paid message when the correct amount has been deposited. The automatic ticket issuing machine (ATIM) is used exclusively in a closed ticket system to issue a ticket to the user at the entry points to the facility. The ticket commonly shows time, date, facility entry location and tolls assessed at the various exits ahead. At the exit plaza, the ticket is returned to the attendant for use in determining the toll due, which is based on vehicle classification and distance traveled. If the ticket is lost or damaged beyond recognition, subject to agency policy, the user is charged a toll based on entry at a plaza located furthest from the exit location.

5.1.1 State-of-the-Practice

U.S. agencies historically have procured automatic coin machines manufactured by a variety of vendors with varying performance capabilities and features. The following list provides the names of some of the better known vendors in the toll industry:

- Cubic Toll Systems,
- Toller and Cooper
- CS Route
- Mitsubishi
- TST
- Intrans Group/TDC
- Ascom Transport Systems (formerly Ascom Trindel Corp.)
- TransCore (TST)

The industry has since experienced some consolidation and the last three companies listed above currently capture the largest market share of new procurements. Although electronic toll collection (ETC) has eroded sales of ACMs, agencies continue to purchase coin machines, particularly for ramp plazas, to accommodate customers without ETC transponders and to minimize labor costs. All automatic coin machines include a reject receptacle to collect foreign coins, slugs and other invalid objects tossed into the basket. Depending on the agency's preference, the reject receptacle may be accessible to the customer to retrieve the invalid object. The ACM may also include an integral receipt printer and card reader to read either agency issued cards or credit cards for payment purposes. Although these devices reduce throughput, the card reader can result in less violations, albeit small.

The user is expected to drive-up next to this automated collection equipment without hitting the equipment with their vehicle. A more hazardous condition results when the vehicle stops too far from the equipment and the user either misses the basket with coins or tokens or is unable to reach the ticket, resulting in the user either fully or partially leaving their vehicle to deposit the toll or take a ticket. Given over 50% of lanes with an ACM or ATIM also include ETC equipment based on the survey results, a following ETC equipped vehicle intent on not stopping in the lane can cause a very unsafe situation for a person not safely buckled into their vehicle. Consequently, proper placement and visibility of the equipment is important to ensure the user gets into correct position to deposit coins or take a ticket.

5.1.2 Survey Results

Q0129 Which ACM/ATIM lanes have ETC?		
Choices	**Number of Responses**	**Percentage of all Responses**
All	6	55%
None	3	27%
Some	2	18%

Q0147 What is posted speed limit in the ACM/ATIM lanes?		
Choices	**Number of Responses**	**Percentage of all Responses**
35	1	16.7%
25		
10	1	16.7%
5		
0 (must stop)	3	50%
Not Posted	1	16.7%

Q0157 Please select the ACM/ATIM cabinet feature that best describes your installation:		
Choices	**Number of Responses**	**Percentage of all Responses**
ACM/ATIM with fare display	5	63%
ACM/ATIM without fare display	3	37%
Dual height ACM/ATIM with fare display	0	0%
Dual height ACM/ATIM without fare display	0	0%

5.1.3 Examples

Exhibit 5-1 Illinois Tollway ACM

Exhibit 5-2 Saint Johns Bridge, New Brunswick, Canada

5.1.4 Recommended Guidelines

Automatic Coin Machine Design Issues:

- To minimize damage to the ACM and the user's vehicle, the front lip of the ACM basket or hopper should not protrude into the travel lane;

- To maximize the percentage of coins or tokens tossed toward the basket and processed by the ACM, the circumference and height of the top of the basket should be specified to easily accommodate the majority of customers while adequately handling the remaining customers driving vehicles with height profiles significantly above or below the normal range;

- Visibility of the ACM must be prominent relative to other features on the toll island so the user can quickly identify the location of the ACM and begin maneuvering their vehicle as early as possible to be in good position to deposit coins or tokens into the basket;

- Provisions for a quick means of notifying customers when the correct toll has been deposited and counted as a valid deposit that is visible under all lighting conditions;

- If trucks are allowed to use the ACM lane, determination of whether a dual height ACM is warranted to make depositing coins or tokens by truck drivers essentially equivalent to a passenger car drivers. The increased height of the basket is expected to increase the percentage of coins or tokens tossed toward the basket by truck drivers that are processed by the ACM and reduce transaction time, thereby increasing vehicle throughput;
- Suitability of integrating a card reader into the ACM cabinet as an alternative means of payment.

Automatic Ticket Issuing Machine Design Issues:

- To minimize damage to the ATIM and the user's vehicle, the front edges of the ATIM should not protrude into the travel lane.

- To minimize the difficulty in reaching and taking a ticket, the height of the ticket dispensing feature of the ATIM must be specified to easily accommodate the majority of customers while adequately handling the remaining customers driving vehicles with height profiles significantly above or below the normal range.

- Visibility of the ATIM must be prominent relative to other features on the toll island so the user can quickly identify the location of the ATIM and begin maneuvering their vehicle as early as possible to be in good position to easily reach and take a ticket,

- If trucks are allowed to use the automatic lane, dual ATIMs, at the appropriate heights for passenger cars and truck, are warranted to assure both drivers can safely reach and take a ticket from the driver-side window. Dual ATIMS are expected to reduce the transaction time, thereby increasing vehicle throughput.

Automatic Coin Machine Guideline Development:

- The front lip of the ACM basket or hopper should be approximately coincident with the edge of the toll island and not protrude into the travel lane. While vehicles with extended mirrors pose the greatest damage risk, the natural inclination of passenger cars drivers to avoid getting to close to a raised island or curb will minimize basket and vehicle damage. Installation of the ACM based on this location will also assure the passage of a large maintenance vehicle does not result in damage to the ACM.

- The ACMs manufactured by current vendors locate the basket or hopper at approximately the same height from the bottom of the cabinet. The basket circumference tends to vary among the vendors and is limited by the cabinet dimensions and any supported features. A telephone survey of three well established ACM vendors resulted in the following findings: ASCOM/Trindel provides a basket height of 48 inches and a circumference of 47 inches, TransCore provides a basket height of 39 and a circumference of 46 inches, and InTrans provides a basket height of 39 inches and a circumference of 57 inches. Therefore, the recommended guideline should be based on the median top of basket height and the largest of the three circumferences.

- The ACM cabinet should be finished with a bright color (other than white to retain contrast with the attached basket material) that is distinctive of any other colors used in the toll lane. Because of the reflective property and visibility of white materials, the basket or hopper should be manufactured using white material. Although ACM cabinet lighting, some in the shape of arrows to highlight where the deposit needs to be made, has been used to provide greater visibility, the additional maintenance and energy costs relative to the effectiveness of ACM cabinet lights must be measured. This measurement is problematic and requires extensive field observation with and without the lighting.

- Consistent with the 71% of agencies responding to the survey who use ACMs with fare displays, the ACM cabinet should include an embedded display that shows, as a minimum, a fare paid message and preferably displays the remaining balance to be deposited so the user has immediate feedback when an invalid coin or token is deposited. This feedback is expected to reduce transaction times and throughput delays. The fare display should be installed directly above the coin basket so the user can simultaneously deposit coins or tokens while viewing the display for feedback on the deposit.

- Although convenient to truck drivers, dual height ACMs are not commonly used on U.S. toll road facilities. Reasons for the lack of dual height ACMs are the common exclusion of trucks from automatic lanes to avoid the additional costs incurred to implement a pre-classification system, automatic lanes are often too narrow for safe passage by trucks, the traffic volume of trucks does not warrant special equipment for convenience and a marginal increase in throughput performance, and an increase in capital and maintenance costs. Also, violation enforcement system cameras can be triggered for all vehicles and front license plate images can be subsequently purged when the lane controller confirms the toll paid corresponds to the vehicle post classification. For these reasons, dual height ACMs should not be implemented in automatic lanes unless daily truck volume through the lane exceeds 25%, a volume expected to put truck and passenger car generated revenue approximately on par.

- Since the likelihood of a user without a transponder not having adequate change increases when the toll exceeds one dollar, integrating a card reader into the ACM provides a viable means to pay the toll in an unattended lane. Alternative card types include credit cards, agency charge cards and smart cards. Agency charge cards and smart cards are preferable to a credit card because of bank fees (usually both a flat fee and a percentage of transaction fee), and the impracticality of obtaining a signature confirming the transaction. The primary types of card readers are swipe, insert, and proximity. The performance of a swipe card reader is susceptible to precipitation, requires the magnetic stripe to be properly positioned in the reader, may require multiple swipes for a successful read and requires the user to be positioned within arms length of the reader to swipe the card. An insert card reader requires the magnetic stripe to be properly positioned when inserted into the reader, may require multiple inserts for a successful read and requires the user to be positioned within arms length of the reader to insert the card. A proximity card reader requires the card to be properly positioned in front of the reader for a successful read and the user needs to be positioned reasonably close to the reader to properly present the card. A significant shortcoming when implementing a card reader at a toll facility that also provides electronic toll collection is the potential cannibalization of ETC transactions. An ETC discount or a surcharge on a card transaction can be used to minimize the loss of ETC transactions. Furthermore, based on the foregoing analysis, only a proximity card reader using an agency or smart card should be considered for integration into the ACM.

<u>Automatic Ticket Issuing Machine Guideline Development</u>:

- The front edge of the ATIM should be approximately coincident with the edge of the toll island and not protrude into the travel lane. However, since the ATIM is commonly mounted to the side of a tollbooth that may have one-foot side ledges, the potential for a small overhang into the lane is likely. While vehicles with extended mirrors pose the greatest damage risk, the natural inclination of passenger cars drivers to avoid getting to close to a raised island or curb is expected to minimize damage to the ATIM. A small overhang into the lane is not expected to result in a greater incident of damage due to the passage of large maintenance vehicles through the lane. Preferably, the front edge of the ATIM should be in the same vertical plane as the front face of the island curb or raised barrier.

- The current standard for eye height within a passenger car is 3.5 feet. For trucks, eye heights have been found to range from 71.5 inches to 112.5 with an average height of 90 inches.[1] Assuming a comfortable arm height at approximately 6 inches lower, the height of the ticket dispensing component of the ATIM for passenger cars should be 3 feet from the toll lane pavement. Similarly, the height of the ticket dispensing component of the ATIM for trucks should be 7.25 feet from the toll lane pavement. This clearly shows the impractically of using a single height ATIM for both passenger cars and trucks.

- The ATIM enclosure should be finished with a bright color that is distinctive of any other colors used in the automatic lane. Although lighted arrows and other lighted objects have been used to highlight where the user needs to direct their attention to obtain a ticket, the additional maintenance and energy costs relative to the effectiveness of these enhancements must be measured. This measurement is problematic and requires extensive field observation with and without the arrows or other lighted objects., Alternatively, a fixed, static sign stating “Take Ticket” installed above the ATIM provides an inexpensive and effective means of conveying what is expected of the user.

- Dual height ATIMs installed at the heights suggested above are required if passenger cars and trucks are allowed to use the automatic lane. The majority of automatic lanes at existing closed ticket system facilities are restricted to passenger cars to maintain high throughput rates in these lanes and avoid the additional capital and maintenance costs associated with two (four when high availability and capacity are required) ATIMs. Also, agencies that classify and encode vehicle class on the ticket upon entry would need to install an automated pre-classification system to accommodate trucks. Automatic lanes are often too narrow for safe passage by trucks. Clearly, the operational policy of the agency regarding the use of attendants to issue tickets upon entry ultimately determines if dual height ATIMs can be treated as optional. Limiting entry plaza staffing to maintenance personnel to assure the ATIMs are stocked and operating properly is a viable option. Based on this analysis, if the entry plaza is staffed with attendants, automatic lanes should be restricted to passenger cars using either a single ATIM or a adding a second (i.e., redundant) ATIM, both installed at the same height.

[1] R. D. Layton, Intersection Sight Distance, Discussion Paper No. 8. B, Transportation Research Institute, Oregon State University, Corvallis, Oregon, February 1997.

Toll Collection Equipment Technology Guidelines

Guideline	Toll Collection Equipment Technology Guideline 1
Title	ACM Horizontal Clearance
Text	The front lip of the ACM basket or hopper should be approximately coincident with the edge of the toll island and not protrude into the travel lane.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 2
Title	ACM Hopper/Basket Size & Location
Text	Circumference and height of the top of the basket should be specified to easily accommodate the majority of customers while adequately handling the remaining customers.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 3
Title	ACM Visibility
Text	The ACM cabinet should be finished with a bright color (other than white to retain contrast with the attached basket material) that is distinctive of any other colors used in the toll lane.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 4
Title	ACM Toll Display and User Feedback
Text	ACM cabinet should include an embedded display that shows, as a minimum, a fare paid message.
Commentary	Preferably the remaining balance to be deposited should be displayed so the user has immediate feedback when an invalid coin or token is deposited.

Guideline	Toll Collection Equipment Technology Guideline 5
Title	Provisions for Accommodating Trucks in an ACM Lane
Text	Dual height ACMs should not be implemented in automatic lanes unless daily truck volume through the lane exceeds 25% and this solution is determined to be more economical than a preclass or VES based solution.
Commentary	This recommendation factors in the continued growth in ETC penetration and expansion of payment machines using bill changers and credit card proximity readers capable of handling any toll amount, affectively limiting ACMs to unattended ramp plazas.

Guideline	Toll Collection Equipment Technology Guideline 6
Title	ATIM Horizontal Clearance
Text	The front edge of the ATIM should be in the same vertical plane as the front face of the island curb or raised barrier.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 7
Title	ATIM Mounting Height (excludes trucks)
Text	The ticket dispensing component of the ATIM should be installed a height of 3 feet above the travel lane surface.
Commentary	This height should be field verified to account for local variations in the vehicle mix.

Guideline	Toll Collection Equipment Technology Guideline 8
Title	ATIM Visibility
Text	The ATIM should be finished with a bright color that is distinctive of any other colors used in the automatic lane.
Commentary	A fixed, static sign stating "Take Ticket" installed above the ATIM should be used as an effective means of conveying what is expected of the user.

Guideline	Toll Collection Equipment Technology Guideline 9
Title	Provisions for Accommodating Trucks in an ATIM Lane
Text	If the entry plaza is staffed with attendants, automatic lanes should be limited to passenger cars with either a single ATIM or a redundant second ATIM, both installed at the same height.
Commentary	None.

5.2 ISLAND TRAFFIC SIGNAL DESIGN

The island traffic signal (ITS) is used to control the flow of traffic through each conventional toll plaza lane, including manual, automatic and dedicated lanes. The user is expected to react to the current state of the signal in the same manner as ramp metering, stopping at the toll collection point and exiting the lane when the signal state changes. Each ITS includes a minimum of two vertically aligned signal heads. Red and green signal heads are typically used in manual and automatic lanes and green and yellow in dedicated ETC lanes. In lanes that provide an electronic toll collection (ETC) capability, the familiar yellow signal head is sometimes added to the ITS to provide ETC user feedback on the status of their account, specifically an account balance that requires payment or replenishment. Another common feature of the ITS is the mounting of an alarm and flashing light to the top of the ITS assembly, both of which are activated when a violation occurs. For plaza lanes installed with violation enforcement equipment, this feature is either not installed or not used.

5.2.1 State-of-the-Practice

The ITS is invariably mounted to a pedestal located downstream of the toll collection point and installed with the intent of being equally visible to passenger car and truck users. The signal head has evolved from an incandescent lamp installed behind an 8 inch or 12 inch colored lens to an 8 inch or 12 inch LED signal head. The lens has commonly been stenciled with the words “Thank you” and “Stop” corresponding to the green and red signal heads, respectively. When used to display ETC account information, “Low Balance” or “Call CSC” has been stenciled to the lens of the yellow signal head. The stenciling requires additional maintenance man hours to install, while the perceived benefit to the user is questionable. Some agencies deploy signals with square heads or other unique shapes that are equally effective in controlling flow through the lane and conveying information to the user, but at a higher replacement cost, longer lead time for procuring spares and non-compliance with the MUTCD.

5.2.2 Survey Results

Q0138 What is the distance from the centerline of the ACM/ATIM to centerline of the island traffic signal?

Choices	Number of Responses	Percentage of all Responses
50	1	17%
33	1	17%
5	1	17%
30	1	17%
36	1	17%
8	1	17%

Q0204 What is the distance from the centerline of the tollbooth to centerline of the island traffic signal (in feet)?

Choices	Number of Responses	Percentage of all Responses
21.3	1	6%
0	2	12%
25	1	6%
15	1	6%
3	2	12%
6	1	6%
20	2	12%
10	1	6%
30	2	12%
12	1	6%
36	1	6%
7.67	1	6%
8	1	6%

Q0139 & Q0205 What is the height of the ITS from the island to the bottom of the signal?

Choices	Number of Responses	Percentage of all Responses
60”	7	19%
48”	7	19%
36”	5	14%
40”	3	8%
84”	3	8%
198”	2	5%
55”	2	5%
168”	1	3%
12”	1	3%
30”	1	3%
45”	1	3%
108”	1	3%
120”	1	3%
72”	1	3%
80”	1	3%

Q0141 & Q0207 If no, is any indicator used to display ETC account status?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	13[1]	48%
No	14	52%

1. Indicators used are: 1) LED Display; 2) Amber and blue globe lights; 3) Patron Toll Display (flip disk).

Q0143 & Q0209 Is the diameter of each signal head 8 inches?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	35	69%
No	16	31%

Q0144 & Q0210 If no, what are the dimensions of the island traffic signal?		
Choices	**Number of Responses**	**Percentage of all Responses**
12”	4	36%
3” X 5” Globes	2	18%
24” x 24”	2	18%
4”	2	18%
18” X 18”	1	9%

Q0145 Does the ITS include an operative audible alarm/light for indicating a toll violation?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	16	53%
No	14	47%

Q0146 If yes, how many decibels is the alarm?

Choices	Number of Responses	Percentage of all Responses
85	2	22%
35	2	22%
50	1	11%
94	1	11%
96	1	11%
100	1	11%
110	1	11%

5.2.3 Examples

Exhibit 5-3 Illinois Tollway ITS w/I-PASS Acct.
Status Lights and E-470 ITS w/Violation Alarm & Light (right)

Island Traffic Signal Design Issues

The diameter of signal head used to assemble the ITS must be selected to be consistent in scale and form with other toll lane equipment such as the patron fare display, and be clearly visible to approaching passenger car and truck traffic without excessive brightness, and provide the most economical solution relative to capital and maintenance costs.

The location of the ITS must be selected to assure visibility to approaching passenger car and truck traffic while preventing the displayed signal state intended for the paid exiting vehicle to also be viewed and interpreted as the correct state for a following vehicle approaching or at the toll collection point. The implementation of ETC capability in the lane increases the potential for confusion because the majority of time a leading ETC equipped vehicle will receive a quick green signal allowing an immediate exit from the lane but potentially leaving the green signal in full view for the following vehicle that is not ETC equipped.

The location of the ITS is constrained by the physical features of the toll island, such as the size and shape of tollbooth and columns supporting the canopy as well as the length of departure end of the toll island. Similarly, the location of other toll collection equipment, particularly a patron toll display and an automatic barrier gate, limit locations available for installing the ITS.

Adequate horizontal clearance from the vertical face of the toll island or raised barrier must be provided to avoid damage from passing vehicles.

Similar to the location of the ITS, the height of the ITS also needs to be designed to assure visibility to approaching passenger car and truck traffic.

Island Traffic Signal Guideline Development:

The two most common diameters used for traffic signal heads are 12 inches and 8 inches. Consistent with the survey results, the 8-inch diameter signal is predominantly used in existing agency toll lanes. This diameter uses less of the limited toll island space and is more consistent in scale and form with the patron fare display, thereby avoiding domination of the user's focus upon entering the toll lane. Of the two types of traffic signal heads that can be installed in a toll lane, LED or incandescent lamp, the LED signal clearly has a lower life cycle cost based on energy consumption and lamp replacement costs. Because the LED signal head provides significantly higher nighttime intensity relative to a lamp signal head it may be deemed undesirable. However, toll lane lighting can be designed to mitigate the high intensity affects of the LED signal heads.

The location of the ITS on the toll island is first dependent on the location of any canopy column and any automatic barrier gate. The next consideration is installing the ITS in a location where the window of time that the ITS is within full view of an exiting vehicle is balanced with the ability to display the intended signal state to the following vehicle before the vehicle reaches the toll collection point. Assuming an arming or presence loop is installed at the toll collection point, a practical solution is one that uses the falling signal from the trailing edge of the loop, effectively functioning as a trigger to the lane software to change the state of the ITS. Based on this analysis, the ITS should be installed approximately 15 feet beyond the downstream edge of the loop, assuming 15 feet represents the detection length of a typical vehicle and there are no physical constraints to this location. Visibility issues with the ITS can primarily be resolved by selecting the optimum height of the assembly for viewing by both passenger car and truck users. Although not preferred or recommended, some agencies combine the ITS and automatic barrier gate cabinet or install the ITS immediately behind the cabinet. Separate installations, with the ITS installed in front of the gate, avoids the potential temporary loss of both components resulting from a vehicle collision and ITS visibility loss from a raised gate arm.

With 6-18 inches representing a conservative range for horizontal clearance from the travelway used within the toll industry, a recommended clearance of 12 inches provides the same protection afforded the tollbooth for a location where the vehicle is expected to have maneuvered to the center of the lane in the course of exiting the plaza.

The height of the ITS should be uniform for all toll lanes to minimize pedestal spare parts or the need to custom cut pedestals. The survey results indicate a predominant height of approximately 4 to 5 feet. This height is expected to assure visibility to approaching passenger car and truck traffic under most conditions.

Recommended Guidelines

Guideline	**Island Traffic Signal Design Guideline 1**
Title	ITS Signal Size
Text	Subject to other unique toll plaza considerations, the ITS should consist of 8 inch diameter, LED traffic signal heads.
Commentary	None.

Guideline	**Island Traffic Signal Design Guideline 2**
Title	ITS Location
Text	The ITS should be installed approximately 15 feet beyond the downstream edge of the presence or arming loop.
Commentary	This location assumes 15 feet represents the detection length of a typical vehicle, the installation of a presence loop at the collection point, and there are no physical constraints to this location. Otherwise, alternative locations should be considered and field tested.

Guideline	**Island Traffic Signal Design Guideline 3**
Title	ITS Horizontal Clearance
Text	A horizontal clearance of 12 inches should be used from the face of the toll island or raised barrier to the nearest edge of the ITS signal head.
Commentary	None.

Guideline	**Island Traffic Signal Design Guideline 4**
Title	ITS Height
Text	Subject to the known or forecasted traffic mix, the height to the bottom of all ITS should be in the range of 4 to 5 feet.
Commentary	None.

5.3 PATRON TOLL DISPLAY DESIGN

The patron toll or fare display is traffic control equipment consisting of a changeable alphanumeric sign mounted to a stanchion that is used to show the assessed toll based on the classification of the vehicle. Vehicle classification is entered by the attendant based on counted axles for each vehicle and the associated toll is established by an agency board and displayed on a rate schedule sign normally located off the side of the conventional toll plaza. Other vehicle characteristics used to establish vehicle classification are weight, vertical profile (i.e., height) and horizontal profile (i.e., width and length), either separately or combined. A PTD in an automatic lane is commonly used to show the user the remaining toll balance that is decremented after each valid coin is deposited into the ACM. The PTD is also used to convey completion of the transaction by displaying a "fare paid" message, which should display simultaneously with the state of an island traffic signal (ITS) changing from red to green. The PTD can also be used to display ETC account status messages such as "Acct Low", "E-ZPass Go", and "Call CSC". The patron toll or fare display can pose a safety hazard if mounted to close to the travelway. Conversely, the PTD can have a beneficial affect on operational performance (e.g., improved plaza throughput) if accurate and timely information is displayed to the user during a transaction.

5.3.1 State-of-the-Practice

Of the various PTD display technologies used to convey messages to the user, the following are three of the most common:

- Fluorescent flip disk
- LED
- Fiber optic flip disk

Based on the survey results, the LED displays have displaced the mainstay fluorescent flip disk as the most popular PTD technology. Since energy efficiency offered by LED and fluorescent flip disk are expected to be comparable, clarity of display, vendor product offerings, and maintenance considerations are likely the primary factors favoring the LED display.

5.3.2 Survey Results

Q0158 Is a patron toll display installed on the ACM/ATIM island?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	4	50%
No	4	50%

Q0223 Is a patron toll display installed on the tollbooth island?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	18	75%
No	6	25%

Q0159 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the PTD (feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
0	1	33%
30	1	33%
5	1	33%

Q0224 If yes, what is the distance from the centerline of the tollbooth door to the centerline of the PTD (feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
4	3	18%
0	2	12%
12	2	12%
30	2	12%
8	2	12%
10	1	5.8%
13.1	1	5.8%
15	1	5.8%
40	1	5.8%
3	1	5.8%
6	1	5.8%

Q0160 & Q225 If yes to Q0158, what is the height of the PTD from the island or pavement to the bottom of the PTD?		
Choices	**Number of Responses**	**Percentage of all Responses**
48	4	20%
60	3	15%
55	2	10%
54	2	10%
88.6	1	5%
39.36	1	5%
72	1	5%
51	1	5%

Q0160 & Q225 If yes to Q0158, what is the height of the PTD from the island or pavement to the bottom of the PTD?		
Choices	**Number of Responses**	**Percentage of all Responses**
40	1	5%
39	1	5%
52	1	5%
50	1	5%
45	1	5%

Q0161 & Q0226 What are the dimensions of the PTD (height X width, in inches)?		
Choices	**Number of Responses**	**Percentage of all Responses**
12 x 12	2	10.5%
16 x 16	2	10.5%
6 x 6	2	10.5%
20.5 x 5.9	1	7.7%
3.9	1	7.7%
30 x 30	1	7.7%
4.5 x 14	1	7.7%
36	1	7.7%
2.25 x 10.5	1	7.7%
10	1	7.7%
8 x 24	1	7.7%
4 x 12	1	7.7%
8 x 12	1	7.7%
16 x 22	1	7.7%
24 x 14	1	7.7%
10 x 36	1	7.7%

Q0162 & Q0227 What technology is used for the PTD?		
Choices	**Number of Responses**	**Percentage of all Responses**
Fluorescent flip disk	9	37.5%
LED	13	54%
Fiber optic flip disk	0	0%
Other	2	8.5%

5.3.3 Examples

Exhibit 5-4 Florida Turnpike and Chicago Skyway Patron Toll Display and Tollbooth

5.3.4 Recommended Guidelines

<u>Patron Toll Display Design Issues</u>

- For manual lanes, the patron toll display can be attached to the side of the tollbooth if adequate horizontal clearance is available to prevent overhang into the travel lane. Alternatively, the PTD can be mounted to the top of a pedestal that is installed on the toll island very close to the tollbooth while maintaining adequate horizontal clearance with the front face of the toll island or raised barrier and not blocking attendant access ways.

- For ACM lanes, the PTD or patron fare display (PFD) is commonly an integral part of the ACM cabinet that is installed above the basket or hopper. However, some agencies use a standalone PFD or PTD, either in addition to or in lieu of one built into the ACM. The presence of an ETC capability in the lane supports the need for a display providing a better viewing angle for ETC users who normally bypass the ACM while traveling through the lane, subject to the status of the traffic devices controlling flow. The standalone PFD must be installed in a location that is easily seen after entering the

ETC read zone so that the user is prepared to stop at the ACM if a message such as "deposit $ X.XX" is displayed instead of "Fare Paid". For ATIM lanes, since an alpha-only sign is needed, a blankout sign capable of one or two alpha-only messages, such as "Take Ticket" and "Out of Service" (in the case of two equal height ATIMS), is better suited to meeting the particular needs of this lane type.

- For dedicated lanes, the ITS alone can provide ETC account status using green and yellow, or some other easily recognizable lens color for the signal heads. Therefore, since a valid ETC transaction or a violation are the only transactions possible, neither of which require any user involvement when traveling through the lane, a PTD in these lanes is not warranted. This reduces the agency's capital and system maintenance costs and equipment clutter that can confuse users.

- The height of the PTD must be selected to assure the sign can be seen by all vehicle traffic using a particular toll plaza lane type.

<u>Patron Toll Display Guideline Development:</u>

- The dimensions of the PTD must be consistent with the messages intended to be displayed and result in a size that is: 1) consistent in scale and form of other toll lane equipment such as the ITS; 2) be installed at an angle that is clearly visible to approaching passenger car and truck traffic; 3) provide a minimum 12 inch horizontal clearance setback from the toll island curb or face of raised barrier; and 4) provide the most economical solution relative to capital and maintenance costs. Since the PTD in manual lanes is commonly mounted to the side of the tollbooth, installing the PTD at an angle is usually not done (see Exhibit 5-4). The size of the characters used in the message tend vary within a small range of 3 inches high, which has proven to be a legible size from the distances the display is expected to be read by the user.

- In manual/attended lanes, the location of the PTD must be selected as close to the tollbooth as the size and any toll island access-ways permit to assure visibility to toll-paying passenger car and truck traffic. The location of the PTD is constrained by the physical features of the toll island, such as the size of tollbooth and columns supporting the canopy as well as the distance to the ITS, which should always be located downstream of the PTD. In automatic lanes, the PTD should be located just downstream and within three (3) to eight (8) feet of the ACM, without blocking an existing or planned accessway.

- In manual collection lanes, the height of the PTD needs to be selected so that it can be seen by all vehicles classes. The optimum viewing height should be set for the predominant vehicle class, which is a two-axle passenger car. However, consideration must be given to the extent to which passenger cars are the primary users of the ETC dedicated and express lanes (if any) and thereby less likely to use a manual collection lane. As a result, the PTD height should be optimized for view by drivers of SUVs and light trucks, resulting in more equal, albeit opposite, viewing angles for both truck and passenger car drivers. Given ETC dedicated and express lanes are expected to expand over time, the higher viewing height of the PTD is warranted even if the initial truck volumes are low.

The ability of an ETC accountholder who fails to obtain a valid ETC transaction in a manual lane to quickly maneuver their vehicle to the booth to pay the attendant is dependent on the width of the toll lane, the vehicles lateral/transverse position in the lane and the driver's longitudinal location when the PTD's stop pay toll message is noticed. Since the ETC antenna is commonly installed just before the tollbooth door to minimize the software complications of handling RF signal reflections, the driver must be watching the PTD to react quickly enough to be in position to pay a toll. The ETC accountholder may put their vehicle in reverse to get into a position to pay the attendant. This creates a very unsafe situation. The two recommended solutions, in the order listed, for handling this problem are to 1) move the antenna location upstream if the software can support this location; 2) add VES equipment (i.e., front and rear cameras if necessary) to the lane to capture the vehicle's license plate and modify the software to provide a green light if a transponder Agency Code is read, regardless of account status. The PTD would only display a toll due message.

Patron Toll Display Guidelines

Guideline	Patron Toll Display Design Guideline 1
Title	PTD Horizontal Clearance
Text	Provide a minimum 12 inch horizontal clearance setback from the toll island curb or face of raised barrier.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 2
Title	Character Size for PTD Messages
Text	The height of characters comprising a message should be a nominal size of 3 inches.
Commentary	Character height is expected to vary based on the size of the message to be displayed or the viewing distance.

Guideline	Patron Toll Display Design Guideline 3
Title	PTD Location in Automatic Lanes
Text	In automatic lanes, the PTD should be located just downstream and within three (3) to eight (8) feet of the ACM, without blocking an existing or planned accessway.
Commentary	For ACMs without a built PFD, the PTD should be located so the user can easily view the display while depositing coins or tokens in the coin machine.

Guideline	Patron Toll Display Design Guideline 4
Title	PTD Location in Manual/attended Lanes
Text	In manual/attended lanes, the PTD should either be mounted to the side of the tollbooth just downstream of the door or attached to a stanchion installed within three (3) feet of the downstream edge of the tollbooth and angled to achieve maximum visibility.
Commentary	None.

Guideline	Patron Toll Display Design Guideline 5
Title	PTD Height in Manual/attended Lanes
Text	The PTD height should be optimized for view by drivers of SUVs and light trucks.
Commentary	This assumes eventually the majority of passenger cars will use ETC (dedicated and express) lanes and truck usage will exceed passenger care usage in these lanes.

Guideline	Toll Collection Equipment Technology Guideline 6
Title	PTD Height in ACM/ATIM Lanes
Text	The PTD height should be optimized for view by drivers of passenger cars, not exceeding a height of 4 feet.
Commentary	None.

5.4 AUTOMATIC BARRIER GATE DESIGN

An automatic barrier gate is traffic control equipment that is primarily used for violation enforcement by blocking traffic from exiting the lane until the toll due is paid. In manual and automatic lanes equipped for ETC, gates are also used to reduce the speed of ETC traffic for the safety of attendants who must walk across plaza lanes. The gate is comprised of a cabinet containing a gate motor, controller interface, gate arm support assembly and gate arm. Upon a fare being paid, the lane subsystem transmits a signal to the gate controller that energizes the motor to automatically raise the gate arm from a horizontal position to a vertical position, thereby releasing the paid vehicle. The gate arm is returned to a horizontal positions after the exiting vehicle is no longer detected by one or more detection devices installed adjacent to the barrier gate and connected to either the gate controller or lane controller.

5.4.1 State-of-the-Practice

Agencies historically have used automatic barrier gates from several suppliers offering machines with differing gate arm speeds and reliabilities and used in both toll plaza and parking applications. Magnetek, a German manufacturer, has gained a majority share of the toll industry's barrier gate market primarily because of superior performance in gate speed and reliability. Their high reliability is the result of minimizing the number of moveable parts comprising the gate assembly. Vehicle detection equipment is invariably used in conjunction with the automatic barrier gate to prevent the gate arm from lowering when a vehicle is present.

