**REPORT OF THE VIRGINIA
DEPARTMENT OF TRANSPORTATION**

Technologies for Toll Facility Mobility Enhancement

**TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA**

HOUSE DOCUMENT NO. 14

**COMMONWEALTH OF VIRGINIA
RICHMOND
2008**

COMMONWEALTH of VIRGINIA

DEPARTMENT OF TRANSPORTATION
1401 EAST BROAD STREET
RICHMOND, VIRGINIA 23219-2000

David S. Ekern, P.E.
COMMISSIONER

January 1, 2008

Members of the General Assembly

Dear Ladies and Gentlemen:

Chapter 896 from the 2007 Acts of Assembly requests the Virginia Department of Transportation (VDOT) to report on its plans to enhance mobility and free-flowing traffic on Department-controlled toll facilities by embracing technological advances. The attached report was drafted by IBI Group, a transportation and systems consulting organization. IBI Group has international experience in research, planning, design, deployment, and operation of transportation technologies, including tolling and traffic management.

The report includes information on the current status of Virginia's tolling facilities, a review of mobility enhancement technologies, and future steps needed for Virginia to implement these technologies. The report focuses on Open Road Tolling (ORT) technology which allows road users to travel at normal speeds without having to slow down to pay a toll. This technology is becoming more popular due to the increased use of electronic toll collection systems. The report examines six locations that use ORT technologies. The case studies explain the benefits and issues associated with deployment of ORT toll facilities. The report also provides various recommendations to implement ORT on a statewide basis.

ORT technologies are already being deployed on some Virginia toll roads. Virginia's Pocahontas Parkway has implemented some ORT technologies and the RMA is working on incorporating this technology at the mainline plaza on the Powhite Parkway.

Attached is a copy of the report for your review. If you have questions or need additional information, please let me know.

Sincerely,

David S. Ekern

Attachment

cc: The Honorable Pierce R. Homer

Virginia Department of Transportation

TECHNOLOGIES FOR TOLL FACILITY MOBILITY ENHANCEMENT

REPORT

DECEMBER 2007

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GLOSSARY

Automated Coin Machine (ACM)-	A machine at a toll lane that accepts coins for payment in a plastic basket. The coins fall through the bottom of the basket into a mechanism that is used to count them.
Automated Vehicle Identification (AVI)-	The process of electronically identifying vehicles using a roadside reader and an in-vehicle transponder.
Cashless ORT system-	An Open Road Tolling system where all forms of accepted payment methods are electronic, without a cash option.
Congestion Charging-	The practice of setting the toll rate based on time of day or measured traffic in order to reduce traffic demand in peak periods.
Dedicated Short Range Communications (DSRC) Tolling-	Tolling using radio frequency identification of vehicle transponders.
E-ZPass-	The interoperable tolling network of the Northeast and Midwest Unites States. Virginia is part of this network and uses the associated E-ZPass transponder technology to implement its electronic tolling.
Global Positioning System (GPS) Tolling-	Tolling achieved by tracking the movements of vehicles via a satellite network.
High-Occupancy Vehicle (HOV) / High-Occupancy Toll (HOT) Lanes-	Dedicated lanes where vehicles with multiple passengers (e.g. 2+, 3+) are allowed to drive for free and single occupancy vehicles are required to pay a toll.
Infrared Tolling-	Tolling using infrared communications with specialized transponders to identify vehicles.
Inter-Agency Group (IAG)-	The governing body responsible for E-ZPass. Virginia is a member of IAG.
License Plate Recognition (LPR)-	An automated process that extracts license plate data from video evidence.
Manual toll collection-	Toll collection involving driver interaction with a toll booth attendant to pay using cash or credit card.
Mixed Cash/ORT system-	An Open Road Tolling system where forms of accepted payment methods include both electronic and cash options. Cash payments are remitted in slow-speed toll lanes.
Open Road Tolling (ORT)-	The practice of tolling road users while they travel at normal speed along a given road without needing to slow down.
Optical Character Recognition (OCR)-	The capability of computer software to process images and recognize particular written characters of interest. This is the technology that is the basis for License Plate Recognition.
Traffic Management Center (TMC)-	An operations center that monitors and controls traffic and responds to incidents on the roadways.
Transponder-	A small electronic device that is typically mounted on a vehicle's windshield to identify it as it passes toll reader systems. Transponders of two basic types exist: radio frequency based and infrared.
Variable Message Sign (VMS)	An electronic sign, often used on the road-side, to display dynamic messages to drivers.
Vehicle Classification-	The process of classifying different vehicle types based on some vehicle characteristics. Most toll facilities in Virginia classify vehicles based on the number of axles.
Video "fingerprinting"-	The practice of using the entire picture of a vehicle to identify the vehicle and not relying solely on the identification of license plate characters.
Video Toll (V-Toll)-	A toll that is charged to an E-ZPass customer in Virginia based on video evidence of toll road use. This is a backup system that is provided as a customer service in case transponders are not read.
Video Tolling-	Tolling that uses video evidence as the basis to identify vehicle usage of a toll facility.

EXECUTIVE SUMMARY

This report has been produced based on the results of a study requested by Chapter 896 of the 2007 Acts of Assembly to investigate recent technological advances that could be applied in the Commonwealth of Virginia to enhance travelers' mobility on Virginia's toll facilities. Particular focus is given to information on Open Road Tolling (ORT) technology, which is the practice of tolling road users while they travel at normal speed along a given road without slowing to pay.

Virginia Tolling Background

There are currently ten toll road facilities in Virginia. The facilities vary widely in size, accepted payment methods, geometry, and gate use. Accepted payments vary but are always some subset of manual toll collection, Automated Coin Machines (ACMs), credit cards, and E-ZPass electronic toll collection.

E-ZPass-VA, previously known as Smart Tag, is Virginia's implementation of the E-ZPass Inter-Agency Group (IAG) Electronic Toll Collection system. The IAG is the largest interoperable toll collection network in the U.S. with full reciprocity between agencies throughout the Northeast, Indiana and Illinois. VDOT currently operates a single, state-wide account management and Customer Service Center (CSC) E-ZPass back office system for all facilities within the Commonwealth.

In combination with the E-ZPass back office, VDOT also operates a centralized violation processing system that will pursue collections of tolls based on video evidence collected in the lanes from non-paying customers. This system currently processes violations for the three VDOT toll facilities: Coleman Bridge, Powhite Parkway Extension and Dulles Toll Road.

Open Road Tolling Technology

Until somewhat recently, the most common approach for collecting tolls was to have the driver stop and pay a toll collector sitting in a tollbooth. The toll collector determines the amount to be paid by each vehicle based upon its characteristics or classification. Enforcement was primarily addressed by the use of gates that were raised after the toll was paid. Manual lanes can accept an extensive variety of payment means, such as cash, checks, credit/debit cards, and smart cards.

A manual lane can process approximately 400 vehicles per hour in comparison to a free-flow freeway lane, with capacity approaching 2,000 vehicles per hour. Open Road Tolling technology has therefore been developed to allow tolling road users while they travel at normal speed along a given road.

ORT has many benefits including:

- ORT allows higher traffic throughput thus reducing traffic congestion usually caused by a toll plaza and providing more comfort for the users who can drive through the toll gantry at normal highway speeds.
- ORT minimizes environmental impacts (pollution, visual, and noise).
- ORT increases highway safety.
- ORT lowers investments costs for new toll roads due largely to the fact that less property is needed for toll plazas.
- ORT induces lower operational and maintenance costs.
- ORT enables tolling on new roads, where manual tolling is not possible, e.g. for congestion charging schemes, where no space is available (bridges) or where manual operational costs are inappropriate.

There are potential constraints, however, to tolling upgrades in the state that include the following:

- Toll rate constraints
- Existing E-ZPass/IAG membership
- Right-of-way availability
- Collecting revenue from out-of-state violators
- Cost of upgrades

- Privacy
- Safety
- Throughput

ORT requires several technologies working together to provide an effective revenue collection system. Most systems rely heavily on electronic toll collection, such as E-ZPass, supported by video billing and enforcement for those users who do not have a transponder.

These ORT technologies can be used to create completely *cashless* toll roads in which all payments are collected electronically at high-speed without the option of toll collectors or coin machines. There are several toll facilities in North America and around the world that are operating in this mode. Alternatively, these technologies can be utilized in a *mixed cash/ORT* arrangement. This involves the collection of tolls via both ORT and accepting cash at a more traditional toll plaza usually provided on a separated parallel facility. This option is potentially more attractive to agencies that need to provide customers with more payment options due to customer service or demographic mix.

There are an expanding number of ORT deployments in North America. The majority of these are mixed cash/ORT, but there is expected to be movement towards cashless ORT as electronic toll collection and video billing become more ubiquitous. Some examples of North American mixed ORT/cash deployments can be seen on:

- New Jersey Turnpike and Parkway
- Denver's E-470
- Miami Dade Expressway (MDX)
- Illinois Tollway

Examples of North American cashless deployment can be seen on:

- Tampa-Hillsborough Expressway
- Toronto's 407 Electronic Toll Road (ETR)
- Miami Dade Expressway (MDX)

Future Steps

Virginia does have several advantages when compared with some of its peers in terms of being in position to move forward with ORT deployment. Some advantages are as follows:

- Virginia already has some experience with ORT implementation through the Pocahontas Parkway and a pending implementation at the RMA.
- Many of Virginia's tolling facilities have good E-ZPass penetration rates, which is a prerequisite for making good use of ORT facilities.
- Virginia has recently upgraded its online and interactive voice response back office capabilities for both customer service and violation processing, permitting more automated self service capabilities.
- Virginia already has a deployed and established violation processing system that includes legislative support.
- The state is already in the midst of establishing processes with the courts to deal with non-paying violators.

To progress an initiative to move towards ORT, there are a number of actions that should be taken by the commonwealth to prepare for a statewide deployment including the following:

- Maximize transponder usage.
- Optimize back office (Customer Service Center) operations.
- Address processes to effectively deal with out-of-state video billings and violations.
- Consider removing Automatic Coin Machines ACM lanes.
- Consider implementing ORT as part of other projects and upgrades.
- Evaluate cost and efficiency of investment.
- Evaluate Cashless vs. Mixed ORT/Cash systems.

The appropriate application of tolling technology must be assessed on a facility-by-facility basis. In terms of timing, this assessment is best done before making any major changes to existing operations, tolling equipment or toll rates or where congestion or safety issues warrant consideration of alternative tolling strategies. The general assessment process that should be followed for each Virginia toll facility includes the following:

- Identify potential tolling concepts.
- Gather data.
- Perform micro-simulation.
- Evaluate diversion potential.
- Develop capital costs.
- Perform cost-benefit analysis including operations and capital costs.
- Analyze results and develop recommendations.

