Background Paper #8
Toll Technology Considerations, Opportunities, and Risks

Introduction

This report focuses on the technology required to support the collection of tolls, both manual and electronic, for the range of potential toll facilities under consideration in Washington State. We describe the different types of toll collection methods, how they are applied to various toll facilities, note lessons learned from past experiences, and identify the advantages and disadvantages.

Toll Collection Technology Overview

The appropriate combination of technology and operational procedures is needed to meet the functional requirements of the emerging tolling program in Washington State. Furthermore, the combination also must provide a path for migration from a single facility to multiple facilities, and be able to evolve along with changes in technology. Toll collection, in all of its forms, consists of the following five primary components:

1. **Setting the Toll Rate.** The toll rate must be determined, and the fees clearly conveyed to the user. Traditionally, tolls are fixed amounts based upon vehicle characteristics such as number of axles. Tolls can be assessed at a point on a road, or based upon the distance traveled. Advances in traffic conditions monitoring now allow toll rates to vary based on the level of congestion.

2. **Collecting the Toll.** Toll collection can involve a direct cash transfer at a toll booth or a transfer of data via electronic technology, with actual money changing hands through other means. Either way, it is necessary to ensure the correct toll is collected, and that user and collector fraud is discouraged.

3. **Enforcement against Violations.** Although most users want to be honest, some will try to evade payment. Like any business, toll collection enterprises must identify, quantify, and mitigate these potential losses. The primary goal of enforcement is to ensure that there is an acceptable level of compliance, and enforcement efforts are fair and consistent.

4. **Management and Accounting.** Finally, toll collection, audit, accounting, maintenance, security, customer service, and enforcement must be managed, with a full accounting of all revenue and costs associated with the operation.

5. **Interoperability.** As customers use different toll facilities in the State, they have an expectation that electronic toll collection mechanisms will be fully compatible at all toll facilities.

The remainder of this section provides an overview of the basics of toll collection technology.

Manual Toll Collection

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. 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 as illustrated in Exhibit 8.1. Traffic demand, coupled with the need for each vehicle to stop, still resulted in significant congestion at many of these toll plazas.

An early attempt to improve productivity and reduce labor costs involved installing Automatic Coin Machines (ACM) for accepting coin payments in an unattended lane. These lanes can process 600 vehicles per hour for lower value tolls (under $1.00). Again, gates were used as the primary method of ensuring payment. As toll rates increased, the ACM offered less benefit. Newer deployments at lower-volume locations have incorporated automatic card payment machines for payment by credit/debit cards and smart cards.

Electronic Toll Collection (ETC)

Automatic Vehicle Identification (AVI) technology can accurately identify a specific vehicle at highway speeds, thereby, enabling a wide variety of ETC applications. In its basic form, a vehicle passing through a toll collection point has its identification device read, after which the toll is deducted from the customer's preexisting account or the customer is sent an invoice. The driver pays the toll without stopping and tollbooths are not required. ETC also determines whether the cars passing are enrolled in the program, and gathers information on the vehicle for further collection or enforcement action.