5.4.2 Survey Results

Q0094 Are barrier gates installed in the dedicated ETC lanes?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	7	32%
No	15	68%

Q0163 Is a barrier gate installed on the toll island (ACM/ATIM)?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	4	50%
No	4	50%

Q0228 Is a barrier gate installed on the toll island (Manual)?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	13	52%
No	12	48%

Q0095 If yes, what is the distance from the centerline of the ETC antenna to the centerline of the gate (in feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
15	2	32%
13.12	1	17%
43	1	17%
7	1	17%
30	1	17%

Q0164 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the gate (in feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
10	2	50%
13	1	25%
12	1	25%

Q0229 If yes, what is the distance from the centerline of the tollbooth door to the centerline of the gate (in feet)?		
Choices	**Number of Responses**	**Percentage of all Responses**
6.5	1	9%
9.84	1	9%
35	1	9%
20	1	9%
13	1	9%
10	1	9%
43	1	9%
15	1	9%
28	1	9%
12	1	9%
14	1	9%

Q0165 Is gate closure protected by loop detection?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	18	75%
No	6	25%

Q0166 Is gate closure protected by photoelectic beam detection?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	13	59%
No	9	41%

Q0167 If no (to Q0166) is gate closure protected by another means?		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	3[1]	20%[1]
No	12	80%

5.4.3 Examples

Exhibit 5-5 Indiana Toll Road Automatic Barrier Gate W/Gate Arm Impact Sensor

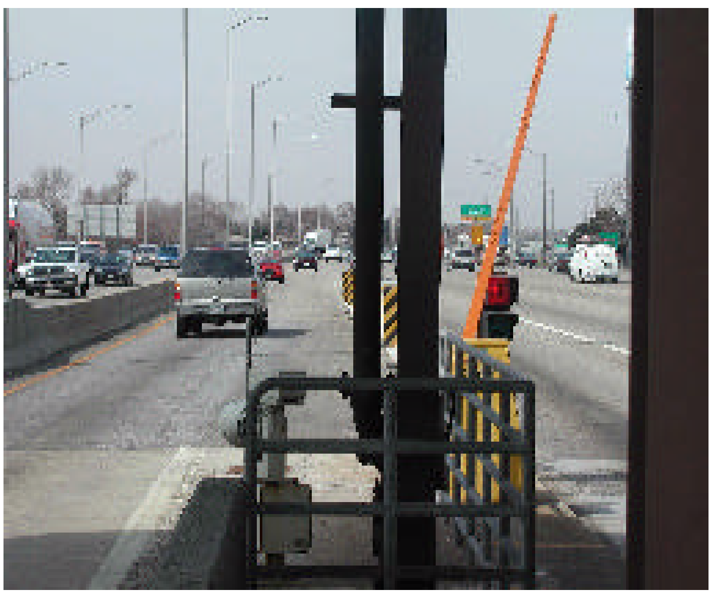


Exhibit 5-6 Illinois Tollway Automatic Barrier Gate

5.4.4 Recommended Guidelines

Automatic Barrier Gate Design Issues

- While the automatic barrier gate has historically been effective in discouraging violations, particularly in manual lanes, gates installed in automatic lanes can be problematic during ACM malfunctions and when the user fails to pay the toll. Each of these conditions requires quick identification of the problem and raising the gate remotely or on-site by a lane walker to release the user waiting to exit the lane. Remote rising of the gate is usually done from the nearest attended tollbooth or the toll plaza administration building. This results in vehicle processing delays and often causes longer plaza lane queues that increase the incident of unsafe lane changing. This problem is compounded if vehicle identification information is manually collected prior to releasing the vehicle.

- Although the automatic barrier gate technology has improved over the years, such as the reduction of moving parts, equipment malfunction periodically occurs. This condition first requires identification of the problem by either an attendant in the lanes, an on-site maintenance technician or the plaza supervisor stationed in the operations room of the toll plaza administration building. After manually locking the gate arm in an open position and clearing the lane, the agency can either close the lane or continue to operate with an open gate until operation of the gate is restored. As a minimum, this process causes processing delays resulting in longer plaza lane queues that increase the incident of unsafe lane changing. If the maintenance staff response to this malfunction is slow, the impact on plaza throughput and safe operations can be significant.

- In automatic lanes, the failure of the gate arm to rise to release a waiting vehicle because of a malfunction of the ACM or gate or a failure to pay the toll, may result in a broken gate arm when an impatient user is unwilling to continue waiting for an extended time period and breaks-off the gate arm. Depending on the extent of damage to the gate and the availability of spare gate arms, the time required to restore the lane could be significant. Temporarily closing the lane in lieu of operating without the benefit of a gate during high traffic periods will likely result in increased lane changes and longer queues resulting from a reduction in plaza throughput.

- The automatic barrier gate cabinet must be installed either a safe distance from the toll lane travelway and/or behind the front face of a toll island or raised barrier to avoid damage from passing vehicles. The length of the gate arm when in a horizontal (i.e., closed) position must be visible to all vehicles allowed to use the lane where it is installed.

- Since the majority of vendor furnished standard gate arms lengths are eight (8) and ten (10) feet, the selected arm length and setback from the travelway may leave a gap sufficient for passage of a motorcycle when the arm is in the closed position.

Automatic Barrier Gate Guideline Development:

- Toll plazas configured with dedicated and/or express lanes are very likely to include violation enforcement equipment, such as cameras and image processors that capture license plate images of violating vehicles. Consequently, VES equipment can easily be installed in automatic lanes, particularly if these lanes also include ETC equipment, to capture the plates of users who fail to pay the toll due. Although violations in the manual lanes of plazas that offer multiple collection mode lanes are usually minimal, VES equipment can also be deployed to capture the license plate of violators in these lanes. The remaining benefit derived from barrier gates, specifically, reducing speed in lanes attendants must cross to safely get to their assigned tollbooth, is dependent on whether these lanes actually have a vehicle speed problem.

- Based on the above issues related to the installation of automatic barrier gates as well as the annual costs to maintain and repair the gates, automatic barrier gates should only be considered for installation in plazas that include ETC equipment when the attendant must cross more than one lane to safely reach their tollbooth. In plazas that do not include an ETC capability, gates are recommended for use in automatic lanes when there is an adjacent manual lane in addition to the plaza supervisor's workstation functionality, to remotely open the gate. For toll island installation, the gate cabinet should be setback 12 inches from the face of the toll island or raised barrier.

- Under all circumstances, a ten (10) foot gate arm should be used to minimize the end gap within the toll lane without materially slowing the gate arm speed and to increase visibility of the arm to approaching vehicles. To further increase visibility, the gate arm finish should be striped using two distinct, contrasting colors. A breakaway gate arm assembly should be specified to minimize repair time when a vehicle collides with a gate arm.

Automatic Lane Barrier Gate Guidelines

Guideline	Automatic Lane Barrier Gate Guideline 1
Title	Provisions for Automatic Lane Barrier Gates in Toll Plaza Deploying VES Equipment
Text	VES equipment should be used in lieu of automatic barrier gates unless vehicle speeds through the automatic lane pose a safety hazard to attendants who must cross more than one lane.
Commentary	To avoid the revenue loss from opening the gate for customers who fail to fully pay the displayed toll, plus the operational costs incurred to assure the gate arm raises and to maintain the gates, VES equipment should be deployed instead of automatic barrier gates. The automatic barrier gate installed at the departure end of the toll island to control the flow of traffic through a lane should not be confused with a pedestrian gate installed on the toll island to prevent staff or visitors from walking into a toll lane. This particular gate is rarely automated.

Guideline	**Automatic Lane Barrier Gate Guideline 2**
Title	Provisions for Automatic Lane Barrier Gates in Toll Plazas with no VES Equipment Deployment
Text	Barrier gates should only be deployed in these lanes if both the supervisor's workstation functionality and an adjacent manual/attended lane toll terminal functionality are capable of remotely raising the gate in the automatic lane.
Commentary	None.

Guideline	**Automatic Lane Barrier Gate Guideline 3**
Title	Provisions for Manual/Attended Lane Barrier Gates in Toll Plaza Deploying VES Equipment
Text	VES equipment should be used in lieu of barrier gates unless vehicle speeds through the manual/attended lane pose a safety hazard to attendants who must cross the lane.
Commentary	None.

Guideline	**Automatic Lane Barrier Gate Guideline 4**
Title	Barrier Gate Horizontal Clearance
Text	For toll island installation, the gate cabinet should be setback 12 inches from the face of the toll island or raised barrier.
Commentary	None.

Guideline	**Automatic Lane Barrier Gate Guideline 5**
Title	Barrier Gate Arm
Text	A ten (10) foot gate arm attached to a breakaway assembly should be specified. The gate arm finish should be striped using two distinct, contrasting colors.
Commentary	The 10 foot gate arm minimizes the end gap within the toll lane and maintains good visibility to approaching traffic while compromising gate arm speed, albeit a small reduction.

5.5 TOLLBOOTH DESIGN

The tollbooth is used in manual collection lanes to protect the attendant and collection equipment from both weather conditions and users who maneuver their vehicles unreasonably close to the tollbooth to pay the toll and receive change and a receipt. The dimensions of tollbooths installed in conventional toll plazas vary considerably. In nearly all instances, the tollbooth is installed on an elevated toll island that extends beyond the outside width of the tollbooth, providing horizontal clearance on each side with the expectation of avoiding damage to the booth and vehicles. Safety and operational issues related to the user's interaction with the tollbooth is limited primarily to horizontal clearance and protection of the attendant from errant vehicles in maneuvering toward the tollbooth to pay the attendant. Manual lanes deploying ETC equipment pose the most significant safety concern resulting from the user not recognizing a failed ETC transaction until the vehicle is downstream of the tollbooth.

5.5.1 State-of-the-Practice

New facilities are commonly using prefabricated tollbooths constructed of stainless steel sheets and tubular structural steel framing that are shipped to the toll plaza for installation. The equipment installed inside the tollbooth may include a toll terminal for entering vehicle class, fare paid or an unusual condition, a receipt printer, a badge reader for accessing the system, a ticket validator and stacker for validating and storing tickets and various security devices. The tollbooth typically includes a dutch door or sliding window to keep the attendant within the booth while providing a large opening for reaching up and down to exchange money. Some tollbooth designs provide the equivalent of a small "porch" consisting of short walls extending from the side of the booth and intended to make vehicle contact with the booth much less likely. This assumes the height of the "porch" walls is below extended mirrors and other overhanging apparatus. Although the tollbooth cannot be strictly construed as traffic control equipment, the time to complete a transaction provides a metering affect on plaza traffic throughput. The tollbooth design needs to address both the safety of the collector and the user as they interact along the toll lane.

5.5.2 Examples

Exhibit 5-7 E-470 Public Highway Authority And Indiana Toll Road Tollbooth W/Dutch Door Design

5.5.2 Examples

Exhibit 5-8 Chicago Skyway Bridge Tollbooth and Planter

Exhibit 5-9 Halifax Dartmouth Bridge Commission Tollbooth/ ACM Combination

5.5.3 Recommended Guidelines

Tollbooth Design Issues

- The tollbooth horizontal clearance from the face of the toll island curb or a raised barrier must accommodate easy exchange of money between attendant and user for all vehicles types including motorcycles while also avoiding contact with any vehicle, vehicle cargo, or vehicle attachment as it maneuvers to come within arms reach of the attendant.

- The combined height of the toll island and tollbooth floor tends to improve servicing drivers of high cab trucks and worsen the ability to exchange money with low profile sports cars. For obvious safety reasons, the attendant should not stray from the booth to service any vehicle.

- Policy provisions for the attendant to enter the toll lane when safe to retrieve dropped money or other valuables that minimizes the time the attendant is outside the tollbooth.

- The appropriateness of using bollards in advance of the tollbooth that may partially block the vision of the attendant, degrade the aesthetics of the plaza and possibly discourage drivers from positioning their vehicle, particularly those with extended mirrors or other overhanging apparatus, close enough to the booth to complete a transaction.

- For manual collection lanes providing an ETC capability, the ability of a driver of an ETC equipped vehicle that fails to record a valid ETC transaction to be able to quickly maneuver their vehicle into position to pay the attendant before exiting the lane.

Tollbooth Guideline Development:

- The horizontal clearance from the face of the toll island curb or raised barrier to the side of the tollbooth from where the attendant collects tolls must allow the exchange of money and receipts with drivers of all vehicle types while also providing sufficient separation to avoid having the vehicle come into contact with the booth. Recently constructed toll facilities have commonly used a 12 inch horizontal clearance with good results. Clearances closer to 18 inches and 6 inches, considered practical upper and lower limits, respectively, may be equally effective. However, clearances closer to 18 inches makes exchanges for attendants of smaller stature more difficult for servicing trucks and those closer to 6 inches may unnecessarily increase the likelihood of damage to the tollbooth. Therefore, a nominal 12 inch is the recommended for horizontal clearance.

- The combined height of the toll island and tollbooth floor above the toll lane pavement surface primarily works to the detriment of the attendant in servicing low profile sports cars. The height of the tollbooth floor above the toll island surface should be mitigated by constructing a blockout in the concrete island to accommodate both a wireway for cables and any ducts plus the depth of the tollbooth floor. Consequently the height of the tollbooth floor above the toll island surface is limited to the thickness of a rubber mat or pad that is commonly used in tollbooths.

- On occasion the attendant needs to leave the tollbooth to retrieve dropped money or other valuables from the toll lane. Although agency policy may require the attendant to close the lane before leaving the booth and walking into the lane, in cases where strict adherence is not enforced or no related policy exists, the tollbooth design must provide quick and easy access to the toll lane for both safety and operational considerations. A tollbooth invariably provides two doors, typically in opposing walls, for the attendant to have an escape route if one of the doors becomes blocked. Clearly, access to the lane from the door that is opened to exchange money and receipts provides the quickest path to the lane. This is easily accommodated for a booth design incorporating just a sliding dutch door at the front of the booth. For a booth design that also incorporates a low height wall forming a “porch” that extends a very short distance from the side of the booth, the front of this wall must open and close. The recommended tollbooth design includes a front door that 1) allows the attendant to service all vehicle types while providing protection against straying into the lane; and 2) provides a means for the attendant to quickly enter the lane and then return to the booth, when traffic conditions permit.

- Vehicles with extended mirrors and other apparatus or objects protruding from the side of the vehicle can easily damage the tollbooth and possibly injure the attendant as the vehicle maneuvers to pull up close to the booth and then departs without pulling away until further down the lane. This problem has been addressed by some agencies by the installation of near booth height bollards in front of the tollbooth and with the same horizontal clearance as the tollbooth to the lane. Given the operational shortcomings of trying to control the path of the vehicle in the toll lane, bollards are likely the least obtrusive solution available. However, the issues with using bollards as identified above are not easily mitigated. A near booth height bollard installed in front of the tollbooth will partially block the vision of the attendant at some angle of view. Some agencies have installed lower height bollards that do not extend above the bottom sill of the to tollbooth window. While these bollards cannot protect the booth from extended mirrors and other objects protruding from the side of trucks, a limited amount of booth protection from errant vehicles is provided. To assure high visibility the bollards must be painted a distinctive color, which effectively highlights a feature that can only be viewed as an eyesore that negatively impacts plaza aesthetics. The distinctive colored bollard will also attract the attention of approaching vehicles that will be less inclined to maneuver to close to the booth to avoid coming into contact with the bollard. For the vehicles the bollards are primarily intended to protect against, the distance between the vehicle and the booth may make it difficult for the attendant to safely handle the transaction. Based on these shortcomings, the use of bollards to protect the tollbooth is not recommended. Use of the proper horizontal clearance should be used to protect the tollbooth from passing vehicles and ramparts and mass concrete formations, such as platters, should be used to protect the booth and attendant from errant vehicles. For existing installations with insufficient horizontal clearance, bollards may provide the best means for protecting the booth and attendant as well as toll equipment after consideration of all reasonable alternatives.

- The ability of an ETC accountholder who fails to obtain a valid ETC transaction in a manual lane to quickly maneuver their vehicle to the booth to pay the attendant is dependent on the width of the toll lane, the vehicles lateral/transverse position in the lane and the driver's longitudinal location when the PTD's stop pay toll message is noticed. Since the ETC antenna is commonly installed just before the tollbooth door to minimize the software complications of handling RF signal reflections, the driver must be watching the PTD to react quickly enough to be in position to pay a toll. The ETC accountholder may put their vehicle in reverse to get into a position to pay the attendant. This creates a very unsafe situation. The two recommended solutions, in the order listed, for handling this problem are to 1) move the antenna location upstream if the software can support this location; 2) add VES equipment (i.e., front and rear cameras if necessary) to the lane to capture the vehicle's license plate and modify the software to provide a green light if a transponder Agency Code is read, regardless of account status. The PTD would only display a toll due message.

Tollbooth DesignGuidelines

Guideline	**Toll Booth Design Guideline 1**
Title	Tollbooth Horizontal Clearance
Text	A nominal 12-inch horizontal clearance should be used from the face of the toll island curb or raised barrier to both sides of the tollbooth.
Commentary	None

Guideline	**Toll Booth Design Guideline 2**
Title	Height of Tollbooth Floor
Text	For new construction, the tollbooth floor should be 8 inches above the toll lane pavement surface.
Commentary	Tollbooth floor surface area block-out should be installed in the toll island to maintain an island and tollbooth floor height of 8 inches.

Guideline	Tollbooth Design Guideline 3
Title	Tollbooth Front Door Design
Text	For new construction, tollbooth design should include a front door that 1) allows the attendant to service all vehicle types while providing protection against slipping or falling into the toll lane; and 2) provides a means for the attendant to quickly enter the lane and then return to the booth, when traffic conditions permit.
Commentary	None

Guideline	Tollbooth Design Guideline 4
Title	Tollbooth Protection
Text	For new construction, the tollbooth should be protected by concrete ramparts and/or mass concrete formations, such crash blocks and planters.
Commentary	Bollards pose problems with plaza aesthetics, attendant visibility and customer's additional repellence from the tollbooth due to a perceived hazard, thereby making the exchange of money and receipts more difficult.

Guideline	Tollbooth Design Guideline 5
Title	Tollbooth Accessibility after Failed ETC Transaction
Text	To eliminate the incident of vehicles backing up in the lane to pay the attendant after a failed ETC transactions, the following alternatives should be evaluated: 1) move the antenna location further upstream if the plaza canopy and software can support this location; 2) add VES equipment (i.e., front and rear cameras if necessary) to capture a license plate images and modify the software to provide a green light if a transponder Agency Code is read.
Commentary	Failure to read an agency code may be the result of a failed battery or other transponder malfunction or the Agency code is unrecognizable to the ETC reader.

5.6 VES DESIGN

The implementation of ETC in toll plaza dedicated and express lanes gave rise to the need for a reliable and automated means of identifying violators and mailing legally enforceable citations levying a fine or a fee. This was achieved by deploying cameras and supplemental lighting in the toll lanes to capture the license plate and, in some instances, the rear view of the vehicle. The cameras and lights are mounted either overhead or along the side of the toll lane or roadway. Only cameras mounted on the side and adjacent to the toll lane pose a safety hazard if installed to close to travelway. Conversely, lights mounted either overhead or along the side of a toll lane or roadside can impair the vision of motorists, resulting in a single or multi-car accident. Early implementations relied almost exclusively on cameras and lights installed to capture only the rear license plate. This approach proved to be ineffective in identifying the owner of commercial vehicles, since the trailer being hauled may belong to a third party who should not be responsible for the driver's violation. Consequently, current VES deployments are including both rear and front license plate image capture equipment, including cameras and supplemental lighting.

5.6.1 State-of-the-Practice

Early violation enforcement system (VES) implementations relied on high resolution CCD cameras with moderately high shutter speed and supplemented by high intensity, continuously-on lighting, effectively equivalent to flood lighting. The technology has evolved to progressive scan cameras that capture a full instead of partial image frame and are capable of very high shutter speed to handle higher vehicle speeds.

The majority of vendors are now implementing pulsed or flashed, high intensity LED white lighting and infrared lighting, although some implementations measure ambient lighting and supplement with continuous lighting as needed to successfully perform optical character recognition on the captured image. Cameras can be mounted either overhead or along the side of the toll lane(s). Only when the camera is mounted on a toll island or top of a concrete barrier does it pose potential safety and operational concerns, particularly when visible to the user. If the camera is visible, regardless of location, the user may maneuver their vehicle in an unsafe manner in an attempt to avoid the capture of their license plate, subject to physical constraints preventing such action. Similarly, supplemental lighting can be mounted either overhead or along the side of the toll lane(s). However, for supplemental lighting both mounting locations pose potential safety and operational concerns.

5.6.2 Survey Results

Q0233 If no (to Q0228), are violation enforcement cameras installed to capture violators? (Roadway and bridge manual lanes)		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	10	48%
No	11	52%

Q0099 If no (to line 94), are violation enforcement cameras installed to capture violators? (Roadway and bridge dedicated lanes)		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	14	78%
No	4	22%

Q0056 Are violation enforcement cameras installed to capture violators? (Roadway and bridge Express Lanes)		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	10	83%
No	2	17%

Q0168 If no (to Q0163), are violation enforcement cameras installed to capture violators? (Roadway ACM/ATIM lanes)		
Choices	**Number of Responses**	**Percentage of all Responses**
Yes	3	60%
No	2	40%

Q0057 If yes, the cameras and associated lights are installed (check all that apply) (Express Lanes)		
Choices	**Number of Responses**	**Percentage of all Responses**
Overhead rear capture	9	60%
Overhead front capture	3	20%
Side fire/barrier front capture	1	7%
Side fire/barrier rear capture	0	0%
Side fire/island front capture	0	0%
Side fire/island rear capture	2	13%

Q0234 If yes, the cameras and associated light are installed (Manual, Dedicated and ACM/ATIM Lanes):		
Choices	**Number of Responses**	**Percentage of all Responses**
Overhead rear capture	6	21%
Overhead front capture	1	3%
Side fire/barrier front capture	2	7%
Side fire/barrier rear capture	4	14%
Side fire/island front capture	3	10%
Side fire/island rear capture	13	45%

Q0058 If yes, the light's effect on a driver's vision is mitigated by (check all that apply) (Express Lanes):

Choices	Number of Responses	Percentage of all Responses
Infrared light	4	40%
Diffusers	2	20%
Flash lighting	2	20%
Low wattage light	0	0%

1. Agency response to other methods are: (a) not mitigated, (b) angle and focus area of the light.

Q0235 If yes, the light's effect on a driver's vision is mitigated by (Manual, Dedicated and ACM/ATIM Lanes):

Choices	Number of Responses	Percentage of all Responses
Infrared light	7	26%
Diffusers	9	33%
Flash lighting	2	7.5%
Low wattage light	3	11%
Other	6[2]	22%

1. Agency response to other methods are:a) Auto iris; b) Angle, focus area of the light; c) Filters

5.6.3 Examples

Exhibit 5-9 Illinois Tollway VES Equipment

Exhibit 5-10 Biddle Toll Plaza Delaware DOT

5.6.4 Recommended Guidelines

VES Design Issues

- For VES cameras installed on a stanchion and mounted to the toll island or the top of a barrier, adequate horizontal clearance from the vertical face of the toll island curb or travelway, respectively, must be provided to avoid damage from passing vehicles.

- For supplemental lighting that is not an integral part of the camera assembly and is installed on a stanchion and mounted to the toll island or the top of a barrier, adequate horizontal clearance from the vertical face of the toll island curb or travelway, respectively, must be provided to avoid damage from passing vehicles.

- Mounting the camera on the toll island or to the top of a concrete barrier where visibility to passing motorists is high, the incidence of unsafe evasive moves by violators to avoid detection is expected to be higher.

- Supplemental lighting mounted at the approach and departure end of the toll island for rear and front license plate image capture, respectively, must not blind or impair the vision of the motorist when passing through a toll lane.

- Supplemental lighting mounted overhead at the approach and departure ends of the toll island below must not blind or impair the vision of the motorist when passing through the toll lane.

VES Guideline Development:

- To limit the number of camera lenses deployed and stored as spares to an absolute minimum, a toll island mounting location and associated image capture trigger distance that applies to all plaza lanes for both approach and departure cameras must be found. Since it is common for alternate toll islands to have canopy column supports and tunnel stairwells and for tollbooths to be protected by ramparts and concrete structures (e.g., crash blocks, planters), finding a common image capture trigger distance can be problematic. Once a common distance is found, a camera mounting angle within the vendor specified range of image capture angles must be selected that results in a high success rate of license plate optical character recognition. This angle effectively determines the camera mounting location on the toll island. Using the same guideline development logic that was used for the island traffic signal, a minimum horizontal clearance of 12 inches from the vertical face of the toll island curb should be maintained.

- When concrete barrier is installed along the lane, the camera can either be installed on a stanchion mounted behind the barrier or mounted to the top or the barrier if it is a minimum of 12 inches from the travelway. Increasing the horizontal clearance may be warranted to accommodate an agency's roadway maintenance operations and vehicles.

- Vendor solutions for assuring toll facility users are not blinded or have their vision impaired by supplemental lighting used to improve the quality of captured license plate images vary from triggered pulsed/flashed or strobe lighting, infrared lighting (continuous and triggered), continuous white lighting with filters and diffusers/baffles, and continuous concentrated white directional lighting. Pulsed or flashed lighting usually involves high intensity LEDs producing white lighting that is best suited to handling multiple colored license plate characters and backgrounds corresponding to different jurisdictions. The millisecond flashes for pulsed and strobe lighting that are only triggered when a violation is detected are intended to be unnoticeable by the user. Supplemental lighting is always installed either adjacent to a camera or combined with a camera into a single unit of equipment. For cameras mounted to a stanchion and installed on a toll island, the lighting is either mounted to the same stanchion or separately on another stanchion. All of the lighting alternatives listed above can be used for both front and rear license plate image capture when deployed on a toll island or barrier. For cameras mounted overhead, continuous white lighting, even with the use of filters and diffusers, is likely to cause visual impairment to the user when passing through a toll lane. Triggered lighting using a reliable and accurate trigger should assure the light is not energized when a vehicle's windshield and light rays from the installed supplemental lighting intersect. While the user is far less susceptible to vision impairment from rear license plate overhead lighting (i.e., continuous white lighting), empirically supported by a number of agencies that have deployed and are still using continuous white lighting for rear capture, front license plate lighting must dictate the type of lighting used system-wide. Using the same light source assures the following: 1) consistency in the quality of all images captured and processed by a violation processing system; 2) less spares and corresponding storage space; and 3) less time needed to repair or replace due to technician familiarity. If only rear license plate image capture is to be deployed, continuous lighting should only be considered if the VES supplier can demonstrate superior image quality and consistency using continuous white lighting. Otherwise the disadvantages of continuous lighting, namely user vision impairment when using the rear view mirror, and incurring significantly higher utility and lamp replacement costs, are expected to exceed the identified benefits. From a safety and operational perspective, it is recommended continuous white lighting of front license plates not be deployed when mounted overhead.

VES Design Guidelines

Guideline	VES Design Guideline 1
Title	VES Equipment Horizontal Clearance
Text	A minimum horizontal clearance of 12 inches from the vertical face of the toll island curb should be maintained for the VES camera and light. For barrier separated dedicated toll lanes, the VES camera and light should be mounted to a stanchion installed behind the barrier.
Commentary	The camera and light can also be mounted to the top of the barrier if a minimum horizontal clearance of 12 inches from the travelway is provided.

Guideline	VES Design Guideline 2
Title	VES Light Impairment Mitigation
Text	Continuous white lighting should not be deployed for front license plates when the camera and light are mounted overhead.
Commentary	Flashed/pulsed, strobe and infrared lighting solutions should be considered to avoid impairing the user's vision.

Guideline	VES Design Guideline 3
Title	VES Lighting
Text	Pulsed or flashed lighting involving high intensity LEDs producing white lighting should be deployed when multiple colored license plate characters and backgrounds corresponding to different jurisdictions must be captured.
Commentary	Other solutions, such as changing the beta factor for infrared lighting, can be used if field tests verify quality images and a high optical character recognition success rate can be achieved.

CHAPTER 6

SUMMARY OF RECOMMENDATIONS

6.1 INTRODUCTION

This chapter presents a summary of all the proposed Guidelines from the previous chapters. Each is listed in the following sections in the order presented in this report as follows:

6.2 Chapter 2 - PLAZA OPERATIONS AND TOLL LANE CONFIGURATION
6.3 Chapter 3 - SIGNING, MARKINGS AND CHANNELIZATION
6.4 Chapter 4 - GEOMETRIC AND SAFETY DESIGN
6.5 Chapter 5 - TOLL COLLECTION EQUIPMENT TECHNOLOGY

6.2 PLAZA OPERATIONS AND TOLL LANE CONFIGURATION

This section presents a summary of all the proposed Guidelines from Chapter 2. Each is listed in the following subsections in the order presented in the report as follows:

- Plaza Locations
- Electronic Toll Collection (ETC) Dedicated Lane
- Electronic Toll Collection (ETC) Express Lane
- Lane Assignments
- Toll Plaza Branch and Satellite Plazas
- Reversible Toll Lanes
- Administration Building Configuration and Access

6.2.1 Plaza Locations

Guideline	Plaza Locations Guideline 1
Title	Plaza and Interchange Intervals
Text	The 2001 AASHTO Policy on Geometric Design of Highways and Streets (the “Green Book”) recommends separation of 1 mile (urban sections) or 2 miles (rural sections) between interchanges. It is recommended this be used as a guideline for selection of new mainline toll plaza sites: no closer than 1 mile to the nearest interchange in urban sections, or 2 miles in other sections.
Commentary	It may not be possible to meet this design guideline at bridge and tunnel crossings, but the interval spacing minimums should remain a goal.

Guideline	**Plaza Locations Guideline 2**
Title	Site Selection and Sight Distance
Text	New toll plazas should be sited such that motorists will be able to see the plaza, while driving at posted speeds with adequate stopping distance before the queuing zone. Ideally the plaza site will be on a tangent pavement section.
Commentary	None.

Guideline	**Plaza Locations Guideline 3**
Title	Ramp Plaza Movements
Text	New toll plazas should not have merging or exiting movements within the plaza approach and departure zones. New plaza construction should not be located within trumpet interchange areas if at all possible.
Commentary	Some older toll plaza locations have merging and exiting movements within their plaza approach and departure zones. Other appropriate treatment options could be applied to improve their operations.

6.2.2 Electronic Toll Collection (ETC) Dedicated Lane

Guideline	ETC Dedicated Lane Guideline 1
Title	ETC Dedicated Lane Count
Text	In new construction, in locations where express lanes are not feasible, the number of dedicated lanes should equal or exceed the number of approach roadway lanes or the total roadway design volume / 1,500.
Commentary	This provision almost assures that a given toll plaza will no longer require future modifications or lane conversions to meet customer demand for non-stop lanes. In theory, it could be appropriate to not provide dedicated lanes for new toll plaza construction, and instead rely on mixed-use lanes until ETC participation increases to levels required to fully use dedicated lanes. In practice, all major new toll roads rely heavily on non-stop ETC to be publicly acceptable. This is because the provision of non-stop toll collection is typically a requirement to "sell" the project to the public.

Guideline	ETC Dedicated Lane Guideline 2
Title	ETC Dedicated Lane Orientation – Mainline Toll Plazas
Text	Where possible, all payment type lanes should be clustered. On mainline plazas, dedicated lanes should be clustered to the left as vehicles approach the plaza.
Commentary	Exceptions may be warranted when interchange ramps are in the approach or departure zones, or high volumes of commercial traffic are present. In these conditions, a supplemental dedicated lane towards the right of the plaza, to support traffic entering or exiting the system, or to isolate ETC commercial vehicles from the large volumes of commuter traffic in the left dedicated lanes, may be warranted.

Guideline	**ETC Dedicated Lane Guideline 3**
Title	ETC Dedicated Lane Orientation – Ramp Toll Plazas
Text	Assignment of ETC dedicated lanes is dependent on ramp geometry and proximate merges and splits. Consistent locations should be used to enable quick recognition and simplify the plaza approach for repeat drivers.
Commentary	The conversion of cash toll collection lanes into dedicated lanes at ramp plazas has been challenging, particularly for ticket system operators which have plazas located close to at least two merges and splits in trumpet interchanges. Dedicated lane selection must be made based on traffic characteristics of the individual toll operator. The New York Thruway, for example, often uses center lanes in these plazas for dedicated lanes, as this allows a single dedicated lane to serve traffic departing the plaza area to the left or the right without weaving.

Guideline	ETC Dedicated Lane Guideline 4
Title	Directional Separation of Traffic – Mainline Toll Plazas
Text	As mainline plazas are upgraded with ETC dedicated lanes, opposing directions of traffic should be separated by permanent barrier, or moveable barrier for reversible lanes, that is capable of absorbing the impact of a vehicle with limited movement and deflection, except where the separation between opposing directions equals or exceeds the AASHTO guidelines on highway clear zone.
Commentary	As ETC participation climbs above 50%, the need for reversible toll lanes lessens in most locations other than those with reversible mainline lanes. Permanent barrier is expected to assist the driver in navigating the plaza. Also, the task of moving cones to shift plaza centerlines is a dangerous field assignment, and with increasing driver speeds is becoming more dangerous. Notwithstanding the use of rigidly followed safety procedures when visibility is good, this practice should be discontinued as soon as it is feasible. For major bridge and tunnel crossings, where significant reversible lane or contra-flow traffic operations are used, the use of moveable concrete barrier could be considered if the expense is warranted. When available, a clear zone between opposing traffic directions provides an open area (i.e., no obstacles present) considered sufficient for a driver to regain control of the vehicle and avoid a collision.

Guideline	ETC Dedicated Lane Guideline 5
Title	ETC Dedicated Lane Widths
Text	Twelve feet (3.6m) is the recommended width for dedicated lanes that allow commercial vehicles (CV). For dedicated lanes that only allow passenger cars, 11 feet (3.4m) is the recommended minimum width.
Commentary	Retrofits of existing plazas may deviate from these guidelines, but the designer needs to consider expected operating speed and protection of adjacent obstacles.

Guideline	ETC Dedicated Lane Guideline 6
Title	ETC Dedicated Lane Island Widths
Text	In the absence of any other site conditions or safety requirements, dedicated lane islands should replicate the dimensions of other conventional plaza islands, in accordance with any agency or adopted design standards.
Commentary	For new or reconstructed facilities, island width should be dictated by the more controlling toll booth width plus lane clearance or lane clearance plus safe access to toll island equipment.

Guideline	ETC **Dedicated Lane Guideline 7**
Title	ETC Dedicated Lane Posted Speeds
Text	Given compliance with other dedicated lane guidelines, a maximum-posted speed of 25 - 30 mph (40 – 48 kph) is recommended. In locations with many curves, merges and diverges within several hundred feet (i.e., one hundred meters) of the plaza, lower maximum-posted speeds are recommended.
Commentary	Maximum-posted speeds lower than 25 mph may apply for ramp plazas located within trumpet interchanges.

Guideline	ETC Dedicated Lane Guideline 8
Title	ETC Dedicated Lane Speed Differential Mitigation
Text	Barrier or pavement markings are recommended to separate dedicated lanes from cash lanes for a length of approximately one half of the queue zone.
Commentary	

6.2.3 Electronic Toll Collection (ETC) Express Lanes

Guideline	**ETC Express Lane Guideline 1**
Title	ETC Express Lane Count
Text	New express lane plaza design and construction should include the number of express lanes equal to the number of approach roadway lanes, including provisions for widening if the approach roadway is configured for future widening.
Commentary	This provision assures that a given toll plaza will never require future modifications or lane conversions to meet customer demand for non-stop lanes. This design guideline is important for several reasons: 1) The appearance of a wide-open path "through the plaza" is a very effective marketing tool 2) Once constructed, future changes are not required to accommodate higher ETC demand at the toll facilities, assuming the mainline is not widened. This eliminates additional express lane design and construction along with the risk of reduced revenue resulting from delays caused by reconstruction. This guideline applies to full express lane plazas in new construction or re-construction.

Guideline	ETC Express Lane Guideline 2
Title	ETC Express Lane Orientation
Text	Express lanes should be oriented to the left, as a continuation of the mainline approach pavement.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline through the tolling zone or point, not requiring any change in driving pattern.

Guideline	**ETC Express Lane Guideline 3**
Title	ETC Express Lane Separation of Traffic
Text	Express lanes should be protected and separated from conventional plaza traffic according to the expressway design criteria applied on the approach and departure roadways.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline lanes, not requiring any change in driving pattern.