1. INTRODUCTION

This report has been produced based on the results of a study to investigate recent technological advances that could be applied in the Commonwealth of Virginia to enhance travelers' mobility on Virginia's toll facilities. Particular focus is given to information on Open Road Tolling (ORT) technology, which is the practice of tolling road users while they travel at normal speed along a given road without slowing to pay.

This document presents a current status of tolling in the Commonwealth, a review of applicable technologies and examples of deployment, and an outline of future steps that could be taken in the Commonwealth to leverage these technologies. The document is organized into the following sections:

- Current Virginia toll facilities overview and technologies used (Chapter 2;)
- Current Virginia Smart Traffic Centers (STCs) and technologies used (Chapter 2;)
- Current Virginia tolling integration with traffic management, upgrade constraints, and relevant near-term projects (Chapter 2;)
- Overview of ORT and the main facilitating technologies – Dedicated Short Range Communications (DSRC), Infrared, Video, and GPS (Chapter 3;)
- Examples of prominent ORT systems in the U.S. and Canada (Chapter 4;)
- Evaluation of the current status of toll technology deployment in the Commonwealth (Chapter 5;)
- An outline of the steps that can be taken in the Commonwealth to further evaluate the opportunities for specific toll facilities and develop implementation plans for taking advantage of the new technologies. (Chapter 5;) and
- Detailed description of current Virginia toll facilities (Appendix A.)

2. VIRGINIA'S CURRENT TOLLING STATUS

2.1 Virginia toll facilities and technology used

There are currently ten tolled road facilities in Virginia. These facilities vary in type, size, ownership and tolling systems deployed. There are several private toll facilities along with those owned and operated by various public agencies around the Commonwealth. All facilities are barrier toll facilities, i.e. tolls are paid as the traveler passes the toll point rather than paying a distance based toll calculated from their entry and exit. A listing of these toll facilities, their comparative size and the technologies deployed is provided in Appendix A.

As indicated above, each of the toll facilities uses different toll collection systems and methods of operation. The following paragraphs summarize the methods used across the Commonwealth:

- **Automated gates**: Toll gates are used to prevent access to the toll facility to vehicles that have not paid or do not meet the requirements of the toll facility (e.g. overweight vehicles on the Chesapeake Bay Bridge Tunnel). Gates are also used to slow and/or stop traffic for safety reasons, especially where toll attendants are required to cross toll lanes to gain access to their toll booth. There is a mix of gated and non-gated systems in the Commonwealth. Some facilities raise or lock their gates up during high traffic volume to maximize vehicle throughput.

- **Automated coin machines**: Several facilities utilize these machines to collect and automatically count coins deposited by the customers. This technology is not 100% reliable and typically is a high maintenance item.

- **Electronic toll collection**: Electronic toll collection using the E-ZPass brand is deployed in all but one of the Virginia toll facilities. The use of a vehicle mounted transponder and a prepaid central account provide rapid payment of a toll. Most facilities have equipped all toll lanes to accept E-ZPass and have dedicated sometimes high-speed, E-ZPass lanes.

- **Open Road Tolling**: Open road tolling using E-ZPass and video violation enforcement is currently available at the Pocahontas Parkway main plaza and is being deployed by RMA.

- **Credit cards**: The Dulles Greenway has provided credit card payment options at its remote ramps since opening and has recently expanded this facility to its mainline plaza. The Pocahontas Parkway also began accepting credit card payments in their manned toll collection lanes in 2007. This has proved a useful option for patrons arriving at the toll plaza with out cash available to pay the toll.

- **Manual toll collection**: All facilities in Virginia utilize some form of attended lane with a toll collector either collecting tolls or making change and depositing currency in the automated coin machines. The use of attended lanes has declined in recent years, with many remote plazas either not offering this full service option or only offering it during the day.

2.2 E-ZPass in Virginia

E-ZPass-VA, previously known as Smart Tag, is Virginia's implementation of the E-ZPass Inter-Agency Group (IAG) Electronic Toll Collection system. The IAG is the largest interoperable toll collection network in the U.S. with full reciprocity between agencies throughout the Northeast, Indiana and Illinois. To date, more than 16 million E-ZPass tags have been distributed. Last year, over $3 billion in tolls was collected and distributed amongst the participating agencies via the E-ZPass technology. This represents about 60% of tolls collected by the participating agencies.

Virginia's E-ZPass compatible electronic toll collection system was established in 1996 to service both the public and private toll facilities. Virginia became a fully participating member of IAG in 2004. The main Customer Service Center (CSC) is housed in Clifton Forge, VA with satellite walk-in centers located in Gloucester, Richmond, and Reston.

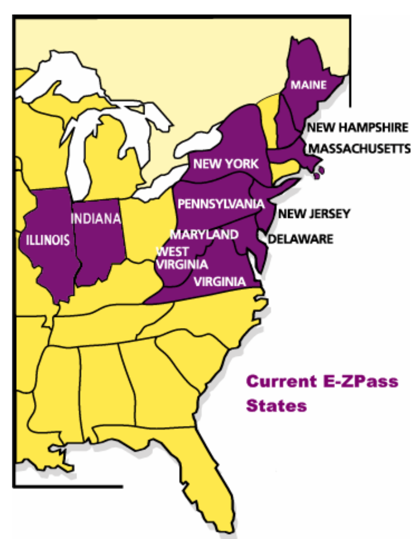

Figure 1 – The E-ZPass network

The CSC interfaces with all toll facilities to distribute the status of the millions of active E-ZPass tags and to receive transactions carried out by E-ZPass customers on these facilities. Financial clearing occurs daily with the toll facilities in Virginia and monthly with the other IAG agencies.

Functionally, Virginia's CSC is more advanced than many of the other IAG centers due to its support for and daily reconciliation with each of the separate toll facilities and agencies within the Commonwealth.

2.3 Violation enforcement

In combination with the E-ZPass back office located in Clifton Forge, Virginia Department of Transportation (VDOT) also operates a centralized violation processing system. This system currently accepts violation transactions, including violating vehicle license plate images, from the three VDOT toll facilities: Coleman Bridge, Powhite Parkway Extension and Dulles Toll Road. The center processes the transactions, performs Video Toll (V-Toll) lookups (charges an E-ZPass account for violators identified as customers with a positive account balance using video evidence), sends notices, processes payment and pursues collections and court processes.

The system was designed to also provide violations review and processing services to any of the other Virginia toll facilities desiring to utilize this service. RMA will be taking advantage of the full central violations processing capability for pursuing violations on its new ORT lanes.

2.4 VDOT Traffic Management Centers (TMCs)

VDOT has deployed advanced traffic management systems, several of which cover regions that contain toll facilities. These centers monitor traffic using video and automated detectors and manage responses to incidents. Typically, the interface between the toll facilities and the traffic management center is by email or telephone. For example, if a major incident occurs on the toll facility, they will call the local TMC to request a message be put on dynamic message signs on approaches to the toll facility. The following paragraphs summarize the capabilities provided by these centers.

2.4.1 HAMPTON ROADS TMC

This center serves the Hampton Roads, VA region. Vehicle detection units are used to sense slow traffic. Cameras on the roadway can be used by the operations staff to find the exact location of incidents. VMS signs and highway advisory radio are used to provide drivers with near real-time information.

2.4.2 NORTHERN VIRGINIA TMC

This center manages more than 100 miles of roads in the Northern Virginia area. The center has a large amount of equipment available, including 100+ cameras, 200+ VMS, gates for controlling HOV access on I-66 and reversible HOV lanes on I-95/I-395, 25 ramp meters, 30 lane control signals, 23 vehicle classification stations, and 177 controllers with sensors and loop detectors. The center also has two highway advisory radio sites in the region.

2.4.3 RICHMOND TMC

Located in Chester, VA, this TMC operates in the 14 counties and four cities that comprise the Richmond District. The center has seven traffic cameras, fourteen permanent VMS signs, nine temporary VMS signs, six highway advisory radio sites, and six pavement sensors. The pavement sensors are used to detect precipitation and monitor temperatures on bridges along some major interstates.

2.4.4 I-81 TRAFFIC MANAGEMENT CENTERS

In western Virginia, traffic monitoring using cameras and other devices is used on I-81. Information is disseminated via roadside VMS signs. There are two TMCs collecting and disseminating information: one is Salem, VA and the other in Staunton, VA.

2.5 Operational integration between TMCs and toll facilities (public and private)

The Northern Virginia TMC has some traffic management equipment on the Dulles Toll Road. Embedded loop detectors monitor traffic flow. There are also several CCTV cameras along the road. In the past, there was an effort to consider deploying Variable Message Signs (VMS) near entry locations to the Dulles Toll Road to inform drivers about road conditions, but this has not yet been completed.

2.6 Potential constraints on VDOT upgrades

Toll rate constraints. Altering toll rates is always a sensitive issue. Balancing operational and maintenance costs with bond payments against toll changes needed to support certain technological and operational structures will be challenging. For example, time-of-day pricing and cashless toll collection could both require changes to toll rates.

Existing E-ZPass / IAG membership. Since Virginia is part of E-ZPass IAG and benefits greatly from the common technology and interagency reciprocity, tolling enhancements should be consistent with ongoing participation. The current tolling technology used by IAG consists of Mark IV reader systems and transponders. As a member, Virginia's technology must be compatible with the E-ZPass IAG technology.

Right-of-way availability. In many locations, there is little room for expanding the land used for tolling operations that include manual cash collection options.

Collecting revenue from out-of-state violators. Currently, there is no interstate agreement to fully enforce revenue collection from out-of-state toll road payment evaders. For Commonwealth residents, if payment is not remitted, Virginia courts have the ability to prosecute the in-state violators and request the DMV to hold vehicle registrations until violations have been settled. The lack of interstate enforcement must be taken into account in solutions that may require extensive post-billing of out-of-state customers such as cashless ORT deployments where no manual toll collection options are made available. This revenue loss could be significant on Virginia toll roads due to the number of out-of-state users.

Cost of upgrades. For any planned upgrade, a cost-benefit analysis would be required and should consider both the cost of upgrading the toll facility as well as the cost and risk involved with any upgrades to the central E-ZPass and violations processing.

Privacy. Virginia already has privacy policies in place to protect citizens' private data with respect to toll collection. Implementation of new technologies must maintain this level of privacy and potentially address additional privacy concerns in order to achieve adequate public support.

Safety. Safety near the toll plazas must be ensured. In arrangements where technology is utilized to create high speed throughput, sufficient separation between high speed and low speed traffic must be maintained as well as proximity of exit ramps to physical toll plaza barrier structures. Where toll attendants are required to cross toll lanes to reach their assigned toll booth there are additional considerations in ensuring their safe passage.

Throughput. Many toll plazas operate at or near capacity during peak periods. Any solution to improve mobility must provide the ability to maintain this capacity during deployment and transition.