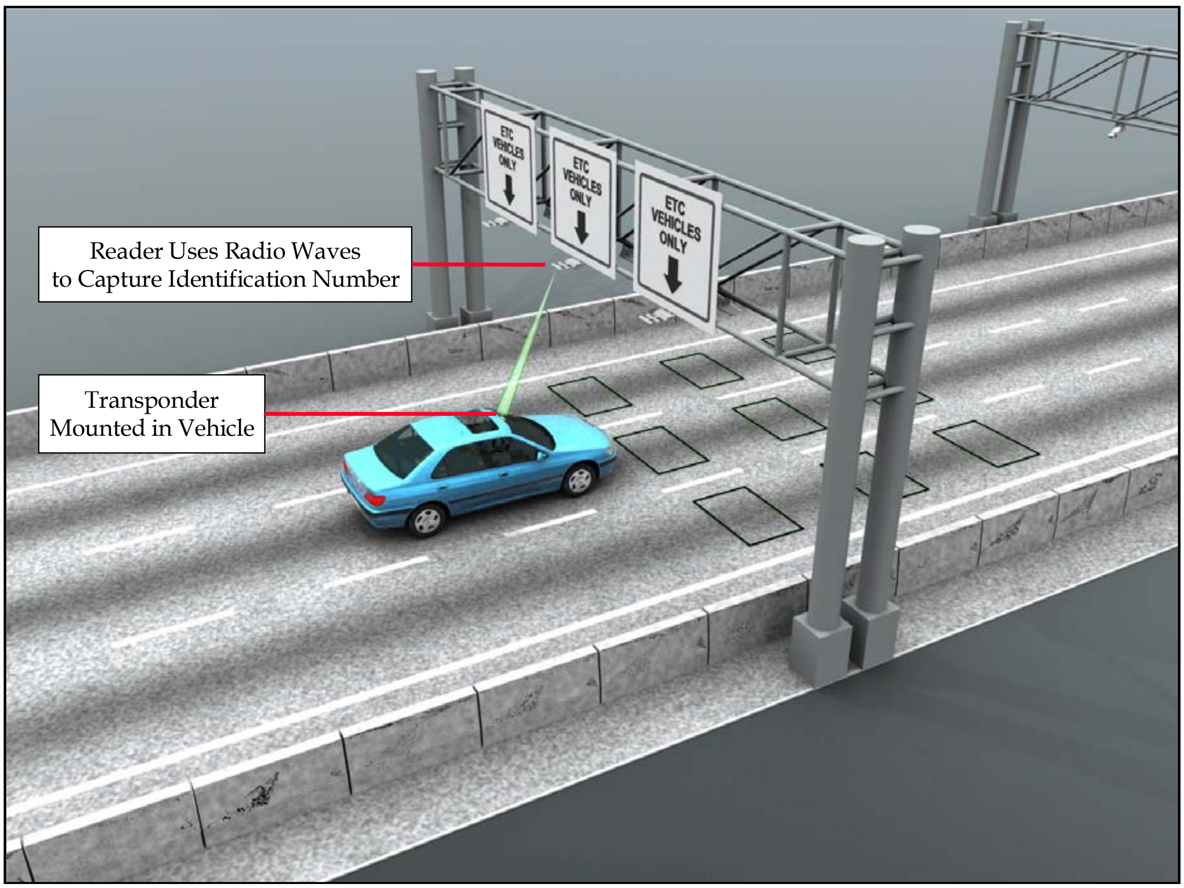
Exhibit 8.1 Typical Traditional Toll Plaza
George Washington Bridge

ETC systems incorporate four major components, namely AVI, Automated Vehicle Classification (AVC), Customer Service, and Violation Enforcement. Each component is described below.

Automated Vehicle Identification (AVI)

The automatic identification of a vehicle involves the transmission of an identification code between an in-vehicle device and a roadside reader. Vehicles are identified at fixed points along the roadway as shown in Exhibit 8.2. The in-vehicle device, called a transponder, is a Radio Frequency Identification (RFID) unit that transmits radio signals. The transponder is a two-way radio with a microprocessor, operating in the 900 MHz radio frequency band (within the United States) using dedicated short-range communication (DSRC) protocols. Stored in this RFID transponder is basic information, such as an identification number, toll facility, vehicle type, etc. The roadside electronic readers use antennas to emit radio frequencies that communicate with the transponder. These two devices, the transponder and the roadside reader, interact to complete the transaction. For ETC, the vehicle identification number is linked to the customer's account from which the appropriate toll is automatically deducted or the customer is billed.

Exhibit 8.2 Automatic Vehicle Identification
Identification Number Used to Charge Customer



Transponders have additional common characteristics:

- Transponders can be read-only or read-write. Read-write transponders allow information to be sent back to and stored on the transponder (e.g., the last time that the transponder was read).

- Nonbattery transponders use radio wave energy to "bounce" information back to the reader. Nonbattery transponders have an "official" life of 15 years but could theoretically last forever.

- Battery transponders can incorporate lights, audible tones, or LED displays that provide information to the driver. However, the initial cost is higher and the overall life-cycle cost is increased because of the need to replace batteries or the entire transponder. Most toll agencies are phasing out transponders that provide driver feedback.

- Transponders, until recently, have been packaged in small plastic cases that are generally mounted with Velcro strips to the windshield of a vehicle. The case is required for the internal electronics, battery and any lights or tones. Recently, nonbattery-powered transponders are packaged as stickers (or decals) that are applied to the windshield of a vehicle.