Guideline	**ETC Express Lane Guideline 4**
Title	ETC Express Lane Utilization Restrictions
Text	Express lanes should not restrict usage by particular vehicle types, such as “cars only,” or “trucks only,” beyond those restrictions in force on the approach and departure roadway or the roadway facility in general.
Commentary	Express Lanes should appear to the driver as a simple continuation of the toll facility, not requiring any change in driving pattern. An exception is a single lane express lane, which should prohibit truck usage because the operational performance of trucks tends to cause delays and safety concerns when mixed in the same lane with passenger cars

Guideline	**ETC Express Lane Guideline 5**
Title	ETC Express Lane Roadway Geometry
Text	Express lanes should be designed meeting the same geometric requirements for grades, cross-slopes, clearances and clear zones, stopping sight distance and horizontal and vertical curvature, as is applied to the proximate approach and departure roadways.
Commentary	Express Lanes should appear to the driver as a simple continuation of the toll facility, not requiring any change in driving pattern.

Guideline	**ETC Express Lane Guideline 6**
Title	ETC Express Lane Posted Speeds
Text	Express lane posted speed should not deviate from the posted speed on the interconnecting mainline.
Commentary	Express Lanes should appear to the driver as a simple continuation of the mainline, not requiring any change in driving pattern.

6.2.4 Lane Assignments

Guideline	**Lane Assignment Guideline 1**
Title	Lane Clustering
Text	All payment type lanes should be grouped together or clustered, particularly during peak traffic periods in the case of multi-mode capability. This enables advance plaza configuration signing to enable early decision-making on lane selection.
Commentary	This provision is intended to enable driver decision making to be done in stages, first to select the payment type, then selecting a particular lane offering the selected payment type based on queue length and its vehicle composition.

Guideline	**Lane Assignment Guideline 2**
Title	Permit or Over-Size Vehicles
Text	The far right lane should be sized to accept permit or oversized vehicles.
Commentary	This is consistent with common practice, and allows the slowest vehicles to stay to the right. Note that if ETC dedicated lanes are oriented to the right of the plaza, this requires permit-vehicles to pay with ETC. Provisions for oversized vehicles may not be possible at constrained plazas and the underlying facility (e.g., size, structural capacity and safety considerations), particularly for bridges and tunnels.

Guideline	**Lane Assignment Guideline 3**
Title	Attended Lanes
Text	Attended lanes are slower processing lanes because of truck transactions, receipt processing and informational assistance, and should be located to the right side of the conventional plaza.
Commentary	Ramp plaza lanes may need attended lanes on both the left and right sides to more safely accommodate traffic arriving from and or departing to multiple directions.

Guideline	**Lane Assignment Guideline 4**
Title	ACM/ATIM Lanes
Text	ACM/ATIM lanes are capable of processing vehicles at a higher rate than attended lanes and should be located to the left of the attended lanes.
Commentary	None.

Guideline	**Lane Assignment Guideline 5**
Title	ETC Dedicated Lanes or ETC Express Lanes
Text	ETC dedicated lanes should be grouped or clustered and located to the left of the conventional plaza. Consideration should be given to locating dedicated lanes in the center of a ramp plaza if the plaza approach or departure receives or feeds, respectively, multiple directions of travel. Express lanes, by definition, must abut, be physically separated from the conventional plaza, and consist of at least two lanes.
Commentary	The intent is to breed familiarity by users when traveling multiple facilities.

6.2.5 Toll Plaza Branch and Satellite Plazas

Guideline	**Toll Plaza Branch and Satellite Plazas Guideline 1**
Title	Use of Branch and Satellite Plazas
Text	New toll plaza design should not include branch lanes and satellite plazas. Existing plazas containing these lanes should develop a plan for removal of these lanes by transitioning to ETC dedicated lanes that eventually provide throughput capacity equivalent to the satellite plaza capacity.
Commentary	As ETC participation grows after implementation, the overall plaza capacity increases and eliminates the need for branch and satellite plaza lanes.

6.2.6 Reversible Toll Lanes

Guideline	Reversible Toll Lane Guideline 1
Title	Use of Reversible Toll Lanes on Standard Expressway Cross-Sections
Text	Reversible toll lanes should be avoided where possible and excluded from the design of new toll facilities.
Commentary	For existing barrier system plazas, it is recommended that the use of reversible lanes be discontinued as soon as possible for operations and safety reasons, as soon as ETC participation rates allow. At existing ticket-system plazas, it may be practically impossible to eliminate the use of reversible lanes, as overall operations are slow in these plazas, and additional capacity is often needed regardless of ETC participation.

6.2.7 Administration Building Configuration and Access

Guideline	Administration Building Configuration and Access Guideline 1
Title	Accessway
Text	Toll plaza administration building accessway should be located downstream from the toll collection point, on the side where the administration building is planned, which is normally the right side.
Commentary	An exception would be at ramp plazas or one-way roadways where the slower, cash toll lanes are located to the left. In these cases, the building accessway should be located on the left. Design should be prepared following AASHTO design guidelines applicable in the departure area, where speeds are still slow.

Guideline	Administration Building Configuration and Access Guideline 2
Title	Personnel Lane Access
Text	For all new plaza construction with ETC dedicated lanes or express lanes and one administration building, provide a tunnel or overhead walkway.
Commentary	Toll island access to the tunnel or overhead walkway should be spaced so that toll collectors should not have to cross more than one live toll lane (i.e., access on every third toll island).

6.3 SIGNING, MARKINGS AND CHANNELIZATION

This section presents a summary of all the proposed Guidelines from Chapter 3. Each is listed in the following subsections in the order presented in the report as follows:

- Advance Toll Plaza Signing
- Canopy Signing
- Toll Lane Signing
- Speed Control/Mitigation
- Lane-use Control Signals
- Changeable Message Signs
- Pavement Markings/Channelization/Impact Attenuators
- Delineation
- Flashing Beacons/Warning Lights

6.3.1 Advance Toll Plaza Signing

Guideline	**Advance Toll Plaza Signing Guideline 1**
Title	Sign Spacing and Location – Express lanes
Text	Provide advance signs at approximately 1 and ½ miles in advance of the divergence of mainline express lanes (or some subset of the mainline lanes) from the conventional plaza lanes similar to interchange guide sign spacing. Where the conventional plaza offers multiple payment types, an overhead sign should be installed approximately 800 feet from the canopy to provide guidance on the payment types available in the toll lanes ahead.
Commentary	It may not be possible to meet this guideline due to geometric constraints, but a minimum of two signs at 1 and ½ mile from the conventional plaza lane divergence should be provided. After further analysis, an advance sign at approximately 2 miles from the stated reference point is considered optional, contrary to Table 3.4. The location of these signs should be determined based on field conditions to maximize their contribution to plaza operational performance and safety.

Guideline	Advance Toll Plaza Signing Guideline 2
Title	Sign Spacing and Location – Express lanes
Text	Provide a bridge structure with a sign array at the divergence of conventional plaza from the express lanes that continue on the roadway mainline alignment to display allowed payment types, vehicle restrictions and lane-use guidance.
Commentary	None

Guideline	Advance Toll Plaza Signing Guideline 3
Title	Lettering and letter-spacing
Text	Standard letter heights and letter-spacing in the FHWA's MUTCD and *Standard Highway Signs* Book should be used in designing toll plaza sign messages at a minimum, with increased letter height desired to increase sign legibility in the vicinity of toll plazas.
Commentary	Complex driver maneuvers in the vicinity of toll plazas require increased sign legibility to enhance sign comprehension.

6.3.2 Canopy Signing

Guideline	Canopy Signing Design Guideline 1
Title	Canopy Signs
Text	Plazas offering lanes with multiple payment types and services should include canopy signing centered above each lane to indicate the payment type and service supported. Lanes supporting the same payment type(s) should be grouped together and use the same background color for the fixed, static sign panel. Lane use signals should be installed above each conventional plaza lane to display the operating status (i.e., open or closed) of each toll lane that is visible from the start of the queue zone, as a minimum.
Commentary	Information to be provided on canopy signing may include payment types accepted (i.e., ETC, exact change/tokens, or change & receipts), and vehicle restrictions (e.g., cars only, trucks only, cars and trucks). A CMS is required to provide the flexibility of changing the payment type(s) supported by the lane and the lane status, thereby eliminating the need for a separate lane use signal.

6.3.3 Toll Lane Signing

Guideline	Toll Lane Signing Guideline 1
Title	Stop Signs
Text	Stop signs should be deployed in cash toll lanes to require all users to stop to either pay a toll or take a ticket. A standard stop sign above a plaque containing supplemental information (e.g., pay toll, take ticket) or a modified stop sign stating "Stop Pay Toll" should be installed in the manual and ACM lanes and "Stop Take Ticket" should be installed in the ATIM lanes.
Commentary	A compliant ETC user in a multi-payment type lane is not expected to be inconvenienced by stopping in the cash lanes, even though the island traffic signal may display a green state when observed by the user.

Guideline	Toll Lane Signing Guideline 2
Title	Speed Limit Signs
Text	Speed limit signs should be installed at the approach end to the toll island for all ETC dedicated lanes.
Commentary	Although deployment of speed limit signs in conjunction with stop signs should be avoided, where speed display signs are deployed in particular cash lanes because of excessive toll lane entry speeds, a speed limit sign should be installed in conjunction with the speed display sign.

Guideline	Toll Lane Signing Guideline 3
Title	Miscellaneous Signs
Text	Deployment of miscellaneous signs should be based on an assessment of the particular problem the sign is intended to address or the value of the benefit derived by the user from the information the sign provides.
Commentary	None.

Guideline	Toll Lane Signing Guideline 4
Title	Sign Horizontal Clearance
Text	A horizontal clearance of 12 inches should be used from the face of the toll island or raised barrier to the nearest edge of the sign or display.
Commentary	None.

6.3.4 Speed Control/Mitigation

Guideline	Speed Control/Mitigation Guideline 1
Title	Approach Speed Reduction
Text	Speed bumps, turtles or other raised in-pavement materials should not be used to reduce vehicle speed before entering a conventional plaza toll lane.
Commentary	This recommendation is not intended to preclude or discourage the use of rumble strips (slotted or raised thermoplastic) used to warn drivers veering out of a travel lane.

Guideline	Speed Control/Mitigation Guideline 2
Title	Departure Speed Control
Text	Signs should be placed to require trucks using cash lanes located to the right of the conventional plaza to use the right lane/ stay to the right when departing the plaza.
Commentary	This strategy may not be feasible when the length of the approach zone and queue zone is inadequate for trucks to safely merge to the right. Furthermore, manual lanes may not be located to the far right of the plaza, which primarily applies to ramp toll plazas being fed traffic from two directions

6.3.5 Lane-use Control Signals

Guideline	Lane-use Control Signals Design Guideline 1
Title	Signal Design
Text	Recommend use of MUTCD standard green arrow and red "X" design for lane-use signals in lieu of traditional signal heads.
Commentary	Use of traditional signal head may cause confusion, as the green and red signal head indications generally mean "go" and "stop", not "open" and "closed". Color blindness of an expected small percentage of the users justifies the display from a safety perspective.

Guideline	Lane-use Control Signals Design Guideline 2
Title	Lane-Use Signal Specifications
Text	Lane-use signal faces shall provide a minimum nominal height of 450mm (18 in.) or 12" diameter, be visible from a minimum distance of 600', provide readily accessible power and communication interconnections, be comprised of long life, high intensity LEDs, and be installed with a minimum vertical clearance of 17'.
Commentary	These requirements are considered general and are not intended for procurement purposes.

6.3.6 Changeable Message Signs

Guideline	CMS Guideline 1
Title	CMS Technology
Text	CMS using a LED technology should be used for all new installations.
Commentary	When budget is a significant consideration and if visibility concerns can be adequately addressed for a particular installation, a CMS using a mechanical technology should be considered to satisfy a message variability requirement.

Guideline	CMS Guideline 2
Title	CMS Visibility
Text	The CMS should be visible for a distance at least equal to the depth of the queue zone plus an additional 40 - 50% approach factor. The minimum letter height should be 10.6 inches. Word messages for a conventional plaza canopy CMS should be created using all Upper Case letters.
Commentary	None.

Guideline	CMS Guideline 3
Title	CMS Brightness
Text	CMS using a light based technology should be capable of a minimum of three levels of brightness that are based on data inputs from a minimum of three photocells.
Commentary	Fog conditions may severely impact visibility regardless of the brightness level.

6.3.7 Pavement Markings/Channelization/Impact Attenuator

Guideline	Pavement Marking/Channelization/Impact Attenuator Guideline 1
Title	Toll Island/Attenuator Pavement Markings
Text	Gore or chevron pavement markings should be installed immediately in front of the impact attenuator, as applicable, or the toll island.
Commentary	While winter visibility and maintenance expenses are important considerations, the safety and operational benefits of reducing space for unsafe lane changes and maneuvering within the plaza and highlighting the areas of the plaza queue zone that do not lead to a toll lane justify the recommended pavement markings

Guideline	Pavement Marking/Channelization/Impact Attenuator Guideline 2
Title	Lane Separation using Pavement Marking
Text	Extension of physical separation of ETC dedicated lanes and cash lanes should be accomplished using double 8 inch wide pavement markings.
Commentary	Except for standard edge markings, use of pavement markings within the queue and recovery zones should be evaluated based on such factors as traffic patterns, weather conditions, delays caused by maintenance, and improvements to operational performance.

Guideline	Pavement Marking/Channelization/Impact Attenuator Guideline 3
Title	Dedicated Lane Channelization
Text	Dedicated lanes within a conventional plaza should use both barrier and pavement markings that extend upstream to approximately the point where approaching vehicle speed to the cash lanes drops below 30 mph during off peak hours.
Commentary	The 30 mph threshold is deemed to be a reasonable maximum speed through an ETC dedicated lane. Channelization is intended to prevent or discourage vehicles from attempting to enter a dedicated lane by unsafely crossing the cash lanes when the driver inadvertently failed to get into the proper lane when approaching the plaza.

Guideline	Pavement Marking/Channelization/Impact Attenuator Guideline 4
Title	Toll Island/Impact Attenuator
Text	Impact attenuators/crash cushions should be installed at the approach end of all mainline plaza toll islands whenever the approach speed of vehicles can exceed 25 mph.
Commentary	For agencies to assure approach speeds do not exceed 25 mph, continuous rigorous enforcement using both enforcement personnel and speed detection devices in conjunction with a license plate capture system to issue high fines should be deployed. Exhibit 3-8 shows the condition of a 1999 Volkswagen Passat after a front end collision with a stationary object when traveling at 35 miles per hour. The damage shown should not be considered indicative of the damage sustained by other types of vehicles, which may be considerably more severe and therefore supports use of a lower threshold speed for deploying an attenuator.

Guideline	Pavement Marking/Channelization/Impact Attenuator Guideline 5
Title	Toll Island/Impact Attenuator
Text	Impact Attenuator/crash cushions for cash lanes should be designed for selected percent above the posted approach zone speed limit, plus 5 mph. For existing plazas, this percentage should be determined from field studies. Each impact attenuator/crash cushion type has specific requirements relative to cross slopes, grades, curbs, etc. Consequently, profile grades and cross slopes for new construction should be designed per the specification of the impact attenuator/crash cushion.
Commentary	Pavement markings offering warning to approaching motorists should be considered for placement immediately in front of the impact attenuator/crash cushions, in the form of a gore taper with diagonal striping or tapered chevrons.

6.3.8 Delineation

Guideline	Delineation Guideline 1
Title	Plaza Delineation
Text	Flexible delineators for lane separation should not be installed within a conventional plaza unless a quantitative and qualitative benefit-cost analysis supports the use of these devices.
Commentary	High maintenance cost and a lack of true physical separation are expected to eventually lead to more durable and reliable alternatives for separating vehicles. For reversible lanes, the expected high maintenance costs of pop-up delineators may be less than the equipment, labor and materials costs and the possible delay cost imposed when relocating the barrier that are associated with moveable barrier, the primary physical separation alternative.

6.3.9 Flashing Beacons/Warning Lights

Guideline	Flashing Beacons/Warning Lights Design Guideline 1
Title	Supplement to Lane-use Signals
Text	Flashing beacons should not be installed together with lane-use signals, as it provides contradictory information to drivers.
Commentary	Use with lane-use signals presents contradiction to MUTCD.

Guideline	Flashing Beacons/Warning Lights Design Guideline 2
Title	Supplemental to Canopy Signs
Text	Flashing beacons may be used as warning devices with canopy lane status signs for ETC dedicated lanes only, with the intended purpose of indicating the location of the dedicated ETC lane(s) when approaching the conventional plaza lanes.
Commentary	Installation of the flashing beacon at the bottom of the lane status sign has been shown to be effective in highlighting the location of the ETC dedicated lanes when maneuvering within the queue zone to find the toll lane with the shortest vehicle queue.

Guideline	Flashing Beacons/Warning Lights Design Guideline 3
Title	Overall use of Flashing Beacons
Text	Flashing beacons may be used in overhead mounts to supplement canopy lane status signs for ETC dedicated lanes, or on impact attenuators, backup blocks or toll island crash blocks/ramparts at toll plazas.
Commentary	Use should be limited as much as possible to minimize distractions to drivers. Only the yellow color application should be considered. An automatic dimming device may be used to reduce the brilliance during night operation. The flashing beacons mounted on the island should be at an appropriate height above the ground for viewing.

6.4 GEOMETRIC AND SAFETY DESIGN

This section presents a summary of all the proposed Guidelines from Chapter 4. Each is listed in the following subsections in the order presented in the report as follows:

- Approach Zone
- Departure Zone
- Express Lane
- Lane and Shoulder Width
- Toll Island
- Cross Slope
- Vertical Profile Grade
- Lighting

6.4.1 Approach Zone

Guideline	Approach Zones Design Guideline 1
Title	Queue Zone Lengths
Text	The length of queuing zone should be based on estimated or actual peak hour queue lengths, determined by an analysis, plus an added safety factor, with a minimum of 200 feet. Design year traffic volumes should be used.
Commentary	For plaza reconstruction and expansion, design should make use of a simulation model to calibrate existing plaza operations and to estimate plaza queuing and toll lane usage, or use professionally acceptable manual calculation methods (note: vehicle mix, daily/weekend/holiday profiles, and unusual demand generators). The analysis must account for increased usage of express lanes and ETC dedicated lanes, which is expected to reduce conventional plaza queuing in the future.

Guideline	Approach Zones Design Guideline 2
Title	Transition Zone Tapers
Text	Transition zone tapers approaching the conventional plaza should use the minimum taper rates presented in the McDonald 1999[1] and McDonald and Stammer 2001[2] reports. The diverge tapers from the latter publication for speeds of 40 mph or less is specified as L=WS/105 and for speeds 45 mph or more and L=3/8 WS for speeds 45 mph or more, where L= minimum length (ft.), S= posted approach speed in mph, and W= offset distance in feet. Use of a smaller taper for wide plazas and a minimum taper of 10:1 for speeds less than 30 mph was recommended.
Commentary	Reference the ITE Freeway and Interchange Geometric Design Handbook – Chapter 13 for further design information on taper rates.

Guideline	**Approach Zones Design Guideline 3**
Title	Proximity to On-ramp
Text	If the distance to safely change lanes to access the express lanes after entering the mainline from an upstream interchange on-ramp is not sufficient, this movement should be physically prevented through the use of barrier or delineator separated auxiliary lane extensions.
Commentary	Existence of an ETC dedicated lane or provisions to add one within the conventional plaza should minimize any inconvenience to the ETC customer.

Guideline	**Approach Zones Design Guideline 4**
Title	Express Lanes
Text	The approach transition zone begins at the start of the gore where the conventional plaza and express lanes split.
Commentary	For tunnel and bridge plaza approach zones, sensors and physical constraints should be deployed to prevent oversized trucks from entering a toll lane. Provisions for safely maneuvering the vehicle out of the plaza area are required.

6.4.2 Departure Zone

Guideline	**Departure Zones Design Guideline 1**
Title	Recovery Zone Lengths
Text	The departure recovery zone should be equal to at least 200 feet and preferably 300 feet, a length expected to allow sufficient driver re-orientation, acceleration, and initial merge distance after exiting the plaza.
Commentary	For tunnel and bridge toll plazas, a longer recovery zone may be warranted for oversized vehicles to safely maneuver out of the plaza area if sensors and physical constraints are not available or deployed to detect an oversized vehicle prior to entering a toll lane, thereby precluding any maneuver to exit the plaza on or before the plaza approach.

Guideline	Departure Zones Design Guideline 2
Title	Transition Zone Tapers
Text	Transition zone tapers departing the toll plaza should use the minimum taper rates presented in the McDonald 1999[1] and McDonald and Stammer 2001[2] reports. The departure tapers presented in the latter publication for speeds of 40 mph or less is specified as L= (1.5)WS/105 + 5W where L= 3/8 WS for speeds 45 mph or more, where L= minimum length (ft), S= posted approach speed in mph and W= offset distance in feet. Use of a smaller taper for wide plazas and a minimum taper of 10:1 for speeds less than 30mph was recommended.
Commentary	Reference the ITE Freeway and Interchange Geometric Design Handbook – Chapter 13 for further design information on taper rates.

Guideline	Departure Zones Design Guideline 3
Title	Proximity to Off-ramp
Text	If the distance to safely change lanes to reach the exit lane of a nearby downstream interchange from an express lane is not sufficient, this movement should be physically prevented by a downstream extension of the raised median or barrier separating express lanes and merging conventional plaza lanes.
Commentary	New construction should avoid potential information overload related to informing ETC users to exit the facility through the conventional plaza lanes in lieu of the express lanes by locating the plaza a sufficient distance from entry and exit ramps. For existing facilities, advance signing should be used to direct traffic that will be exiting at an interchange ramp just downstream of the plaza to use the conventional toll plaza lanes in lieu of the express lanes. Existence of an ETC dedicated lane or provisions to add one within the conventional plaza should minimize any inconvenience to ETC customers. The number of ETC dedicated lanes required should be calculated by estimating the percentage of ETC users exiting at a nearby downstream interchange ramp after traveling through a conventional plaza and or the percentage of ETC users entering the conventional plaza from a nearby upstream interchange on ramp. These percentages are then converted to volumes of dedicated lane ETC traffic and combined with an estimated residual of ETC traffic that elects to use the dedicated lane in lieu of the express lanes or all ETC mainline traffic if there are no express lanes.

Guideline	Departure Zones Design Guideline 4
Title	Express Lane Departure
Text	The departure recovery and transition zones should be fully completed prior to the merge with continuing express lanes. (i.e. merged lanes should equal the number of lanes on the typical roadway section downstream of the plaza area), subject to provisions for merging with any express lanes.
Commentary	An auxiliary lane may be used to temporarily increase the number of lanes merging with the continuing roadway lanes after exiting the conventional plaza.

Guideline	Dedicated Lane Design Guideline 5
Title	Recovery Zone Dedicated Lane Design
Text	Placement of physical separation devices for dedicated lane traffic should be extended beyond the toll islands until traffic in the adjacent lanes that had stopped to pay the toll has accelerated to 50% of the operating speed. As a minimum, solid white striping should continue until the accelerating traffic has reached a point of approximately two-thirds (66%) of the operating speed based on the average acceleration rate of a mid-size vehicle.
Commentary	Although specific locations are provided, the intent is to minimize the potential hazards of differential speeds when exiting a toll plaza.

6.4.3 Express Lanes

Guideline	Express Lane Design Guideline 1
Title	Lane Placement
Text	To avoid or minimize potential conflicts, express lanes should be located to the far left of the plaza.
Commentary	This is consistent with general highway travel, therefore, meets the expectations of the drivers. This effectively prohibits any reversible lane operation. Facilities where staff must access tollbooths or toll equipment from a facility located in the median, a tunnel or overhead walkway is needed to accommodate express lanes located to the far left. See Chapter 2 for more information on toll plaza configuration.

Guideline	Express Lane Design Guideline 2
Title	Express Lane Design
Text	Design of express lanes should preferably be a continuation of the normal mainline lanes with similar features (i.e. design speed, lane widths, and shoulder widths). The split between the express lanes and the conventional plaza lanes should occur prior to approach transition zone for the adjacent conventional plaza, and the merge downstream of the toll plaza should occur after the departure transition zone. (see Figure-3 and subsections 4.1 and 4.2).
Commentary	A barrier wall, guardrail, delineators and/or other types of physical separation should be considered between the express lanes and the conventional toll plaza lanes when highway standard clear zone separation is available to prevent confused and deviant drivers from trying to access the conventional plaza.

Guideline	Express Lane Design Guideline 3
Title	Diverging and Merging Express Lane and Conventional Plaza Lane Traffic
Text	Design of the conventional plaza approach and departure zones from and to the roadway mainline should comply with pertinent elements of interchange design, whereby the express lanes function the same as the mainline through lanes.
Commentary	The design must account for the available right-of-way and the ultimate number of express and conventional plaza lanes, shoulder widths, and median. The ultimate express lane width should be equal to the ultimate mainline cross section.

6.4.4 Lane and Shoulder Width

Guideline	Lane and Shoulder Width Design Guideline 1
Title	Manual and ACM/ATIM Lanes
Text	Toll lane width should be a minimum of 11 feet, with 12 feet desirable to accommodate large vehicles.
Commentary	A far right manual lane width of at least 16 feet should be considered for over-sized vehicles. For existing facilities, this same objective may be achieved by a 12 foot lane and a 4 foot shoulder.

Guideline	Lane and Shoulder Width Design Guideline 2
Title	Dedicated ETC Lanes
Text	Toll lane width should be a minimum of 11feet, with 12 feet desirable to accommodate larger vehicles, if permitted.
Commentary	None

Guideline	Lane and Shoulder Width Design Guideline 3
Title	Express ETC Lanes
Text	Toll lane and shoulder widths should match the typical section design used for the approaching roadway.
Commentary	Some shoulder restriction may be needed to the inside shoulder to accommodate a bridge or gantry structure foundation used to support overhead toll and violation enforcement equipment when the median width is insufficient. This isolated shoulder reduction should be tapered and be limited in length to minimize the impact on an emergency vehicle using the shoulder to bypass congested traffic conditions when the shoulder width is sufficient for vehicle travel.

6.4.5 Toll Island

Guideline	Toll Island Guideline 1
Title	Toll Island Width
Text	The island width should be a minimum of six (6) feet, and provide at least a minimum of one (1) foot of clearance on each side of the tollbooth or combined booth and ACM/ATIM equipment. For standalone ACM/ATIM equipment lanes, the width should be based on safe clearance for servicing (e.g., changing coin vaults, stacking tickets, maintenance servicing) the equipment, subject to the recommended minimum.
Commentary	Design must consider an acceptable clearance offsets for ACM/ATIM equipment from the curb face for customer convenience during transactions.

Guideline	Toll Island Guideline 2
Title	Toll Island Length
Text	The length of a toll island can vary based on the following: design of island access facilities (e.g., stairwell, stairway), space requirements for toll collection and traffic control equipment, and provisions for tollbooth and equipment protection. Toll island length in a conventional plaza should be uniform even though the island supporting manual collection tends to be the longest and ETC dedicated lanes tend to be the shortest. Specifically, the length of a manual island depends on the design of the tollbooth; design of any stairway for an overhead walkway or stairwell for an access tunnel; provisions for violation enforcement and traffic control equipment; tollbooth protection; design of canopy supports; provisions for staff access across the islands; and aesthetic considerations.
Commentary	A possible exception to the manual lane being the control island length is when ACM/ATIM equipped lanes (i.e., automatic lanes) permit truck use and thereby deploy a pre-classification subsystem that requires a minimum 5-axle truck length in advance of the ACM/ATIM equipment so the correct toll or class can be displayed or printed to the ticket, respectively.

Guideline	Toll Island Guideline 3
Title	Rampart and Crash Blocks
Text	Tollbooth protection provided by ramparts and crash blocks should be designed to withstand anticipated loads of design vehicles. The rampart should be designed to redirect errant vehicles and not launch the vehicle. Crash blocks are constructed of reinforced concrete and can incorporate aesthetic features such as planters.
Commentary	Double crash blocks should be considered if large vehicles are permitted. Longer blocks may be considered in lieu of a rampart. Design should be performed by an experienced structural engineer. If planters are used, any planted vegetation should not block the collector's vision of approaching vehicles and a filtered drainage outlet is required.

Guideline	Toll Island Guideline 4
Title	Staff Access
Text	Grade separated access to toll islands should be considered so no more than a single lane must be crossed to gain access to the intended island. Design should include a means to block access into the adjacent lane by installing a pedestrian gate, moveable barrier, or a chain or rope strung between two posts at the edges of the toll island to warn and protect staff crossing lanes.
Commentary	Two alternatives for grade-separated crossing access are an access tunnel immediately below the tollbooth and an overhead walkway. In addition to stairway access to these facilities, for new construction ADA regulations may require the inclusion of elevator access subject to official job descriptions and minimum requirements to perform the work If using a pedestrian gate or moveable barrier, it should not extend into the adjacent toll lane when "open".

6.4.6 Cross Slopes

Guideline	Cross Slope Design Guideline 1
Title	Cross Slope Ranges
Text	Design of cross slopes should follow the methods and guidelines provided by the AASHTO "Green Book" and or the respective state DOT design manuals. Drainage design needs to address runoff from the canopy. Cross slopes will typically range from 1%-2% on tangent roadway sections and higher on curves.
Commentary	The drainage design must combine cross slopes with longitudinal grade to avoid any water ponding within the toll plaza. Canopy runoff should be directly piped into the drainage system.

Guideline	Cross Slope Design Guideline 2
Title	Rollover Ranges
Text	Design of rollover of adjacent lanes should follow the methods and guidelines provided by the AASHTO "Green Book" and or the respective state DOT design manuals. Rollover should be limited to a combine grade differential of 4%.
Commentary	None

6.4.7 Vertical Profile Grade

Guideline	Vertical Profile Grade Guideline 1
Title	Plaza Approach and Departure Profile Grades
Text	In cases of mixed flow traffic, the vertical profile grade approaching and departing the toll plaza should be greater than or equal to ± 1% and less than or equal to ±2%.
Commentary	The upper limit on vertical profile grades may be increased to +3 when the percentage of commercial vehicles is low and the toll plaza is located at the crest of the profile grade.

Guideline	Vertical Profile Grade Guideline 2
Title	Toll Lane Profile Grades
Text	The vertical profile grade in a toll lane should be equal to or greater than ± 0.5% and less than or equal to ±2%.
Commentary	The cross slope and profile grade should be designed in conjunction to avoid storm drainage flows across the entrance to the toll lane. The canopy and storm drainage system design should direct collected water away from the toll lanes and help reduce precipitation within the toll lane.

6.4.8 Lighting

Guideline	Lighting Design Guideline 1
Title	Intensity and Uniform Coverage
Text	Intensity levels and uniformity ratios should be based on adaptations from the American National Standards Institute (ANSI) and Illuminating Engineering Society (IES).
Commentary	ITE recommends an average illuminance of 1.0-4.0 foot-candles for pedestrian facilities, which is deemed insufficient for supporting a CCTV security system and providing a high level of visibility to agency staff.

Guideline	Lighting Design Guideline 2
Title	Minimize Lighting Spillover
Text	Use proper shielding and aiming to minimize lighting spillover into adjacent properties, especially residential communities.
Commentary	Migration of light pollution should be in accordance with approved environmental document(s).

Guideline	Lighting Design Guideline 3
Title	Quantity of Plaza Approach and Departure Lights
Text	High mast and tower pole designs for mounting luminaries should be used to minimize the addition of roadway hazards that must be protected by barrier if inadequate clear zone is available or is impractical.
Commentary	Tower design, and to a lesser extent high mast design (based of an internal luminaries lowering mechanism) must address the issue of accessing the luminaries for maintenance.

Guideline	Lighting Design Guideline 4
Title	Toll Lane Lighting
Text	Lighting intensity and uniformity should be based on adaptations from the American National Standards Institute (ANSI) and Illuminating Engineering Society (IES).
Commentary	Toll lane lighting should provide a minimum of 20 foot-candles for at least 25 feet each side of the tollbooth or automatic machine (i.e., coin, payment or ticket issuing) centerline, subject to consideration of contributions from other site-specific light sources. This level of lighting is intended to enhance plaza security including camera video and improve visibility of agency staff crossing a toll lane.

6.5 TOLL COLLECTION EQUIPMENT TECHNOLOGY

This section presents a summary of all the proposed Guidelines from Chapter 5. Each is listed in the following subsections in the order presented in the report as follows:

- Automatic Coin Machines
- Automatic Ticket Issuing Machine
- Island Traffic Signal
- Patron Toll Display
- Barrier Gates
- Toll Booth Design
- Violation Enforcement System

6.5.1 Automatic Coin Machines

Guideline	Toll Collection Equipment Technology Guideline 1
Title	ACM Horizontal Clearance
Text	The front lip of the ACM basket or hopper should be approximately coincident with the edge of the toll island and not protrude into the travel lane.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 2
Title	ACM Hopper/Basket Size & Location
Text	Circumference and height of the top of the basket should be specified to easily accommodate the majority of customers while adequately handling the remaining customers.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 3
Title	ACM Visibility
Text	The ACM cabinet should be finished with a bright color (other than white to retain contrast with the attached basket material) that is distinctive of any other colors used in the toll lane.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 4
Title	ACM Toll Display and User Feedback
Text	ACM cabinet should include an embedded display that shows, as a minimum, a fare paid message.
Commentary	Preferably the remaining balance to be deposited should be displayed so the user has immediate feedback when an invalid coin or token is deposited.

Guideline	Toll Collection Equipment Technology Guideline 5
Title	Provisions for Accommodating Trucks in an ACM Lane
Text	Dual height ACMs should not be implemented in automatic lanes unless daily truck volume through the lane exceeds 25% and this solution is determined to be more economical than a preclass or VES based solution.
Commentary	This recommendation factors in the continued growth in ETC penetration and expansion of payment machines using bill changers and credit card proximity readers capable of handling any toll amount, affectively limiting ACMs to unattended ramp plazas.

6.5.2 Automatic Ticket Issuing Machines

Guideline	Toll Collection Equipment Technology Guideline 6
Title	ATIM Horizontal Clearance
Text	The front edge of the ATIM should be in the same vertical plane as the front face of the island curb or raised barrier.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 7
Title	ATIM Mounting Height (excludes trucks)
Text	The ticket dispensing component of the ATIM should be installed a height of 3 feet above the travel lane surface.
Commentary	This height should be field verified to account for local variations in the vehicle mix.

Guideline	**Toll Collection Equipment Technology Guideline 8**
Title	ATIM Visibility
Text	The ATIM should be finished with a bright color that is distinctive of any other colors used in the automatic lane.
Commentary	A fixed, static sign stating "Take Ticket" installed above the ATIM should be used as an effective means of conveying what is expected of the user.

Guideline	**Toll Collection Equipment Technology Guideline 9**
Title	Provisions for Accommodating Trucks in an ATIM Lane
Text	If the entry plaza is staffed with attendants, automatic lanes should be limited to passenger cars with either a single ATIM or a redundant second ATIM, both installed at the same height.
Commentary	None.

6.5.3 Island Traffic Signals

Guideline	**Island Traffic Signal Guideline 1**
Title	ITS Signal Size
Text	Subject to other unique toll plaza considerations, the ITS should consist of 8 inch diameter, LED traffic signal heads.
Commentary	None.

Guideline	**Island Traffic Signal Guideline 2**
Title	ITS Location
Text	The ITS should be installed approximately 15 feet beyond the downstream edge of the presence or arming loop.
Commentary	This location assumes 15 feet represents the detection length of a typical vehicle, the installation of a presence loop at the collection point, and there are no physical constraints to this location. Otherwise, alternative locations should be considered and field tested.