2.7 Existing and near-term projects related to operations and toll collection

A number of projects around the country are deploying HOV/HOT lanes. These lanes use toll collection with variable, congestion-based rates to make spare capacity from HOV lanes available to single occupant vehicles. With construction beginning in spring 2008 and expected to take about five years, the I-495 HOV/HOT project is a key near-term project in Northern Virginia. Two HOV/HOT lanes will be built in each direction from Springfield to just north of the Dulles Toll Road.

These lanes are intended to serve the purpose of easing congestion along the I-495 corridor by providing assurance of flow to high occupancy vehicles and the option to pay to utilize the extra capacity for single occupancy vehicles. It is anticipated that alternative route decision support will be provided on feeder routes to the HOT lanes if significant delays are expected. Incident detection using video based systems is anticipated, and VMS signs will convey deteriorated road conditions to travelers. Details regarding tolling, traffic management, and integration of the two are currently being developed. However, toll collection on the HOT lanes will be accomplished via open road tolling.

3. OPEN-ROAD TOLLING (ORT) OVERVIEW

Until somewhat recently, the most common approach for collecting tolls was to have the driver stop and pay a toll collector sitting in a tollbooth. The toll collector determines the amount to be paid by each vehicle based upon its characteristics or classification. Generally, vehicle sensors (called Automatic Vehicle Classification) are used to crosscheck these characteristics against the toll collected by the toll attendant. Enforcement was mainly addressed by the use of gates that were raised after the toll was paid. Such manual lanes can accept an extensive variety of payment means, such as cash, checks, credit/debit cards, and smart cards.

A manual lane can process approximately 400 vehicles per hour in comparison to a free-flow freeway lane, with capacity approaching 2,000 vehicles per hour. Meeting peak period demand required the construction of large toll plazas with many lanes. Traffic demand, coupled with the need for each vehicle to stop, still resulted in significant congestion at many of these toll plazas.

The technology that allows tolling at free-flow speeds is called Open-Road Tolling (ORT). ORT is the practice of tolling road users while they travel at normal speed along a given road.

Some benefits of ORT compared with traditional tolling are:

- ORT allows higher traffic throughput thus reducing traffic congestion usually caused by a toll plaza and providing more comfort for the users who can drive through the toll gantry at normal highway speeds.
- ORT minimizes environmental impacts (pollution, visual, and noise).
- ORT increases highway safety.
- ORT lowers investments costs for new toll roads, in particular because less property is needed for toll plazas.
- ORT induces lower operational and maintenance costs.
- ORT enables tolling on new roads, where manual tolling is not possible, e.g. for congestion charging schemes, where no space is available (bridges) or where manual operational costs are inappropriate.

ORT is particularly applicable in highway-speed environments where the time-cost of slowing down is high. On roadways where entrance and exit ramps are used to collect tolls, ORT can still make sense since it will create toll collection cost savings. However, since drivers will naturally be driving slower on ramps, regular divided, non-ORT Automated Vehicle Identification (AVI) tolling lanes (as is currently widely used in Virginia) would likely suffice. Similar statements can be made regarding implementing

ORT on bridges. If, without any toll plazas the flow of traffic would be high-speed, then ORT will be more beneficial. The slower the traffic would otherwise go, the less ORT is beneficial.

ORT relies heavily on electronic toll collection supported by video billing and enforcement. Technologies that support electronic payment for ORT include:

- Dedicated Short Range Communications (DSRC) (i.e. Radio Frequency)
- Infrared
- Video
- Global Positioning Systems (GPS)

These four technologies are described in detail in Sections 3.1 through 3.3 in terms of their application to ORT.

These technologies can be utilized in cashless (no cash payment option is provided) or mixed cash/ORT deployments. Section 3.4 provides further information on the differences between these two applications of ORT technology and the issues associated with application type.

3.1 Dedicated Short Range Communications (DSRC) Tolling Systems & Infrared ORT Tolling Systems

DSRC and Infrared Tolling systems are very similar. The main difference is the wireless communications medium that is used between tag and reader systems.

3.1.1 DSRC TOLLING SYSTEMS

DSRC involves the transmission of an identification code between an in-vehicle device and a roadside reader. The in-vehicle device, called a tag or transponder, is a Radio Frequency Identification (RFID) unit that transmits a radio signal to the roadside reader. Vehicles are identified at fixed points along the roadway. The E-ZPass technology currently utilized by Virginia falls into this category. It has been most widely deployed in non-ORT environments but has also been shown to be accurate in ORT environments with the technology vendor having developed reader enhancements to support this application.

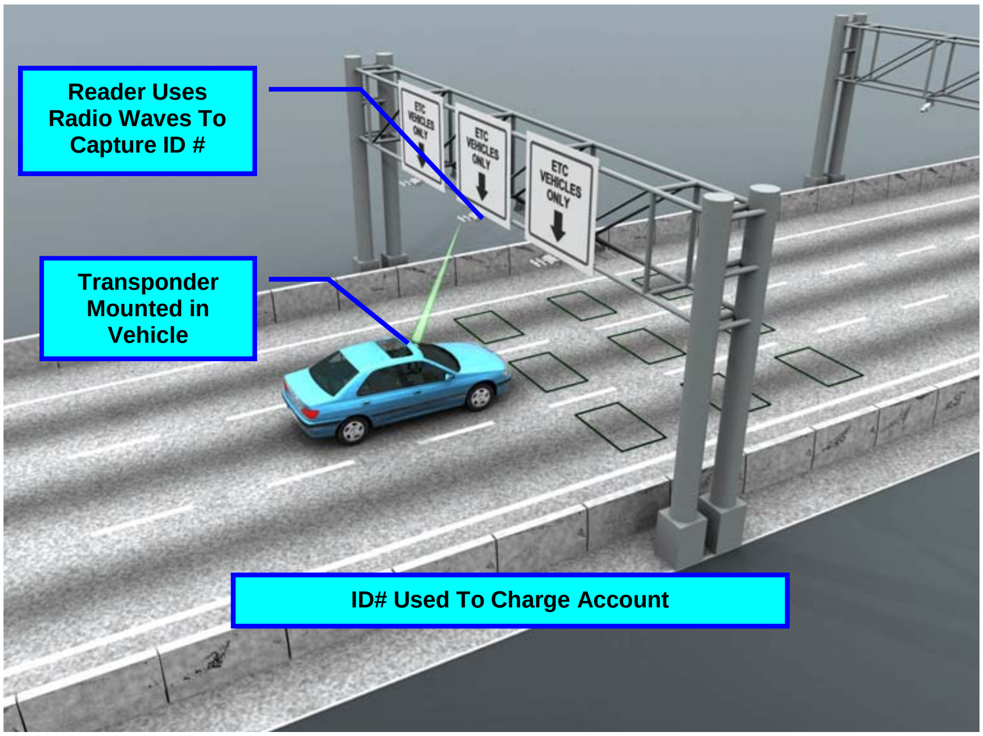

Figure 2 – DSRC ORT operations

Currently, there are several incompatible DSRC systems deployed across the U.S. Interoperability requires both use of a compatible technology in the vehicles and at the roadside as well as reciprocity between systems that operate the user accounts. Most areas have achieved regional interoperability between toll systems with the IAG being the largest interoperable network.

There is work underway at the national level to develop a standard for communications between vehicles and the roadside. This effort is part of the Vehicle Infrastructure Integration (VII) program. An RF communications frequency (5.9 GHz) has been selected along with a protocol. The goals of this technology are much broader than tolling or revenue collection although these standards could possibly be leveraged to provide a nationwide compatible technology. There is also hope that this technology will be built into new vehicles, negating the need to distribute transponders. However, it is unclear yet when this will happen and when or if this deployment will support toll collection without significant modification to the existing toll collection infrastructure. Systems are currently being tested and demonstrated. Most estimates predict that there will not be enough of these devices installed in the vehicle population to support tolling for at least another 10 years.

3.1.2 INFRARED TOLLING SYSTEMS

Infrared tolling systems are similar to DSRC systems, but instead of RF wireless communications, infrared (IR) communications are used between transponders and reader systems. IR systems can be attractive by eliminating radio frequency interference issues that DSRC systems can encounter. However, IR can also have interference issues of its own. Sunlight can actually be a source of interference, as can heavy rain, dust, or fog. A benefit of the IR systems is that the regulatory effort for dealing with licensing for RF systems is eliminated. A company called Efkon, from Austria, has been offering IR based tolling system for some time. They have deployed their systems in numerous countries. They have enjoyed particular success in Malaysia. At the same time, the fact that these tags appear to be supplied by only one company limits sourcing options. In any case, Virginia's membership in IAG will preclude the use of Infrared tags unless IAG decides to move to Infrared tolling.

3.1.3 ROAD-SIDE EQUIPMENT LAYOUT

In the toll zone, there is not a defined plaza. Typically, one or two gantries span the roadway, on which the required devices are mounted.

Vehicle Classification

Axle treadles and light curtains are not suitable for vehicle classification use in an ORT environment because vehicles are allowed to proceed side by side in multiple lanes and to change lanes in the toll zone. Technologies that can be used for ORT are identified below.

'Smart' Loops

These consist of an array of inductive loops embedded in each lane, along with a special purpose control computer that processes the loop data. Smart loops can detect and separate vehicles at speeds from 0 to 150 mph, and track the location of vehicles within the roadway cross-section, including shoulders. Classification parameters include number of axles, vehicle direction, speed, length, axle spacing, dual tires, and motorcycles. They operate well in all types of weather and maintenance is a function of the quality of the road surface.

Overhead Scanners

This technology employs one or more dual-beam overhead laser scanners as necessary to cover the roadway width. The scanners provide vehicle detection and separation data, along with vehicle location across the roadway. Classification parameters include vehicle direction, speed, length, and motorcycles, as well as a height profile. Performance in rain and snow is always a concern, but has been improved in recent years. Maintenance primarily consists of cleaning and alignment.

Video Detection

Video image processing has potential to meet toll requirements. However, it is primarily used for traffic management applications.

Figure 3 - Video vehicle detection

Customer Identification

Customer identification is done in a similar manner as is currently done in Virginia's E-ZPass equipped lanes. However, in an ORT environment, there is an added complexity of tracking vehicles in the "payment zone" and associated correct images with violating vehicles. In the standard tolling environment with separated lanes, vehicles will not change lanes in the toll zone, whereas in the ORT environment they can. Reader systems communicate with tags mounted in windshields. The license plate recognition (LPR) system is used to capture images of vehicle license plates that pass through a toll point without a valid tag read. The LPR system is really a form of tolling, that can and is used independently in some cases around the world such as for London, England's and Stockholm, Sweden's central congestion charge schemes. This is called "Video" tolling and is described further in Section 3.2 In the case of a typical DSRC system, however, video is used as a back-up enforcement tool.

3.1.4 CHARGING

Charging in a DSRC ORT environment is similar to current E-ZPass practices. If a tag is not read, then the LPR read is used to track down non-paying customers for a Video toll (V-Toll) or to find violators via Department of Motor Vehicles (DMV) records.