- Transponders used for high-speed toll collection can range in cost from $10.00 to $40.00 apiece. Most battery powered transponders used for toll collection application range from $20.00 to $35.00 per unit. The sticker tags cost approximately $10.00 per unit.

Over the years, various agencies have expressed an interest in using transponder technology as electronic license plates. There are available transponder models that can be attached to the license plate frame for exterior mounting. This concept is technically feasible, but has policy and cost implication. The decision to install transponders on all vehicles raises privacy concerns. The cost of equipping all vehicles is certainly higher than the cost of equipping vehicles that would use the nearer term toll facilities. The transponders that can be mounted on license plates are more expensive than the newer sticker transponders.

Recently, policy considerations have suggested that vehicles that generate reduced emissions should pay reduced tolls. The identification of "green" vehicles can be accomplished through the use of transponders.

While transponders have many common features, the deployment of five different DSRC protocols for electronic toll collection in the United States have significant impact on interoperability. These deployments are generally geographically separated with limited need for interoperability initially. However, the lack of interoperability among these AVI technologies has been recognized as a significant problem. Accordingly, U.S. Department of Transportation (DOT) has commissioned a consortium of the major transponder manufacturers to develop a national DSRC standard. The device is being built around a newly allocated radio frequency (5.9 GHz) and the specific requirements of DSRC for transportation applications. The new DSRC transponder should be available for testing in early 2006, with a deployment decision by the U.S. DOT and the automotive industry expected in 2008. The new transponders could be part of new vehicles shortly after 2010. This means that it will take until at least 20 years for transponders to be incorporated into all U.S. autos, since it takes approximately 15 years for the entire America car fleet to turn over.

To bridge this gap between available and future technology, the Washington State DOT has:

- Selected the e-Go™, battery-less, sticker transponders from a single vendor as the primary AVI technology for ETC in the State;
- Installed dual DSRC protocol readers to allow the reading of the existing battery powered, transponders installed on commercial vehicles participating in the WSDOT electronic weigh station bypass program, in addition to the e-Go™ tags; and,
- Developed and implemented a plan for migrating to the new U.S. standard 5.9 GHz transponder so that multiple vendors can supply a standard toll transponder to the State in the future.

Other Approaches to Vehicle Identification

Another approach is to install a Global Positioning System (GPS) in a vehicle to locate itself within a given charge area or network. The on-board unit will contain the appropriate charging structure, as well as information concerning when the vehicle should be charged. Charges are applied using the position information provided by the GPS system. The charge can either be deducted directly from a smart card located in the on-board unit or stored for later uploading and charging against the customers account or billing the customer. Charged corridors can be defined around specific zones in urban or rural areas where all vehicles (or specific categories) using the roadway will be subject to charges. The cost of the on-board units is estimated at between $200 and $400, depending on the level of sophistication of the device.

Vehicle location pricing technology is being used for truck tolling systems in Germany and Switzerland. The Puget Sound Regional Council (PSRC) is conducting a demonstration of value pricing using this approach. The intent of this pilot project is to determine traveler response to value pricing and the effect of pricing on traveler decision-making, and to help identify a potential path towards implementation. This technical approach is better suited to regional pricing applications as opposed to facility-based tolling.

A third approach to vehicle identification involves the use of License Plate Readers to capture an electronic image of a vehicle's license plate. This information is used to charge the accounts of customers who have registered vehicles in advance. For vehicles that are not registered, this license plate number is used to determine the owner's name and address. The owner is then sent an invoice for the toll and a service fee. Highway 407 in Toronto uses a combination of transponders for regular customers and license plate readers for infrequent users to collect tolls. There are no tollbooths on this facility. Some facilities allow infrequent users to register their vehicle for the day over the telephone or