Guideline	Island Traffic Signal Guideline 3
Title	ITS Horizontal Clearance
Text	A horizontal clearance of 12 inches should be used from the face of the toll island or raised barrier to the nearest edge of the ITS signal head.
Commentary	None.

Guideline	Island Traffic Signal Guideline 4
Title	ITS Height
Text	Subject to the known or forecasted traffic mix, the height to the bottom of all ITS should be in the range of 4 to 5 feet.
Commentary	None.

6.5.4 Patron Toll Display Guidelines

Guideline	Patron Toll Display Guideline 1
Title	PTD Horizontal Clearance
Text	Provide a minimum 12 inch horizontal clearance setback from the toll island curb or face of raised barrier.
Commentary	None.

Guideline	Toll Collection Equipment Technology Guideline 2
Title	Character Size for PTD Messages
Text	The height of characters comprising a message should be a nominal size of 3 inches.
Commentary	Character height is expected to vary based on the size of the message to be displayed or the viewing distance.

Guideline	Patron Toll Display Design Guideline 3
Title	PTD Location in Automatic Lanes
Text	In automatic lanes, the PTD should be located just downstream and within three (3) to eight (8) feet of the ACM, without blocking an existing or planned accessway.
Commentary	For ACMs without a built PFD, the PTD should be located so the user can easily view the display while depositing coins or tokens in the coin machine.

Guideline	Patron Toll Display Design Guideline 4
Title	PTD Location in Manual/attended Lanes
Text	In manual/attended lanes, the PTD should either be mounted to the side of the tollbooth just downstream of the door or attached to a stanchion installed within three (3) feet of the downstream edge of the tollbooth and angled to achieve maximum visibility.
Commentary	None.

Guideline	Patron Toll Display Design Guideline 5
Title	PTD Height in Manual/attended Lanes
Text	The PTD height should be optimized for view by drivers of SUVs and light trucks.
Commentary	This assumes eventually the majority of passenger cars will use ETC (dedicated and express) lanes and truck usage will exceed passenger care usage in these lanes.

Guideline	Toll Collection Equipment Technology Guideline 6
Title	PTD Height in ACM/ATIM Lanes
Text	The PTD height should be optimized for view by drivers of passenger cars, not exceeding a height of 4 feet.
Commentary	None.

6.5.5 Barrier Gates

Guideline	Automatic Lane Barrier Gate Guideline 1
Title	Provisions for Automatic Lane Barrier Gates in Toll Plaza Deploying VES Equipment
Text	VES equipment should be used in lieu of automatic barrier gates unless vehicle speeds through the automatic lane pose a safety hazard to attendants who must cross more than one lane.
Commentary	To avoid the revenue loss from opening the gate for customers who fail to fully pay the displayed toll, plus the operational costs incurred to assure the gate arm raises and to maintain the gates, VES equipment should be deployed instead of automatic barrier gates. The automatic barrier gate installed at the departure end of the toll island to control the flow of traffic through a lane should not be confused with a pedestrian gate installed on the toll island to prevent staff or visitors from walking into a toll lane. This particular gate is rarely automated.

Guideline	Automatic Lane Barrier Gate Guideline 2
Title	Provisions for Automatic Lane Barrier Gates in Toll Plazas with no VES Equipment Deployment
Text	Barrier gates should only be deployed in these lanes if both the supervisor's workstation functionality and an adjacent manual/attended lane toll terminal functionality are capable of remotely raising the gate in the automatic lane.
Commentary	None.

Guideline	Automatic Lane Barrier Gate Guideline 3
Title	Provisions for Manual/Attended Lane Barrier Gates in Toll Plaza Deploying VES Equipment
Text	VES equipment should be used in lieu of barrier gates unless vehicle speeds through the manual/attended lane pose a safety hazard to attendants who must cross the lane.
Commentary	None.

Guideline	Automatic Lane Barrier Gate Guideline 4
Title	Barrier Gate Horizontal Clearance
Text	For toll island installation, the gate cabinet should be setback 12 inches from the face of the toll island or raised barrier.
Commentary	None.

Guideline	Automatic Lane Barrier Gate Guideline 5
Title	Barrier Gate Arm
Text	A ten (10) foot gate arm attached to a breakaway assembly should be specified. The gate arm finish should be striped using two distinct, contrasting colors.
Commentary	The 10 foot gate arm minimizes the end gap within the toll lane and maintains good visibility to approaching traffic while compromising gate arm speed, albeit a small reduction.

6.5.6 Tollbooth Design

Guideline	Toll Booth Design Guideline 1
Title	Tollbooth Horizontal Clearance
Text	A nominal 12-inch horizontal clearance should be used from the face of the toll island curb or raised barrier to both sides of the tollbooth.
Commentary	None

Guideline	Toll Booth Design Guideline 2
Title	Height of Tollbooth Floor
Text	For new construction, the tollbooth floor should be 8 inches above the toll lane pavement surface.
Commentary	Tollbooth floor surface area block-out should be installed in the toll island to maintain an island and tollbooth floor height of 8 inches.

Guideline	Tollbooth Design Guideline 3
Title	Tollbooth Front Door Design
Text	For new construction, tollbooth design should include a front door that 1) allows the attendant to service all vehicle types while providing protection against slipping or falling into the toll lane; and 2) provides a means for the attendant to quickly enter the lane and then return to the booth, when traffic conditions permit.
Commentary	None

Guideline	Tollbooth Design Guideline 4
Title	Tollbooth Protection
Text	For new construction, the tollbooth should be protected by concrete ramparts and/or mass concrete formations, such crash blocks and planters.
Commentary	Bollards pose problems with plaza aesthetics, attendant visibility and customer's additional repellence from the tollbooth due to a perceived hazard, thereby making the exchange of money and receipts more difficult.

Guideline	Toll Collection Equipment Technology Guideline 29
Title	Tollbooth Accessibility after Failed ETC Transaction
Text	To eliminate the incident of vehicles backing up in the lane to pay the attendant after a failed ETC transactions, the following alternatives should be evaluated: 1) move the antenna location further upstream if the plaza canopy and software can support this location; 2) add VES equipment (i.e., front and rear cameras if necessary) to capture a license plate images and modify the software to provide a green light if a transponder Agency Code is read.
Commentary	Failure to read an agency code may be the result of a failed battery or other transponder malfunction or the Agency code is unrecognizable to the ETC reader.

Guideline	Toll Collection Equipment Technology Guideline 25
Title	Tollbooth Horizontal Clearance
Text	A nominal 12-inch horizontal clearance should be used from the face of the toll island curb or raised barrier to the side of the tollbooth from where the attendant collects tolls.
Commentary	None

6.5.7 Violation Enforcement Systems

Guideline	VES Design Guideline 1
Title	VES Equipment Horizontal Clearance
Text	A minimum horizontal clearance of 12 inches from the vertical face of the toll island curb should be maintained for the VES camera and light. For barrier separated dedicated toll lanes, the VES camera and light should be mounted to a stanchion installed behind the barrier.
Commentary	The camera and light can also be mounted to the top of the barrier if a minimum horizontal clearance of 12 inches from the travelway is provided.

Guideline	VES Design Guideline 2
Title	VES Light Impairment Mitigation
Text	Continuous white lighting should not be deployed for front license plates when the camera and light are mounted overhead.
Commentary	Flashed/pulsed, strobe and infrared lighting solutions should be considered to avoid impairing the user's vision.

Guideline	VES Design Guideline 3
Title	VES Lighting
Text	Pulsed or flashed lighting involving high intensity LEDs producing white lighting should be deployed when multiple colored license plate characters and backgrounds corresponding to different jurisdictions must be captured.
Commentary	Other solutions, such as changing the beta factor for infrared lighting, can be used if field tests verify quality images and a high optical character recognition success rate can be achieved.

6.5.8 Ongoing Research and Activities

RECENT RELATED RESEARCH, REPORTS, EXPERIMENTS AND STUDIES RELATED TO TRAFFIC CONTROL STRATEGIES AT TOLL PLAZAS

Description	Date
Expressway Authority Guidelines for Preparation of Signing and Pavement Marking Plans prepared by Orlando-Orange County Expressway by Authority with support from Post Buckley, Schuh & Jernigan	July 2005
These guidelines intended to guide Section Engineer Consultants in the preparation of Signing and Pavement Marking Plans for the Orlando-Orange County Expressway Authority.	
Traffic Control Devices at Transponder-controlled Toll Booth Lanes - Final Report prepared by Gary A. Golembiewski and Richard L. Knoblauch Center with Applied Research, Inc. with contributions from the Pooled Fund Consortium.	December 29, 2004
This study reviewed selected ETC toll road signs in the United States to help determine four basic elements (background color, font color, underlay color, and pictograph) and options to be used in a laboratory experiment. Analysis of the results showed the following: • *Overall, green as a background color obtained the longest guidance information legibility distance,* • *Fonts that provided the highest contrast to the background color (such as white) were most effective for legibility,* • *The EZ TAG pictograph (which was purple, as were all pictographs in this study) showed dramatically longer legibility distances than did the other pictographs, this result was consistent across all underlay colors,* • *The underlay colors that showed the highest contrast to the pictographs were most effective and included all the lighter colors tested (white, yellow, and light blue)*	
Texas DOT Manual Chapter 2J Toll Road Signing, 2006 Edition	2006
Criteria for signing toll roads for various conditions and scenarios including details on route shields, regulatory, and guide signs used on toll roads.	
Harris Country Toll Road Authority requested (December 29, 2005) and received approval (February 10, 2006) from the FHWA Office of Transportation Operations to experiment with purple background guide signs under the provisions of Section 1A.10, Interpretation, Experimentations, and Changes of the Manual on Uniform Traffic Control Devices (MUTCD).	February 10, 2006
The experiment involves the installation of purple background guide signs on direct connect ramps to the all electronic Westpark Tollway facility. These signs would be compared to green guide signs with a purple banner across the top. The evaluation plan includes an assessment of driver comprehension, legibility, and recognition. The revised work plan also clarifies the durability analysis and expects to answer technical questions previously posed by FHWA. The evaluation will be conducted by the Texas Transportation Institute with Dr. Susan Chrysler serving as Principal Investigator.	
Freeway and Interchange Geometric Design Handbook published by the Institute of Transportation Engineers 2006 (companion to AASHTO's A Policy on Geometric Design of Highways and Streets, 5th Edition (Greenbook).	2006
Recognizing the geometric design procedures for freeways and interchanges may vary among agencies; this handbook sets forth the techniques and procedures successfully applied on numerous constructed and reconstructed projects. This handbook focuses on geometric and operational characteristics of freeways and interchanges including toll facilities and HOV/managed lanes.	

GLOSSARY OF TERMS AND DIAGRAMS

GLOSSARY

This Glossary of terms and associated diagrams is intended to provide a common definition and form a mutual understanding for all users of this report:

AASHTO – American Association of State Highway and Transportation Officials.

ACM – Automatic Coin Machine – Unattended toll collection equipment installed on a toll island consisting of a coin hopper to collect and funnel coins or tokens, a coin processor for identifying and recording coin denominations, and automatic locking coin vaults for storing coins or tokens.

ADA – Americans with Disabilities Act.

Approach Queue Zone – A rectangular shaped area extending longitudinally from the far approach edge of the toll islands to a distance in front of the toll plaza where one or both of the outside edges of the zone begin to taper toward the center of the plaza and transversely to encompass all toll plaza lanes (excluding express lanes). This area is intended to provide space for vehicle queues without blocking approaching vehicle access to any of the open toll lanes.

Approach Transition Zone – The area upstream of the toll plaza where the roadway widens from the typical roadway section in advance of the toll plaza to the width of the approach queue zone.

ATIM – An automatic ticket issuing machine or automatic ticket dispenser (ATD) that is used to dispatch a ticket coded with time, date, a default vehicle class and entry location information used to determine the toll due when exiting the facility. A loop detector activation is commonly used to signal the ATIM or ATD to automatically issue a ticket.

Barrier Gate – An automatic gate consisting of a breakaway gate arm, motor assembly and housing installed at the departure end of a toll island. A barrier gate is used to reduce violations and speed through a toll lane. Barrier gates installed in both attended and unattended lanes commonly includes a remote control capability to raise the gate for patrons with insufficient funds.

Beacon - A traffic signal, commonly consisting of one signal head that operates in a flashing mode. It is used to draw attention to a sign, obstruction, or hazardous condition.

U.S. Department of Transportation
Federal Highway Administration

Branch Toll Lanes – Channelized toll lanes located either in advance of or after a toll plaza that are used to increase toll plaza capacity within existing right-of-way constraints. A single main toll plaza lane is effectively converted to multiple lanes using the same modes of collection available in the main toll plaza by shifting the collection points either upstream or downstream.

Bypass Lanes – A lane that circumvents the toll plaza that is typically used by special permit and oversized vehicles. When this lane is routed around the administration building, it is also used for deliveries to the toll plaza and building. The lane may also be used for an oversized vehicle to turnaround. Gates, cameras and other security control features are commonly used to restrict access to these lanes.

Canopy – A structure consisting of a roof and support columns used to protect toll attendants and customers from precipitation. This structure is commonly used to support overhead signs and signals along with ETC and violation enforcement equipment.

Cars-only ETC Lane - A dedicated ETC lane allowing only cars equipped with a valid transponder to use the lane to record a toll transaction.

CMS - Changeable Message Sign – A traffic control device capable of changing state by displaying one or more messages. These signs support a blank mode, multiple messages alternately displayed, and more than one message with one message continuously displayed. A CMS displays pertinent traffic operational, regulatory, warning, and guidance information. These signs are capable of being changed manually, by remote control, or by automatic controls. Toll plazas typically use a single or multi-line electronic sign mounted overhead to display the operating status and toll collection mode of a single or group of toll lanes located ahead or directly below the CMS. LEDs and illuminated fiber strands are the most common technologies used to display messages. The CMS can be mounted to a canopy, gantry, bridge, or cantilever structure and requires provisions for accessing the signs internal components from the front, rear or interior of the sign.

Crash Block – Formed reinforced or mass concrete placed in front of a tollbooth to protect the tollbooth and attendant from direct vehicle collisions. A crash block can be placed monolithic with a toll island or separately after placement of the toll island. The height of the crash block is limited by the tollbooth window height and the width is normally limited by the width of the toll island minus a setback to minimize damage to passing vehicles. Single crash blocks are commonly used in conjunction with ramparts and dual crash blocks are commonly used on longer length toll islands.

Crash Cushion – See "Impact Attenuator".

Dedicated ETC Lane – A toll lane within a conventional toll plaza that is dedicated to an ETC method of payment, thereby limiting use of the lane to vehicles having a valid transponder. Except for maintenance servicing, this lane is typically open 24 hours per day. Three common variations of these lanes are mixed-use, cars-only, and trucks-only. These lanes are normally located to the left of a directional toll plaza, but may be located in the center or on the right side because of vehicles entering the plaza from two directions, to accommodate reversible lanes, reduce implementation cost by converting only ACM lanes and low expected usage.

Delineator – A retro-reflective device mounted on the roadway surface or at the side of the roadway, typically in a series, to indicate alignment of the roadway and to channelize vehicles to form queues and/or prevent crossing into an adjacent lane or accessway.

Departure Recovery Zone – A rectangular shaped area extending longitudinally from the far departure edge of the toll plaza islands to a distance downstream of the toll plaza where one or both of the outside edges of the zone begin to taper toward the center of the plaza and transversely to encompass all toll plaza lanes (excluding express lanes). This area allows motorists to orient themselves to the approaching tapers and the possible need to merge to the left or right after exiting the toll lane.

Departure Transition Zone - The area immediately downstream of the departure recovery zone of the toll plaza where the width of the roadway narrows to the width of the typical roadway section.

Diffusers – Slightly angled horizontal slats mounted in front of a high intensity light to diffuse a light beam used to enhance the capture of a vehicle license plate. The slats are commonly welded to a four-sided box. Diffusers are used to mitigate impairment of a driver's visions when viewed directly or from a rear-view mirror.

DOT – Department of Transportation

ETC – Electronic Toll Collection – A subsystem capable of electronically charging a toll to an established customer account by reading a number matched to an account and encoded on a transponder that is mounted inside or to the bumper of a vehicle. Lane level equipment consists of an overhead mounted antenna, a transceiver/modulator for processing RF signals, a reader/controller for both verification processing and data storing, and a vehicle mounted transponder.

Express Lanes – Roadway lanes effectively equivalent in design to the approach and departure roadway sections with the exception of roadside barrier installed to minimize the severity of collisions with a vertical support of a bridge, gantry or cantilever structure used to support toll collection, vehicle classification and violation enforcement equipment. Tolls are predominately charged using an electronic process for vehicles having a valid transponder and to a much lesser extent by capturing vehicle license plates and assessing a toll to the registered vehicle owner. The primary method of violation enforcement in these lanes is license plate capture using overhead or side mounted cameras. All toll and violation transactions are recorded while vehicles are traveling through the lanes at prevailing highway speeds.

Green Book – A Policy on Geometric Design of Highways and Streets published by American Association of State Highway and Transportation Officials. This document provides design guidance based on established practices and forms a comprehensive reference manual for assistance in administrative, planning and educational efforts pertaining to design formulation.

High Mast Lighting – Multiple luminaries typically installed in a ring configuration at the top of a pole at least 55 feet tall. The interior of the pole commonly houses components of a lowering mechanism used to drop the ring of luminaries to an adjustable distance above ground level for maintenance.

Impact Attenuator – An energy absorbing crash cushion designed to decrease the momentum of a vehicle traveling at a particular speed and reducing the severity of property damage and injuries to the driver of the vehicle and the toll attendant operating from inside a downstream toll booth. The back end of the impact attenuator is anchored a concrete back-up block for stability and to minimize the potential of the vehicle colliding with a toll booth or equipment.

ITE – Institute of Transportation Engineers - An international association of transportation professionals responsible for planning, designing, implementing, operating, and maintaining the surface and ground transportation systems of the world. ITE provides for the professional development of members and others in meeting society's needs for safe, efficient and environmentally compatible transportation.

ITS – Island Traffic Signal – Two or three vertically stacked standard traffic signal heads mounted to the top of a stanchion or post. The ITS is mounted at the downstream end of the toll island. Red and green signal heads convey the same meaning as traffic signals installed at intersection, while a yellow signal head is commonly used to indicate a low ETC account balance. The ITS may also include a combination alarm and light mounted to the top of the assembly that is activated by the System whenever a vehicle exits the lane without recording a paid transaction.

Lane Use Signal – A device commonly mounted over the center of a toll lane and used to display an open or closed lane operating status. The most common signal types installed in toll plazas use a red "X" for closed and green "↓" for open. These symbols are primarily formed from LEDs or illuminated fiber strands, either installed in an off-the-shelf environmental enclosure or part of a multi-line changeable message sign. Horizontally placed red and green traffic signal heads are also used to display lane status.

Light Curtain – An array of photoelectric sensors that emit and receive sequenced and modulated light beams that are used to detect the presence and/or define a profile of a vehicle. A controller is used to receive an output signal from each receiver, apply logic for reliable detection or profiling under varying environmental conditions, and communicate output and operational messages to an interconnected processor (e.g. lane controller).

Manual Toll Collection - A method of toll collection involving a toll attendant classifying vehicles, collecting cash or swiping magnetic cards, providing change and receipts, and collecting vehicle information for instances of unpaid tolls.

Mixed-Use ETC Lane – A dedicated ETC lane allowing both cars and trucks equipped with a valid transponder to use the lane to record a toll transaction.

ML Plaza – Mainline Toll Plaza –A toll plaza located on the mainline of a tollway which effectively creates a barrier to prevailing traffic flow, with the exception of express lanes, and to a lesser extent, dedicated lanes.

Moveable Barrier – A series of linked concrete or sand-filled barriers used to separate opposing flows of traffic and capable of being moved by automated, continuous-flow, mechanical means to change traffic patterns.

MUTCD – Manual on Uniform Traffic Control Devices

Photoelectric Beam – An electrical device that is used to detect the presence of a vehicle at the location of the barrier gate arm. Toll facility implementations commonly consist of either emitter and receiver self-contained units or a self-contained emitter/receiver and reflector. The receiver sends an analog or digital output signal when changes in light intensity are detected.

PTD – Patron Toll Display - A relatively small electronic sign installed downstream of a toll booth or ACM to display toll due and toll paid messages and amounts for a particular vehicle class. A flip disc matrix consisting of movable discs coated with fluorescent dots is the most commonly used sign display technology.

Queue – A stacking of vehicles waiting to be serviced and/or processed by a toll attendant, ACM/ATIM, or ETC equipment.

Rampart – Sloped reinforced or mass concrete on the approach of the toll island intended to redirect an errant vehicle. The sloped concrete rises toward the booth and often connects to a crash block. The rampart may have rounded or approximately square edges.

RF – Radio Frequency – An electromagnetic wave frequency intermediate between audio frequencies and infrared frequencies, used especially in radio and television transmission as well as for transmission of information between a vehicle-mounted transponder and an overhead antenna.

Superelevation – An increase in the normal roadway cross slope or transitional removal of adverse crown or cross slope to flat before gradually increasing the roadway slope or tilting the roadway surface to partially counterbalance the centripetal force (i.e., lateral acceleration) on a vehicle that is negotiating a horizontal curve. The process is reversed upon exiting the curve.

Superelevation Rate – The rate of rise in cross section of the finished surface of a roadway on a curve, measured from the lowest or inside edge to the highest of outside edge.

Taper Rate – The transverse distance a roadway or pavement marking edge moves over a longitudinal length, as a ratio or a percent when multiplied by 100.

Tapered Chevron –White pavement markings of varying lengths that slope down at a 45 degree angle on both sides from a projected centerline of the obstruction (e.g. impact attenuator, toll island) to intersect a tapered white channelizing line. The total width at the approach end of the obstruction shall equal the width of the obstruction plus 1 to 2 feet on each side.

Throughput Volume – The number of vehicles passing through a toll lane or toll plaza in one direction over a one-hour or other defined time period.

Toll Collection Equipment - Equipment and devices used to detect vehicle presence, length, height and number of axles for the purpose of classifying vehicles, to collect cash/ script or account ID numbers, process transactions, and to display fares, messages and indications to exit the lane.

Toll Facility – A road, bridge or tunnel for which travelers pay a specified toll for a particular class of vehicle to travel on, over, or through, respectively, the transportation facility.

Toll Island – A raised island or platform constructed with concrete that protects a toll booth, ACM, ATIM and other toll collection and violation enforcement equipment from damage caused by passing vehicles and to provide a sound foundation for securely mounting these items. Formed mass concrete is commonly placed at the approach end of the island to provide additional protection from errant vehicles.

Tolling Point – The location along a roadway lane where either a toll is charged to an established account using an electronic process for vehicles having a valid transponder or by capturing the vehicle's license plate and assessing a toll to the registered vehicle owner.

Toll Schedule Sign – A sign that displays vehicle class and associated toll collected at a toll plaza. This sign is typically located on the right roadside, a short distance in advance of the plaza toll islands.

Truck-only ETC Lane - A dedicated ETC lane allowing only trucks equipped with a valid transponder to use the lane to record a toll transaction.

Figures 1-3 on the following pages are diagrams of toll plaza designs for reference purposes while reading this Report. Figure 1 shows a plan view of a Manual Lane and a dedicated ETC Lane with associated glossary terms labeled on the diagram. Figure 2 presents a similar diagram for an ACM/ATIM Lane. Figure 3 shows a plan view and a transverse centerline cross section of a typical mainline toll plaza with adjacent express lanes, including some of the geometric design features addressed in this report.

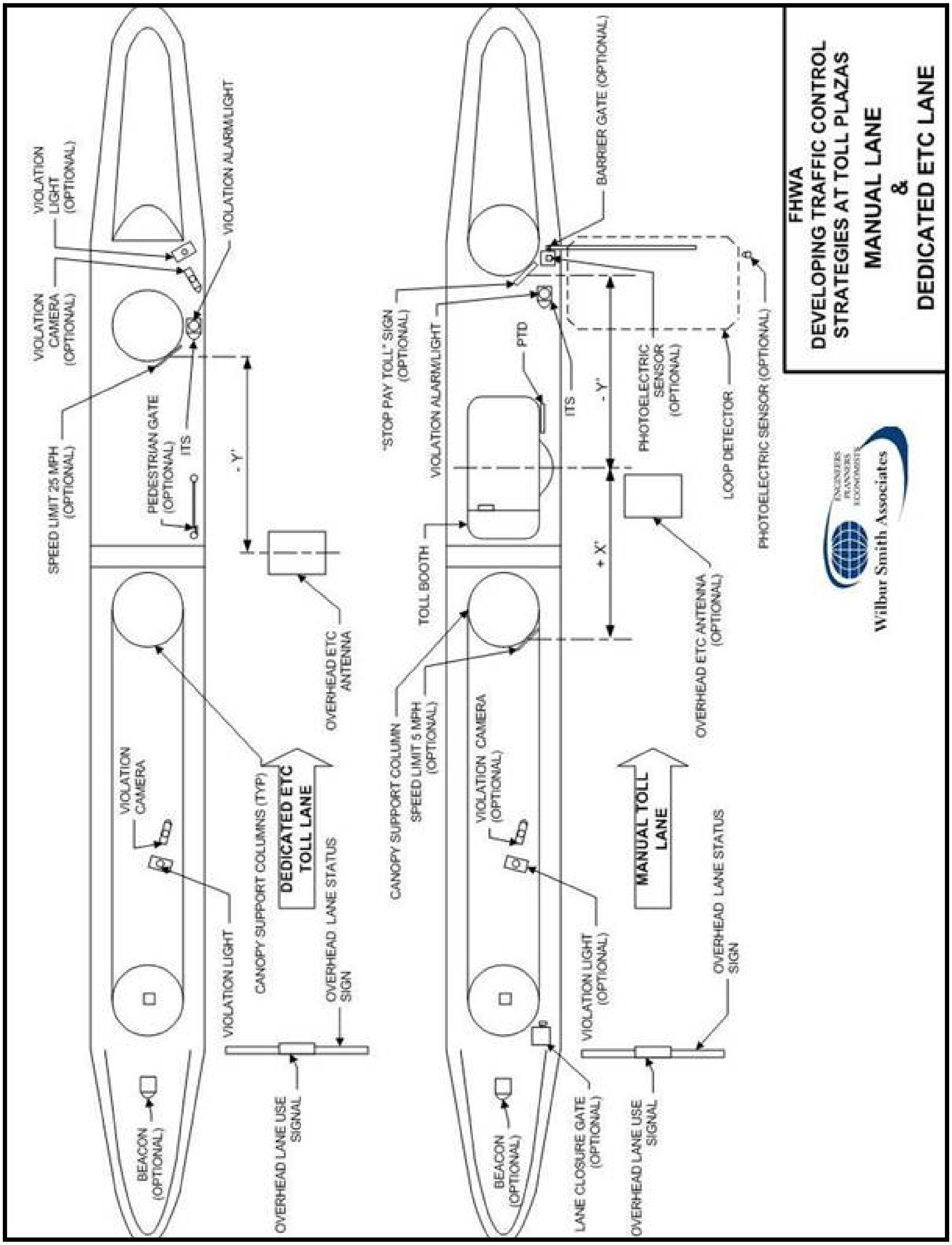


FIGURE 1 MANUAL LANE AND DEDICATED ETC LANE

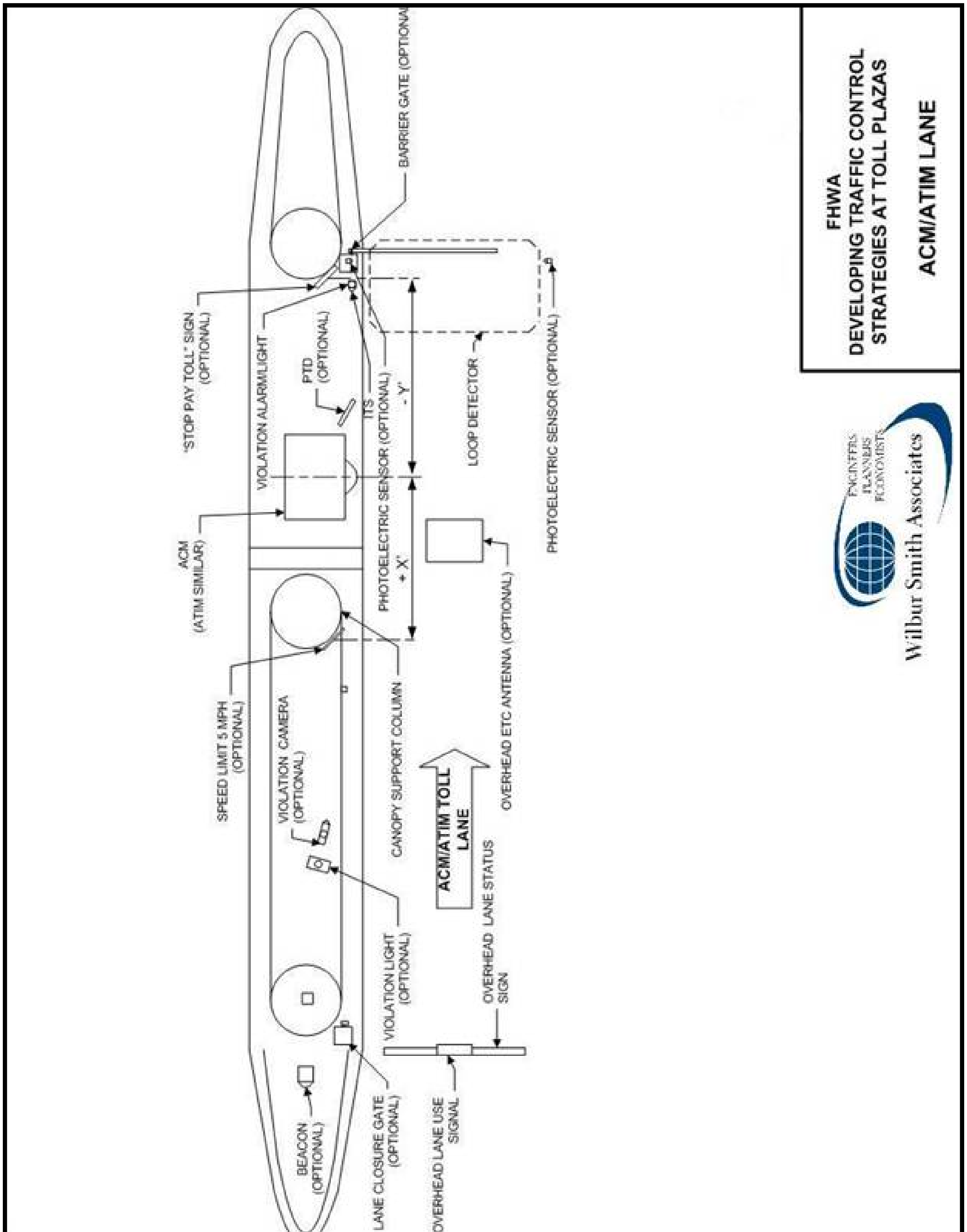


FIGURE 2 ACM/ATIM LANE

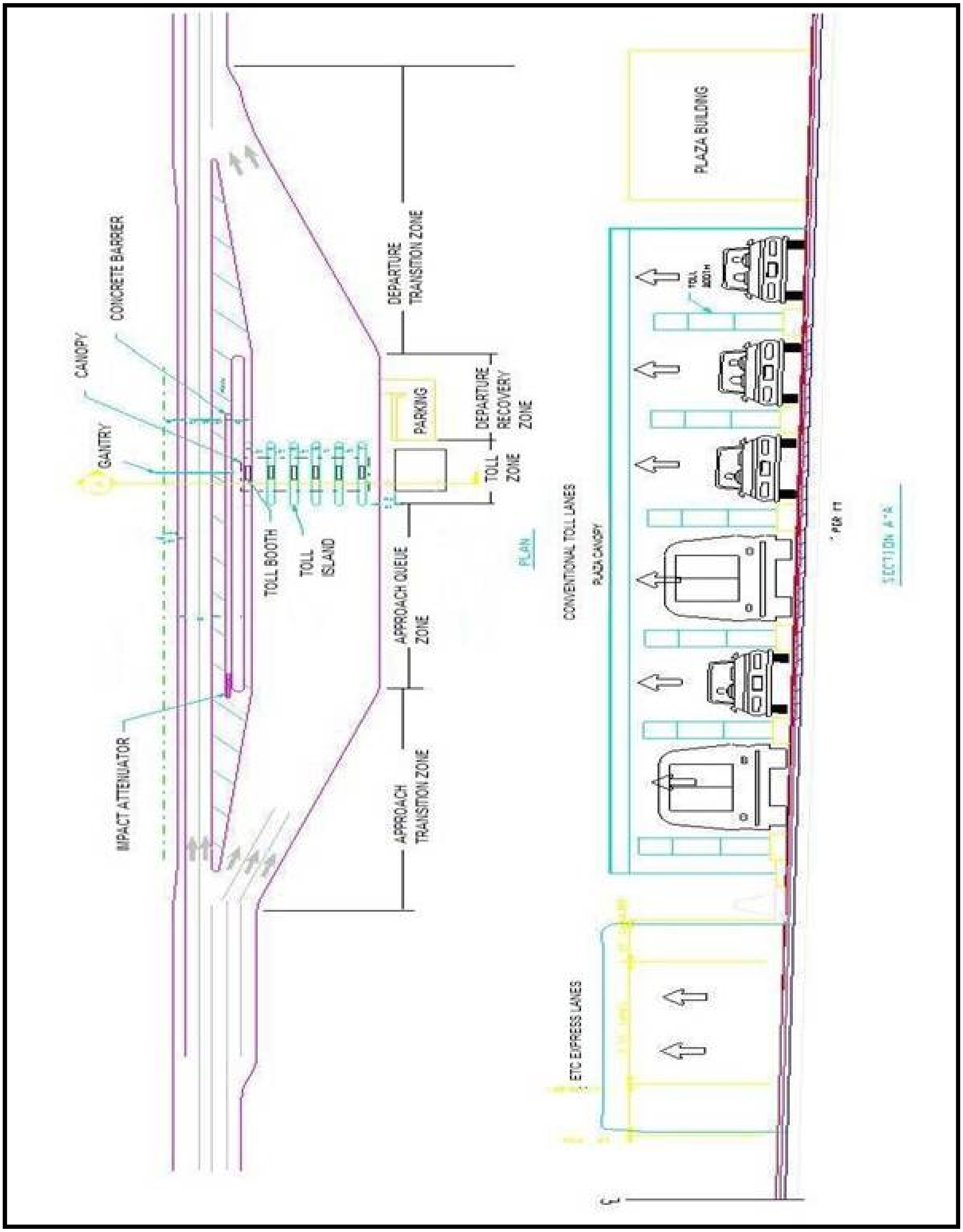


FIGURE 3 MAINLINE TOLL PLAZA WITH ADJACENT EXPRESS LANE

APPENDIX A

Toll Agencies Responding to Survey

AGENCY	Completed?	Survey Completed			Sections Completed				
		Road	Bridge	Tunnel	General	Express ETC	Dedicated ETC	ACM/ATIM	Manual
ABCR	Complete	X			X		X		X
Autopistas del Sol, S. A.	Complete	X			X		X		X
BRISA, Auto-Estradas de Portugal, S. A.	Complete	X			X	X	X		X
E-470 Public Highway Authority	Complete	X			X	X	X	X	X
Florida Turnpike Enterprise	Complete	X			X		X		X
Foothill/Eastern Transportation Corridor Agency	Complete	X			X	X	X		X
Golden Gate Bridge, Highway & Transportation District	Complete		X		X		X		X
Halifax-Dartmouth Bridge Commission	Complete		X		X		X		X
Illinois State Toll Highway Authority	Complete	X			X	X	X	X	X
Indiana Department of Transportation	Complete	X			X			X	X
International Bridge Administration	Complete		X		X				X
Lee County Toll Facilities	Complete		X		X		X	X	X
MTA Bridges & Tunnels	Complete		X	X	X		X		X
Miami-Dade Expressway Authority (MDX)	Complete	X			X		X	X	
New York State Bridge Authority Headquarters	Complete		X		X		X		X
New York State Thruway Authority	Complete	X			X		X		X
New Jersey Turnpike Authority	Complete	X			X	X	X	X	
Niagara Falls Bridge Commission	Complete		X		X			X	X
North Texas Tollway Authority	Complete	X			X	X	X		X
Ohio Turnpike Commission	Complete	X			X				X
Orlando-Orange County Expressway Authority	Complete	X			X	X	X	X	X
Port Authority of NY&NJ	Complete		X		X		X		X
Pennsylvania Turnpike Commission	Complete	X			X	X	X		X
Pocahontas Parkway Association	Complete	X			X	X	X	X	X
South Carolina Department of Transportation	Complete	X			X		X		X
Texas Turnpike Authority	Complete	X			X	X	X		
Thousand Islands Bridge Authority	Complete		X		X				X
United Toll Systems, LLC	Complete		X		X	X	X		X
Virginia Department of Transportation (Dulles Toll Road)	Complete	X			X	X	X	X	X
Count	**28**	**19**	**10**	**1**					

Agency Standards and Facility Types

Do you have guidelines/standards that are used for plaza design?