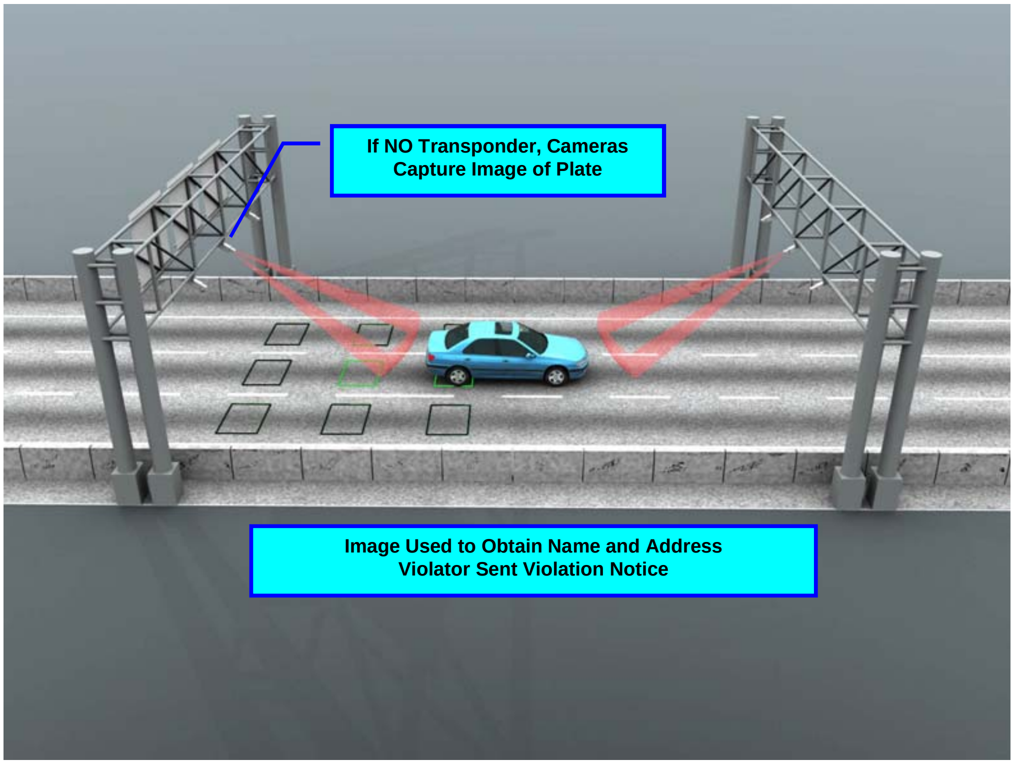

Figure 4 - License capture and use

Just as with the current E-ZPass, there are inevitably tolls that could be easily collected at the toll zone that will be uncollectible via the plate identification and post-billing process. However, in an ORT environment, an increase in violation numbers can, at least initially, be expected. This can be due to problems with the plate identification function (plate image unreadable), the DMV lookup function, the mailing function (address does not exist), or the customer just does not want to pay after the fact. To facilitate toll payment by non-tag users, various types of customer-initiated payments are possible:

- **License Plate Pre-registration –** Customers may register with the toll agency before using the roadway. They provide the vehicle plate number and jurisdiction, the vehicle category, the toll facility(s), and pay the toll using a credit card. This can be done by telephone, Internet, or at a kiosk (perhaps located at a rest area). When the vehicle passes through the toll zone, the plate is identified as pre-paid, and no further processing is required. A discount is typically offered to encourage this type of payment. Examples of places that use this are CityLink, Australia; Costanera Norte and Vespucio Expressway, Chile.

  Customers must be aware of the opportunity before commencing their journey. Signing on the roadway is potentially dangerous as it may cause drivers to carry out the transaction over their mobile phones while in motion.

- **License Plate Post-registration** – Customers may register with the toll agency after using the roadway. An acceptable time interval or grace period for payment is clearly stated. When the vehicle passes through the toll zone, the plate is identified and the transaction allocated for post-billing. Subsequently, the customer contacts the toll agency by telephone, Internet, or kiosk. They provide the vehicle plate number and jurisdiction, the vehicle category, the toll facility(s), and pay the toll using a credit card. The transaction is then removed from the post-billing list, and no further processing is required. A discount is typically offered to encourage this type of payment. Examples of places that use this are London Congestion Charging, UK; CityLink, Australia; and Costanera Norte, Chile.

3.1.5 DSRC EXAMPLES

Prominent examples of DSRC ORT cashless systems include:

- Highway 407, Canada
- Citylink, Australia
- Costanera Norte, Chile
- Highway 6, Israel
- SR-91 Express Lanes, USA
- Singapore Electronic Road Pricing (ERP)
- Austria: “go” Weight-Distance truck toll program

3.2 Video ORT Tolling Systems

The use of cameras for vehicle identification in tolling is referred to as video tolling. Video tolling is done by means of license plate recognition (LPR) using Optical Character Recognition (OCR). This system is already used as a backup to E-ZPass in Virginia, but can also be used as a stand-alone tolling technology.

3.2.1 ROAD-SIDE EQUIPMENT LAYOUT

Vehicle Classification

Although trials have been carried out to demonstrate that video technology can be used to differentiate between cars and trucks, it should be noted that video technology has not yet been used for vehicle classification in an operational environment.

Customer Identification

Cameras are mounted on gantries to allow the cameras' field of view to span the roadway. A network of fixed camera sites is typically used; however, mobile units, whereby the camera is attached to the vehicle, are mainly used for enforcement (see Figures below).

Figure 5 - Video tolling equipment

Some systems use infrared lighting to take a sharper image of the plates. Video systems can operate in both day and night conditions and respond to weather-related changes in ambient lighting. A small roadside cabinet may be required for storage of the video data before transferring to a central data center for processing. Processing can also occur in the roadside cabinet rather than at a data center.

The software aspect of the system runs on standard PC hardware and can be linked to other applications or databases. It first uses a series of image manipulation techniques to detect, normalize and enhance the image of the license plate, and finally OCR to extract the alphanumeric data of the license plate.

Video systems using OCR are generally deployed in one of two basic approaches:

- **OCR processing in field** – This method allows for the entire process to be performed at the lane location in real-time. The information captured of the plate alphanumeric data, date-time, lane identification, etc. is transmitted in small data packets to some remote computer for further processing if necessary, or stored at the lane for later retrieval. This approach has been used for the deployment of the western extension of the London Congestion Charging Scheme.

- **OCR processing at a central location** – This method transmits all the images from many lanes to a remote computer location and performs the OCR process there at some later point in time. Typically a server is used to handle the high processing demands, such as those found in the initial camera deployment of the London Congestion Charge Scheme. Often in such systems, there is the requirement for larger bandwidth transmission media.

License plate arrangements may be designed using varied font sizes and positioning. Therefore, Video systems must be able to handle such differences in order to be truly effective. Overall, there is an error rate that makes manual verification desirable.

Once the license plates have been distinguished, these numbers are then matched to a list of plate registrations to identify the owner of the vehicle.

3.2.2 CHARGING

Typically, as a vehicle passes through the toll zone:

- Images of the vehicle are captured by overhead cameras;
- Image data is processed using OCR either in the field or at a central site;
- Manual license plate identification is completed; and
- License plate numbers are matched to a list of vehicle registration records.

There are two types of payment options:

- **Registered Accounts -** The motorist must first register the vehicle's plate with the tolling agency prior to using the toll system. Customers provide their vehicle plate number and jurisdiction, vehicle category, toll facility, etc. This can be done through telephone, Internet, or at a kiosk. When the vehicle passes through the toll zone, the plate is identified and matched from a list of registered accounts. The amount of the toll will then be debited from the account if it is prepaid, otherwise, a bill of the toll fee is sent to the address associated with the account.
- **Unregistered Accounts –** For motorists who have not registered their vehicle's plate prior to using the toll system, the plate is identified and matched against a list of vehicle registration information available from the DMV database. A bill of the toll fee is sent to the address associated with the vehicle registration information found. Additional fees are typically administered for such post payments.

3.2.3 ENFORCEMENT

Types of fraud that can occur include cloned license plates, intentional license plate obstruction, and obscuration (where the driver intentionally tailgates behind another vehicle to avoid being caught on camera). Enforcement can be both mobile and fixed.

In terms of revenue leakage prevention with video enforcement, it is important to ensure that (a) there is no systematic way of evasion, and (b) enough customers think they are unlikely to get away with it. In addition to this, the penalty for trying to evade the charge must be made quite punitive.

3.2.4 ADVANCED VIDEO TECHNOLOGY

Advanced video technology is available to make video tolling more accurate both by itself as a tolling mechanism and as a backup violation enforcement system. One such technology is vehicle "fingerprinting" and is available from companies such as Jai Pulnix and Raytheon. Jai Pulnix performed a pilot deploying on Virginia's Dulles Greenway. Raytheon has implemented a similar system on Toronto's 407 Electronic Toll Road (ETR) (see section 4.6 for more about this road). In both cases, the technology appears to have been successful

The fingerprinting technology works by allowing the tolling agency to create a "master" vehicle image database, in which high-confidence captured images of vehicles who have used the facility in the past are held. In these master images, plates can clearly be read with high confidence. For future images that have low OCR license plate read confidence or are completely unreadable, cross-matching to the master set can be done to try to find a close matching master fingerprint image with a clear view of the license plate. The cross-matching can be mostly automated, and uses both vehicle and plate characteristics to perform the matching. Initial "master" images are always verified by a human.

The Dulles Greenway proof of concept showed that the system can match 83% of images to the original master images with full automation. The ones that could not be matched would be sent for manual review, as was originally the case for all images. This advancement can minimize manual labor costs associated with image processing. The proof of concept also showed that with the aid of this technology, over 98% of all captured images could now result in correct license plate data. The system also showed a clear ability to differentiate vehicles with very similar license plates but different vehicles. In some cases, the exact same license plate was re-issued to the different vehicles, and the system again showed an ability to differentiate the “fingerprints” by differentiating vehicle characteristics.

In Toronto’s 407 ETR’s case, prior to the “fingerprinting” pilot, they had 60-66% of transactions that were routed to violation enforcement processing with “low confidence” OCR results. The goal of the pilot was to reduce the number of transactions that need manual intervention. At this point, more than 480,000 vehicles have been “fingerprinted” and entered into the master database. For their pilot, they were able to reduce the number of low confidence reads that needed manual intervention by 45% using this technology. They hope to raise this percentage to 75% in the future. In addition to manual labor cost savings, they have significantly lowered their unreadable plate percentages. Incorrect processing of transactions has also decreased.

3.2.5 VIDEO TOLLING EXAMPLES

Prominent examples of video ORT tolling are:

- London central congestion charging
- Stockholm, Sweden central congestion charging

3.3 GPS ORT Tolling Systems

Global Positioning System (GPS) tolling is a tolling methodology that uses satellite based vehicle tracking to determine the appropriate toll charges based on the vehicle travel information (distance, speed, time, and location) and vehicle characteristics (such as vehicle type, emissions class, and maximum laden weight).