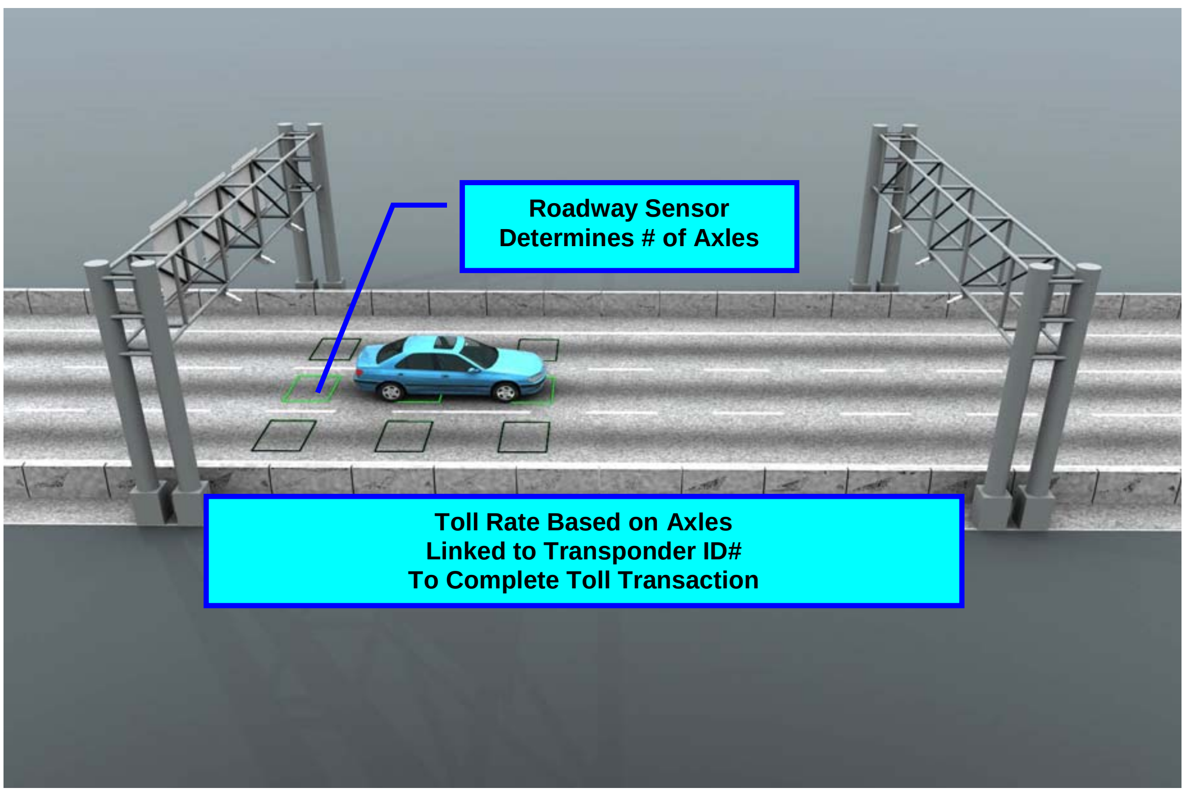
Internet to pay their toll. This reduces the administrative cost of finding the owner and sending an invoice.

Automated Vehicle Classification (AVC)

The inherent potential for fraud on the part of toll collectors led to the deployment of vehicle sensor technology that can classify a vehicle based upon its characteristics. The number of axles is the most common vehicle toll classification scheme. AVC equipment can provide a check on manual toll collection and determine the proper vehicle classification for electronic toll collection. AVC equipment has been demonstrated to work at highway speed and under congested traffic conditions.

A variety of vehicle sensors are used. Treadles count the number of axles as a vehicle passes over them. Light-curtains and laser profilers record the shape of the vehicle, which can help distinguish trucks and trailers. Advanced Inductive Loop sensors embedded in the road surface can determine length, speed, and number of axles of vehicles at highway speeds as illustrated in Exhibit 8.3.

Exhibit 8.3 Automatic Vehicle Classification



Customer Service

Customer service may be provided at a physical customer service center, by telephone, or over the Internet. Most customer service operations provide for all three. The functions of the customer service center include:

- **Creation and Maintenance of Customer Accounts –** The customer service center is responsible for the creation and maintenance of customer accounts, adding funds, and assisting customers with account questions.

- **Issuing Transponders –** The customer service center assigns a transponder to each vehicle under a given account. These transponders must be requested from the toll authority's tag warehouse and tracked as inventory. Once assigned to an account, the status of the transponder (active, inactive, lost/stolen, etc.) becomes part of a customer's account history. For accounts opened via mail or online, the customer service center may mail transponders to customers along with instructions on installation.