	No.	Road	Bridge	Tunnel
Yes	31	22	9	1
No	12	4	7	1
Total	43			

Standards used in plaza design?

	No.	Road	Bridge	Tunnel
AASHTO	22	17	5	
MUTCD	22	16	6	
DOT Roadway Design Manual	22	15	7	1
ADA	17	11	6	

Type of Facility

	No.
Toll Road	27
Toll Bridge	17
Toll Tunnel	1

Which of the following apply to your facility?

	No.	Road	Bridge	Tunnel
Express ETC lanes	20	18	1	1
Dedicated ETC lanes	33	23	10	
ACM lanes	26	19	6	1
Manual lanes	44	27	16	1

Toll Road Responses - Part 1

Q0007 Distance from canopy to furthest plaza advance sign?

Distance (Miles)	Max	Min	Mode	Average
1.24	2	0.5	2	1.37
0.625				
1.2				
1				
2				
1				
1.5				
2				
1.5				
0.98				
1.5				
2				
2				
1.25				
2				
0.5				
1.5				
0.8				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.5	2	1.37
Second Sign	0.31	1.2	0.76
Third Sign	0.05	0.6	0.31

Q0008 Distance from Canopy to Second Plaza Advance Sign?

Distance (Miles)	Max	Min	Mode	Average
0.62	1.2	0.3125	1	0.76
0.3125				
0.5				
0.5				
1				
0.8				
1.14				
1				
0.75				
0.45				
1				
1				
1				
0.7				
1				
0.375				
1.2				
0.4				

Q0009 Distance from Canopy to Closest Plaza Advance Sign?

Distance (Miles)	Max	Min	Mode	Average
0.31	0.6	0.05	0.5	0.31
0				
0.05				
0.25				
0.5				
0.6				
0.114				
0.5				
0.1				
0.29				
0.5				
0.25				
0.5				
0.2				
0.5				
0.1875				
0.3				
0.2				

Toll Road Responses - Part 1

Q0010 Distance from Plaza Centerline to Toll Schedule Sign?

Distance (Feet)	Max	Min	Mode	Average
1640	7900	72	1000	1378.46
820				
variable				
1000				
n/a				
920				
200				
not posted - on ticket				
7900				
72				
1100				
n/a				
200				
300				
none				
656				
1000				
2112				

Q0011 Approaching the plaza, the toll schedule sign is located:

	No.	%
On the left roadside	1	5%
On the right roadside	10	50%
On both left and right roadsides	2	10%
Overhead, on the canopy	0	0%
None of the above	7	35%
Total	20	

Toll Road Responses - Part 1

Q0012 Length of Approach Queue Zone?

Length (ft)	Max	Min	Mode	Average
443	1320	100	600	528.7
825				
Variable				
1320				
500				
280				
450				
600				
Variable				
320				
150				
150				
1000				
600				
100				
400				
792				

Length of Queue Zone (Feet)

	Min	Max	Average
Approach	100	1320	528.7
Departure	100	1378	500.67

Q0013 Length of Departure Queue Zone?

Length (ft)	Max	Min	Mode	Average
1378	1378	100	200	500.7
660				
Variable				
1320				
250				
200				
140				
600				
Variable				
320				
150				
200				
500				
500				
100				
400				
792				

Q0014 Approach Queue Zone Taper Rate?

Length (ft)	Max	Min	Mode	Average
0.235	0.268	0.025	0.067	0.113
0.075	3.73	40.00		8.82
0.087				
0.067				
0.125				
0.025				
0.120				
0.250				
0.067				
0.083				
0.100				
0.050				
0.036				
0.268				

Taper Rates

	Min	Max	Average
Approach	1:40	1:3.73	1:8.82
Departure	1:40	1:3.4	1:8.52

Q0015 Departure Queue Zone Taper Rate?

Length (ft)	Max	Min	Mode	Average
0.294	0.294	0.025	0.067	0.117
0.075	3.40	40.00		8.52
0.059				
0.067				
0.125				
0.025				
0.140				
0.250				
0.067				
0.083				
0.100				
0.050				
0.040				
0.268				

Toll Road Responses - Part 1

Q0017 Plaza approach and departure lighting is provided by (check all that apply):

	No.	%	
High mast - multiple luminare	8	35%	
Tower - single or dual luminare	2	9%	
Std. pole and mast arm - single luminare	12	52%	
Other	1	4%	Standard pole and dual mast arms with single luminare
Total	23		

Q0018 Plaza lighting is provided by (check all that apply):

	No.	%
Canopy mounted luminare	17	57%
Booth mounted luminare	3	10%
Column/pole mounted luminare	10	33%
Total	30	

Q0019 Luminare used to light the plaza is (check all that apply)?

	No.	%	
Halogen	0	0%	
High pressure sodium	16	73%	
Metal halide	3	14%	
Mercury vapor	1	5%	
Other	2	9%	Flourescent lights
Total	22		

Q0020 Is there an administrative building parking lot adjacent to the plaza?

	No.	%
Yes	19	90%
No	2	10%
Total	21	

Q0021 Access and egress of parking lot relative to plaza lanes is?

	No.	%
Downstream on the right	12	63%
Downstream on the left	2	11%
Upstream on the right	4	21%
Upstream on the left	1	5%
Total	19	

Q0022 Distance from plaza centerline to centerline of parking lot driveway (feet)?

Distance (feet)	Max	Min	Mode	Average
197	375	75	100	199.9
164				
varies				
230				
350				
100				
160.5				
375				
150				
varies				
172				
300				
175				
100				
120				
200				
330				
75				

Toll Road Responses - Part 2 Express Lanes

Q0024 Does your mainline plaza have Express ETC lanes?

	No.	%
Yes	10	91%
No	1	9%
Total	11	

Q0027 What is the width of each Express lane (feet)?

	Min	Max	Average
9.5	9.5	14	12.0
14			
12			
12			
12.5			
12			
12			
11.8			
12			

Q0028 If you have more than one express lane, are inside pavement markings thru toll zone solid or skipped?

	No.	%
Solid	8	80%
Skipped	2	20%
Total	10	

Q0029 What is the width of left shoulder (feet)?

	Min	Max	Average
4	1	12	6.4
10			
6			
12			
4			
4			
9.8			
1			

Q0030 What is the width of right shoulder (feet)?

	Min	Max	Average
12	0	12	10.8
10			
9.2			
0			
10			
12			
11.808			
0			

Toll Road Responses - Part 2 Express Lanes

Q0031 The barrier type installed on the left is (check all that apply)?

Concrete	8
Guard rail	2
None	0
Other	1 Earth Berm

Q0032 The barrier type installed on the right is (check all that apply)?

Concrete	7
Guard rail	3
None	1
Other	0

Q0033 Relative to the mainline through lanes, express lanes:

	No.	%
Are a continuation	10	91%
Taper to the left	1	9%
Taper to the right	0	0%
Total	11	

Q0034 If a taper exists, what is the offset of the projected centerline of the mainline thru lanes to the centerline of the express lanes?

40 feet

Q0035 If a taper exists, what is the taper rate from the mainline thru lanes approaching the tolling point?

15 degrees

Q0036 If a taper exists, what is the taper rate from the tolling point departing to the mainline thru lanes?

15 degrees

Q0037 What is the posted Express lane speed limit thru plaza (mph)?

Posted Speed (mph)	Max	Min	Mode	Average
40	70	35	55	54
70				
65				
55				
45				
65				
55				
55				
35				

Q0038 What is the Express lane design speed (mph)?

Design Speed (mph)	Max	Min	Mode	Average
75	75	45	70	64
70				
70				
45				
70				
65				
50				

Toll Road Responses - Part 2 Express Lanes

Q0039 What is the cross slope of the pavement thru the plaza (percent)?

	Max	Min	Mode	Average
2	3	1.5	2	2.07
2				
1.5				
2.08				
2				
2				
2				
3				

Q0040 Transversely, the Express lanes slope to?

	No.	%
The left	0	
The right	7	
Both directions	2	

Q0041 If the Express lane slopes both directions, where is the cross slope crown located relative the outside edge of the left lane (feet)?

5 percent

Q0042 Is the tolling point located on a curved section of the roadway?

	No.	%
Yes	1	
No	9	

Q0043 If yes, what is the roadway pavement superelevation?

2 percent

Q0044 Distance from canopy to furthest express lane sign?

Distance (Miles)	Max	Min	Mode	Average
1.2	2	0.5	0.5	0.95
1				
0.8				
0.82				
0.5				
1.25				
2				
0.5				
0.5				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.5	2	0.95
Second Sign	0.25	1	0.50
Third Sign	0.01	0.5	0.21

Q0045 Distance from Canopy to Second express lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.5	1	0.25	0.5	0.50
0.5				
0.6				
0.35				
0.25				
0.7				
1				
0.375				
0.25				

Q0046 Distance from Canopy to Closest express lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.05	0.5	0.01	0.25	0.21
0.25				
0.23				
0				
0.5				
0.25				
0.01				

Toll Road Responses - Part 2 Express Lanes

Q0047 Is a lane-use signal installed above each Express lane?

	No.	%
Yes	3	27%
No	8	73%
Total	11	

Q0048 If yes, does the lane use signal consist of a red X and green down-arrow?

	No.	%
Yes	1	17%
No	5	83%
Total	6	

Q0049 What are the dimensions of the lane use signal (height X width) in inches?

42 inches

Q0050 If no, does the lane use signal consist of red and green traffic signal heads?

	No.	%
Yes	2	33%
No	4	67%
Total	6	

Q0051 If yes, what is the diameter of each signal head (in inches)?
Diameter (inches)
8
12

Q0052 Does each Express lane provide an indication of successful ETC transaction?

	No.	%
Yes	5	42%
No	7	58%
Total	12	

Q0053 If yes, the technology used is (check all that apply)?

	No.	%	
Globe light	3	50%	
Strobe light	1	17%	
LED	1	17%	
Other	1	17%	Transponder beep
Total	6		

Q0054 Is the activation of this light used by police to identify violators?

	No.	%
Yes	3	43%
No	4	57%
Total	7	

Q0055 Is this light visible to the motorists when driving under the gantry/canopy frame?

	No.	%
Yes	4	67%
No	2	33%
Total	6	

Q0056 Are violation enforcement cameras installed to capture violators?

	No.	%
Yes	10	91%
No	1	9%
Total	11	

Q0057 If yes, the cameras and associated lights are installed (check all that apply):

	No.	%
Overhead rear capture	9	60%
Overhead front capture	3	20%
Sidefire/barrier front capture	1	7%
Sidefire/barrier rear capture	0	0%
Sidefire/island front capture	0	0%
Sidefire/island rear capture	2	13%
Total	15	

Q0058 If yes, the light's effect on a driver's vision is mitigated by (check all that apply):

	No.	%	
Infrared light	4	27%	
Diffusers	2	13%	
Flash lighting	2	13%	
Low wattage light	0	0%	
Other	2	13%	(a) not mitigated, (b) angle and focus area of the camera
Total	10		

Toll Road Responses - Part 3 Dedicated Lanes

Q0060 Does your safest mainline plaza have dedicated ETC lanes?

	No.	%
Yes	15	88%
No	2	12%
Total	17	

Q0061 If no, does any of your mainline plazas include dedicated ETC lanes?

	No.	%
Yes	2	100%
No	0	0%
Total	2	

Q0063 Is there more than one dedicated lane per direction?

	No.	%
Yes	14	82%
No	3	18%
Total	17	

Q0064 If yes, how many dedicated ETC lanes are available per direction for each lane type?

Mixed Use	Trucks Only	Cars Only
0		3 or more
2		
variable		
2		
2		
1		2
2		
2		
2		
3		
3		
n/a		
4		
2		
2		

Q0065 If yes, are the dedicated ETC lanes grouped together?

	No.	%
Yes	11	79%
No	3	21%
Total	14	

If No, please describe layout?

1 ETC per direction, in the mid left approach
Cars Far Left, Mixed between Manual and Automatic
Dependent upon approach ramps at each plaza
Left center of entry and exit side of plaza
Alternate Cash/ETC

Q0066 If yes, are the dedicated ETC lanes adjacent to, and in the direction of travel, to:

	No.	%
The left of the manual lanes	11	85%
The right of the manual lanes	1	8%
The left of the ACM/ATIM lanes	1	8%
The right of the ACM/ATIM lanes	0	0%
Other	0	0%
Total	13	

Toll Road Responses - Part 3 Dedicated Lanes

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.3125	1.25	0.88
Second Sign	0.25	0.62	0.47
Third Sign	0.02	0.5	0.21

Q0067 Distance from canopy to furthest dedicated ETC lane sign?

Distance (Miles)	Max	Min	Mode	Average
1.24	1.25	0.3125	1	0.88
0.3125				
1.2				
1				
1				
1				
0.4				
0.5				
1.25				

Q0068 Distance from Canopy to Second dedicated lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.62	0.62	0.25	0.5	0.47
0.5				
0.5				
0.5				
0.52				
0.375				
0.25				

Q0069 Distance from Canopy to Closest dedicated lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.5	0.5	0.02	0.25	0.21
0.05				
0.25				
0.25				
0.18				
0.019				
0.25				

Q0070 Does a collector need to walk across a dedicated ETC lane to access a toll booth?

	No.	%
Yes	4	24%
No	13	76%
Total	17	

Q0071 If yes, crossing the dedicated lane is protected by (check all that apply)?

	No.	%	
Gate	2	29%	
Chain/rope	3	43%	
Cone/delineator	1	14%	
Nothing	0	0%	
Other	1	14%	Lights and Signs for Lane Walkers & Maintenance
Total	7		

Q0072 What is the width of each dedicated lane (feet)?

Width	Max	Min	Mode	Average
12	12	9.5	12	11.1
9.84				
9.5				
14				
12				
12				
10				
10				
12				
12				
12				
10				
11.81				
12				
12				

Toll Road Responses - Part 3 Dedicated Lanes

Q0073 For a typical dedicated lane, a toll island is located:

	No.	%
On the left side of the lane onl	0	0%
On the right side of the lane or	4	24%
On both sides of the lane	10	59%
On neither side of the lane	3	18%
Total	17	

Q0074 If a toll island is on one or both sides of the lane, what is the width of the island (feet)?

	Max	Min	Mode	Average
10.8	16	2	6	7.2
4.9				
6.5				
16.0				
6.0				
2.0				
7.0				
6.0				
8.0				
6.0				
6.0				

Q0075 If there is an adjacent toll island, installed on the island is a (check all that apply):

	No.	%	
ACM/ATIM	5	28%	
Toll Booth	10	56%	
Combination toll booth and AC	1	6%	
no equipment	1	6%	
Other	1	6%	ETC equipment
Total	18		

Q0076 If adjacent toll island exists, is a barrier installed on the toll island?

	No.	%
Yes	9	60%
No	6	40%
Total	15	

Toll Road Responses - Part 3 Dedicated Lanes

Q0077 Does the dedicated ETC lane include an island traffic signal?

	No.	%
Yes	12	71%
No	5	29%
Total	17	

Q0078 If yes, is the diameter of each signal head 8 inches?

	No.	%
Yes	10	77%
No	3	23%
Total	13	

Q0079 If no, what are the dimensions of the island traffic signal?

Inches
12
5" x 3 " globe

Q0080 If yes to Q0077, what is the height of the ITS from the island to the bottom of the signal?

Height (feet)	Max	Min	Mode	Average
4.6	9.0	3.0	5	4.8
3.3				
9				
5				
4				
3.3				
7				
3				
5				
4				

Q0081 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	10	63%
No	6	38%
Total	16	

Q0082 If no, is any indicator used to display ETC account status?

	No.	%
Yes	4	44%
No	5	56%
Total	9	

Q0083 If yes, what indicator is used to display ETC account status?

Green/ı Fluorescent flip disk	Blue light = Valid, Amber = Low Balance
Low Balance word	Patron Toll Display - Flip disc

Toll Road Responses - Part 3 Dedicated Lanes

Q0084 What is posted speed limit in the dedicated ETC lanes?

Speed (mph)	Max	Min	Mode	Average
24	70	5	24	33
24				
40				
70				
25				
65				
30				
25				
5				
15				
45				
35				
5				
55				
30				
35				

Q0085 Where is the speed limit sign located relative to the centerline of the ETC antenna ((+)X' ahead or (-)X' behind)?

+24.6
-2640
+15
+20
+2
+ 2400
+150
0
+1320

Q0086 Are impact attenuators installed in advance of the dedicated ETC lane?

	No.	%
Yes	10	59%
No	7	41%
Total	17	

Q0088 If yes, what pattern of pavement markings is installed in advance of the attenatuators (check all that apply):

	No.	%	
Tapered Chevron	3	25%	
Gore Taper	7	58%	
None	1	8%	
Other	1	8%	Object marker
Total	12		

Q0089 For dedicated ETC lanes, a beacon light is installed:

	No.	%
on each side of the lane mounted on a pedestal attached to the pavement	1	7%
on each side of the lane mounted to island concrete	8	53%
centered overhead attached to the canopy	2	13%
mounted overhead on each side of a sign	0	0%
no beacon is installed	4	27%
Total	15	

Q0090 If a beacon is installed, what is the distance from the beacon to the centerline of the ETC antenna?

Distance (feet)	Max	Min	Mode	Average
0	65	0	20	26.2
45.9				
20				
39				
6				
65				
30				
10				
20				

Q0091 If a beacon is installed but not overhead, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (feet)	Max	Min	Mode	Average
3.3	4	1.6	4	2.94
1.64				
3				
4				
2				
4				
2.67				

Q0092 What is the diameter of the beacon (in inches)?

	Max	Min	Mode	Average
8	12	8	12	11.0
12				
12				
12				
12				
12				
12				
8				

Q0093 The beacon is:

	No.	%
Steady bum	2	18%
Flashing	9	82%
Strobe	0	0%
Total	11	

Toll Road Responses - Part 3 Dedicated Lanes

Q0094 Are barrier gates installed in the dedicated ETC lanes?

		No.	%
Yes		4	25%
No		12	75%
	Total	16	

Q0095 If yes, what is the distance from the centerline of the ETC antenna to the centerline of the gate (in feet)?

15
13.12
15

Q0096 If yes, is gate closure protected by loop detection?

		No.	%
Yes		3	50%
No		3	50%
	Total	6	

Q0097 If yes, is gate closure protected by photoelectic beam detection?

		No.	%
Yes		2	40%
No		3	60%
	Total	5	

Q0098 If no (to line 97) is gate closure protected by another means?

		No.	%	
Yes		1	17%	Traffic Cone
No		5	83%	
	Total	6		

Q0099 If no (to line 94), are violation enforcement cameras installed to capture violators?

		No.	%
Yes		11	85%
No		2	15%
	Total	13	

Q0100 If yes, the cameras and associated light are installed:

		No.	%
Overhead rear capture		3	20.0%
Overhead front capture		0	0.0%
Sidefire/barrier front capture		1	6.7%
Sidefire/barrier rear capture		1	6.7%
Sidefire/island front capture		3	20.0%
Sidefire/island rear capture		7	46.7%
	Total	15	

Toll Road Responses - Part 3 Dedicated Lanes

Q0101 Is speed measured through the dedicated ETC lane(s)?

	No.	%	
Yes	10	67%	
No	5	33%	
Total	15		

Q0102 If yes, what device is used to measure speed?

	No.	%	
Loop detector	6	60%	
Light curtain	1	10%	
Overhead laser sensor	1	10%	
Radar device	1	10%	
Other	1	10%	Treadle
Total	10		

Q0103 Does the dedicated ETC lane include a travel speed display sign?

	No.	%
Yes	2	13%
No	14	88%
Total	16	

Q0104 If yes, what distance in front of the ETC antenna is the speed display sign (in feet)?

Distance	
20	Only mixed use lanes
50	

Q0105 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	2	
Fiberoptic flip disk	0	
Other	0	

Toll Road Responses - Part 3 Dedicated Lanes

Q0106 Is a lane use signal installed above each dedicated ETC Lane?

		No.	%
Yes		12	75%
No		4	25%
	Total	16	

Q0107 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		5	42%
No		7	58%
	Total	12	

Q0108 What are the dimensions of the lane use signal (height X width, in inches)?

21 x 21	Mixed Use lanes only
18	
40 x 14	
15 x 40	

Q0109 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		6	75%
No		2	25%
	Total	8	

Q0110 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)	Max	Min	Mode	Average
8	12	8	12	11.3
12				
12				
12				
12				
12				

Q0111 Is a sign mounted above each dedicated ETC lane?

		No.	%
Yes		14	88%
No		2	13%
	Total	16	

Q0112 If yes, is the sign:

		No.	%	
Fixed panel		10	71.4%	
Changeable (CMS, VMS, DMS)		2	14.3%	
Other		2	14.3%	Fixed panel, fold or rotate
	Total	14		Changeable Prism

Q0113 If changeable, what is the maximum number of lines supported?

No. lines
2
3
3

Q0114 What is the height of each character?

Height (inches)
14
10
12
10
18

Q0115 Is more than one message displayed above the dedicated ETC lane?

		No.	%
Yes		2	50%
No		2	50%
	Total	4	

Q0116 If yes, the selectable messages are the following:

Manual/Manual Pass/Pass
E-ZPass No Tickets/E-ZPass No Cash/Tickets or E-Zpass/Cash or E-Zpass/Tickets Only/Cash Only

Q0117 If overhead sign is not changeable, the permanent message displayed is the following:

"I-PASS USERS ONLY"
TollTag Only symbol
Cash/ETC program symbol

Toll Road Responses - Part 3 Dedicated Lanes

Q0118 Does the plaza handle traffic in both directions?

		No.	%	
Yes		12	75%	
No		4	25%	
	Total	16		

Q0119 If yes, does a permanent physical barrier separate each direction of flow?

		No.	%	
Yes		6	46%	
No		7	54%	
	Total	13		

Q0120 If no, is one of the following mounted overhead on the backside of the lane:

		No.	%	
Red traffic signal		5	63%	
Red X		1	13%	
Red globe		0	0%	
Other		2	25%	Permanent physical barrier
	Total	8		

Q0121 If no (to Q 119), are the dedicated ETC lanes reversible?

		No.	%	
Yes		4	40%	
No		6	60%	
	Total	10		

Q0122 If yes, reversing dedicated ETC flow involves:

		No.	%	
Shifting moveable barrier		1	14%	
Changing delineator layout		0	0%	
Shifting cones/drums		4	57%	
No physical separation changes		1	14%	
Other		1	14%	
	Total	7		

Q0125 If violation enforcement cameras are installed, the light's effect on a driver's vision is mitigated by:

		No.	%	
Infrared light		2	15%	
Diffusers		4	31%	
Flash lighting		2	15%	
Low wattage light		2	15%	
Other		3	23%	Autoiris
	Total	13		Filters if patrons complain.
				Angle and focus of the light

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0127 Does your safest mainline plaza include ACM/ATIM lanes?

	No.	%
Yes	8	57%
No	6	43%
Total	14	

Q0128 If no, do any of your mainline plazas include ACM/ATIM lanes?

	No.	%
Yes	5	71%
No	2	29%
Total	7	

Q0129 Which ACM/ATIM lanes have ETC?

	No.	%
All	6	55%
None	3	27%
Some	2	18%
Total	11	

Q0130 If yes to Q0127, do these lanes also have manual toll collection capability?

	No.	%
Yes	6	75%
No	2	25%
Total	8	

Q0131 Are the ACM/ATIM lanes grouped together?

	No.	%
Yes	5	71%
No	2	29%
Total	7	

Q0132 If yes, relative to the manual lanes, the ACM/ATIM lanes (in the direction of travel) are:

	No.	%
To the right	1	25%
To the left	3	75%
Total	4	

Q0133 What is the width of the ACM/ATIM lane (feet)?

Width (feet)	Max	Min	Mode	Average
14	14	10	10	11.00
10				
10				
10				
12				
10				

Q0134 What is the width of the toll island on which the ACM/ATIM is mounted (feet)?

Width (feet)	Max	Min	Mode	Average
6.5	6.5	4	6	5.50
6				
4				
6				
5				

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0135 Distance from canopy to furthest sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0.25	0.82	0.25	0.5	0.52
0.82				
0.5				
0.5				

Q0136 Distance from canopy to the second sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0.35	0.35	0.25		0.30
0.25				

Q0137 Distance from canopy to closest sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0.12	0.23	0.12		0.17
0.23				

Q0138 What is the distance from the centerline of the ACM/ATIM to centerline of the island traffic signal?

Distance (feet)	Max	Min	Mode	Average
50	50	5		30.80
33				
5				
30				
36				

Q0139 What is the height of the ITS from the island to the bottom of the signal?

Height (inches)	Max	Min	Mode	Average
60	198.0	36.0		85.2
36				
198				
84				
48				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.25	0.82	0.52
Second Sign	0.25	0.35	0.30
Third Sign	0.12	0.23	0.17

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0140 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	3	43%
No	4	57%
Total	7	

Q0141 If no, is any indicator used to display ETC account status?

	No.	%		
Yes	3	60%	LED states Account Balance low	Blue light = Valid, Amber = Low Balance/Invalid
No	2	40%	Amber lens-low balance	Patron Toll Display - Flip disc
Total	5			

Q0143 Is the diameter of each signal head 8 inches?

	No.	%
Yes	2	29%
No	5	71%
Total	7	

Q0144 If no, what are the dimensions of the island traffic signal?

Inches
3 X 5 Globes
24 x 24
4

Q0145 Does the ITS include an operative audible alarm/light for indicating a toll violation?

	No.	%
Yes	4	57%
No	3	43%
Total	7	

Q0146 If yes, how many decibels is the alarm?

Decibels
35
85
50

Q0147 What is posted speed limit in the ACM/ATIM lanes?

Speed (mph) **	**Max**	**Min**	**Mode**	**Average**
35	35	0	0	9
0				
0				
0				
10				
Not posted				

** all except 10 mph indicated vehicles must stop.

Q0148 Where is the speed limit sign located relative to the centerline of the ACM/ATIM ((+)X' ahead or (-)X' behind)?

Feet ((+) ahead, (-) behind)
1320
-8
-15

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0149 Are impact attenuators installed in advance of the ACM/ATIM island?

		No.	%
Yes		4	100%
No		0	0%
	Total	4	

Q0150 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		2	50%
Gore Taper		1	25%
None		0	0%
Other		1	25%
	Total	4	

Q0151 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		0	0%
Gore Taper		1	33%
None		2	67%
Other		0	0%
	Total	3	

Q0152 Is a beacon installed in the front of the toll island?

		No.	%
Yes		3	43%
No		4	57%
	Total	7	

Q0153 If yes, what is the distance from the beacon to the centerline of the ACM/ATIM?

Distance (feet)
20
30

Q0154 If yes to Q0152, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (feet)	Max	Min	Mode	Average
4	4.5	4.0		4.19
4.5				
4.1				

Q0155 What is the diameter of the beacon (in inches)?

Diameter (inches)	Max	Min	Mode	Average
12	12	6	12	10.0
6				
12				

Q0156 The beacon is:

		No.	%
Steady burn		0	0%
Flashing		3	100%
Strobe		0	0%
	Total	3	

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0157 Please select the ACM/ATIM cabinet feature that best describes your installation:

	No.	%
ACM/ATIM with fare display	5	71%
ACM/ATIM without fare display	2	29%
Dual height ACM/ATIM with fare display	0	0%
Dual height ACM/ATIM without fare display	0	0%
Total	7	

Q0158 Is a patron toll display installed on the ACM/ATIM island?

	No.	%
Yes	4	57%
No	3	43%
Total	7	

Q0159 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the PTD (feet)?

Distance (feet)

0
30
5

Q0160 If yes to Q0158, what is the height of the PTD from the island or pavement to the bottom of the PTD?

Height (inches)	Max	Min	Mode	Average
52	60	52		55.7
55				
60				

Q0161 What are the dimensions of the PTD (height X width, in inches)?

12 x 12
16 x 16
6 x 6

Q0162 What technology is used for the PTD?

	No.	%
Flourescent flip disk	1	20%
LED	3	60%
Fiberoptic flip disk	0	0%
Other	1	20%
Total	5	

Q0163 Is a barrier gate installed on the toll island?

	No.	%
Yes	3	43%
No	4	57%
Total	7	

Q0164 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the gate (in feet)?

Distance (feet)

13
10
10

Q0165 Is gate closure protected by loop detection?

	No.	%
Yes	3	100%
No	0	0%
Total	3	

Q0166 Is gate closure protected by photoelectic beam detection?

	No.	%
Yes	2	67%
No	1	33%
Total	3	

Q0167 If no (to Q0166) is gate closure protected by another means?

	No.	%	
Yes	1	50%	Sensor bar attached to gate
No	1	50%	
Total	2		

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0168 If no (to Q0163), are violation enforcement cameras installed to capture violators?

	No.	%
Yes	3	60%
No	2	40%
Total	5	

Q0169 If yes, the cameras and associated light are installed:

	No.	%
Overhead rear capture	2	40.0%
Overhead front capture	0	0.0%
Sidefire/barrier front capture	0	0.0%
Sidefire/barrier rear capture	1	20.0%
Sidefire/island front capture	0	0.0%
Sidefire/island rear capture	2	40.0%
Total	5	

Q0170 If yes, the light's effect on a driver's vision is mitigated by:

	No.	%	
Infrared light	2	67%	
Diffusers	0	0%	
Flash lighting	0	0%	
Low wattage light	0	0%	
Other	1	33%	Not mitigated unless patron complains
Total	3		

Q0171 Does the toll island include a stop sign?

	No.	%
Yes	4	50%
No	4	50%
Total	8	

Q0172 If yes, what is the distance from the centerline of the ACM/ATIM to the stop sign (in feet)?

Distance (feet)
-8
+15
+22
0

Q0173 Is speed measured through the ACM/ATIM lane(s)?

	No.	%
Yes	2	29%
No	5	71%
Total	7	

Q0174 If yes, what device is used to measure speed?

	No.	%	
Loop detector	1	33%	
Light curtain	1	33%	
Overhead laser sensor	0	0%	
Radar device	0	0%	
Other	1	33%	Treadle
Total	3		

Q0175 Does the ACM/ATIM lane include a travel speed display sign?

	No.	%
Yes	0	0%
No	7	100%
Total	7	

Q0176 If yes, what is the distance of the speed display sign from the centerline of the ACM/ATIM (in feet)?

Distance

Q0177 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	1	

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0178 Is a lane use signal installed above each ACM/ATIM Lane?

		No.	%
Yes		4	80%
No		1	20%
	Total	5	

Q0179 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		3	75%
No		1	25%
	Total	4	

Q0180 If yes, what are the dimensions of the lane use signal (in inches) ?

Dimensions (inches)
21 x 21
24 x 24
30 x 30

Q0181 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0182 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)

Q0183 Is a sign mounted above each ACM/ATIM lane?

		No.	%
Yes		3	60%
No		2	40%
	Total	5	

Q0184 If yes, is the sign:

		No.	%
Fixed panel		3	75.0%
Changeable (CMS, VMS, DMS)		1	25.0%
Other		0	0.0%
	Total	4	

Q0185 If changeable, what is the maximum number of lines supported?

No. lines
2

Q0186 What is the height of each character?

Height (inches)
12
12

Q0187 For CMS, is more than one message displayed above the ACM/ATIM lane?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0188 If yes, the selectable messages are the following:

Amount of toll

Q0189 If overhead sign is not changeable, the permanent message displayed is the following:

AUTOMATIC COINS OR I-PASS
Cars Only/15 cents
EXACT COINS
Exact Change Cars

Toll Road Responses - Part 4 ACM/ATIM Lanes

Q0190 Does the plaza handle traffic in both directions?

	No.	%	
Yes	3	50%	
No	3	50%	
Total	6		

Q0191 If yes, does a permanent physical barrier separate each direction of flow?

	No.	%	
Yes	1	33%	
No	2	67%	
Total	3		

Q0192 If no, is one of the following mounted overhead on the backside of the lane:

	No.	%	
Red traffic signal	1	33%	
Red X	1	33%	
Red globe	0	0%	
Other	1	33%	Permanent physical barrier
Total	3		

Q0193 If no (to Q 191), are the ACM/ATIM lanes reversible?

	No.	%	
Yes	4	40%	
No	6	60%	
Total	10		

Q0194 If yes, reversing ACM/ATIM flow involves:

	No.	%	
Shifting moveable barrier	0	0%	
Changing delineator layout	0	0%	
Shifting cones/drums	1	50%	
No physical separation changes	0	0%	
Other	1	50%	
Total	2		

Toll Road Responses - Part 5 Manual Lanes

Q0196 Does your safest mainline plaza include manual lanes?

	No.	%
Yes	16	100%
No	0	0%
Total	16	

Q0197 If no, do any of your mainline plazas include manual lanes?

	No.	%
Yes	3	100%
No	0	0%
Total	3	

Q0198 If yes, are the manual lanes grouped together?

	No.	%
Yes	15	94%
No	1	6%
Total	16	

Describe layout

side by side
3 lanes side by side
11 manned, 9 on right, 2 left of ETC
6 adjacent lanes
Grouped on the right.
Lanes 2 to 4, starting right to left
ALL LANES ARE MANUAL
Manual lanes to the left of express lanes
manual lanes split by dedicated E-ZPass lanes
SIDE BY SIDE
To the right ETC & exact change lanes

Q0199 What is the width of the manual lanes (feet)?