An On-Board Unit (OBU) through the utilization of GPS technology and odometer readings can record vehicle locations, speed of travel, time of travel, and distance of travel. The vehicle characteristics are stored in the OBU as well. The OBU can then transmit the information to a back office through cellular data networks.

3.3.1 ROAD-SIDE EQUIPMENT LAYOUT

Satellite tolling based on GPS usually requires pay terminals, which can be erected anywhere. Additionally, control bridges or mobile units equipped with DSRC are options for enforcement.

Vehicle classifications are stored in the OBUs and are transmitted to a back office via cellular data networks. Customer identification is done prior to driving when a vehicle user activates their OBU.

There is no infrastructure required at a tolling point. Tolling points can be easily added, moved or removed through use of software configuration. This technology is therefore highly desirable in large networks using distance based tolling. The major disadvantages of this technology include the need for cellular type communications, the current relatively high-cost of the in-vehicle unit and privacy concerns relating to the ability to track all vehicle movements.

3.3.2 CHARGING

In a satellite tolling system, drivers are immediately categorized as either paying customers or violators. Unidentified customers that have not arranged to pay are automatically considered violators of the system. Charging for a satellite tolling system can utilize either a pre or post payment function.

In the German truck toll, there are three payment options available, all of which employ a pre payment function. The three payment options are:

- Automatic charging on an OBU,
- Manual payment through the Internet, or
- Manual payment at one of the roughly 3500 toll station terminals.

Automatic charging on an OBU is where GPS is mainly utilized, while the manual charging options do not require GPS. Manual charging via Internet or toll station operate based on vehicle's driver's origin, destination and characteristics (which are manually entered), after which an appropriate route and fee are presented.

In the Switzerland HVF truck toll program, vehicles with an OBU can make payments by inserting a smart card into the OBU. The smart card data must be submitted monthly to customs authorities, either directly by post or electronically by Internet, who then check the validity of the data, calculate a fee and return an invoice. For non-OBU users (including foreign vehicles), a smart card is issued upon entry into Switzerland containing the maximum fee parameters of authorized weight and emissions class. The truck driver then inserts his card at a self service station at the border and declares the current kilometer reading of his tactograph. When leaving the country, the driver is issued a declaration slip, upon which he records his kilometer reading again. The kilometer declarations are checked randomly by customs. The fee must be paid before leaving Switzerland, either by cash or credit card.

In terms of variable charging, both the German truck toll and the Swiss HVF employ a variable charge per kilometer based on the number of vehicle axles and the vehicle's emission category.

3.3.3 ENFORCEMENT

DSRC has been used for enforcing GPS collected tolls. Enforcement can be done through automated enforcement, mobile enforcement, or a combination of both, as done in the German truck toll and the Swiss HVF toll.

Automated enforcement can be implemented using control gantries, as in the German truck toll. Control gantries use DSRC, which allows communication with the OBU's to determine if they are present and operating in a truck. The truck is scanned three dimensionally to determine how many axles it has and what its maximum weight is. Finally, a camera captures its licence plate. The truck's information is sent to a back office where it is compared with the registered licence plate and travel information for that truck. The process reportedly takes only a few seconds, after which the information is immediately deleted if the truck is properly logged into the system, otherwise the authorities are informed and an administrative fine is processed. Local enforcement units are also immediately informed if the control gantry finds a discrepancy, and are assisted in determining which trucks to stop for toll violation.

For mobile enforcement, vehicles equipped with DSRC can detect:

- Whether the OBU has been correctly licensed;
- Whether the OBU is working properly and has not been tampered with; and
- Whether credit payers have sufficient credit remaining (for pre-payment).

The mobile enforcement vehicles perform these checks without stopping as they pass vehicles on the roadway.

3.3.4 GPS TOLLING EXAMPLES

As mentioned, the prominent examples of GPS ORT tolling systems include:

- o Switzerland: “HVF” Weight-Distance-Emission truck toll program
- o Germany: “Toll Collect” Weight-Distance-Emissions truck toll program

3.4 Cashless versus mixed cash/ORT

The ORT technologies described can be used to create completely ***cashless*** toll roads in which all payments are collected electronically at high-speed without toll collectors or coin machines. There are several toll facilities in North America and around the world that are operating in this mode.

Alternatively, these technologies can be utilized in a ***mixed cash/ORT*** arrangement. This involves the dual collection of tolls via both ORT means as well as accepting cash at a traditional toll plaza. This option is potentially more attractive to agencies that need to provide customers with more payment options due to customer service or demographic mix.

Virginia’s Pocahontas Parkway (illustrated to the right) is an example of a mixed ORT/cash toll road. At the tolling location, the road is split into ORT lanes on the left and lanes on the right where a customer can pay cash or interact with a toll booth attendant. Afterwards, the roadway again merges together. E-ZPass DSRC transponders are used as payment in the ORT lanes at Pocahontas Parkway.

Figure 6- Pocahontas Parkway toll zones

In Section 4, information on various ORT systems in North America is outlined. Many of these are mixed ORT/cash, since that is the most common arrangement currently in the United States. However, as ETC penetration increases and the benefits of full open road operation are witnessed, a greater number of agencies are making plans to move to cashless tolling systems.

There are a number of issues to consider for an agency when deciding whether cashless ORT or a mixed ORT/cash tolling solution is best. Table 1 presents a comparison of these ORT tolling techniques.

Table 1- Cashless vs. Mixed ORT/Cash comparison

Issue	Cashless (ORT only)	Mixed ORT/Cash
Payment options.	Due to limited payment options, customers may not use the toll road. Others, who are unaware of the special road type, will violate, increasing the violation rate.	Customers will have more payment options.
Safety.	The toll plaza is relatively safe since customers will not be tempted to switch lanes in the last minute from high speed to low speed lanes and vice versa.	Customers may become a safety hazard if they decide to merge into the attended lanes in the last second from the ORT lanes. This can result in particularly devastating accidents due to the high speed at which these vehicles will likely be travelling. Toll attendants will not be able to cross the toll facility to reach toll booths in the opposite direction without special facilities (e.g. tunnel.)
Toll Revenue.	Due to some customers who were willing to pay cash not being able to do so, direct toll revenue will decrease because some of these customers will not be successfully post-billed using the License Plate Recognition system. Long-term, however, a cashless system can encourage more customers to sign up with the tolling agency, which would help to bring toll revenue back up.	Customers who only could pay cash have that option and thus more toll revenue will be collected. However, they would not be as encouraged to sign up with the toll agency for electronic payment.
Toll Plaza Requirements.	There is no need for regular toll plaza layouts. Instead, a regular road cross-section and typically, two overhead gantries and road-side equipment are all that is needed. This results in significant capital expense savings.	A fairly complicated toll plaza layout is required to accommodate both ORT and cash payment. To move toll plaza staff from one side of the toll plaza to the other will require a tunnel or over-bridge.
Operational Costs.	All costs related to cash collection and cash handling at the plaza are eliminated. This is in addition to the capital expense savings. At the same time, customers who are considering intentionally violating will likely feel less threatened and intimidated by proceeding through a plaza at highway speeds than through slow-speed plaza with toll attendants. This, along with other factors, will require an increased cost and effort in the customer service center to process video transactions and violations.	Cash collection and handling costs are still necessary.

Electronic collection sign-up rate.	In order to make cashless ORT systems feasible, a large enough transponder subscription rate needs to be first established. This at least is true in the case of DSRC or Infrared tolling systems. In the cases of Video or GPS tolling systems, customer pre-registration is not necessarily a requirement for legitimate (i.e. non-violating) road use.	A high electronic collection sign-up rate is still desired to ensure adequate use of the ORT lanes. However, the sign-up rate will not have such a large impact on the tolls successfully collected.
Plaza Length.	Plaza length can be eliminated.	The length of the plaza may need to be lengthened to accommodate splitting and merging of highway speed and slowing traffic.

4. EXAMPLES OF ORT IMPLEMENTATIONS IN U.S. & CANADA

4.1 New Jersey

New Jersey has been heavily active in deploying ORT using E-ZPass technology. Both the Garden State Parkway and the New Jersey Turnpike have significant numbers of ORT installations. On the Parkway, 5 toll plazas with 18 lanes have been converted to ORT. On the Turnpike, 3 plazas with 10 lanes have been converted. All conversions have been in the form of mixed ORT/cash plazas with the standard arrangements of ORT lanes on the left and regular E-ZPass/cash lanes on the right. As an agency, their E-ZPass penetration rate is 70%. Of the customers who are using E-ZPass, 96% are using the ORT lanes on the Parkway and 98% are using ORT lanes on the Turnpike. The main reason that some customers do not use the ORT lanes to pay with E-ZPass is because in the express lanes there is no confirmation from a light box signifying an accepted payment. The agency has found that particularly older drivers with E-ZPass prefer to have this confirmation even if it means losing time in going through regular toll lanes. The agency has also found that the cost of implementing ORT at toll plazas has been mostly related to civil engineering work. Some upgrades to the toll system were also necessary, including integration of Idris embedded loops in the ORT lanes to properly track and classify vehicles.

Figure 7 - New Jersey Mixed ORT/Cash toll plaza

4.2 E-470 (Denver)

The E-470 is a toll road that loops around the eastern perimeter of the Denver metropolitan area. The entire road spans about 47 miles. DSRC tolling technology called ExpressToll is used for electronic payment on this road. Mixed ORT/cash systems are employed here.

The first segment of the E-470 was opened in 1991 and it was built already at that time with Mixed ORT/cash system. Now, the road has 5 mainline plazas, all with ORT and cash lane infrastructure. There are also 32 ramp plazas that are ACM and ExpressToll capable.

Currently, 73% of their transactions are with the ExpressToll. Due to this relatively high penetration rate, they are currently working towards converting the mainline plazas from mixed ORT/cash to cashless ORT. They hope this can be achieved by mid 2009.

One lesson learned from operating this system was that the signage for mixed ORT/cash operations has to be very clear. Leading up to toll plazas, they have 4-5 sets of signs directing drivers to the left lanes if they want to go through the ORT lanes or otherwise to the right lanes.

Figure 8 - Denver E-470

4.3 Miami Dade Expressway

The Miami Dade Expressway (MDX) network consists of five expressways in Miami-Dade county:

- State Road 112 (Airport Expressway),
- State Road 836 (Dolphin Expressway),
- State Road 874 (Don Shula Expressway),
- State Road 878 (Snapper Creek Expressway) and
- State Road 924 (Gratigny Parkway).

The length of the five expressways that MDX manages totals more than 31 center-lane miles. 95% of the revenue that funds these roads comes from toll receipts. They use a DSRC system for tolling called SunPass. They have begun deploying ORT along some of these roads, utilizing both cashless and mixed ORT/cash plazas. Part of the motivation to establish ORT here is to make tolls more equitable. Since toll collection with ORT is easier for the customers, more collection points can be set up and tolling can be more proportionate to the extent of the toll road use.