- **Accounting –** There is a significant financial element to the customer service center, in regards to accurate reconciliation of toll transactions and payments against customer accounts. Customer account balances are constantly fluctuating in real time as a result of toll transactions, automatic replenishment via credit cards and/or bank account transfers, customer invoicing, and in-person transactions at the customer service center.

Typically, an individual toll authority serves a single region or facility, resulting in multiple authorities and multiple customer service centers across a given state. In order to provide a more seamless customer experience, these disparate toll authorities frequently work together to interface their systems to accept transponder transactions from each other's customers, and to reconcile these transactions "behind the scenes" via a financial clearinghouse. In launching a new statewide tolling program, there is the opportunity to provide toll patrons with a single point of contact (one telephone number, one web site, one account) for their toll accounts.

Many auto manufacturers will be installing transponders as factory equipment in new cars because of the anticipated adoption of the national DSRC standard. These transponders will go far beyond toll payment, potentially to include a wide variety of retail (such as drive-through restaurant service), traveler information, and road safety applications. Essentially, these transponders would function as an in-vehicle credit card, with the likely expectation from the customer that they will receive a single invoice for all of their in-vehicle transactions. With built-in transponders, the state tolling authority would interface with a third-party service provider to bill each customer's account.

Violation Enforcement

Manual toll collection operations sometimes use gates in toll lanes to discourage drivers from driving straight through and not paying the toll. Other systems rely on toll collectors noting the license plate numbers of violators. Some operations work on the honor system, with spot enforcement by police.

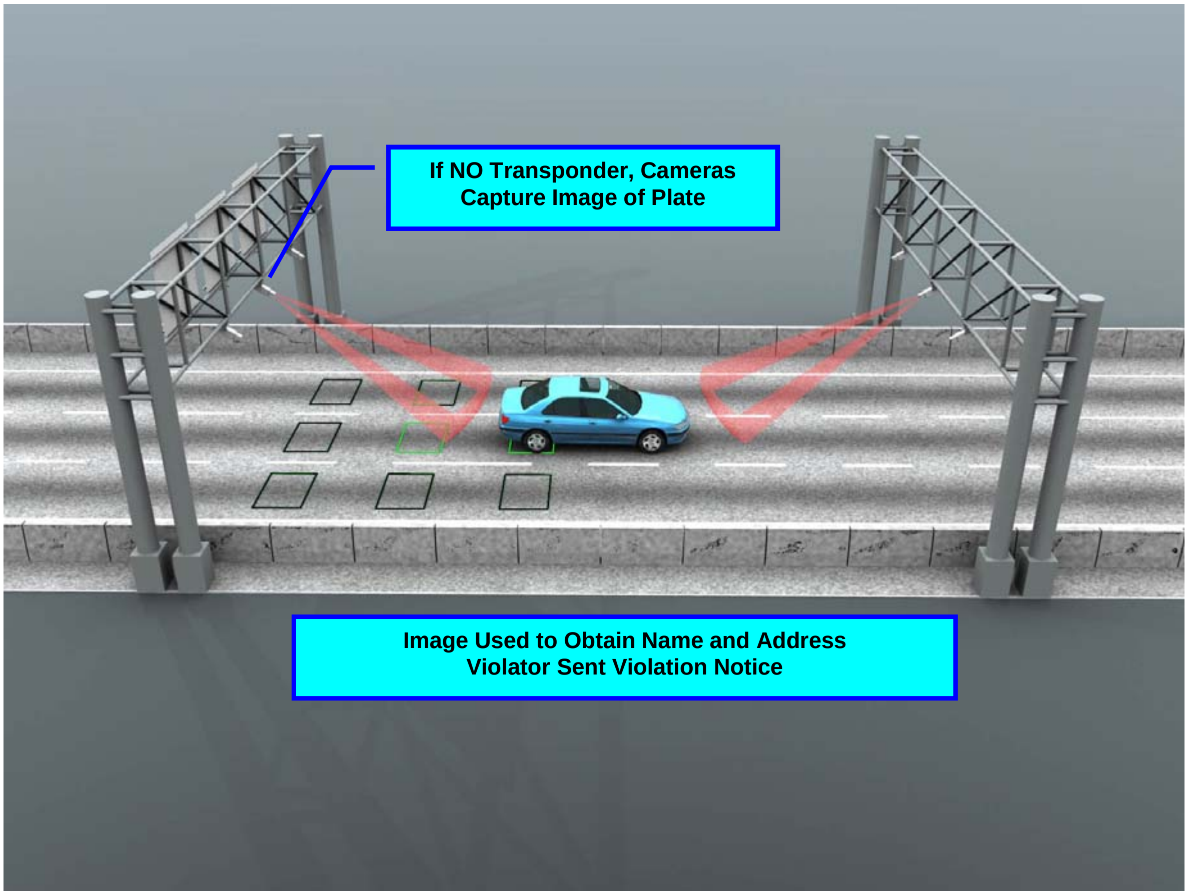
The introduction of ETC without gates and toll collectors has resulted in the deployment of technology to automatically identify toll evaders and demand the payment of the required tolls. The primary goal of enforcement is to ensure that there is an acceptable level of compliance, and enforcement efforts are considered to be fair and consistent. The following are the key elements of violation enforcement:

- **License Plate Image Capture –** When a vehicle fails to pay the correct toll at either a manual or electronic toll collection point, cameras installed at the lane electronically capture images of the vehicle's license plate. The cameras are configured to capture license plates from the full range of vehicle makes and models, to zoom in only on the plate itself, and to capture multiple photos so as to improve the probability of a legible image. Washington State law allows images of the vehicle or the license plate to be used in photo enforcement activities. In-lane image capture for violations enforcement is show in Exhibit 8.4.

- **Name and Address Acquisition –** Critical to the collection of outstanding tolls, fees, and fines is determining the name and address of the toll evader. Using the license plate number obtained from the image of the toll evader's vehicle, an electronic request is made to the appropriate Department of Motor Vehicles (DMV) or other source to obtain the registered owner's name and address. According to the U.S. Bureau of Census, 17 percent of Americans change their residence every year. As a result, hit rates for successfully obtaining current names and addresses from the DMV are generally between 80 percent and 90 percent. The effort is compounded for out-of-state vehicles and vehicles from Canada. The implication is that, for a certain portion of violators, it will not be possible to mail them a notice to request payment.

- **Violator Payment –** Experiences from other toll authorities and similar programs (e.g., parking tickets) indicate that most people will pay their toll and service processing fees upon receipt of a demand letter. At this point, monies collected are remitted to the toll authority. A second means of enforcement for in-state violators is placing a hold on annual vehicle registration renewal process until outstanding tolls and related fees are paid. However, a certain portion will continue to violate. Additional focused efforts to identify and locate flagrant violators will be required for all types of toll facilities.

Exhibit 8.4 In-Lane Violation Enforcement



- **Legal System Interfaces –** While the laws and legalities surrounding the collection of delinquent tolls vary from state to state, at some point, toll violations become a citable offense, generally under traffic or parking laws and regulations. For legal enforcement of toll violations, toll authorities must look to law enforcement officers and the local courts. In jurisdictions where citations may be issued electronically, officers may review an online "evidence package" that includes the photo(s) of the violator's license plate, the date and time of the violation, and the violator's name and address. The officer can use an electronic signature to sign the citation, which is then printed and mailed by the toll authority. This mitigates the resource demands placed on the officers for reviewing citations.

  As with any traffic or parking ticket, some violators will wish to appeal the citation to the courts. New tolling authorities must work with local courts to determine the legal, technical, and resource-related issues surrounding toll enforcement, in terms of how toll violations will be processed in the court computer system, what are the evidentiary requirements, and what is a reasonable violation penalty. The penalty must effectively discourage violators without being so harsh as to potentially tax the resources of the courts with a large number of appeals.

The enforcement program will need to be balanced against the desire to bring more travelers into compliance. Many toll agencies are initially treating violators as potential customers before they start aggressive enforcement measures. The initial enforcement efforts at Tacoma Narrows Bridge (TNB) will be a mixture of education and enforcement.

Interestingly, while the toll authority usually bears the cost of enforcement, the money collected from traffic or parking fines is distributed to the general fund, courts, relevant local jurisdictions, and enforcement agencies, and not the toll authority. Therefore, enforcement costs are a real cost to the toll authority, not completely offset by revenue collection.

Interoperability

The deployment of ETC is well established in North America and overseas. The E-ZPass Program, under the Interagency Group in the eastern part of the United States, involves over 20 separate toll agencies and 11 million transponders. The FasTrak Program in California has over 1.25 million transponders and is statewide. Out of this experience, key customer service expectations have been identified based upon experience at other toll facilities, and market research, including surveys and focus groups.