Width (feet)	Max	Min	Mode	Average
9.8	15	9.8	10	10.68
9.84				
9.5				
14				
12				
5 @ 10.5 and 1 @ 14				
10				
10				
10 to 12				
11				
10				
12				
10				
12 and 15				
12 to 14				
10				

Q0200 What is the width of the toll island on which a toll booth is mounted (feet)?

Width (feet)	Max	Min	Mode	Average
5.7	9.25	4.92	6	6.53
4.92				
6.5				
8				
6				
6				
6.5				
6				
7				
9.25				
7.66				
6				
8				
6				
6				
5				

Toll Road Responses - Part 5 Manual Lanes

Q0201 Distance from canopy to furthest sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
1.24	2	0.50	0.5	1.01
0.5				
1.2				
1				
0.8				
0.82				
2				
0.5				
0.5				
2				
0.496				
1.25				
0.8				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.50	2	1.01
Second Sign	0.25	1	0.60
Third Sign	0.05	0.50	0.25

Q0202 Distance from canopy to the second sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
0.62	1	0.25	1	0.60
1				
0.5				
0.5				
0.6				
0.35				
1				
1				
0.372				
0.25				
0.4				

Q0203 Distance from canopy to closest sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
0.31	0.50	0.05		0.25
0.05				
0.25				
0.38				
0.12				
0.5				
0.19				
0.25				
0.2				

Toll Road Responses - Part 5 Manual Lanes

Q0204 What is the distance from the centerline of the toll booth to centerline of the island traffic signal?

Distance (feet)	Max	Min	Mode	Average
21.3	36	0		15.33
0				
25				
15				
3				
6				
20				
10				
30				
12				
6				
15				
36				

Q0205 What is the height of the ITS from the island to the bottom of the signal?

Height (inches)	Max	Min	Mode	Average
55	198.0	5.0		62.0
5				
60				
198				
40				
48				
84				
36				
48				
60				
48				

Q0206 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	8	53%
No	7	47%
Total	15	

Q0207 If no, is any indicator used to display ETC account status?

	No.	%
Yes	4	57%
No	3	43%
Total	7	

Q0208 If yes, describe what indicator is used to display account status:

Green/red lights

Fluorescent flip disk

Low balance word

No ITS on Manual Lanes; Blue Light = Valid Transaction; Yellow Light = Invalid Transaction. Amber message "low balance"

Green - "Thank You"; Yellow -MaybeAccount problem; Red - Immediate tag problem

Patron Toll display - Flip disc

Amber Light not used in manual lane

Patron Toll Display

Amber lens-low balance

Q0209 Is the diameter of each signal head 8 inches?

	No.	%
Yes	9	64%
No	5	36%
Total	14	

Q0210 If no, what are the dimensions of the island traffic signal?

Inches
12
18 x 18
24 x 24
12
4

Q0211 Does the ITS include an operative audible alarm/light for indicating a toll violation?

	No.	%
Yes	10	67%
No	5	33%
Total	15	

Q0212 If yes, how many decibels is the alarm?

Decibels
110
94
35
100
90
85

Toll Road Responses - Part 5 Manual Lanes

Q0213 Is there a speed limit sign posted on the toll island?

	No.	%
Yes	4	25%
No	12	75%
Total	16	

Q0214 If yes, where is the speed limit sign located relative to the centerline of the toll booth ((+)X' ahead or (-)X' behind)?

Feet ((+) ahead, (-) behind)

+10
+15
+75

Q0215 Are impact attenuators installed in advance of the toll booth island?

	No.	%
Yes	14	88%
No	2	13%
Total	16	

Q0216 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

	No.	%
Tapered Chevron	5	36%
Gore Taper	8	57%
None	1	7%
Other	0	0%
Total	14	

Q0217 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

	No.	%
Tapered Chevron	1	20%
Gore Taper	0	0%
None	3	60%
Other	1	20%
Total	5	

Q0218 Is a beacon installed in the front of the toll island?

	No.	%
Yes	12	75%
No	4	25%
Total	16	

Q0219 If yes, what is the distance from the beacon to the centerline of the toll booth?

Distance (feet)	Max	Min	Mode	Average
28.5	125	9		49.5
12				
45				
75				
20				
90				
23				
125				
54				
18				
95				
9				

Q0220 If yes to Q0218, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (feet)	Max	Min	Mode	Average
2	4.33	1.6		3.19
1.64				
4				
3				
3.75				
4.33				
4.08				
2.75				

Q0221 What is the diameter of the beacon (in inches)?

Diameter (inches)	Max	Min	Mode	Average
8	12	6	12	10.4
12				
12				
8				
12				
12				
12				
6				
8				
12				
12				

Q0222 The beacon is:

	No.	%
Steady burn	2	17%
Flashing	10	83%
Strobe	0	0%
Total	12	

Toll Road Responses - Part 5 Manual Lanes

Q0223 Is a patron toll display installed on the tollbooth island?

	No.	%
Yes	12	75%
No	4	25%
Total	16	

Q0224 If yes, what is the distance from the centerline of the tollbooth door to the centerline of the PTD (feet)?

Distance (feet)	Max	Min	Mode	Average
13.1	40	0		12.65
0				
15				
12				
4				
30				
10				
40				
3				
12				
0				

Q0225 If yes, what is the height of the PTD from the island or pavement to the bottom of the PTD?

Height (inches)	Max	Min	Mode	Average
88.6	88.6	39		55.72
39.36				
72				
51				
54				
40				
39				
55				
54				
60				
60				

Q0226 What are the dimensions of the PTD (height X width, in inches)?

Dimensions (inches)
20.5 x 5.9
3.9
30 x 30
4.5 x 14
12 x 12
36
2.25 x 10.5
16 x 16
10
6 x 6

Q0227 What technology is used for the PTD?

	No.	%
Flourescent flip disk	5	38%
LED	7	54%
Fiberoptic flip disk	0	0%
Other	1	8%
Total	13	

Q0228 Is a barrier gate installed on the toll island?

	No.	%
Yes	7	44%
No	9	56%
Total	16	

Q0229 If yes, what is the distance from the centerline of the toll booth door to the centerline of the gate (in feet)?

Distance (feet)
6.5
9.84
35
20
13
10

Q0230 Is gate closure protected by loop detection?

	No.	%
Yes	4	67%
No	2	33%
Total	6	

Q0231 Is gate closure protected by photoelectic beam detection?

	No.	%
Yes	2	33%
No	4	67%
Total	6	

Q0232 Gate closure protected by another means?

	No.
Manual switch	1

Toll Road Responses - Part 5 Manual Lanes

Q0233 If no (to Q0228), are violation enforcement cameras installed to capture violators?

	No.	%
Yes	7	47%
No	8	53%
Total	15	

Q0234 If yes, the cameras and associated light are installed:

	No.	%
Overhead rear capture	1	11.1%
Overhead front capture	1	11.1%
Sidefire/barrier front capture	1	11.1%
Sidefire/barrier rear capture	2	22.2%
Sidefire/island front capture	0	0.0%
Sidefire/island rear capture	4	44.4%
Total	9	

Q0235 If yes, the light's effect on a driver's vision is mitigated by:

	No.	%	
Infrared light	1	14%	
Diffusers	2	29%	
Flash lighting	0	0%	
Low wattage light	1	14%	
Other	3	43%	Autoiris
Total	7		Angle, focus area of the light

Q0236 Does the toll island include a stop sign?

	No.	%
Yes	9	56%
No	7	44%
Total	16	

Q0237 If yes, what is the distance from the centerline of the of the toll booth door to the stop sign (in feet)?

Distance (feet)
+19.7
-12
+10
+4
+3
+20
+5
0

Q0238 Is speed measured through the manual lane(s)?

	No.	%
Yes	4	25%
No	12	75%
Total	16	

Q0239 If yes, what device is used to measure speed?

	No.	%	
Loop detector	2	50%	
Light curtain	0	0%	
Overhead laser sensor	0	0%	
Radar device	0	0%	
Other	2	50%	Treadle
Total	4		

Q0240 Does the manual lane include a travel speed display sign?

	No.	%
Yes	0	0%
No	15	100%
Total	15	

Q0241 If yes, what is the distance of the speed display sign from the centerline of the toll booth door (in feet)?

Distance

Q0242 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	1	

Toll Road Responses - Part 5 Manual Lanes

Q0243 Is a lane use signal installed above each manual Lane?

		No.	%
Yes		7	100%
No		0	0%
	Total	7	

Q0244 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		8	50%
No		8	50%
	Total	16	

Q0245 If yes, what are the dimensions of the lane use signal (in inches) ?

Dimensions (inches)
18
12 diameter
21 X 21
24 x 24
18
30 x 30

Q0246 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		8	89%
No		1	11%
	Total	9	

Q0247 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)
8
12
12
12
8
12
12

Q0248 Is a sign mounted above each manual lane?

		No.	%
Yes		10	63%
No		6	38%
	Total	16	

Q0249 If yes, is the sign:

		No.	%
Fixed panel		8	80.0%
Changeable (CMS, VMS, DMS)		2	20.0%
Other		0	0.0%
	Total	10	

Q0250 If changeable, what is the maximum number of lines supported?

No. lines
2

Q0251 What is the height of each character?

Height (inches)
13.65
10
12
10

Q0252 For CMS, is more than one message displayed above the manual lane?

		No.	%
Yes		2	50%
No		2	50%
	Total	4	

Q0253 If yes, the selectable messages are the following:

Manual/PASE;
Manual PASE

Q0254 If overhead sign is not changeable, the permanent message displayed is the following:

Indicates "Passenger cars" or "Any Vehicle"
"MANUAL/CASH OR I-PASS"
Toll Booth Icon Sign
CHANGE RECEIPTS
Cash and below ETC program symbol
Exact Change Cars

Toll Road Responses - Part 5 Manual Lanes

Q0255 Does the plaza handle traffic in both directions?

	No.	%	
Yes	12	75%	
No	4	25%	
Total	16		

Q0256 If yes, does a permanent physical barrier separate each direction of flow?

	No.	%	
Yes	6	46%	
No	7	54%	
Total	13		

Q0257 If no, is one of the following mounted overhead on the backside of the lane:

	No.	%	
Red traffic signal	4	50%	
Red X	2	25%	
Red globe	0	0%	
Other	2	25%	Permanent physical barrier
Total	8		

Q0258 If no (to Q 256), are the manual lanes reversible?

	No.	%	
Yes	5	50%	
No	5	50%	
Total	10		

Q0259 If yes, reversing manual lane flow involves:

	No.	%	
Shifting moveable barrier	0	0%	
Changing delineator layout	0	0%	
Shifting cones/drums	5	71%	
No physical separation changes	0	0%	
Other	2	29%	
Total	7		

Q0260 Are oversized and special permit vehicles allowed to travel through your plazas?

	No.	%	
Yes	15	94%	
No	1	6%	
Total	16		

Q0261 If yes, what type of toll lane is used to allow these vehicles to pass through the toll plaza?

	No.	%	
Bypass lane circumventing plaza	1	5%	
Far right lane that includes lane width plus sho	13	62%	
Wide dedicated ETC lane	2	10%	
Express lane plus shoulder	2	10%	
Other	3	14%	one single lane for both directions
Total	21		Far right lane 12 to 14 feet wide.
			overwidth toll lanes within the plaza

Q0262 Oversized and special permit vehicles are directed to these lanes by:

	No.	%	
Roadside signs	6	33%	
Overhead guide signs	2	11%	
Canopy lane use sign	1	6%	
Permit instructions	6	33%	
Other	3	17%	plaza personnel
Total	18		SGNS DIRECT VEHS TO SHLDR, INTERCOM TO PLZ.
			pulling onto shoulder and asking toll collector

Toll Road Responses - Part 5 Manual Lanes

Q0263 Are branch toll lanes forming segregated "mini" plazas used at your toll plaza?

	No.	%
Yes	1	7%
No	14	93%
Total	15	

Q0264 If yes to Q0263, where are the branch lane plazas located relative to the main toll plaza?

	No.	%
Before the main plaza	0	0%
After the main plaza	1	100%
Total	1	

Q0265 If the "mini" plazas are located after the main toll plaza, what is the measured average speed of vehicles using the branch toll lanes and those using the main plaza when the two merge?

Speed (mph)
37.26

Q0266 If the "mini" plaza is located before the main toll plaza, what type of signing is used to distinguish the branch toll lanes and main plaza?

	No.	%
Overhead permanent static advance sign with	0	0%
Overhead lane use sign at entry location only	0	0%
Overhead advance signing (CMS/permanent s	0	0%
Roadside advance and lane use permanent st	0	0%
Other	1	100%
Total	1	

Q0268 Which manual lanes have ETC?

	No.	%
All	2	
Some	1	
None	0	

Toll Bridge Responses - Part 1

Q0007 Distance from canopy to furthest plaza advance sign?

Distance (Miles)	Max	Min	Mode	Average
1.9	4	0.5	1	1.83
0.5				
4				
2.8				
0.8				
1				
1.5				
1				
3				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.5	4	1.83
Second Sign	0.00	2.6	1.00
Third Sign	0	2.4	0.70

Q0008 Distance from Canopy to Second Plaza Advance Sign?

Distance (Miles)	Max	Min	Mode	Average
0	2.6	0	1	1.00
1				
2.6				
0.4				
1				
0.75				
0.25				
2				

Q0009 Distance from Canopy to Closest Plaza Advance Sign?

Distance (Miles)	Max	Min	Mode	Average
0	2.4	0	0.5	0.70
0.3				
0.5				
2.4				
0.5				
0.5				

Q0010 Distance from Plaza Centerline to Toll Schedule Sign?

Distance (Feet)	Max	Min	Mode	Average
3	1500	0	0	201.63
60				
0				
0	Sign mounted on canopy			
25				
25				
1500				
0				

Q0011 Approaching the plaza, the toll schedule sign is located:

	No.	%
On the left roadside	0	0%
On the right roadside	4	40%
On both left and right roadsides	2	20%
Overhead, on the canopy	2	20%
None of the above	2	20%
Total	10	

Toll Bridge Responses - Part 1

Q0012 Length of Approach Queue Zone?

Length (ft)	Max	Min	Mode	Average
142	1000	142	300	333.6
1000				
300				
450				
160				
150				
300				
250				
250				

Length of Queue Zone (Feet)

	Min	Max	Average
Approach	142	1000	333.6
Departure	75	1000	313.89

Q0013 Length of Departure Queue Zone?

Length (ft)	Max	Min	Mode	Average
400	1000	75	100	313.9
1000				
500				
100				
250				
75				
100				
150				
250				

Q0014 Approach Queue Zone Taper Rate?

Length (ft)	Max	Min	Mode	Average
0.125	0.500	0.058		0.194
0.1	2.00	17.39		5.15
0.133				
0.058				
0.25				
0.5				

Taper Rates

	Min	Max	Average
Approach	1:17.39	1:2	1:5.15
Departure	1:10.9	1:4	1:6.1

Q0015 Departure Queue Zone Taper Rate?

Length (ft)	Max	Min	Mode	Average
0.125	0.250	0.092	0.250	0.164
0.1	4.00	10.87		6.10
0.167				
0.092				
0.25				
0.25				

Q0017 Plaza approach and departure lighting is provided by (check all that apply):

	No.	%	
High mast - multiple luminare	4	31%	
Tower - single or dual luminare	2	15%	
Std. pole and mast arm - single luminare	6	46%	
Other	1	8%	Aimed halogen lights
Total	13		

Q0018 Plaza lighting is provided by (check all that apply):

	No.	%
Canopy mounted luminare	10	56%
Booth mounted luminare	2	11%
Column/pole mounted luminare	6	33%
Total	18	

Q0019 Luminare used to light the plaza is (check all that apply)?

	No.	%	
Halogen	1	9%	
High pressure sodium	7	64%	
Metal halide	1	9%	
Mercury vapor	2	18%	
Other	0	0%	Flourescent canopy mounted
Total	11		

Q0020 Is there an administrative building parking lot adjacent to the plaza?

	No.	%
Yes	9	90%
No	1	10%
Total	10	

Q0021 Access and egress of parking lot relative to plaza lanes is?

	No.	%
Downstream on the right	5	56%
Downstream on the left	1	11%
Upstream on the right	2	22%
Upstream on the left	1	11%
Total	9	

Q0022 Distance from plaza centerline to centerline of parking lot driveway (feet)?

Distance (feet)	Max	Min	Mode	Average
200	300	40	200	183.1
300				
300				
100				
40				
250				
200				
75				

Toll Bridge Responses - Part 2 Express Lanes

Q0024 Does your bridge plaza have Express ETC lanes?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0026 How many express lanes do you have?

2

Q0027 What is the width of each Express lane (feet)?

	Min	Max	Average
14	14	14	14.0

Q0028 If you have more than one express lane, are inside pavement markings thru toll zone solid or skipped?

	No.	%
Solid	1	100%
Skipped	0	0%
Total	1	

Q0029 What is the width of left shoulder (feet)?

	Min	Max	Average
3	3	3	3.0

Q0030 What is the width of right shoulder (feet)?

	Min	Max	Average
3	3	3	3.0

Q0031 The barrier type installed on the left is (check all that apply)?

	No.
Concrete	1
Guard rail	0
None	0
Other	0

Q0032 The barrier type installed on the right is (check all that apply)?

	No.
Concrete	0
Guard rail	0
None	1
Other	0

Toll Bridge Responses - Part 2 Express Lanes

Q0033 Relative to the mainline through lanes, express lanes:

	No.	%
Are a continuation	1	100%
Taper to the left	0	0%
Taper to the right	0	0%
Total	1	

Q0034 If a taper exists, what is the offset of the projected centerline of the mainline thru lanes to the centerline of the express lanes?

Q0035 If a taper exists, what is the taper rate from the mainline thru lanes approaching the tolling point?

Q0036 If a taper exists, what is the taper rate from the tolling point departing to the mainline thru lanes?

Q0037 What is the posted Express lane speed limit thru plaza (mph)?

Posted Speed (mph)	Max	Min	Mode	Average
not posted				

Q0038 What is the Express lane design speed (mph)?

Design Speed (mph)	Max	Min	Mode	Average
NA				

Q0039 What is the cross slope of the pavement thru the plaza (percent)?

	Max	Min	Mode	Average
NA				

Q0040 Transversely, the Express lanes slope to?

	No.	%
The left	0	
The right	1	
Both directions	0	

Q0041 If the Express lane slopes both directions, where is the cross slope crown located relative the outside edge of the left lane (feet)?

NA

Q0042 Is the tolling point located on a curved section of the roadway?

	No.	%
Yes	0	
No	1	

Q0043 If yes, what is the roadway pavement superelevation?

NA

Q0044 Distance from canopy to furthest express lane sign?

Distance (Miles)	Max	Min	Mode	Average
0.2	0.2	0.2		0.20

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.2	0.2	0.20
Second Sign	0.00	0	0.00
Third Sign	0.00	0	0.00

Q0045 Distance from Canopy to Second express lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0				

Q0046 Distance from Canopy to Closest express lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0				

Toll Bridge Responses - Part 2 Express Lanes

Q0047 Is a lane-use signal installed above each Express lane?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0048 If yes, does the lane use signal consist of a red X and green down-arrow?

	No.	%
Yes	0	0%
No	1	100%
Total	1	

Q0049 What are the dimensions of the lane use signal (height X width) in inches?

NA

Q0050 If no, does the lane use signal consist of red and green traffic signal heads?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0051 If yes, what is the diameter of each signal head (in inches)?
Diameter (inches)
15

Q0052 Does each Express lane provide an indication of successful ETC transaction?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0053 If yes, the technology used is (check all that apply)?

	No.	%
Globe light	1	50%
Strobe light	0	0%
LED	1	50%
Other	0	0%
Total	2	

Q0054 Is the activation of this light used by police to identify violators?

	No.	%
Yes	0	0%
No	1	100%
Total	1	

Q0055 Is this light visible to the motorists when driving under the gantry/canopy frame?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0056 Are violation enforcement cameras installed to capture violators?

	No.	%
Yes	0	0%
No	1	100%
Total	1	

Q0057 If yes, the cameras and associated lights are installed (check all that apply):

	No.	%
Overhead rear capture	0	
Overhead front capture	0	
Sidefire/barrier front capture	0	
Sidefire/barrier rear capture	0	
Sidefire/island front capture	0	
Sidefire/island rear capture	0	
Total	0	

Q0058 If yes, the light's effect on a driver's vision is mitigated by (check all that apply):

	No.	%
Infrared light	0	
Diffusers	0	
Flash lighting	0	
Low wattage light	0	
Other	0	
Total	0	

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0060 Does your bridge plaza have dedicated ETC lanes?

	No.	%
Yes	7	100%
No	0	0%
Total	7	

Q0063 Is there more than one dedicated lane per direction?

	No.	%
Yes	6	86%
No	1	14%
Total	7	

Q0064 If yes, how many dedicated ETC lanes are available per direction for each lane type?

Mixed Use	Trucks Only	Cars Only
0		1 late nights, 4 during a.m. peak
4		
All ETC Lanes		
2 - 5		
2		0

Q0065 If yes, are the dedicated ETC lanes grouped together? **If No, please describe layout?**

	No.	%
Yes	5	100%
No	0	0%
Total	5	

Q0066 If yes, are the dedicated ETC lanes adjacent to, and in the direction of travel, to:

	No.	%
The left of the manual lanes	5	83%
The right of the manual lanes	1	17%
The left of the ACM/ATIM lanes	0	0%
The right of the ACM/ATIM lanes	0	0%
Other	0	0%
Total	6	

Q0067 Distance from canopy to furthest dedicated ETC lane sign?

Distance (Miles)	Max	Min	Mode	Average
1.9	1.9	0.5		0.97
0.76				
0.7				
0.5				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.5	1.9	0.97
Second Sign	0.50	0.57	0.54
Third Sign	0.38	0.38	0.38

Q0068 Distance from Canopy to Second dedicated lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.57	0.57	0.5		0.54
0.5				

Q0069 Distance from Canopy to Closest dedicated lane Sign?

Distance (Miles)	Max	Min	Mode	Average
0.38	0.38	0.38		0.38

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0070 Does a collector need to walk across a dedicated ETC lane to access a toll booth?

		No.	%	
Yes		5	83%	
No		1	17%	
	Total	6		

Q0071 If yes, crossing the dedicated lane is protected by (check all that apply)?

		No.	%	
Gate		1	20%	
Chain/rope		0	0%	
Cone/delineator		1	20%	
Nothing		2	40%	
Other		1	20%	Pedestrian crossing
	Total	5		

Q0072 What is the width of each dedicated lane (feet)?

Width	**Max**	**Min**	**Mode**	**Average**
9.5	14	9.5	10	10.7
9.6				
10				
11				
10				
14				

Q0073 For a typical dedicated lane, a toll island is located:

		No.	%
On the left side of the lane only		1	17%
On the right side of the lane only		0	0%
On both sides of the lane		5	83%
On neither side of the lane		0	0%
	Total	6	

Q0074 If a toll island is on one or both sides of the lane, what is the width of the island (feet)?

	Max	**Min**	**Mode**	**Average**
4	12	3		6.3
3				
7.5				
5				
12				

Q0075 If there is an adjacent toll island, installed on the island is a (check all that apply):

	No.	%	
ACM/ATIM	0	0%	
Toll Booth	5	71%	
Combination toll booth and ACM/ATIM	1	14%	
no equipment	0	0%	
Other	1	14%	ETC equipment
Total	7		

Q0076 If adjacent toll island exists, is a barrier installed on the toll island?

	No.	%
Yes	3	50%
No	3	50%
Total	6	

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0077 Does the dedicated ETC lane include an island traffic signal?

	No.	%
Yes	6	86%
No	1	14%
Total	7	

Q0078 If yes, is the diameter of each signal head 8 inches?

	No.	%
Yes	6	100%
No	0	0%
Total	6	

Q0079 If no, what are the dimensions of the island traffic signal?

Inches

Q0080 If yes to Q0077, what is the height of the ITS from the island to the bottom of the signal?

Height (feet)	Max	Min	Mode	Average
10	10.0	3.0		6.1
6				
6.67				
3				
5				

Q0081 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	5	71%
No	2	29%
Total	7	

Q0082 If no, is any indicator used to display ETC account status?

	No.	%
Yes	1	50%
No	1	50%
Total	2	

Q0083 If yes, what indicator is used to display ETC account status?

BOTTOM LIGHT OF SIGNAL
EZ Pass Paid/Account Low/Call EZ Pass
Call EZPass low balance
Green for good, yellow for low balance

Q0084 What is posted speed limit in the dedicated ETC lanes?

Speed (mph)	Max	Min	Mode	Average
5	31	5	5	14.2
31	35mph toll plz, 5mph toll lane(non-enforcable)			
15	1 -Stop			
5	1 -Not posted			
15				

Q0085 Where is the speed limit sign located relative to the centerline of the ETC antenna ((+)X' ahead or (-)X' behind)?

+12
Ahead
On the canopy
+ 7
0

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0086 Are impact attenuators installed in advance of the dedicated ETC lane?

		No.	%
Yes		3	43%
No		4	57%
	Total	7	

Q0088 If yes, what pattern of pavement markings is installed in advance of the attenatuators (check all that apply):

		No.	%
Tapered Chevron		1	33%
Gore Taper		2	67%
None		0	0%
Other		0	0%
	Total	3	

Q0089 For dedicated ETC lanes, a beacon light is installed:

		No.	%
on each side of the lane mounted on a pedestal attached to the pavement		0	0%
on each side of the lane mounted to island concrete		2	29%
centered overhead attached to the canopy		2	29%
mounted overhead on each side of a sign		0	0%
no beacon is installed		3	43%
	Total	7	

Q0090 If a beacon is installed, what is the distance from the beacon to the centerline of the ETC antenna?

Distance (feet)	Max	Min	Mode	Average
16	16	10		12.7
12				
10				

Q0091 If a beacon is installed but not overhead, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (feet)	Max	Min	Mode	Average
4.5	4.5	4.5		4.50

Q0092 What is the diameter of the beacon (in inches)?

Diameter (inches)	Max	Min	Mode	Average
12	12	8	8	9.0
8				
8				
8				

Q0093 The beacon is:

		No.	%
Steady burn		1	25%
Flashing		3	75%
Strobe		0	0%
	Total	4	

Q0094 Are barrier gates installed in the dedicated ETC lanes?

		No.	%
Yes		3	50%
No		3	50%
	Total	6	

Q0095 If yes, what is the distance from the centerline of the ETC antenna to the centerline of the gate (in feet)?

Distance (feet)
43
7
30

Q0096 If yes, is gate closure protected by loop detection?

		No.	%
Yes		3	100%
No		0	0%
	Total	3	

Q0097 If yes, is gate closure protected by photoelectic beam detection?

		No.	%
Yes		3	100%
No		0	0%
	Total	3	

Q0098 If no (to line 97) is gate closure protected by another means?

		No.	%	
Yes		0	0%	Light Curtain also
No		4	100%	
	Total	4		

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0099 If no (to line 94), are violation enforcement cameras installed to capture violators?

		No.	%
Yes		3	60%
No		2	40%
	Total	5	

Q0100 If yes, the cameras and associated light are installed:

		No.	%
Overhead rear capture		0	0.0%
Overhead front capture		0	0.0%
Sidefire/barrier front capture		0	0.0%
Sidefire/barrier rear capture		1	25.0%
Sidefire/island front capture		1	25.0%
Sidefire/island rear capture		2	50.0%
	Total	4	

Q0101 Is speed measured through the dedicated ETC lane(s)?

		No.	%
Yes		2	40%
No		3	60%
	Total	5	

Q0102 If yes, what device is used to measure speed?

		No.	%	
Loop detector		0	0%	
Light curtain		1	50%	
Overhead laser sensor		0	0%	
Radar device		0	0%	
Other		1	50%	loop detector and overhead laser sensor
	Total	2		

Q0103 Does the dedicated ETC lane include a travel speed display sign?

		No.	%
Yes		0	0%
No		7	100%
	Total	7	

Q0104 If yes, what distance in front of the ETC antenna is the speed display sign (in feet)?

Distance

Q0105 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	0	

Q0106 Is a lane use signal installed above each dedicated ETC Lane?

		No.	%
Yes		7	100%
No		0	0%
	Total	7	

Q0107 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		1	14%
No		6	86%
	Total	7	

Q0108 What are the dimensions of the lane use signal (height X width, in inches)?

8 inch circle amber light
18 x 18

Q0109 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		6	100%
No		0	0%
	Total	6	

Q0110 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)	**Max**	**Min**	**Mode**	**Average**
12	15	8	12	11.8
8				
12				
12				
12				
15				

Toll Bridge Responses - Part 3 Dedicated Lanes

Q0111 Is a sign mounted above each dedicated ETC lane?

	No.	%
Yes	6	86%
No	1	14%
Total	7	

Q0112 If yes, is the sign:

	No.	%	
Fixed panel	3	42.9%	
Changeable (CMS, VMS, DMS)	2	28.6%	
Other	2	28.6%	Fixed Hinged
Total	7		Dambauch Prism Sign

Q0113 If changeable, what is the maximum number of lines supported?
No. lines
2
2
3
2

Q0114 What is the height of each character?
Height (inches)
12
10
17
10 to 12
12

Q0115 For a CMS/VMS, is more than one message displayed above the dedicated ETC lane?

	No.	%
Yes	2	50%
No	2	50%
Total	4	

Q0116 If yes, the selectable messages are the following:

"Fastrak Only" or "Fastrak/Cash"
"EZ Pass Only" or "Cash-EZ Pass"

Q0117 If overhead sign is not changeable, the permanent message displayed is the following:

"Fastrak" logo w/Fastrak legend beneath logo visible only when ETC in effect.
MACPASS ONLY
EZPass

Q0118 Does the plaza handle traffic in both directions?

	No.	%
Yes	5	71%
No	2	29%
Total	7	

Q0119 If yes, does a permanent physical barrier separate each direction of flow?

	No.	%
Yes	2	33%
No	4	67%
Total	6	

Q0120 If no, is one of the following mounted overhead on the backside of the lane:

	No.	%	
Red traffic signal	3	60%	
Red X	0	0%	
Red globe	0	0%	
Other	2	40%	WRONG WAY SIGN
Total	5		CLOSED sign

Q0121 If no (to Q 119), are the dedicated ETC lanes reversible?

	No.	%
Yes	2	40%
No	3	60%
Total	5	

Q0122 If yes, reversing dedicated ETC flow involves:

	No.	%
Shifting moveable barrier	0	0%
Changing delineator layout	1	50%
Shifting cones/drums	1	50%
No physical separation changes	0	0%
Other	0	0%
Total	2	

Q0125 If violation enforcement cameras are installed, the light's effect on a driver's vision is mitigated by:

	No.	%	
Infrared light	1	33%	
Diffusers	0	0%	
Flash lighting	0	0%	
Low wattage light	0	0%	
Other	2	67%	use of baffles
Total	3		500 watt light bulb

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0127 Does your bridge plaza include ACM/ATIM lanes?

	No.	%
Yes	3	100%
No	0	0%
Total	3	

Q0129 Which ACM/ATIM lanes have ETC?

	No.	%
All	2	67%
None	1	33%
Some	0	0%
Total	3	

Q0130 If yes to Q0127, do these lanes also have manual toll collection capability?

	No.	%
Yes	1	50%
No	1	50%
Total	2	

Q0131 Are the ACM/ATIM lanes grouped together?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0132 If yes, relative to the manual lanes, the ACM/ATIM lanes (in the direction of travel) are:

	No.	%
To the right	1	100%
To the left	0	0%
Total	1	

Q0133 What is the width of the ACM/ATIM lane (feet)?

Width (feet)	Max	Min	Mode	Average
12	12	12		12.00

Q0134 What is the width of the toll island on which the ACM/ATIM is mounted (feet)?

Width (feet)	Max	Min	Mode	Average
4	4	4		4.00

Q0135 Distance from canopy to furthest sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0	0	0		0.00

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0	0	0.00
Second Sign	0.00	0	0.00
Third Sign	0.00	0.00	0.00

Q0136 Distance from canopy to the second sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0	0	0		0.00

Q0137 Distance from canopy to closest sign providing ACM/ATIM location?

Distance (Miles)	Max	Min	Mode	Average
0.00	0.00	0.00		0.00

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0138 What is the distance from the centerline of the ACM/ATIM to centerline of the island traffic signal?

Distance (feet)	Max	Min	Mode	Average
8	8	8		

Q0139 What is the height of the ITS from the island to the bottom of the signal?

Height (inches)	Max	Min	Mode	Average

Q0140 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0141 If no, is any indicator used to display ETC account status?

	No.	%
Yes	0	
No	0	
Total	0	

Q0143 Is the diameter of each signal head 8 inches?

	No.	%
Yes	1	50%
No	1	50%
Total	2	

Q0144 If no, what are the dimensions of the island traffic signal?

Inches

Q0145 Does the ITS include an operative audible alarm/light for indicating a toll violation?

	No.	%
Yes	0	
No	0	
Total	0	

Q0146 If yes, how many decibels is the alarm?

Decibels

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0147 What is posted speed limit in the ACM/ATIM lanes?

Speed (mph) **	Max	Min	Mode	Average

Q0148 Where is the speed limit sign located relative to the centerline of the ACM/ATIM ((+)X' ahead or (-)X' behind)?
Feet ((+) ahead, (-) behind)

Q0149 Are impact attenuators installed in advance of the ACM/ATIM island?

		No.	%
Yes		1	100%
No		0	0%
	Total	1	

Q0150 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		1	100%
Gore Taper		0	0%
None		0	0%
Other		0	0%
	Total	1	

Q0151 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

		No.	%
Tapered Chevron		0	0%
Gore Taper		0	0%
None		1	100%
Other		0	0%
	Total	1	

Q0152 Is a beacon installed in the front of the toll island?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0153 If yes, what is the distance from the beacon to the centerline of the ACM/ATIM?
Distance (feet)

Q0154 If yes to Q0152, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (feet)	Max	Min	Mode	Average

Q0155 What is the diameter of the beacon (in inches)?

Diameter (inches)	Max	Min	Mode	Average
12	12	12		12.0

Q0156 The beacon is:

		No.	%
Steady burn		0	0%
Flashing		1	100%
Strobe		0	0%
	Total	1	

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0157 Please select the ACM/ATIM cabinet feature that best describes your installation:

	No.	%
ACM/ATIM with fare display	0	0%
ACM/ATIM without fare display	1	100%
Dual height ACM/ATIM with fare displa	0	0%
Dual height ACM/ATIM without fare dis	0	0%
Total	1	

Q0158 Is a patron toll display installed on the ACM/ATIM island?

	No.	%
Yes	0	0%
No	1	100%
Total	1	

Q0159 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the PTD (feet)?
Distance (feet)

Q0160 If yes to Q0158, what is the height of the PTD from the island or pavement to the bottom of the PTD?

Height (inches)	Max	Min	Mode	Average
	0	0		

Q0161 What are the dimensions of the PTD (height X width, in inches)?

Q0162 What technology is used for the PTD?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	0	
Total	0	

Q0163 Is a barrier gate installed on the toll island?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0164 If yes, what is the distance from the centerline of the ACM/ATIM to the centerline of the gate (in feet)?
Distance (feet)
12

Q0165 Is gate closure protected by loop detection?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0166 Is gate closure protected by photoelectic beam detection?

	No.	%
Yes	1	100%
No	0	0%
Total	1	

Q0167 If no (to Q0166) is gate closure protected by another means?