From lessons learned, MDX experience has shown that the Customer Service Center (CSC) needs to be ready for the greater contact volume associated with ORT usage. Also, as more tolling becomes electronic, they expect to expend effort in converting toll attendants to CSC staff.

4.4 Illinois State Toll Highway Authority

The Illinois State Toll Highway Authority has converted 20 mainline toll plazas to ORT on the Illinois Tollway. The technology used is compatible and reciprocal with the E-ZPass DSRC system but is branded as I-PASS in Illinois. All plazas are mixed ORT/cash plazas with cash lanes on the right. They view cashless plazas as the ultimate goal of tolling, but decided that the mixed ORT/cash setup was the appropriate first step. The project was delivered in an expedited manner for political reasons, with design being finished in January 2005 and all plazas converted to ORT capability by October 2006. The grand conversion to ORT was spurred by the Illinois governor's plan to rebuild, widen, open up all plazas (in 2 years), and build 12.5 miles of new highway on the Illinois Tollway. This conversion was part of the governor's congestion relief plan. As part of this plan, the governor wanted to move people to use I-PASS. In order to encourage this, while I-PASS rates would stay the same, cash toll payment amounts would double. Truck rates, although some breaks were provided for off-peak and I-PASS usage, also increased dramatically.

ORT installations are 4 lanes wide with shoulders on the side. To the right are low-speed I-PASS only and manual lanes. I-PASS readers are present in the low-speed lanes also. Before the conversion, there were 4 types of lanes in the system: manual, ACM only, I-PASS only, and I-PASS express lanes on several locations.

The original layout of the plazas, as drivers would see them, was I-PASS only lanes on the left, ACM lanes in the middle, and manual lanes on the right. An example of how conversions were done followed these three basic steps:

1. Remove ACM only lanes
2. Make the old ACM only lanes I-PASS only lanes
3. Make the old I-PASS only lanes ORT lanes

The new ORT installations and toll rate changes appear to have helped to encourage higher I-PASS penetration rates. In 2003, Illinois Tollway had 38% I-PASS penetration rates. In 2007, these rates climbed to 80%, a very high percentage compared to other facilities around the U.S.

Before the conversion, three of their plazas each had 2 express lanes in each direction. This was a similar setup as is currently installed at the Dulles Toll Road in Virginia. Also, before the conversion, a tunnel was present below toll plazas to allow employees to move from one side of the plaza to another. ACM's were also present. After the conversion, the ACM's were removed and an overhead walkway was installed at plazas instead of the tunnels. Slim building design was used to avoid buying extensive new right-of-way and to minimize environmental impact.

Due to the enormity of the project, the Authority broke up the project into 8 design contracts for the 20 plazas. One program management consultant was hired to help manage the project and share information amongst all of the participants.

Plaza conversions were of three different types of upgrade levels: retrofits, facelifts, and full reconstructs. The easier conversions were done first. The total cost of all conversions was $730 million.

The retrofits were done for those plazas that already had the express lanes. In these upgrades, the middle of the road was demolished and replaced with ORT gantries. New buildings were already present at these locations. Costs for these types of conversions varied between several million dollars to $15 million, depending on the size of the plaza.

The facelifts had to be done at plazas where buildings were old. In some cases, half a plaza was taken out and moved to a new location. The average cost for this more involved process was about $20 million per plaza.

In other cases, plazas had to be completely reconstructed. For such conversions, costs ranged from $30 million to $55 million.

The Authority has put up signs at every plaza to reach out to customers and convey the new system setup. Signage is typically present 1 and 1.5 miles before toll plazas, in addition to being present at the actual toll plazas. Cash paying customers are directed to the right. In areas such as O'Hare airport, where out of town drivers are prevalent, additional signage is used to inform these travelers who may not be familiar with mixed ORT/cash toll systems. The Authority believes that as additional, similar deployments are implemented around the U.S., less confusion will be encountered by such unfamiliar travelers.

4.5 Tampa-Hillsborough Expressway Authority Reversible Elevated Lanes (REL)

This was the first reversible lane ORT project in the United States. It involves 3 highway elevated lanes in Tampa Bay, Florida and is a cashless deployment with no cash payment option. The length of the elevated expressway is 9 miles with the western terminus in downtown and eastern terminus in Brandon. Tolls are collected using SunPass DSRC technology which was originally required in order to be able to use the facility. They have recently implemented a "Pay-by-Plate" option that would allow video tolling on the facility for customers without a transponder. The toll for "Pay-by-Plate" is slightly higher to compensate for higher toll processing costs.

Currently, there is one cashless ORT plaza on the elevated structure. The lower, parallel road is a toll road, with regular, slow speed tolling facilities with a cash option. They have found that the violations rates for the ORT elevated lanes is about 6% and is only 3-3.5% system wide. Although they have new OCR equipment which allows an accuracy of over 80%, they still manually review all images. As in other facilities, they are finding that some customers with transponders are using the slow lanes instead of the ORT lanes. They believe that this is largely due to the geometry of the road and inadvertent missing of entry ramps to the elevated structure. In each direction, there are 2 entry ramps at the beginning of the expressway in each direction. There are 2 exit ramps on the downtown side and 3 exit ramps on the Brandon side. The barriers on the sides of the elevated expressway are 3-4 feet in height.

The Expressway Authority experienced a lot of political pressure to implement this system in a rushed timeline. As a result, they launched the system without final system acceptance, but with only a conditional acceptance. As part of their lessons learned, they emphasized the importance of allowing sufficient time for testing for any new system. They also experienced some technical problems in implementing an elevated toll zone. Part of the equipment was housed on the ground level and installing the interconnection between the ground level and the elevated toll plaza equipment presented an added level of complexity when deploying the tolling system. In this scenario, the new ORT lanes had to be elevated due to right-of-way limitations, but the Authority now believes that perhaps they should have still built the toll zone itself at ground level even if the rest of the road would be elevated. Gradual ramps down and back up would then have had to be built near the toll zone. They also have an entry ramp onto the expressway right before the ORT toll zone. This creates an unnecessarily turbulent traffic environment in this zone. However, they have found that the smart loop system that was installed has performed very well in tracking cars, even if they are changing lanes as they pass under the tolling gantries.

According to their experience, the cost of setting up a 3-lane cashless toll plaza is about $750,000 in each direction without the costs of the gantries. In their case, this cost is almost doubled since equipment had to work in both directions.

The Tampa TMC is responsible for managing the expressway. They remotely control access gates to change the direction of use in the middle of the day. They also have a dedicated team that "clears" the road before the direction of travel is reversed for obvious safety reasons.

Originally, when the ORT lanes were installed, the authority experienced the standard public criticism that the lanes were "Lexus lanes". This was due to the $25 cost of the SunPass transponders and need for pre-payment on the accounts. They have found that since the implementation of the "Pay-by-Plate" payment option, some of these objections have subsided since some of the upfront costs to use the ORT lanes were eliminated with this program. In the "Pay-by-Plate" option, customers still need to register their vehicles. They can either pre-pay a minimal amount or can provide a credit card to which the authority can charge for each trip taken.

Figure 9 – Tampa Elevated Cashless ORT lanes

4.6 Toronto 407 Electronic Toll Road (ETR)

The 407 ETR extends 108 km just North of the Toronto central area. It has some 43 interchanges and operates solely as a cashless toll road. The initial phase of the road was opened in 1997, with the intention of allowing drivers to enter and exit the highway at regulatory speed. It currently generates some 300,000 vehicle trips each working day.

The 407 ETR uses a DSRC technology that is similar to, but not compatible with, that used in E-ZPass. 80% of transactions on the road are currently paid for using transponders. The road uses overhead gantries which read customer tags at entry and exit points. A system of cameras captures images of vehicles passing through the toll highway, and the image of the license plate is extracted and used to identify the vehicle for video tolling or violation processing. Customers can sign up for video tolling, but there is an additional fee.

Figure 10 – Toronto 407 ETR toll zone

There are two tag types distributed by the 407 ETR:
• Tags for Light Vehicles with a gross weight or registered weight of 5,000 kilograms and under; and
• Tags for Heavy Vehicles with a gross weight or registered weight of over 5,000 kilograms. It is mandatory for all heavy vehicles to have a valid tag that corresponds to the same classification.

The 407 ETR operates as a closed system, where vehicles pay on the basis of the toll calculated in relation to the point of entry and point of exit. Users, apart from truck drivers can choose to register and receive a tag, with either pre or post pay (in the latter case a direct debit authorization is required) or they can choose to register without a tag (the transactions being carried out by image capture and subsequent analysis), in which case they pay an additional C$2.65 to cover the administration costs. Non-registered drivers are given a 24-hour period to register and thereafter enforcement proceedings commence. All trucks over 5 metric tons are required to have a tag fitted before traveling on the highway.

Tolling gantries, containing antenna, vehicle detection and classification sensors and cameras, together with associated equipment cabinets, are located at all entry and exit ramps. The effective total number of lanes covered by these gantries is in excess of 300. As in all ETC systems, if the system is unable to complete a transaction with a vehicle (for whatever reason) images are captured of the vehicle number plate – around 4 or 5 images are generally stored for subsequent analysis.

The initial operations of the system highlighted that many of the problems were operational rather than problems with equipment. A major area was that of vehicle exception processing; there was a very high demand for this in the early years. The other initial problematic area was that of customer interface with a lack of sufficient resources. The need to reduce the number of non-tag transactions, despite the additional revenue generated in association with these transaction types, quickly became an important goal due to the labor intensive work of charging via video records.

Initially, they also had issues with the ability to detect that video images were beginning to deteriorate at particular locations. By the time images had begun being rejected due to poor quality, it could take a significant amount of time to maintain the camera location resulting in direct loss of revenue. As a result, 407 now uses image quality prediction capabilities to identify where images are about to become unusable. Maintenance can be dispatched to these deteriorating locations before image loss occurs. They now claim to have near zero unreadable video images due to camera issues.

Since about 20% of their transactions are going through the OCR process (with some being manually verified), the issues with unreadable plates that are dirty, obstructed or otherwise unclear was also a significant revenue issue. As a result, they trialed and then deployed vehicle “fingerprinting” technology (see section 3.2.4 for further details on this technology), where the characteristics of the plate and vehicle fingerprint masters are saved for later matching with incomplete or obscured future images. This has allowed them to invoice a greater number of transactions.

5. FUTURE STEPS FOR VIRGINIA'S TOLLING

5.1 Evaluation of Current Situation

Virginia is in good position to modernize the state's tolling systems using ORT technology. Due to the state's affiliation with the E-ZPass IAG and IAG's ties to the E-ZPass DSRC technology, it seems only feasible to plan ORT development around this constraint. This would follow precedent of all other North American ORT systems that were researched as part of this study. All of these systems, whether cashless or mixed ORT/cash, used DSRC transponder technology as the primary electronic toll payment method. Video-based toll collection is used in addition to the DSRC systems and serves different levels of importance depending upon the implementation: a) only for enforcement purposes (for mixed cash/ORT and transponder only facilities) and other times also as an alternate and higher cost payment method (for cashless ORT).