- **One "Gizmo" –** Only one on-board device (i.e., transponder) would be required in the customer's vehicle for electronic toll collection payment;

- **One Number –** A single customer service telephone number would be available for all tolling customer inquiries; and

- **One Statement –** A consolidated statement would be provided to the customer for all activity at all tolling facilities.

Interoperability issues are in play at several levels.

At the **transponder level**, a customer can use the same physical transponder on all of the interoperable facilities, but the customer must set up a separate account with each agency or facility. This approach is used for electronic weigh station bypass programs, where trucks are equipped with the same transponder, but must register for the program that is used by a specific state. For example, the program in Washington State uses the same transponder for the program in California, but the trucker must be registered with both programs.

Peer-to-Peer interoperability means that separate customer service centers are maintained by agencies that have agreed that they will exchange transactions and account files so that the customer has only one transponder and one account. However, for transaction and violation inquiries, customers may be required to deal with separate customer service centers, depending on the facility that they used. The E-ZPass Program, which extends from Maine to Virginia with over 20 separate toll agencies and 11 million transponders, is an excellent example of the successful implementation of a Peer-to-Peer approach.

Consolidated Operations is the ultimate form of interoperability. It establishes a single customer service organization where there is one account, one system, and one point of contact. The single consolidated operations approach has evolved in many areas, because of the potential cost savings and the provision of consolidated customer service. A recent example is the consolidation of systems and customer service centers in the San Francisco Bay Area from two to one.

Open Road Tolling

Open Road Tolling (ORT) is defined as the collection of tolls by purely electronic means, through the installation of gantry-based electronic tolling and enforcement systems designed to enable unhindered passage of vehicles through the toll gantry at normal highway speeds. ORT is ETC toll collection without any toll plazas. ORT provides the technological approach to enabling the use of pricing for traffic management without requiring vehicles to stop and pay a toll. Exhibit 8.5 illustrates an operational installation in Chile.

The key to ORT is that each vehicle can be uniquely identified as it passes a charging point. In most existing schemes, vehicles are identified via an electronic transponder, which is mounted inside vehicle windshields.

Vehicles without a tag are identified by a video image of the license plate, which is then checked against a record of ETC account holders, or vehicles registered by drivers who have paid a toll over the telephone or Internet. Identifying vehicles and collecting tolls via license plate images is called “pay by plate.” License plates that cannot be reconciled to an account and have not registered are identified as violators and processed accordingly.

To avoid the need for transponders, some systems, notably the London Congestion Charge scheme, use Automatic Number Plate Recognition (ANPR). Here, a system of cameras captures images of vehicles passing through tolled areas, and the image of the license plate is extracted and used to identify the vehicle. This allows customers to use the facility without any advance interaction with the toll agency. The disadvantage is that fully automatic recognition has a significant error rate, leading to billing errors. Systems that incorporate a manual review stage have much lower error rates, but require a continuing staffing expense.

Example ORT Implementations

- *SR 91 Express Lane in California USA, opened in 1995;*
- *Westpark Tollway in Houston Texas, opened in 2004;*
- *Highway 407 in Toronto Canada, opened in 1997;*
- *Melbourne City Link in Australia, opened in 2000;*
- *Cross Israel Highway, opened in mid 2002;*
- *Autopista Central in Santiago Chile, opened at the end of 2004;*
- *Costanera Norte in Santiago Chile, opened in April 2005;*
- *Vespucio Sur in Santiago Chile, to be opened at the beginning of 2006; and*
- *Vespucio Norte Express in Santiago Chile, to be opened at the beginning of 2006.*