	No.	%
Yes	0	
No	0	
Total	0	

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0168 If no (to Q0163), are violation enforcement cameras installed to capture violators?

	No.	%
Yes	0	
No	0	
Total	0	

Q0169 If yes, the cameras and associated light are installed:

	No.	%
Overhead rear capture	0	0.0%
Overhead front capture	1	50.0%
Sidefire/barrier front capture	1	50.0%
Sidefire/barrier rear capture	0	0.0%
Sidefire/island front capture	0	0.0%
Sidefire/island rear capture	0	0.0%
Total	2	

Q0170 If yes, the light's effect on a driver's vision is mitigated by:

	No.	%
Infrared light	0	
Diffusers	0	
Flash lighting	0	
Low wattage light	0	
Other	0	
Total	0	

Q0171 Does the toll island include a stop sign?

	No.	%
Yes	1	50%
No	1	50%
Total	2	

Q0172 If yes, what is the distance from the centerline of the ACM/ATIM to the stop sign (in feet)?

Distance (feet)

+8

Q0173 Is speed measured through the ACM/ATIM lane(s)?

	No.	%
Yes	0	0%
No	1	100%
Total	1	

Q0174 If yes, what device is used to measure speed?

	No.	%
Loop detector	0	
Light curtain	0	
Overhead laser sensor	0	
Radar device	0	
Other	0	
Total	0	

Q0175 Does the ACM/ATIM lane include a travel speed display sign?

	No.	%
Yes	0	0%
No	2	100%
Total	2	

Q0176 If yes, what is the distance of the speed display sign from the centerline of the ACM/ATIM (in feet)?

Distance

Q0177 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	0	

Toll Bridge Responses - Part 4 ACM/ATIM Lanes

Q0178 Is a lane use signal installed above each ACM/ATIM Lane?

		No.	%
Yes		2	100%
No		0	0%
	Total	2	

Q0179 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		0	0%
No		2	100%
	Total	2	

Q0180 If yes, what are the dimensions of the lane use signal (in inches) ?

Dimensions (inches)

Q0181 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0182 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)
12

Q0183 Is a sign mounted above each ACM/ATIM lane?

		No.	%
Yes		2	100%
No		0	0%
	Total	2	

Q0184 If yes, is the sign:

		No.	%
Fixed panel		1	50.0%
Changeable (CMS, VMS, DMS)		1	50.0%
Other		0	0.0%
	Total	2	

Q0185 If changeable, what is the maximum number of lines supported?

No. lines
3

Q0186 What is the height of each character?

Height (inches)
12

Q0187 For CMS, is more than one message displayed above the ACM/ATIM lane?

		No.	%
Yes		0	0%
No		1	100%
	Total	1	

Q0188 If yes, the selectable messages are the following:

Q0189 If overhead sign is not changeable, the permanent message displayed is the following:

Q0190 Does the plaza handle traffic in both directions?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0191 If yes, does a permanent physical barrier separate each direction of flow?

		No.	%
Yes		0	0%
No		1	100%
	Total	1	

Q0192 If no, is one of the following mounted overhead on the backside of the lane:

		No.	%
Red traffic signal		1	100%
Red X		0	0%
Red globe		0	0%
Other		0	0%
	Total	1	

Q0193 If no (to Q 191), are the ACM/ATIM lanes reversible?

		No.	%
Yes		1	50%
No		1	50%
	Total	2	

Q0194 If yes, reversing ACM/ATIM flow involves:

		No.	%
Shifting moveable barrier		0	0%
Changing delineator layout		0	0%
Shifting cones/drums		1	100%
No physical separation changes		0	0%
Other		0	0%
	Total	1	

Toll Bridge Responses - Part 5 Manual Lanes

Q0196 Does your bridge plaza include manual lanes?

	No.	%
Yes	10	100%
No	0	0%
Total	10	

Q0198 If yes, are the manual lanes grouped together?

	No.	%
Yes	8	89%
No	1	11%
Total	9	

Describe layout

Rightmost lanes
4 manual lanes to the right of 4 EZPass lane
Changeable configuration
2 Manual Collection Lanes, 2 ETC Lanes
4 lanes under one canopy

Q0199 What is the width of the manual lanes (feet)?

Width (feet)	Max	Min	Mode	Average
11.5	12	10	12	11.41
10.17				
12				
10				
11				
12				
12				
12				
12				

Q0200 What is the width of the toll island on which a toll booth is mounted (feet)?

Width (feet)	Max	Min	Mode	Average
4	10	4	4	5.61
5				
4				
5				
7.5				
4				
5				
6				
10				

Q0201 Distance from canopy to furthest sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
0.76	3	0.75		1.50
0.75				
3				

Distance to Advance Sign (Miles)

	Min	Max	Average
Furthest Sign	0.75	3	1.50
Second Sign	0.50	2	1.02
Third Sign	0.30	0.50	0.39

Q0202 Distance from canopy to the second sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
0.57	2	0.5		1.02
0.5				
2				

Q0203 Distance from canopy to closest sign providing manual lane location?

Distance (Miles)	Max	Min	Mode	Average
0.38	0.5	0.3		0.39
0.3				
0.5				

Q0204 What is the distance from the centerline of the toll booth to centerline of the island traffic signal?

Distance (feet)	Max	Min	Mode	Average
7.67	30	0		11.45
3				
20				
30				
8				
0				

Toll Bridge Responses - Part 5 Manual Lanes

Q0205 What is the height of the ITS from the island to the bottom of the signal?

Height (inches)	Max	Min	Mode	Average
168	168.0	4.0		49.2
12				
30				
45				
4				
36				

Q0206 Does the ITS include a amber/yellow light for ETC account status?

	No.	%
Yes	5	56%
No	4	44%
Total	9	

Q0207 If no, is any indicator used to display ETC account st	No.	%	Q0208 If yes, describe what indicator is used to display account status:
Yes	1	25%	Pay toll, $5 paid, "emp," "acct. low," "invalid fastrak," "call fastrak"
No	3	75%	Low account printed on amber lens
			EZ Pass Paid/ Account Low/
Total	4		Call EZ Pass
			Green for good account, yellow for low balance

Q0209 Is the diameter of each signal head 8 inches?

	No.	%
Yes	7	78%
No	2	22%
Total	9	

Q0210 If no, what are the dimensions of the island traffic signal?

Inches
12

Q0211 Does the ITS include an operative audible alarm/light for indicating a toll violation?

	No.	%
Yes	2	25%
No	6	75%
Total	8	

Q0212 If yes, how many decibels is the alarm?

Decibels
96
Not sure

Toll Bridge Responses - Part 5 Manual Lanes

Q0213 Is there a speed limit sign posted on the toll island?

	No.	%
Yes	2	20%
No	8	80%
Total	10	

Q0214 If yes, where is the speed limit sign located relative to the centerline of the toll booth ((+)X' ahead or (-)X' behind)?

Feet ((+) ahead, (-) behind)

+4'

Top of Toll Booth +2'

Q0215 Are impact attenuators installed in advance of the toll booth island?

	No.	%
Yes	4	40%
No	6	60%
Total	10	

Q0216 If yes, what pattern of pavement markings is installed in advance of the island (check all that apply):

	No.	%
Tapered Chevron	2	50%
Gore Taper	2	50%
None	0	0%
Other	0	0%
Total	4	

Q0217 If no, what pattern of pavement markings is installed in advance of the island (check all that apply):

	No.	%
Tapered Chevron	0	0%
Gore Taper	2	40%
None	3	60%
Other	0	0%
Total	5	

Q0218 Is a beacon installed in the front of the toll island?

	No.	%
Yes	5	56%
No	4	44%
Total	9	

Q0219 If yes, what is the distance from the beacon to the centerline of the toll booth?

Distance (feet)	Max	Min	Mode	Average
8	20	4.5		11.9
4.5				
15				
20				

Q0220 If yes to Q0218, what is the height of the beacon from the island or pavement to the bottom of the beacon (in feet)?

Distance (inches)		Max	Min	Mode	Average
	54	54.00	8.0		36.67
	8				
	48				

Q0221 What is the diameter of the beacon (in inches)?

Diameter (inches)	Max	Min	Mode	Average
6 x 8	8	6	8	7.3
8				
8				
6				

Q0222 The beacon is:

	No.	%
Steady burn	1	20%
Flashing	4	80%
Strobe	0	0%

Total	5	

Q0223 Is a patron toll display installed on the tollbooth island?

	No.	%
Yes	6	75%
No	2	25%
Total	8	

Q0224 If yes, what is the distance from the centerline of the tollbooth door to the centerline of the PTD (feet)?

Distance (feet)	Max	Min	Mode	Average
8	30	4		10.00
4				
4				
30				
8				
6				

Q0225 If yes, what is the height of the PTD from the island or pavement to the bottom of the PTD?

Height (inches)	Max	Min	Mode	Average
48	50	45	48	47.83
48				
48				
45				
50				
48				

Q0226 What are the dimensions of the PTD (height X width, in inches)?

Dimensions (inches)
8 x 24
4 x 12
8 x 12
16 x 22
24 x 14
10 x 36

Q0227 What technology is used for the PTD?

	No.	%
Flourescent flip disk	3	50%
LED	3	50%
Fiberoptic flip disk	0	0%
Other	0	0%
Total	6	

Toll Bridge Responses - Part 5 Manual Lanes

Q0228 Is a barrier gate installed on the toll island?

		No.	%
Yes		6	67%
No		3	33%
	Total	9	

Q0229 If yes, what is the distance from the centerline of the toll booth door to the centerline of the gate (in feet)?

Distance (feet)
43
15
28
12
14

Q0230 Is gate closure protected by loop detection?

		No.	%
Yes		4	80%
No		1	20%
	Total	5	

Q0231 Is gate closure protected by photoelectic beam detection?

		No.	%
Yes		3	75%
No		1	25%
	Total	4	

Q0232 Gate closure protected by another means?

	No.
Light curtain	1

Q0233 If no (to Q0228), are violation enforcement cameras installed to capture violators?

		No.	%
Yes		3	50%
No		3	50%
	Total	6	

Q0234 If yes, the cameras and associated light are installed:

		No.	%
Overhead rear capture		0	0.0%
Overhead front capture		0	0.0%
Sidefire/barrier front capture		0	0.0%
Sidefire/barrier rear capture		1	33.3%
Sidefire/island front capture		1	33.3%
Sidefire/island rear capture		1	33.3%
	Total	3	

Q0235 If yes, the light's effect on a driver's vision is mitigated by:

		No.	%	
Infrared light		1	50%	
Diffusers		0	0%	
Flash lighting		0	0%	
Low wattage light		0	0%	
Other		1	50%	Baffles
	Total	2		

Toll Bridge Responses - Part 5 Manual Lanes

Q0236 Does the toll island include a stop sign?

		No.	%
Yes		4	44%
No		5	56%
	Total	9	

Q0237 If yes, what is the distance from the centerline of the of the toll booth door to the stop sign (in feet)?

Distance (feet)
+43
+16
+5
+3

Q0238 Is speed measured through the manual lane(s)?

		No.	%
Yes		2	25%
No		6	75%
	Total	8	

Q0239 If yes, what device is used to measure speed?

		No.	%
Loop detector		1	33%
Light curtain		1	33%
Overhead laser sensor		1	33%
Radar device		0	0%
Other		0	0%
	Total	3	

Q0240 Does the manual lane include a travel speed display sign?

		No.	%
Yes		1	13%
No		7	88%
	Total	8	

Q0241 If yes, what is the distance of the speed display sign from the centerline of the toll booth door (in feet)?

Distance

Q0242 If yes, what technology is used for the speed display sign?

	No.	%
Flourescent flip disk	0	
LED	0	
Fiberoptic flip disk	0	
Other	0	

Q0243 Is a lane use signal installed above each manual Lane?

		No.	%
Yes		9	100%
No		0	0%
	Total	9	

Q0244 If yes, does the lane use signal consist of a red "X" and a green arrow?

		No.	%
Yes		2	22%
No		7	78%
	Total	9	

Q0245 If yes, what are the dimensions of the lane use signal (in inches) ?

Dimensions (inches)
18 x 18
14 x 24

Q0246 If no, does the lane use signal consist of red and green traffic signal heads?

		No.	%
Yes		7	100%
No		0	0%
	Total	7	

Q0247 If yes, what is the diameter of each signal head (in inches) ?

Diameter (inches)
12
8
6
12
12
8
10
15

Toll Bridge Responses - Part 5 Manual Lanes

Q0248 Is a sign mounted above each manual lane?

		No.	%
Yes		7	78%
No		2	22%
	Total	9	

Q0249 If yes, is the sign:

		No.	%	
Fixed panel		3	42.9%	
Changeable (CMS, VMS, DMS)		2	28.6%	
Other		2	28.6%	Hinged changes on fixed signs
	Total	7		Dambauch Prism Sign

Q0250 If changeable, what is the maximum number of lines supported?

No. lines
2
3
1

Q0251 What is the height of each character?

Height (inches)
12
10
17
10 - 12
12

Q0252 For CMS, is more than one message displayed above the manual lane?

		No.	%
Yes		2	50%
No		2	50%
	Total	4	

Q0253 If yes, the selectable messages are the following:

"Fastrak Only" or "Fastrak/Cash"
1. FULL SERVICE - E-ZPASS 2. FULL SERVICE - ONLY 3. CLOSED
CASH- EZ PASS/EZ PASS ONLY

Q0254 If overhead sign is not changeable, the permanent message displayed is the following:

"Wide Lanes" sign mounted above toll booth between two rightmost lanes.
Stop Pay Toll
CASH

Toll Bridge Responses - Part 5 Manual Lanes

Q0255 Does the plaza handle traffic in both directions?

		No.	%	
Yes		6	67%	
No		3	33%	
	Total	9		

Q0256 If yes, does a permanent physical barrier separate each direction of flow?

		No.	%	
Yes		2	29%	
No		5	71%	
	Total	7		

Q0257 If no, is one of the following mounted overhead on the backside of the lane:

		No.	%	
Red traffic signal		4	67%	
Red X		1	17%	
Red globe		0	0%	
Other		1	17%	Wrong Way sign
	Total	6		

Q0258 If no (to Q 256), are the manual lanes reversible?

		No.	%	
Yes		2	29%	
No		5	71%	
	Total	7		

Q0259 If yes, reversing manual lane flow involves:

		No.	%	
Shifting moveable barrier		0	0%	
Changing delineator layout		1	33%	
Shifting cones/drums		2	67%	
No physical separation changes		0	0%	
Other		0	0%	
	Total	3		

Q0260 Are oversized and special permit vehicles allowed to travel through your plazas?

		No.	%	
Yes		10	100%	
No		0	0%	
	Total	10		

Q0261 If yes, what type of toll lane is used to allow these vehicles to pass through the toll plaza?

		No.	%	
Bypass lane circumventing plaza		4	31%	
Far right lane that includes lane width pl		8	62%	
Wide dedicated ETC lane		0	0%	
Express lane plus shoulder		0	0%	
Other		1	8%	16' wide lane with no canopy
	Total	13		

Q0262 Oversized and special permit vehicles are directed to these lanes by:

		No.	%	
Roadside signs		4	31%	
Overhead guide signs		1	8%	
Canopy lane use sign		2	15%	
Permit instructions		3	23%	
Other		3	23%	Must call in advance. Break in northbound traffic.
	Total	13		Supervisor contact and collector contact

Toll Bridge Responses - Part 5 Manual Lanes

Q0263 Are branch toll lanes forming segregated "mini" plazas used at your toll plaza?

		No.	%
Yes		0	0%
No		10	100%
	Total	10	

Q0264 If yes to Q0263, where are the branch lane plazas located relative to the main toll plaza?

		No.	%
Before the main plaza		0	
After the main plaza		0	
	Total	0	

Q0265 If the "mini" plazas are located after the main toll plaza, what is the measured average speed of vehicles using the branch toll lanes and those using the main plaza when the two merge?

Speed (mph)
37.26

Q0266 If the "mini" plaza is located before the main toll plaza, what type of signing is used to distinguish the branch toll lanes and main plaza?

		No.	%
Overhead permanent static advance sign with overhead lane use sign at entry		0	
Overhead lane use sign at entry location only		0	
Overhead advance signing (CMS/permanent sign) only		0	
Roadside advance and lane use permanent static sign		0	
Other		0	
	Total	0	

Q0268 Which manual lanes have ETC?

	No.	%
All	2	
Some	0	
None	1	

APPENDIX B

APPENDIX B

TRAFFIC CONTROL STRATEGIES AT TOLL BOOTH PLAZAS

EXPERT PANEL WORKSHOP SUMMARY

AUGUST 17-18, 2004

BACKGROUND

Wilbur Smith Associates (WSA) organized an Expert Panel workshop on August 17th and 18th, 2004 in Lisle, Illinois. The workshop is one element of the Federal Highway Administration (FHWA) sponsored study on **"Traffic Control Strategies at Toll Booth Plazas".** The WSA Team for this project also includes Post, Buckley, Schuh & Jernigan (PBSJ) and Terry Geohegan, a subconsultant to WSA.

The objectives of the study are to review current practices and develop guidelines for designing traffic control devices for toll plazas that inform drivers which lanes to use for specific methods of payment, to reduce speed variance, and minimize lane changing. The goal is to have a consistent strategy to accommodate the mix of non-stop traffic and stop-and-go traffic in retrofitted conventional toll facilities. This requires identifying and handling the potential points of conflict at toll plazas so that safety and operations are enhanced, better efficiency and economy of design are achieved, and motorist recognition and comprehension are improved. A major objective of the study is to create consensus agreement among the toll agencies to ensure use and ideally, adoption of the design guidelines developed by this project.

Prior to the workshop, the WSA Team developed a detailed survey addressing design considerations for toll plazas, specifically focused on the placement, design and usage of traffic control devices. The survey also addressed geometric design and operational aspects of toll plazas as they relate to traffic control strategies employed by agencies. Express Electronic Toll Collection (ETC), Dedicated ETC, Automatic Coin Machine/Automatic Ticket Issuing Machine, and Manual Toll Collection toll lanes were addressed in detail by the survey. The survey was designed for completion on-line, hosted on the Wilbur Smith Associates corporate website, and toll agencies were notified of the survey in early May 2004. Toll agencies were provided instructions on how to complete the survey, as well as a detailed "Terms and Definitions" document.

The WSA Team analyzed the survey and distributed the results to all participants and observers prior to the workshop. The survey results and summaries of selected design elements were provided at the workshop. These materials, together with a brief program, were used as the basis for the Expert Panel workshop discussions. The WSA Team also prepared a presentation on toll plaza signing, hardware and equipment to illustrate the variety of usage and serve as a basis for initiating the discussion.

The Expert Panel consisted of seven panel members, four team members, and observers from FHWA and the International Bridge, Tunnel and Turnpike Association (IBTTA). Panel members were selected to represent a wide range of experience and toll facilities. The size of the panel was intentionally limited to a small number to ensure in-depth discussion of the issues outlined in the program. The workshop was moderated by Glenn Havinoviski, the WSA Project Director. The participants in the workshop are listed below.

Panel Participants:
Terry Geohegan (Bader & Geohegan)
David McDonald (Hanson Prof. Svcs.)
Greg LeFrois (HNTB)
Michael Davis (PBSJ and Florida Turnpike)
Sam Wolfe (Indiana Toll Road)
Kerry Ferrier (Ohio Turnpike Commission)
Roxane Mukai (Maryland Transportation Authority)

Team Participants:
Glenn Havinoviski (WSA)
Raghu Kowshik (WSA)
George Scheuring (WSA)
Phil Miller (PBSJ)

Observers:
Linda Brown (FHWA)
Neil Gray (IBTTA)

The workshop was divided into four sessions, each focused on a particular topic area. The following session topics were selected prior to the panel discussion based on anticipated impact on toll plaza operations and safety:

Session A: Signing, Pavement Markings & Channelization
Session B: Lane Configuration/Plaza Operations and Safety
Session C: Geometric Design, Attenuators, Safety Barriers
Session D: Manual, ACM/ATIM, ETC Equipment Implementation

WORKSHOP SUMMARY

Introduction and Study Objectives

The workshop began with introduction of the participants, project team members and observers. Following the introductions, WSA's Project Director, Glenn Havinoviski, described the overall objectives of the study. Linda Brown, FHWA's Project Manager, then described the intended outcome of the study. Ms. Brown indicated that FHWA would like to develop a section of the Manual on Uniform Traffic Control Devices (MUTCD) addressing traffic control devices for toll facilities by 2005-6. She indicated that the best practices and guidelines for toll plaza traffic control device design and implementation developed in this study would provide input into the new section of the MUTCD.

Several panel members asked whether the intent of the study was to provide traffic control device guidelines for new toll facilities, or whether the guidelines would also apply to existing facilities. The WSA Team responded that while the design guidelines would be most easily adopted when designing new facilities, they could also be adopted by toll agencies when retrofitting or rebuilding existing toll plazas. The WSA Team further explained that toll agencies would not be expected to immediately conform to the best practices and design guidelines produced by this study. Rather, the product of this study would serve as a guide for agencies to voluntarily adopt when they rebuild or retrofit existing facilities. In addition, WSA indicated that when a section is added to the MUTCD addressing toll facility traffic control devices, there would typically be a period within which agencies would be required to comply. It was generally agreed that the design guidelines produced by this study would focus on new installations, although agencies should strongly consider using the recommendations as guidelines when retrofitting existing facilities.

The WSA Team then presented a compilation of photographs from various agencies to illustrate the variety of signing and other traffic control devices used at toll plazas.

Session B: Plaza Operation and Lane Configuration

It was suggested that the panel begin by discussing plaza lane configuration and layout (Session B) before discussing plaza signing, pavement markings and channelization (Session A). The WSA Team explained that plaza operation/lane configuration issues (such as whether similar payment types are grouped or vary based on traffic demand) often dictate the types and placement of traffic control devices. Grouping lanes by payment type, and the location of these lanes at the plaza (e.g. grouping non-stop ETC lanes on the left of the plaza) allows advance signing to orient drivers further away from the plaza. However, several agencies vary the number of lanes of a specific payment type, their location at the plaza, and vehicle types permitted to accommodate varying traffic demands. The types and location of traffic control devices to address these situations will differ from those used when lane configurations do not vary.

The panel then took up the issue of grouping of lanes and the placement of non-stop ETC lanes at the plaza. Discussion first focused on Express ETC lane plazas. Some panelists asked what constitutes an Express lane plaza. The WSA Team responded that these lanes are typically nonstop ETC-only lanes that operate at highway speed, are separated from the conventional toll plaza lanes by a barrier (such as concrete wall or earth berm), and the plaza canopy does not usually extend over these lanes. The panel indicated that there is a need to standardize the terminology used to describe various plaza types. Discussion focused on the location of Express ETC lanes, with the consensus being that as a general guideline Express ETC lanes be placed on the left side of mainline plazas, when constructing new plazas. It was recognized that this recommendation might not apply to retrofitted plazas. Some panelists also indicated that the placement of Express lanes on the left permits the area separating the Express and conventional lanes to be used as a staging area for enforcement vehicles. One panelist indicated that trucks are not permitted in their Express lanes. This restriction exists due to the need to perform security checks on trucks prior to entering bridges and tunnels. Another panelist indicated that at ramp plazas, Express ETC lanes are provided on the right of exact-change coin machine lanes. This lane configuration protects toll plaza workers who have to service the coin machines, by keeping the workers away from the non-stop traffic.

Dedicated ETC lane configuration was discussed next. The panel concluded that, as a general guideline, it is recommended to keep faster moving traffic to the left of the plaza, consistent with typical highway speeds, and to minimize the amount of weaving needed to access plaza lanes. In addition, the panel recommended that grouping lanes of similar payment types together is preferable. Some panelists noted that the location of the plaza administration building also influences the placement of lanes. The recommendation of the panel was to provide a lane configuration that minimizes the number of lanes of live traffic that toll plaza workers have to cross to reach toll booths, or to service equipment.

The discussion then turned to how best to provide advance warning to drivers of toll plaza lane configuration, what types of payment are accepted, whether the lanes are open or closed, distance to the toll plaza, speed restrictions through toll plaza lanes and toll rates. Panelists also noted that the information provide to drivers could also include the use of tokens/tickets, and whether ETC is accepted in every lane etc. It was noted that some agencies have not installed ETC in every lane due to funding limitations. The general recommendation was that it was desirable to provide ETC in all lanes.

Session A: Signing, Pavement Markings and Channelization

Toll Plaza Sign Placement and Message Content

The discussion of toll plaza signing began with a general discussion of the factors that should be considered. The WSA Team listed the basic elements that influence motorist understanding of signing including: visible elements, such as the lane types and plaza; invisible elements, such as payment types accepted, toll amounts; and, user elements, such as driver familiarity. The WSA Team stressed that the driver population consists of commuters or frequent users of the facility who do not need to always read the sign, and tourists or infrequent users, who need significantly more information. The WSA Team suggested that there is a need to provide signing for the unfamiliar traveler, since even though these drivers represent a small proportion of users, they can have a significant impact on toll plaza operation and safety by making last-minute lane changes/choices or by stopping in non-stop lanes.

The MUTCD requirements for Freeway Guide Sign spacing was raised as a possible starting point for the discussion of toll plaza advance sign placement. The MUTCD recommends that advance guide signing for major/intermediate freeway interchanges be provided at distances of 2, 1 and ½ mile from the interchange. The advance sign at the 2-mile distance is optional, but recommended. For minor interchanges, the MUTCD requires advance signs at 1 and ½ mile distances from the interchange. In addition, the MUTCD recommends placing signs overhead when three or more mainline lanes exist in one direction, or at complex interchanges.

One panelist said that Florida provides a minimum spacing of 1000 ft between toll plaza advance signs. The discussion then turned to whether it is necessary to provide information on plaza lane configuration on all signs in advance of the toll plaza, or whether it is better to separate plaza lane configuration signing from toll plaza advance signing. Examples of toll plaza advance signing from Florida and Illinois were reviewed to determine the advantages and disadvantages of combining advance toll plaza signing with lane configuration signing. Combining lane configuration signing with toll plaza advance signing reduces the number of signs needed, and reduces sign clutter. However, this results in drivers having to absorb more information from each sign. The panel agreed that the first advance toll plaza sign should only provide information on the toll plaza ahead. The panel also concluded there was a need to separately address advance signing for Express lane toll plazas since signing needs to be provided for the divergence of express lanes from the mainline lanes that feed the conventional toll plaza. The panel discussion led to the following signing schemes for Express ETC lane and Conventional toll plazas.

Table 1 summarizes the panel's recommended signing scheme for Express lane toll plazas. The panel recommended providing toll plaza advance signs at distances of approximately 2, 1 and ½ mile from the point at which the Express lanes and mainline lanes feeding the Conventional plaza diverge.

In addition, the panel recommended that the advance sign 2 miles from the divergence point be placed overhead. However, this sign could be installed as a ground-mounted sign on the side of the road. The 1 and ½ mile signs were recommended to be placed overhead. The distances of 2, 1 and ½ mile were chosen as desirable locations, although it was recognized that local conditions would dictate the specific placement distance of these signs from the divergence point. The panel recommended that providing toll rate information on the 2, 1 and ½ mile signs should be optional.

At the gore (i.e. the divergence point of Express and mainline lanes), it was recommended that overhead signs be placed that indicate the payment methods accepted in the Express vs. Conventional lanes. In addition, vehicle restriction information and lane use signs should be provided at the divergence point.

The panel recommended that, provided sufficient distance exists from the gore to the plaza canopy, a sign be placed a minimum of 800 feet from the canopy that provides payment methods accepted at various plaza lanes. This distance was selected to ensure that the sign did not obstruct plaza canopy signing. The panel also determined that providing lane-speed restrictions could be provided as an option on this sign.

Recommended information to be provided on canopy signing included: payment types accepted (ETC, exact coins, tokens, tickets, or change), vehicle restrictions, lane use messages (open/closed), and lane-speed restrictions.

Detailed toll rate information was only recommended to be provided on a toll schedule sign, placed close to the plaza. The optional toll rate information on the 2, 1 and ½ mile signs should only be provided as brief messages, with detailed toll rate information provided on the separate toll schedule sign.

Table 2 summarizes the panel's recommended signing scheme for Conventional toll plazas. These toll plazas may include dedicated ETC lanes, although these lanes are not fully separated from the cash toll lanes. Vehicles using the dedicated ETC lanes approach the plaza together with cash-paying vehicles, and merge with the cash traffic after going through the plaza.

For the Conventional plaza, distances are measured from the plaza canopy. The panel recommended providing toll plaza advance signs at distances of approximately 2, 1 and ½ mile from the plaza. On the 2 mile sign, the panel recommended including messages warning of the toll plaza ahead, with optional toll rate information. Overhead sign placement was preferred, although ground-mounted roadside signs could be used instead.

TABLE 1
EXPRESS ETC LANE TOLL PLAZA
RECOMMENDED SIGNING SCHEME

Sign Location	Message/Sign Content					
	Toll Plaza Ahead	Payment/Lane Type	Toll Rate	Vehicle Restrictions	Lane-Use	Speed Limits/Restrictions
Distance From Gore						
2 Miles	X Overhead placement preferred.		Optional			
1 Mile	X Overhead		Optional			
1/2 Mile	X Overhead		Optional			
Gore		X		X	X	
At least 800 ft from Canopy		Optional				Optional
Canopy (Over Cash lanes)		X		X	X	X
Toll Schedule (typically 100-200 feet from plaza)			X			

TABLE 2
CONVENTIONAL TOLL PLAZA
RECOMMENDED SIGNING SCHEME

Sign Location	Message/Sign Content					
	Toll Plaza Ahead	Payment/Lane Type	Toll Rate	Vehicle Restrictions	Lane-Use	Speed Limits Restrictions
Distance From Plaza						
2 Miles	X Overhead placement preferred.		Optional			
1 Mile	X Overhead	X	Optional	X		
1/2 Mile	X Overhead	X	Optional	X		
1/4 Mile (Optional sign - depends on distance from the plaza)		Optional			X Overhead	Optional
Canopy		X	Option - Place on Booth	X	X	X
Toll Schedule (typically 100-200 feet from plaza)			X			

The recommended placement of the 1 and ½ mile signs is overhead, with sign content composed of messages warning of a toll plaza ahead, the payment methods accepted, vehicle restrictions, and toll rate information as an option.

An optional sign was also proposed at a distance of ¼ mile from the plaza canopy that provides payment method/lane type information, lane use information (open/closed) and lane-speed restrictions. Payment methods/lane type and lane-speed restrictions messages are optional.

Design of Toll Plaza Signing

The panel also discussed issues of sign background colors, logos signifying ETC programs, diagrammatic signing, symbols and terminology typically used in toll plaza signing.

Advance signing to warn drivers of a toll plaza ahead varies from agency to agency. Examples reviewed by the panel included yellow-background "warning" signs, green "guide" signs, and white "regulatory" signs. Linda Brown indicated that guide signing could be used to inform drivers of toll plazas. However, the panel indicated that there is a need to distinguish toll plazas from interchanges. The majority of the panel recommended that advance signing for toll plazas use yellow-background warning signs.

The panel next discussed background colors for payment types. Some panelists indicated that their agency intends to use purple as the background color for ETC dedicated lanes. Linda Brown indicated that FHWA favors a white background for toll plaza payment-type signing, since customers are required to pay a toll, and the signs serve a "regulatory" purpose. Ms. Brown said that the type of lane (ETC/Exact Change/Manual etc.) could be designated by a supplemental plaque with a distinct color for each payment type. The panel concluded that specific background colors for the various payment types are desirable, although no consensus was reached as to what were the best colors. Candidate colors selected included white and purple for dedicated ETC lanes, although the panel recommended other colors also be evaluated. Some panelists questioned whether logos used on the purple background would be distinguishable during low visibility conditions such as dawn and dusk. One panelist suggested that different background colors for each payment type would provide better recognition/target value at greater distances, rather than using a single color (e.g. white) for all signs. This panelist suggested that white be used as the background color for dedicated ETC lane signing, since only drivers who are part of the ETC program are permitted to use these lanes, and they are often operated as non-stop lanes. In other lanes, drivers are typically required to stop and pay a toll, so the panelist suggested the signing use background colors different from the ETC lanes. The panel unanimously recommended that the red background used by some agencies for manual toll collection lanes not be used.

ETC logos are placed on advance and canopy signing by many agencies. The panel reviewed several different applications of ETC logos. In response to panelists' questions, Ms. Brown indicated that FHWA would not require a national ETC logo. Aspects of ETC logos that panelists suggested should be addressed included size of the logo and contrast between the logo color and sign background. However, FHWA would like to standardize other aspects of toll plaza signing, such as symbols used to identify manual and exact-coin toll collection. Ms. Brown said that FHWA is currently conducting an evaluation of toll plaza signing and symbols under a "Pooled-Fund" study, and that the panel could recommend additional symbols for evaluation. Symbols representing "a toll attendants in a booth" and "a hand dropping coins into a basket" were recommended by the panelists for the Pooled Fund study.

Diagrammatic signs used by the Oklahoma Turnpike Authority (OTA) and Orlando-Orange County Expressway Authority (OOCEA) to convey the divergence of Express ETC lanes from the mainline lanes (Conventional Toll collection) were reviewed. The panel indicated a need to standardize diagrammatic signs, although no specific recommendation was provided.

The panel indicated that the terminology used in toll plaza signing needs to be standardized. Examples of terminology used to designate manual toll collection included: Cashier, Full Service, Attendant, Change/Receipts, Change, Cash/Receipts, Change Provided, and Manual. For exact change toll collection, examples included: Automatic, Exact Change, Exact Coins, and Coins Only. Similar examples were also reviewed for ETC toll collection. No consensus was reached on the terminology, and the panel concluded that additional evaluation needs to be conducted on this issue.

Pavement Striping and Channelization

The panel only discussed pavement striping and channelization with respect to guiding drivers into the lanes and preventing last-minute lane changing. The panel recommended the use of pavement striping and channelization/delineators only for non-stop lanes. The striping extends from the plaza for several hundred feet at some agencies to over a ¼ mile at others. The striping and channelization recommended is distinct from the "gore area" pavement markings used by many agencies to identify toll islands and attenuators.

Session C: Attenuators and Crash Blocks

Attenuator and crash block usage at toll agencies were discussed briefly. The variety of designs currently used were reviewed, with the following recommendations. Use of the "bull nose" crash block design was discouraged due to the potential for directing errant vehicles upward and possibly into a toll booth. The panel indicated that the attenuators used should conform to NCHRP 350 standards. In addition, the panel discussed what vehicle speed should be assumed when designing the attenuators: should the plaza approach speed limit be used, or should the mainline speed limit be used? Panelists commented that a drowsy driver may not slow down approaching the toll plaza, and the best approach would be to assume the operating speed of the mainline. One panelist indicated that Florida assumes a speed of 70 mph, based on the posted speed limit on the mainline.

The panel also discussed the use of two bollards (crash blocks) placed some distance apart upstream of toll booths. The reason for having separate bollards is to act as a vehicle trap - if a speeding vehicle hits the first and is launched upwards, the space between the bollards acts as a vehicle trap, capturing the vehicle before it reaches the toll booth.