Virginia does have several advantages when compared with some of its peers in terms of being in position to move forward with ORT deployment. Some advantages are as follows:

- Virginia already has some ORT implementations at the Pocahontas Parkway and a pending implementation at the RMA. RMA will soon open their first ORT plaza, taking advantage of VDOT's central processing for E-ZPass transactions as well as violation processing.
- Many of Virginia's tolling facilities have good E-ZPass penetration rates, which is a prerequisite for making good use of ORT facilities.
- Virginia has recently upgraded its online and interactive voice response back office capabilities for both customer service and violation processing permitting more automated self service capabilities.
- Virginia already has a deployed and established violation processing system that includes legislative support.
- The state is already in the midst of establishing processes with the courts to deal with non-paying violators.

Although there is a relatively high percentage of E-ZPass users on Virginia toll roads who actually reside in the state, an associated challenge may still need to be overcome. As has been discussed in the earlier chapters, ORT tends to increase violation rates and thus if out-of-state violators cannot be pursued, the revenue loss due to this reason will increase. In addition, cashless ORT effectively increases the use of the video system from a 5-6% violation transactions to 20-30% video billing transactions. To-date, most deployed cashless ORT systems (e.g. Toronto's 407ETR, Tampa Bay's elevated ORT lanes) are located such that their toll roads have high in-state use. Virginia's statewide violation enforcement is still relatively new, and there is not enough experience built up yet to understand how effective the process will be in pursuing these out-of-state violators. Other than mailing a summons to out-of-state violators, it appears that Virginia's code does not have support for in-person serving of out-of-state violators. Furthermore, there are no reciprocal agreements with other states to hold vehicle registration for non-payment of tolls in Virginia.

Additionally, several toll facilities in Virginia have aging toll collection equipment. The replacement of this equipment should be combined with a solid review of toll collection methodologies on the facility to identify the level of ORT that could be employed and the potential for moving to cashless toll collection.

5.2 Recommended Considerations and Actions

ORT clearly has advantages that make its implementation attractive in Virginia. To progress an initiative to move towards ORT, there are considerations and actions that should be taken by the Commonwealth to prepare for a statewide deployment. The following are essential considerations and actions.

- **Maximize transponder usage.** Costs associated with tolling operations are highly dependant on the level of non-transponder transactions (i.e., those processed using license plate images in an ORT scenario), as the processing costs of non-transponder transactions are significantly higher than the cost of transponder transactions. The reasons for this include manual image review costs, invoice mailing, payment processing, dispute processing, processing renter and lessee information, and pursuing non-payers. ORT operations are more transponder dependant and maximizing transponder usage will be important to maximize the benefits of ORT.

  Maximizing transponder usage depends in part on the following:

  - A successful marketing and public relations campaign that reaches all prospective customers and clearly explains the new ORT system, its services, and its benefits;

  - Providing incentives to encourage transponder use, such as issuing transponders free of charge, post-payment for tolls charges incurred, and preferential rates for tag users. Preferential toll rates could be implemented by discounting rates for tag customers, increasing cash or video toll rates and charging administrative fees on video tolls; and

  - Limiting the number of times a customer can be charged by video tolling (to a maximum number of transactions per year, for example) without incurring additional fees.

  It should be noted that ORT lanes themselves will encourage more customers to switch to transponder usage as they more clearly see the mobility benefits provided to electronic toll users.

  It is important to note that, without mandating transponder usage or utilizing devices that are installed in the majority of vehicles (such as future 5.9 GHz devices,) there is likely a maximum electronic toll percentage that can be achieved. This maximum is based on factors such as the types of users on that road and the proximity to other toll facilities. From experience elsewhere it is appears that currently this maximum is in the 75-80% range. It should also be noted that many toll facilities are analyzing usage of transponders and determining that a large percentage of their electronic toll customers do not make frequent trips using their transponders. There have been reports that 60-75% of electronic toll account holders use their transponder on a trip once per week or less. It is therefore prudent to balance the cost of encouraging infrequent users to enroll in the program versus the cost of processing these users with image tolling. There is no evidence that this trade-off has been clearly validated within the industry since the historical focus has been on increasing electronic penetration.

- **Optimize back office operation.** Back office operations include customer service and violations processing. One of the main ways to control operational costs is to optimize the allocation of work between automated and manual processes. This means guaranteeing the maximum level of accuracy and efficiency of the tolling and image capture subsystems. Experience suggests that there is a balance to be struck between investment and operations – there is clearly a threshold beyond which investment in automation costs more than the operational savings it ultimately delivers.

  Critical determinants of the efficiency of the back office include:

  - Accuracy of the license plate recognition and image validation subsystem. The “fingerprinting” technology outlined in Section 3.2.4 can help to maximize LPR rates.

  - Minimizing of customer service center staff time through emphasis on "self-service" techniques, such as online account access and interactive voice response.

  - Integration of non-automated customer service channels for inbound communications (faxes, e-mails, voice recorded messages) with the automated portion. This requires "connectors", which are software modules parsing the events from non-automated channels and generating input necessary for activating back office interventions. This requires ongoing workflow analysis.

  - Efficient use of technology to reduce the costs of communicating with customers (e.g., voice mails with text-to-speech technology).

  - Integration of a centralized workflow management tool that monitors and maximizes the efficiency of operational activities at both an individual and departmental level.

- **Address out-of-state violations.** Given the likely increase in violation rate and the potential need to bill out-of-state travelers, moves toward ORT should be combined with efforts to improve the process for pursuing out-of-state violations. Currently, on VDOT's toll facilities, Virginia plates account for over 77% of the violations and combined with Maryland this number rises to over 92%. Five states account for 97% of violations; however, an additional 9 states (for a total of 15) must be added to the list to account for 99% of violations. Since this issue is important to many agencies, Virginia could look to participate in a multi-state initiative to pursue this issue.

- **Consider removing ACM lanes.** DTR and other Virginia facilities have faced ongoing maintenance problems with automated coin machine lanes. As Virginia adopts ORT solutions, it should consider following the Illinois Tollway example and discontinue use of ACM's. Around the country, the use of ACM lanes has been on the decline. If a non-electronic toll option must be provided, use of toll attendants and/or credit card payment may be just as cost effective.

- **Consider implementing ORT as part of other projects or upgrades.** While initial capital costs may be higher, there will be long term benefits and overall cost savings versus implementing an ORT solution a later date. This is consistent with current Commonwealth transportation legislation.

- **Consider Cashless vs. Mixed ORT/Cash Systems.** Based on experience to-date, the cashless ORT option is clearly effective when combined with deployment of a new facility or in combination with a toll increase. Without such a change it may be difficult to gain public acceptance for the project and maintain sufficient incentive to continue growth of E-ZPass usage.

  Deploying cashless tolling would also require reassessment of the current central violation processing system as well as the corresponding violation technologies deployed on the roadway. Due to the larger percentage of customers that will have their license plate captured due to non-payment (20 – 30% versus 1 - 2% for current violations), small variances in accuracy would no longer be tolerable.

  Cashless tolling may also require updating of bond agreements. Allowing users to pass a tolling point without positively collecting the toll may not be compatible with existing agreements. As the technology is more widely deployed, the financial industry is becoming increasingly comfortable that long term revenues will not be adversely impacted by this type of collection.

  Cashless tolling also requires a change in mindset. Non-payers using toll lanes can no longer be classed as violators until they have failed to respond to invoices or payment requirements some time after the use of the road. Careful review of legislation and related terminology will be required to ensure that it adequately supports this process.

- **Consider cost and efficiency of investment.** The capital cost of deploying ORT will vary enormously with the specific conditions present at each tolling point. Conversion from a toll plaza to a cashless ORT scenario will have the smaller start-up cost since it primarily involves demolishing the existing toll plaza, erecting and integrating the toll collection gantries and resigning. Cashless ORT, however, may release right-of-way or buildings that were previously required. Conversion of a toll plaza to cashless ORT is still likely to cost at least 2 million dollars per collection point per facility. Operational costs of each facility type also need to be factored in.

Overall there are many considerations in determining which type of ORT system would be best for Virginia toll facilities. It is also highly probably that one type of system will not be best for all toll facilities. Each toll facility needs to be assessed individually to determine costs and benefits and therefore feasibility of each system type. The next section provides an outline for the steps that should be taken for each toll facility.

5.3 Recommended Steps to Move Toward Enhanced Toll Facility Mobility

As identified above, the appropriate application of tolling technology must be assessed on a facility by facility basis. The following paragraphs summarize the general process that should be implemented and tailored to each facility under consideration. In terms of timing, this process is best applied before making any major changes to existing operations, tolling equipment or toll rates or where congestion or safety issues warrant consideration of alternative tolling strategies.

Identify potential tolling concepts. This will include consideration of how cashless ORT and mixed cash/ORT could be implemented as well as credit card processing. The concepts should take into account right-of-way restrictions as well as safety in terms of separation of high and low-speed traffic and toll attendant considerations. Several operationally feasible alternate concepts should be developed for evaluation alongside a do nothing scenario that continues the existing tolling strategy on that facility.

Gather data. This will include gathering traffic and operations data and physical constraints relating to each tolling point. Traffic data should include in-state versus out-of-state usage plus distribution between vehicle classes.

Micro-simulation. Primarily for mixed cash/ORT scenarios, perform traffic simulation to identify queuing or safety issues. Any issues identified should be used to refine the alternate tolling concepts.

Evaluate diversion potential. Changes in toll collection processes, especially removal of a cash payment option, may have impacts on the traffic, particularly in the short term. This analysis should be based on experience from other toll facilities, the demographics and characteristics of the users and alternate routing choice.

Develop capital costs. Rough-order-of-magnitude costs should be developed for:

- Plaza removal, renovation and reconstruction.
- Gantry construction.
- Road layout changes (design and civil costs.)
- Toll collection equipment, systems and software.

Perform cost benefit analysis. The cost benefit analysis should utilize a modeling tool that can determine overall long term revenue impacts. The tool should also be used to perform a sensitivity analysis to identify what estimated variables could have a significant impact on revenues and therefore to estimate the risks associated with each option.

This tool should take the following inputs and variables into account:

- Traffic volume forecasts including diversion potential
- Anticipated toll rate changes and potential invoice fees for license plate based tolling
- Configuration of the percentages of transactions that fall into each of the different potential processing categories. For each step, revenues and operational costs should be allocated on a

per transaction basis in order to develop an estimate of the overall revenue and cost associated with each tolling concept. The following breakdown of transaction types should be included:

- Manual cash toll collection,
- V-Toll,
- Successful E-ZPass read,
- Rejected license plate image,
- Automated license plate reading,
- Manual image review,
- In-state versus out-of-state,
- Non-revenue transaction,
- Invoice payment,
- Collections payment, and
- Violations payment.