Session D: Manual, ACM/ATIM and ETC Equipment Implementation

Lane Use Signals, Flashing Beacons, and Transaction Indicators

Panelists raised the issue of inconsistent usage of lane-use signals and flashers. Examples mentioned included the use of yellow flashing beacons next to lane-use signals/signal heads over the lanes. These flashing beacons are sometimes used both on the attenuators/crash blocks as well over the lane. The panel recommended that standard lane-use signals (MUTCD minimum size 18 inches) be used (only green down-arrow and red X), with signal heads as an alternative. If signal heads are used to indicate whether the lane is open or closed, the panel recommended that 12-inch diameter heads be used, and that only red and green heads be installed (no yellow head). The panel recommended that flashing beacons not be installed together with the lane-use signal or signal-heads, as it provides contradictory information to drivers. In addition, the panel recommended that flashing yellow beacons could be placed on both sides of the canopy sign, or over the sign (not below the sign) only for dedicated ETC lanes, but not for other lane types. The purpose of the flashing beacon is to draw attention to the lane, but not to serve as a lane-use signal.

The panel recommended that transaction indicator lights not be used in Express ETC lanes, although they may be installed in dedicated ETC and cash toll lanes. The panel felt that transaction indicator lights may unduly distract drivers in non-stop ETC lanes. However, the panel felt that feedback provided to drivers on account balance in non-stop ETC lanes does have some value. In exact change and attended lanes, the panel indicated that Red, Amber and Green signal heads or pedestrian type displays with messages such as STOP-PAY TOLL/THANK YOU may be used.

The panel also discussed the use of Stop signs in manual and exact change toll collection lanes. Examples of modified Stop signs were reviewed (e.g. with supplemental messages on the Stop sign such as “Pay Toll” and “Get Ticket”). Some panelists indicated that the limited space to place signing on the islands had necessitated placing the supplemental messages on the Stop signs. No consensus recommendation on the use of the modified Stop signs was provided. However, the panel indicated that a new section of the MUTCD could specify a modified Stop sign that included supplemental messages such as “Pay Toll” or “Get Ticket”. This new sign would be restricted for use only at toll plazas. The panel also discussed one agency’s practice of using a rectangular sign with the message “Stop/Pay Toll” using black letters on a white background. The panel recommended against using this sign.

WORKSHOP CONCLUSION AND NEXT STEPS

The preceding summarizes the discussions and recommendations of the Expert Panel on specific issues. The WSA Team indicated that a summary of the workshop would be provided to all participants for review and comment. Subsequently, a report on the state-of-the-practice and design guidelines will be prepared and distributed to toll agencies for review and comment.

APPENDIX C

Developing Traffic Control Strategies at Toll Booth Plazas
Bibliography

Subject/Title	Author/Agency/Company	Publication/Conference	Date	Topics	Relevance
Plaza Design Criteria					
Toll Plaza Design	Schaufler, Albert E. et al.	TRB - NCHRP Synthesis 240	1997	Toll Plaza Configuration, Demand, Lane Capacity, Signing, Safety	High
Contribution to the Development of Guidelines for Toll Plaza Design	Stammer, Jr., Robert E. and David R. McDonald, Jr.	Journal of Transportation Engineering	May/June 2001	Toll Plaza Design, Lane Configuration, Queue Area Lengthe	High
Tollway Sign and Pavement Markings - Recommended Design Guidelines	Stammer, Jr., Robert E. and David R. McDonald, Jr.	Transportation Quarterly	Vol. 54, No. 3, 2000	Toll Plaza Signing and Pavement Marking - State of Practice, Recommended Guidelines	High
Roadway Design Criteria	Illinois State Toll Highway Authority	N/A	Aug-02	LOS, Design Speed, Policy	High
OOCEA Guidelines for the Preparation of Signing and Pavement Marking Plans	Orlando Orange County Expressway Authority	N/A	Apr-01	Signing and pavement marking guidelines	High
Traffic Control for Toll Collection Facilities	Florida DOT	Traffic Engineering Manual	Mar-99	Traffic Control Devices, Signing, Pavement Markings	High
Design Geometrics and Criteria	Florida Turnpike	Turnpike Plans Preparation and Practices Handbook	Apr-03	Design, Signing, Pavement Markings	High
Geometric Design Guide - Ch 11 Toll Plazas	South African National Roads Agency	N/A	N/A	Toll Plaza Design	Mid
Plaza Operational Analysis/Simulation					
New Methodology for Evaluating a Toll Plaza's Level of Service	Klodzinski, Jack and Haitham M. Al Deek	ITE Journal	Feb-02	LOS, Measures of Effectiveness, Toll Plaza Operations	High
New Methodology for Defining Level of Service at Toll Plazas	Klodzinski, Jack and Haitham M. Al Deek	Journal of Transportation Engineering	Vol. 128, No. 2, March/April 2002	Measures of Effectiveness, Simulation	High
Applying Microsimulation to Evaluate, Plan, Design and Manage Toll Plazas	Lieberman, Edward et al. (KLD Associates)	TRB 2004 Annual Meeting	2004	ETC, Microsimulation Model, GENTOPS, Traffic Flow, Geometry	High
Evaluation of Toll Plaza Performance from Adding Express Toll Lanes at a Mainline Toll Plaza	Klodzinski, Jack and Haitham M. Al Deek	TRB 2004 Annual Meeting paper	11/15/2003	Before and after evaluation of ETC Express Lane implementation	Mid
SunPass Lane Location Analysis	PBS&J	N/A	Mar-97	ETC, AVI, Safety	Mid
Modeling Traffic at Toll Collection Facilities by Applying Vehicle Properties, Driver Perception…	Zarrillo, Marguerite L. et al.	TRB 2004 Annual Meeting	2004	Queueing, ETC, Motion Equations, Traffic Flow	Mid
E-Z Pass Evaluation Report	Vollmer Associates LLP for New York State Thruway Authority	N/A	Aug-00	ETC Program evaluation, with discussion of EZPass benefits and signing	Mid
Using Microsimulation to Quantify the Impact of Electronic Toll Collection	Burris, Mark W. and Eric D. Hildebrand	ITE Journal	Jul-96	Simulation, Modeling, ETC Cost-Benefit Analysis	Mid
Operational and Traffic Benefits of E-Z Pass to the New Jersey Turnpike	WSA	N/A	Aug-01	ETC Implementation, Delay Time, Queueing	Mid
Delay Model for Planning Analysis of Mainline Toll Plazas	Lin, F.	Transportation Research Record 1776	2001	Capacity, LOS, Simulation, Traffic Models, Design	Mid
A Framework for Evaluating Level of Service at Electronic Toll Collection Plazas	Al-Deek, H. and A.E. Radwan	ASCE Transportation Conference	N/A	ETC, LOS	Mid
New Model for Evaluation of Traffic Operations at Electronic Toll Collection Plazas	Al-Deek, H.M. et al.	Transportation Research Record 1710	2000	ETC, Simulation, Measures of Effectiveness, Delay	Mid
Analyzing Express Toll Plaza Operations Using Modern Simulation Models	Berenis, Joseph A. et al. - OOCEA	N/A	N/A	Use of VISSIM to model Express lane toll plazas	Low
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Designing the Westerschelde Tunnel Toll Plaza using a Combination of Queueing and Simulation	Van Dijk, Nico M. et al.	Winter Simulation Conference	1999	Queueing, Simulation, Toll Plaza Design, ETC, Safety	Low
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Plaza Safety Enhancements/Evaluation					
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Electronic Toll Collection and Safety at the Holland Tunnel	Menta, V.K. et al.	Traffic Congestion & Traffic Safety in the 21st Century	Jun-97	ETC, Safety, Simulation, Traffi Flow	Mid
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Case Study of Electronic Toll Collection in the Central Artery/Tunnel Project - Boston	Luchian, Sergiu et al.	ASCE Infrastructure: Planning & Management Conference	N/A	Toll plaza operation	Low

APPENDIX C

LITERATURE REVIEW

Vollmer Associates LLP. E-Z Pass Evaluation Report. August 2000.

Keywords: safety, signage

Methodology:

Vollmer Associates LLP was retained by the Federal Highway Administration (FHWA) to evaluate the success of the E-Z Pass implementation program on the New York State Thruway. This study reviewed short and long term policy goals and the anticipated costs and benefits of the E-Z Pass implementation program. An analysis of the changes in traffic volumes, travel patterns, frequency of trips and the total number of accidents were conducted at five tolled locations on the New York State Thruway and the actual results were compared with the anticipated results associated with the E-Z Pass implementation process.

The five analysis locations selected included the Tappan Zee Bridge and Buffalo City mainline barrier toll plazas and Interchanges 16 (Harriman), 24 (Albany) and 49 (Depew) tolled ramps on the controlled system.

In addition, an analysis was conducted to determine the success of the signage regarding the E-Z Pass system on the Thruway. This analysis primarily consisted of discussions with Thruway personnel, violation rates and anecdotal data from Thruway users.

Results:

According to the accident data from 1992 through 1998 obtained from the New York State Thruway, out of the total number of accidents at each of the five locations the percentage of E-Z Pass related accidents increased at each location analyzed. However, the increase at each location was lower than the increase in overall E-Z Pass usage at those locations. In general, the number of accidents per 1,000,000 transactions decreased at most locations, suggesting that E-Z Pass implementation did not result in an increase of total accidents.

As far as signage is concerned, there is a general consensus that the E-Z Pass signage is clear and easily understood. According to the New York State Thruway Authority (NYSTA), the violation rate in 2000 was just over one percent for E-Z Pass lanes compared to the five to ten percent rate for all other toll facilities.

Initially, two alternatives to E-Z Pass signing were reviewed. One option involved the installation of variable message signs on top of the toll plaza canopy and in advance of the toll plaza. The second alternative involved the installation of Manual of Uniform Traffic Control Devices (MUTCD) approved signs that were color coded and contained logos specific to the payment options available when entering the toll plaza. Although different in color and logo, each of the signs was uniform in size. The latter alternative was ultimately selected.

Drivers generally encounter signs approximately one to 1 ½ miles from the toll plaza. The group of signs indicates the type and location of the payment lanes. For most of the barrier plazas on the Thruway, the configuration is such that the signs read: Exact Change Only – Left Lanes, E-Z Pass No Cash 5 MPH – Center Lanes, and Cash Receipts – Left Lanes.

The second group of signs are encountered approximately ½ mile to ⅓ mile after the first group. These signs provide information on the price of and the distance to the toll. For example, a sign would read: Tollbooths ½ Mile – 40¢. Within the last ½ mile of the toll plaza, individual message signs are installed on the roadside indicating the location of each lane payment type. Variable message signs on the toll plaza canopy indicate whether the lanes are opened or closed and in which direction the traffic is flowing (for reversible lanes only).

In addition to the signage, flashing yellow lights have been installed above the E-Z Pass lanes which have further reduced weaving and violations. It should be noted that studies at the Spring Valley toll barrier indicated user confusion long after E-Z Pass was fully operational.

Klodzinski, Jack and Haitham M. Al-Deek. Evaluation of Toll Plaza Performance from Adding Express Toll Lanes at a Mainline Toll Plaza. *Transportation Research Board 83rd Annual Meeting*. November 2003.

Keywords: toll plaza operations

Methodology:

Data were collected at the University Mainline Toll Plaza on the Orlando-Orange County Expressway system prior to and after the addition of two ETC express lanes in each direction to determine the reduction in the level of delay at the plaza.

Prior to the plaza expansion there were a total of eight lanes with the two center lanes being reversible. Generally, five lanes were kept open in the direction of the peak period, leaving three available lanes in the opposite direction. While all lanes accepted ETC payment, the configuration in the peak direction usually consisted of two manual lanes, one automatic lane and two dedicated ETC lanes.

After the plaza expansion, none of the lanes were designated as reversible. Rather, there are six lanes in each direction consisting of two manual lanes, two automatic lanes and two dedicated express ETC lanes. The dedicated ETC lane speed limit was raised from 35 mph to 55 mph.

Cameras were mounted at various locations at and near the plaza to capture traffic upstream and downstream of the plaza. Roughly 30 hours of "typical" week day peak hour footage was recorded prior to and after the expansion of the plaza for a total of 60 hours. In addition, transaction data was obtained through detailed audit (DA) reports to evaluate lane throughput, speed, vehicle classification and the ETC participation rate.

The data collected was analyzed to compare measures of effectiveness prior to and after plaza expansion. The measures of effectiveness evaluated were throughput, vehicular delay (difference between plaza arrival and departure time), queue length, service time (time spent paying toll) and inter-vehicle time.

Results:

Overall throughput, measured in vehicles/hour (vph), increased slightly in the southbound direction and significantly in the northbound direction. This was due to a combination of increased speeds in the dedicated ETC express lanes as well as a decrease in ETC payment in the conventional lanes.

As a result of the plaza expansion, vehicular delay went from an average of 12 seconds in the automatic lanes and 15 seconds in the manual lanes to an average of six and eight seconds respectively. There were no delays in the ETC lanes.

The queue lengths were measured in vehicles/minute (veh/min). Prior to the plaza improvements, the average maximum queue observed in the automatic lane was nine veh/min and five veh/min in the manual lanes, regardless of direction. After plaza improvements the average maximum queue was three veh/min for both automatic and manual lanes. The average service time remained virtually unchanged in the conventional lanes from prior to and after the plaza improvements.

The inter-vehicle time is the difference between two consecutive vehicular departure times at the toll plaza at a specific lane. An overall average inter-vehicle time was derived by calculating the mean of all lanes for each lane type. The average inter-vehicle time for the ETC lanes was reduced by almost 50 percent as a result of the plaza improvements.

Mohamed, Ayman A.; Mohamed Abdel-Aty and Jack G. Klodzinski. Safety Considerations in Designing Electronic Toll Plazas: Case Study. *ITE Journal.* March 2001.

Keywords: toll plaza operations, safety

Methodology:

This study investigates the potential safety concerns occurring around toll plazas, with particular regard to varying payment methods and AVI technology. The Holland-East mainline toll plaza on the Orlando-Orange County Expressway Authority (OOCEA) system in Florida was chosen as the focus of the analysis due to the high number of toll transactions that occur there. At the time of the investigation, the plaza consisted of 14 lanes, five stationary lanes in each direction and four reversible center lanes. Analysis of the Holland-East Plaza occurred under the following four stages of development.

- Stage 1: Conventional lanes.
- Stage 2: Mixed AVI lanes (no dedicated lanes) and the introduction of E-PASS accounting for 15 percent of transactions.
- Stage 3: Single dedicated AVI lane (per direction) and a 28 percent E-PASS transaction rate.
- Stage 4: Two dedicated AVI lanes (per direction) and a 34 percent E-PASS transaction rate.

Three-and-a-half years of crash statistics compiled by the OOCEA were reviewed and categorized into four classification types: merging and sideswipe collisions, queuing and rear-end collisions, speeding and hit-plaza collisions and pedestrian related accidents. In addition, potential conflict points were evaluated on the approach to the Holland-East Plaza. The identification of potential conflict points was based on several factors including the toll lane type, vehicle deceleration rates, final velocity, the number of toll lanes and the volume of cross traffic between the lanes. This identification process was based on a similar study done at the Holland Tunnel in New Jersey.

Results:

Between January 1994 and June 1997, roughly 32 percent of crashes on the OOCEA system occurred at the 10 mainline toll plazas, 46 percent occurred at the ramps and 22 percent on the mainline sections between plazas and ramps. The average monthly crash rate prior to E-PASS (ETC) implementation was roughly 3.5 crashes/month as opposed to 7.5 crashes/month one year after E-PASS implementation. Ten percent of the total crashes were related to the E-PASS system because they either involved an E-PASS vehicle or occurred in a dedicated E-PASS lane.

Out of the 10 mainline toll plazas, the Holland-East plaza has the highest percentage of crashes at roughly 70 percent. The crashes at this plaza account for over 21 percent of all crashes on the OOCEA system. The conflict points that were identified on the approach to this plaza specifically addressed merging, queuing and speeding vehicles.

Merging and sideswipe collisions increased during Stage 3 as a result of the introduction of a new toll payment method (dedicated E-PASS lane). This was due to increased weaving and merging as a result of an additional choice in lane type. However, as drivers became more familiar with the lane configuration of the plaza, merging and sideswipe collisions decreased during Stage 4.

An increase in rear-end collisions also occurred during Stage 3, though queuing decreased. This was primarily attributed to driver confusion as many users stopped in the middle of the dedicated E-PASS lane after realizing that the toll could not be paid through conventional payment methods. Rear-end collisions remained high even at the beginning of Stage 4. This was most likely due to the relative unfamiliarity of the E-PASS system in addition to a second dedicated lane.

Crash severity increased during Stages 3 and 4 as a result of higher speeds through the plaza. The estimated property damage rate was used to represent crash severity. The estimated property damage rate increase is directly related to the implementation of the dedicated E-PASS lanes, as vehicles do not have to stop when passing through the plaza. Hit-plaza (structure) collisions increased as well. This was primarily attributed to drivers misjudging the lane with of the dedicated lanes at higher speeds.

Though crashes involving pedestrians were not reported, the potential for risk is higher with AVI technology. Since E-PASS vehicles using the dedicated lanes are not required to stop at the plaza, plaza employees or any other pedestrians who exit their vehicles for whatever reason are at greater risk of being hit.

Recommendations:

It is recommended that the dedicated E-PASS lanes be moved to the far left of the plaza as opposed to the center of the plaza. This may reduce the number of sideswipe collisions. Since faster drivers typically stay to the left lanes, it is logical to locate dedicated ETC lanes which do not require drivers to stop to the left. In addition, non-E-PASS users would know that there are no lanes to the left of the dedicated lanes and would only have a choice to go to the right.

Another suggestion would be to provide a more gradual and longer diverge area on the approach to the plaza. If drivers diverge from three or four lanes to five or six onto a total of nine, it would provide a smoother transition through the approach.

Advance signing is another useful tool to inform drivers of which lane to use for what specific toll payment method. Variable message signs (VMS) mounted in advance of the plaza as well as on the plaza canopy could provide more organization in identifying payment methods, lane status (open/closed) and even expected delay. Pavement markings could also help to channel drivers, eliminating much of the weaving that occurs.

Wilbur Smith Associates. Toll Plaza Safety Study: Plaza 51, York Road East-West Tollway. November 1999.

Keywords: safety, toll plaza operations

Methodology:

Wilbur Smith Associates (WSA) examined the lane configuration of a "typical" toll plaza on the Illinois State Toll Highway Authority (ISTHA) system in order to determine the impacts on safety anticipated as ISTHA's I-PASS program expands. Plaza 51, York Road, on the East-West Tollway was selected for the study location. At the time of the study Plaza 51 consisted of 20 lanes, nine in the eastbound direction (four manual, four automatic and one I-PASS) and 11 in the westbound direction (six manual, four automatic and one I-PASS).

The traffic volume in each toll lane and the vehicle class was recorded in five minute increments during "shoulder peak" hours of operation. In addition, average approach speeds at the plaza and lane changes were recorded as well. The observed data was then used in WSAs TOLLSIM model to calibrate existing plaza operations and to estimate plaza queuing and toll lane usage under two separate scenarios. One scenario simulated the existing conditions and the other evaluated 1998 conditions which assumed no I-PASS only lanes and an eight percent I-PASS participation rate. Finally, the original data and outputs from the TOLLSIM model were used as inputs into WSAs safety model, SAFESIM, to estimate the probability of conflict points directly related to accidents.

Data collected during the shoulder peak hours (10:00 AM – 12:00 PM and 1:00 PM – 3:00 PM) were used because most accidents occur during these periods. During the off-peak, traffic is light and the probability of a conflict occurring is low. During peak hours, lane changes are rare and occur at slow speeds because queues from the toll plaza extend back into the mainline upstream of the taper.

Results:

When compared to the 1998 pre-I-PASS conditions, the results of the analysis indicate that there is a 13 percent reduction in the probability of a conflict in the eastbound direction and an 11 percent reduction in the westbound direction with the implementation of an I-PASS only lane and increased I-PASS participation. The overall probability of conflict in either direction is higher on the departure side of the plaza than on the approach side. This is due to the fact that there are more lanes on the approach side than the departure side. As was estimated, the probability of conflict was highest during the shoulder peak hours.

Recommendations:

The following recommendations were made to further enhance safety in operations at Plaza 51:

Provide adequate signage prior to the entrance to the toll plaza to inform drivers in advance of exits immediately downstream of the plaza;

Investigate the possibility of providing a second I-PASS only lane in the center of the toll plaza;

Reconfigure the toll plaza to reduce sideswipe collisions; and

Provide a barrier on the I-PASS lane to prohibit drivers from making a lane change at the toll plaza into the conventional lanes. In addition, adequate warning signs should be posted in advance for drivers entering the plaza.

Abdelwahab, Hassan T. and Mohamed A. Abdel-Aty. <u>Artificial Neural Networks and Logit Models for Traffic Safety Analysis of Toll Plazas</u>. *Transportation Research Record 1784: Paper No. 02-2270.*

Keywords: toll plaza operations, safety

Methodology:

This study examines two different modeling approaches in determining measures of safety at toll plazas. One of the models is statistics-based while the other is an artificial neural network (ANN). ANNs can be further categorized into two architectures: Multi-Layer Perception (MLP) and Radial Basis Functions (RBF).

Accident reports from 1999 and 2000 for the Central Florida expressway system were used to construct a database for the analysis. The Central Florida expressway system consists of three state roads: SR 408, SR 417 and SR 528. The entire network contains 79 miles of roadway, 10 mainline toll plazas and 42 ramp plazas. Out of the 1,932 accidents that occurred for the combined years of 1999 and 2000, 23 percent occurred in the vicinity of a toll plaza.

After screening out the incomplete reports, a database of 725 vehicles (drivers) was created. Of those 725 vehicles, 43.6 percent were involved in an accident while approaching the plaza, 43.7 percent were involved in an accident at the plaza and 12.7 percent were involved in an accident while leaving the plaza.

The accidents were further categorized by a variety of measures including driver age, gender, license type, alcohol involvement, violation and whether or not the driver was an E-PASS user; vehicle type, point of impact, number of impacts and speed ratio (estimated running speed to posted speed limit); and the type of toll plaza (mainline or ramp) and road conditions/environmental factors.

Results:

The study revealed that a two-level nested logit model was the most suitable model for identifying probabilities of an accident location. The model elasticity values showed that plaza type, peak period, vehicle type and E-PASS use have the greatest affect on the likelihood of an accident occurring upstream, at or downstream of a toll plaza. E-PASS users have an 11 percent increase in the probability of being involved in an accident at the toll plaza.

The RFB neural network was the best model for analyzing driver injury severity. The results showed that older drivers have a higher risk of being injured in accidents than younger drivers and that female drivers have a greater chance of severe injury than male drivers. Overall, E-PASS users have the highest risk of being injured in an accident. Drivers in passenger cars are more likely to experience severe injuries than drivers of trucks.

Recommendations:

Based on the model results, the following recommendations suggest:

- Improvement is needed in lane markings on the approach to toll plazas.
- Traffic signs should be provided to alert drivers not to stop in ETC lanes under any circumstances.
- The width of ETC lanes should be large enough to accommodate heavy trucks equipped with an ETC transponder.
- The approach zone at a toll plaza should be just as illuminated as the plaza structure.

Lieberman, Edward; Dr. Jinil Chang and Barbara Andrews. Applying Microsimulation to Evaluate, Plan, Design and Manage Toll Plazas. *TRB 2004 Annual Meeting CD-ROM.* 2004.

Keywords: toll plaza simulation, safety

This paper examines the Generic Toll Plaza Simulation (GENTOPS) model as it relates to toll plaza operation and safety considerations. GENTOPS differs from other toll plaza simulation models in that it models free flow or "unchannelized" vehicle movements within the transition zones of the toll plaza while considering the surrounding highway network as well. GENTOPS was designed to be integrated with the WATSim highway microsimulation model so that regional networks containing multiple toll plazas could be analyzed.

GENTOPS assigns vehicles to booths using a "Utility Score" to identify the most attractive booth for each vehicle at the current time. A toll booth is identified as a potential candidate if it services the vehicle type and selected toll payment, is accessible from the vehicle's plaza approach link and is compatible with the vehicle's plaza exit link.

GENTOPS also provides several statistics that can be viewed as potential safety measures of effectiveness. One of these measures is the "Percent of Vehicle Movements that Exceed a Specified Heading." This is a measure of lateral movement within the reception and departure areas of the toll plaza. Though there is no empirical evidence to support the theory, it is often argued that pronounced lateral movement increases the exposure of vehicles to side-swipe collisions. As a result, toll plaza managers frequently erect internal barriers to restrict lateral movements in the interest of safety.

A simulation of the Newburgh-Beacon Bridge toll plaza in New York State was conducted using the GENTOPS model. The model was calibrated based on inputs obtained from the NYS Bridge Authority to develop a base scenario. Once the base scenario was established, analyses of alternative toll both configurations were conducted to determine whether the existing configuration was optimal or could be improved. In addition, scenarios WERE evaluated in which there was an 80 percent E-Z Pass participation rate as opposed to the 60 percent rate at the time of analysis. Overall, nine alternatives were examined.

Results:

Based upon the model outputs, it was determined that the existing plaza configuration consisting of two E-Z Pass only lanes and six mixed use lanes (E-Z Pass and cash) under the current E-Z Pass participation rate at the time provided for the optimal operating conditions at the Newburgh-Beacon Bridge toll plaza. Likewise, the percentages of vehicles with pronounced lateral movement was much lower than in the other alternatives examined.

At the 80 percent E-Z Pass participation rate, an alternative scenario in which a configuration of three cash only lanes and four E-Z Pass only lanes provided for an improvement in operating conditions and safety measures over the original configuration.

Lin, Feng-Bor. **Delay Model for Planning Analysis of Main-Line Toll Plazas**. ***Transportation Research Record 1776: Paper No. 01-0588.***

Keywords: toll plaza simulation, delay

Methodology:

This paper examines an analytical delay model that can be used as an alternative to more complex toll plaza simulation models for the purpose of expediting the toll plaza planning process. The Institute of Transportation, Ministry of Transportation and Communications in Taiwan sponsored the development of a stochastic, microscopic simulation model, referred to as the toll plaza simulation (TPS) model, to calibrate and test the delay model presented in this paper. The delay model estimates total delay by accounting for extra travel time due to deceleration, toll paying, acceleration and time spent waiting in queue. The model is calibrated with simulation data and, for V/C ratios less than 1.4, can yield delay estimates within 10 percent of simulated values.

Recommendations:

It is recommended that the delay model be used for preliminary screening of alternative designs and operations. However, further investigation should be conducted to determine if the model can adequately estimate delay based upon field data.

Al-Deek, Haitham M.; Ayman A. Mohamed and Essam A. Radwan. **New Model for Evaluation of Traffic Operations at Electronic Toll Collection Plazas**. ***Transportation Research Record 1710: Paper No. 00-1519.***

Keywords: traffic simulation, toll plaza operation, delay

Methodology:

The Transportation Systems Institute at the University of Central Florida developed a toll plaza simulation model (TPSIM). TPSIM is a stochastic object-oriented discrete-event microscopic simulation model. The model consists of three main modules. These modules are the data entry interface which allows for inputs representing the plaza geometry, traffic and toll lane characteristics, global parameters (speed, driver reaction time, etc.) and run specifications; the simulation logic and algorithms; and the model output consisting of measures of effectiveness such as throughput, queue length, delay and lane utilization.

The model was verified by eliminating any flaws through debugging and minor modifications. The model was also validated by comparing the outputs of a simulation of the Holland-East mainline toll plaza on the Orlando-Orange County Expressway to real-world observations. Data collection of the toll plaza was achieved by utilizing video cameras to capture queuing delay, service time, queue length and throughput. In addition, a distance-measuring instrument (DMI) was installed on five different vehicles that passed through the plaza during the morning peak hour. Specifically, the DMIs were used to measure each of the vehicles' approach speed and desired acceleration and deceleration rates within the toll plaza area. A total of 35 runs were made (5 morning peak runs for 7 days) during the data collection process. In addition, 20 TPSIM simulations were run with different random number streams and the results were averaged for each 5-minute interval within the simulated hour. Comparisons between the model outputs and the plaza observations were made by examining throughput, average queuing delay and total queuing delay.

Finally, several simulation scenarios were conducted to investigate the impact of electronic toll collection (ETC) market penetration on the benefits of ETC technology. The base scenario was modified by increasing or decreasing E-PASS market penetration in increments of 10 percent. To accommodate the increase in the volume of E-PASS vehicles, additional dedicated E-PASS lanes were introduced to the left of the two existing E-PASS lanes in the base scenario. Throughout the analysis, the proportion of automatic payment vehicles remained fixed at 20 percent. The introduction of a new dedicated E-PASS lane was achieved by converting one of the existing manual payment lanes into an E-PASS lane.

Results:

The findings of this analysis indicate that the benefits of E-PASS operation are sensitive to the plaza configuration. Adding more E-PASS lanes without an increase in E-PASS participation could cause an increase in total plaza queuing delay. However, regardless of the plaza configuration, total plaza delay can be reduced by 50 percent if 10 percent of the vehicles switch from the manual payment lanes to E-PASS lanes.

Recommendations:

In addition to the applications examined in this analysis, it is suggested that the TPSIM model also be use to determine the optimal configuration in toll plaza design, tollbooth scheduling and in finding the best lane arrangement to increase plaza efficiency during off-peak hours.

Stammer, Jr., Robert E. and David R. McDonald, Jr. Tollway Sign and Pavement Markings – Recommended Design Guidelines. *Transportation Quarterly*. Vol. 54, No. 3. Summer 2000.

Keywords: toll plaza design, signage, pavement markings

Methodology:

The intent of this research was to present a set of proposed design standards for toll facilities in the absence of any official design guidelines. This analysis expanded upon earlier efforts to develop toll plaza design standards by examining the increasing use of electronic toll collection (ETC) facilities. The authors of this paper gathered input from toll agencies and consulting firms from 14 states and the Commonwealth of Puerto Rico.

The authors reviewed several elements of toll plaza design such as: pavement markings, lane channelization, plaza island extensions, word and symbol markings and signage. After comparing the design plans obtained from the different agencies/consultants with the Manual on Uniform Traffic Control Devices (MUTCD), design guidelines were created for toll facility pavement markings and signs. These guidelines were presented to the panel of toll experts for review and comment, and recommendations were made based upon the responses.

Results:

Of the three methods of lane channelization presented to the panel, full channelization was preferred. Full channelization consists of pavement markings (striping) through the approach to each individual lane at the toll plaza. The panel recommended the addition of reflective pavement markers as well. With the exception of reversible lanes (which are yellow in color), all line colors should be white. The panel also recommended that solid white lines be used to designate dedicated or express ETC lanes in order to minimize the number of lane changes at these areas.

There was little consistency among the toll agency design plans regarding toll plaza island extensions. The majority of the panel agreed with the suggested island extension design guidelines developed by the researchers. The design recommended a minimum approach length of a 50 foot striped gore with an additional 0 to 25 foot solid line extending from the "V" at ramp plazas and a minimum of a 100 foot striped gore with an additional 25 to 100 foot solid line at mainline plazas. On the departure the gore would be 50 ft and 100 ft at ramps and mainline respectively. All striping would be in white unless it was for a reversible lane.

An overwhelming majority of the panel were against the use of pavement word markings in toll plazas. The panel did not reach a consensus on any of the proposed symbols or ETC names presented by the researchers. One of the panel experts suggested that an official color of ETC be established. As far as signs are concerned, the MUTCD states symbols are more advantageous than words. However, public education would be required for any national toll symbol. It was agreed upon that when using text, the message should be brief and the lettering should be legible.

McDonald, Jr., David R. and Robert E. Stammer, Jr. Contribution to the Development of Guidelines for Toll Plaza Design. *Journal of Transportation Engineering*. May/June 2001.

Keywords: toll plaza design

Methodology:

The intent of this research was to present a set of proposed design standards for toll facilities in the absence of any official design guidelines. This analysis expanded upon earlier efforts to develop toll plaza design standards by examining the increasing use of electronic toll collection (ETC) facilities. The authors of this paper gathered input from toll agencies and consulting firms from 14 states and the Commonwealth of Puerto Rico.

The authors reviewed several elements of toll plaza design such as: lane configurations, queue area, taper rates, transition lengths, lane widths and vertical geometrics. After comparing the design plans obtained from the different agencies/consultants with the Manual on Uniform Traffic Control Devices (MUTCD), design guidelines were created specific to toll facilities. These guidelines were presented to the panel of toll experts for review and comment, and recommendations were made based upon the responses.

Results:

After surveying several toll agencies, it was found that ETC express lanes are generally implemented in sets of two lanes, side-by-side and in the same direction, and operate at speeds in excess of 60 mph. In the case of dedicated ETC lanes, one or more are typically implemented in each direction of travel and are assigned speed limits that range between 15 to 45 mph. All ETC lanes are generally separated from the conventional lanes by some form of concrete barrier. A majority of toll professionals recommended a lane configuration of express or dedicated ETC lanes on the left, automatic coin machine and ticket lanes in the middle and manual lanes on the right; with the ability to pay by ETC in all lanes.

Allowing for express traffic on the left is more difficult when there are reversible lanes present. Based on the panel's response to several proposals, the following guidelines were recommended for plazas with reversible lanes.

- Consider the prohibition of express or dedicated lanes.
- Consider reduced speeds for dedicated lanes.
- Avoid design with high-speed lanes on the right (to ensure uniformity and consistency throughout all plazas).
- If high-speed lanes are required, ensure that the directional peak traffic splits support

their use, that they are barrier separated with adequate identification and that toll collection is exclusively electronic.

There are two methods of design for establishing the length of the queue area. One method is to allow queued vehicles to "stack up" in the approach taper. The other method is to design the queue area to accommodate the entire queue and use the approach taper for any overflow when design traffic volumes are exceeded. The majority of panel members agreed upon a method of a manual lane requirement calculation, lane number adjustment and validation via a simulation model for determining the minimal queue area.

A proposed set of toll plaza approach taper rates for conventional lanes were created by modifying taper equations published in the 1993 Revision to the MUTCD. A majority of the members of the panel agreed with the recommendations. Two modifications were suggested for the proposed approach taper rates. One modification would allow for reduced taper rates at higher speeds due to physical project constraints, such as a lack of sufficient right of way. The other modification was to establish a minimum taper rate of 10:1 for all speeds ≤ 30 mph.

A set of departure (merge) taper rates were also proposed for vehicles exiting the toll plaza. These proposed rates were met with a 90 percent approval rate by the panel. For areas where vehicles are not anticipated to stop (express/dedicated lanes), it was recommended that equations presented in the 2000 MUTCD and the "Green Book" (A Policy on Geometric Design of Highways and Streets) be used for lane additions or subtractions.

Proposed design standards regarding lane widths, pavement cross slopes, profile grades and sight distance for the different lane payment types were developed from a variety of design guide publications such as the MUTCD and the Green Book. The panel responded to these recommendations with mixed opinions, but the majority agreed with the proposed guidelines. In many instances, the guidelines presented in the Green Book were altered only slightly to accommodate toll plaza features, or in the case of sight distance considerations, they were not changed at all.

Recommendations:

The majority of toll experts that served on the panel agreed with the proposed guidelines developed through this research. Most of the members indicated that they favor a national standardization of ETC; however, more so on a regional level. They also indicated a desire for the continued use of ticketing equipment and automatic coin machines in order to maintain payment flexibility.