The outputs of such an analysis would be used to identify the impacts and sensitivity on the following parameters for the different toll collection scenarios:

- Estimated capital costs,
- Ongoing operational costs,
- Toll revenue collection costs,
- Toll revenue collected

Analyze results. The results of this analysis should then be used to identify the feasibility of each of the proposed tolling concepts and the optimal conditions that need to be met to protect ongoing net revenues. For example, this analysis should identify the E-ZPass penetration required to support the concept along with the E-ZPass, cash or license plate toll rates and corresponding administrative fees.

APPENDIX A – DETAILED DESCRIPTION OF VIRGINIA TOLL FACILITIES

Virginia currently has ten primary tolling facilities. This appendix provides a summary of the features and toll collection characteristics of each facility including:

- A description
- Accepted toll payments methods
- Number of toll plazas
- Number of toll lanes
- Number of dedicated E-ZPass lanes
- Number of ORT lanes
- Description of the layout of toll plazas
- Assessment of the way gates (if any present) are used
- E-ZPass penetration (percentage) rates from all transactions
- Any special notes

CHESAPEAKE BAY BRIDGE-TUNNEL

This is a 23-mile bridge and tunnel structure that creates a connection across the entrance to the Chesapeake Bay. Accepted payments methods include E-ZPass and cash.

Number of Plazas: 2 (1 at each end of the bridge)

Number of Lanes: 10 (5 in each plaza)

Number of Dedicated E-ZPass lanes: 2 in each direction (are only sometimes dedicated)

Number of ORT lanes: 0

Layout: 2 dedicated E-ZPass lanes on left at each plaza with toll booths for use during high-wind or other operational situations. They have not used dedicated lanes as of mid-November 2007.

Assessment of Gate Use: Gates used at all times. Gates used to allow staff to inspect vehicles using the facility.

E-ZPass Penetration Rates (Peak and off-Peak): Initial average is 20-22%.

Special Notes: The facility has seasonal and weekend peaks rather than daily peaks. It is not a commuter facility.

CHESAPEAKE EXPRESSWAY

Also known as Route 168, this is a four-lane 16 mile divided highway that connects I-64 in Chesapeake to North Carolina. Accepted payment methods include E-ZPass and cash.

Number of Plazas: 1 (Mainline plaza, two directions)

Number of Lanes: 14

Number of Dedicated E-ZPass lanes: 2 (express lanes)

Number of ORT lanes: 0

Layout: 4 lanes in each direction are used at all times. The E-ZPass dedicated lanes are the left lane in each direction. On each side of the road, there are auxiliary plazas with 3 lanes each, where only cash is accepted. These lanes are open during peak seasonal use times.

Assessment of Gate Use: All manned lanes have gates. Dedicated lanes have no gates.

E-ZPass Penetration Rates (Peak and off-Peak): Approximately 50% on average (of seasonal and regular peak/off-peak). These rates vary widely by season.

Special Notes: Similar regarding peak use as CBBT.

GEORGE P. COLEMAN BRIDGE

This bridge, a part of Route 17, extends over the York River between Yorktown and Gloucester County. Tolls are charged for northbound traffic only. Accepted payment methods include E-ZPass and cash.

Number of Plazas: 1

Number of Lanes: 5

Number of Dedicated E-ZPass lanes: 2 (high-speed) plus 1 in the middle of the plaza is dedicated 2/3 of time (during peak travel of the week)

Number of ORT lanes: 0

Layout: 2 dedicated E-ZPass on left, 1 sometimes dedicated (but with manual booth), 2 manually staffed.

Assessment of Gate Use: Dedicated lanes have gates locked up. Other lanes use gates for transaction control.

E-ZPass Penetration Rates (Peak and off-Peak): 90% peak, 80% off-peak.

DULLES GREENWAY

The Dulles Greenway is a 14-mile long highway that extends from Loudoun County in the vicinity of Dulles International Airport to Leesburg, Virginia. Accepted payment methods include E-ZPass, credit card, and cash.

Number of Plazas: 13 (1 Mainline, 12 ramp)

Number of Lanes: 42

Number of Dedicated E-ZPass lanes: 20 (8 on Mainline, 12 on ramps)

Number of ORT lanes: 0

Layout: Mainline has the same configuration in both directions with 4 lanes on the left dedicated to E-ZPass, then 2 automated credit card/E-ZPass lanes in the middle, and 3 on the right that can be set up as manual toll collection booths. All of Greenway's lanes have E-ZPass capabilities. The ramps have 2 lanes each, with E-ZPass dedicated lanes on the left and a credit card/E-ZPass lane on the right.

Assessment of Gate Use: On the mainline, they open gates at peak hours. Ramps are gated at all times.

E-ZPass Penetration Rates (Peak and off-Peak): Peak 85%, Off-Peak 65%, Average 75%

Special Notes: Ramps have automatic credit card payment systems.

DULLES TOLL ROAD

The Dulles Toll Road (DTR) is an approximately 14-mile long, 8 lane (4 lanes in each direction) toll road stretching from I-495, the "Capital Beltway" to Dulles Greenway. The road also has High-Occupancy Vehicle (HOV) lanes in both directions. They are enforced Monday-Friday during the morning peak for Eastbound and evening peak for Westbound. Accepted payment methods at DTR include E-ZPass and cash. Automated Coin Machines (ACM) are used to collect cash.

Number of Plazas: 20

Number of Lanes: 58

Number of Dedicated E-ZPass lanes: 7 (4 express on Mainline with no canopy, and 3 on ramps)

Number of ORT lanes: 0

Layout: On the Mainline, E-ZPass dedicated lanes are on the left and the manual and ACM lanes are on the right. The three ramp dedicated lanes are either on the right in two cases or in the middle in one case.

Assessment of Gate Use: Gates are locked up on all ramps between 6:00-10:00am and again between 3:00-6:30pm. There are no gates on the dedicated lanes.

E-ZPass Penetration Rates (Peak and off-Peak): Average rate is 67%.

Special Notes: For the high speed dedicated E-ZPass lanes, Idris loops are used instead of light curtains to facilitate high-speed and high-volume operations.

JORDAN BRIDGE

Located in Chesapeake, VA, this two-lane bridge crosses the Elizabeth River. It is a lift bridge that can open for commercial vessels, except during peak rush hours. Cash is the only type of accepted payment.

Number of Plazas: 1

Number of Lanes: 2

Number of Dedicated E-ZPass lanes: 0

Number of ORT lanes: 0

Layout: 2 simple lanes where cash is collected by attendants.

Assessment of Gate Use: No gates.

E-ZPass Penetration Rates (Peak and off-Peak): Not applicable.

POCAHONTAS PARKWAY

This is an 8.8-mile highway in south-east Richmond. It is a connection from I-95 to the east, where the Richmond International Airport is located. Accepted payment methods are E-ZPass, credit card, and cash. ACM machines are used as an option to collect cash.

Number of Plazas: 3 (Mainline, 2 ramps)

Number of Lanes: 12

Number of Dedicated E-ZPass lanes: 4

Number of ORT lanes: 4

Layout: 2 ORT lanes physically separated from regular canopied plaza with 3 manual lanes (with no video capabilities) in each direction the mainline. Ramps have 1 lane each with ACM machines and E-ZPass.

Assessment of Gate Use: No gates.

E-ZPass Penetration Rates (Peak and off-Peak): Average approximately 50%. Slightly higher for peak.

Special Notes: Toll booth attendants accept credit card payments as well as cash payments.

THE RICHMOND DOWNTOWN EXPRESSWAY AND POWHITE PARKWAY

The roads form a 16-mile highway network that extends from Interstates 95 and 195 in Richmond to Powhite Parkway Extension. They are operated by the Richmond Metropolitan Authority. Accepted payment methods on these roads are E-ZPass and cash. (Cash is accepted either in ACMs or by toll collectors.)

Number of Plazas: 11 (2 Mainline, 9 Ramp)

Number of Lanes: 55

Number of Dedicated E-ZPass lanes: 12 that are used as dedicated depending on direction of rush hour. Typical setup is to have 3 dedicated in direction of rush hour and 1 dedicated in opposite direction.

Number of ORT lanes: On the Powhite Parkway mainline plaza, it is planned that by August or September 2008, there will be 3 ORT lanes in each direction.

Layout: On the Mainline plazas, in each direction, from left to right are ACM lanes, Dedicated E-ZPass lanes, and then Full Service lanes all the way on the right. Ramp layouts vary.

Assessment of Gate Use: Manned lanes use gates. Others do not have gates.

E-ZPass Penetration Rates (Peak and off-Peak): Peak ~60%, Average ~50%.

THE BOULEVARD BRIDGE

This bridge in Richmond, VA spans the James River and is owned by the Richmond Metropolitan Authority (RMA). It connects Westover Hills to Maymont Park in the city on Route 161. Accepted payment methods include E-ZPass and cash.

Number of Plazas: 1

Number of Lanes: 5 (3 lanes in one direction and 2 in the other) Some are reversible to accommodate peak traffic.

Number of Dedicated E-ZPass lanes: 0

Number of ORT lanes: 0

Layout: Manned lanes are at the edges of the toll plaza.

Assessment of Gate Use: Use gates for all lanes.

E-ZPass Penetration Rates (Peak and off-Peak): No explicit figures available. Presumably it would be slightly lower than the rates for the Downtown Expressway and Powhite Parkway, which is 50% on average.

POWHITE PARKWAY EXTENSION

Powhite Parkway Extension (PPE) is an approximately 7 mile highway that extends from the end of Powhite Parkway in Richmond, VA to Route 288. Accepted payment methods include E-ZPass and cash.

Number of Plazas: 5 (Mainline and Mainline Ramps is considered 1 plaza, 4 total ramp plazas)

Number of Lanes: 28

Number of Dedicated E-ZPass lanes: 10 (4 on mainline, 6 on ramps)

Number of ORT lanes: 0

Layout: On the actual Mainline, there are 5 lanes in each direction. From left to right, the lanes are designated E-ZPass, ACM only lane, designated E-ZPass lane, and then two manned lanes. The Mainline Ramps have 2 lanes each, with ACM/E-ZPass and manual/E-ZPass lanes. On the Courthouse ramps, where there are 3 lanes on each on the two ramps, the lane types from left to right are ACM only, dedicated E-ZPass, and manual. On the two Midlothian ramps there are 4 lanes each. From left to right, the lane types there are dedicated E-ZPass, ACM/E-ZPass only, dedicated E-ZPass, and manual/E-ZPass.

Assessment of Gate Use: On the Mainline, all lanes are gated. On the ramps, only manual lanes are gated.

E-ZPass Penetration Rates (Peak and off-Peak): 65% peak, 55% off-peak