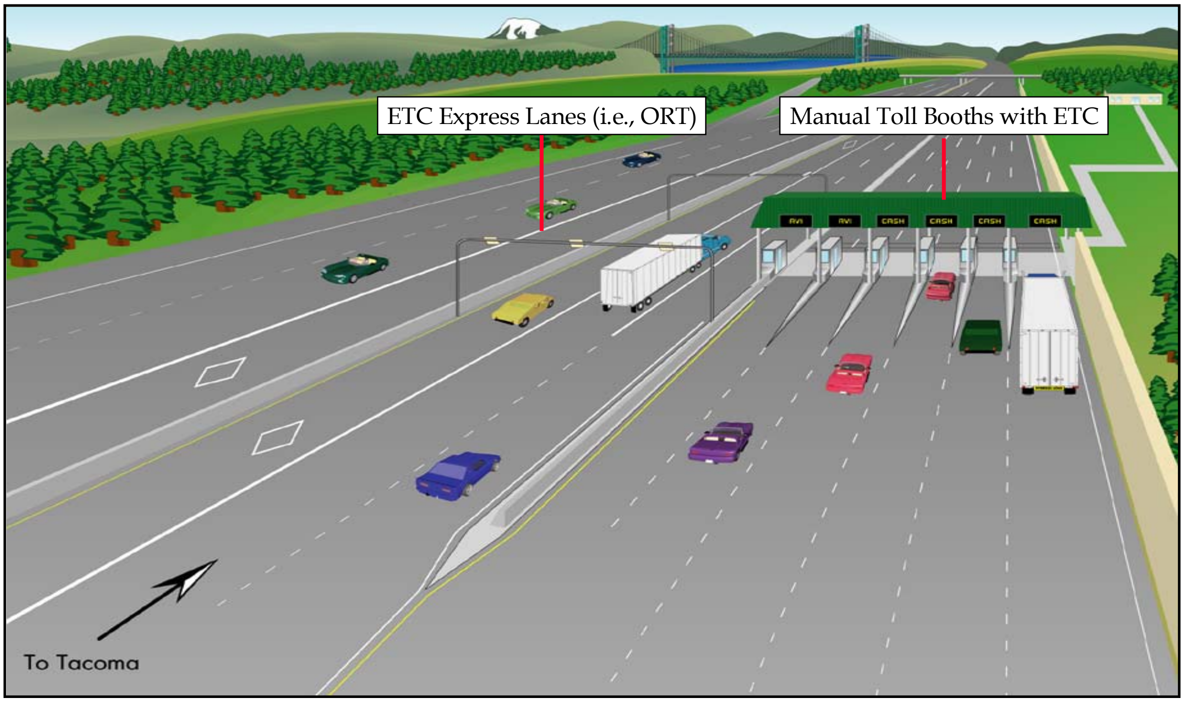
Exhibit 8.5 ORT Gantry Installed on the Santiago Urban Concessions in Chile

The primary challenge with ORT is finding the balance between transponder and image payment methods. Transponders enable the means to pay tolls without requiring human intervention in the payment processing. The use of ANPR requires customer service staff to review images to ensure that the correct customer in charged for the toll. While optical character recognition technology automates much of work in determining license plate numbers, accuracy and quality control do require this level of review. Experience has shown the image processing costs are higher per transaction than transponder-based toll collection.

Electronic Tolling at Tacoma Narrows Bridge

The planning for toll collection at the Tacoma Narrows Bridge (TNB) began near the beginning of the transition period in the industry from manual toll collection to ETC to the current trend of ORT. Given the state of technology at the time and the operational need to accommodate infrequent users, a combination of manual toll collection and ORT lanes was selected as illustrated in Exhibit 8.6. Six lanes of manual toll collection will be provided in a small toll plaza to the right of the mainline of SR 16. Each manual toll collection lane also will be equipped with ETC capabilities to allow these lanes to be operated as manual or ETC-only lanes. The three-lane mainline of SR 16 will continue past the toll plaza for the nonstop collection of tolls using an ORT configuration. The concept does require that a high percentage of users enroll as ETC customers, and install transponders in their vehicles. The approach provides a combination of toll collection capabilities intended to meet the needs for this facility, while minimizing the amount of right-of-way required for the toll plaza.

Exhibit 8.6 Toll Collection at Tacoma Narrows Bridge



The implementation of electronic toll collection at TNB will provide the complete functionality and capability required for a toll customer service center and violations processing. Staff and systems will be in place to perform ETC customer account establishment, transponder distribution, account management, account financial replenishment, call center for customer inquiries, customer Internet-based account access, and statement generation. Violation processing capabilities will include manual and automated license plate image review, owner name and address acquisition, violation notice generation, notice of infraction generation, call center for violator inquires, and interface to the court system. This operation can be expanded to provide service for new facilities in Washington.

The toll collection system for TNB was designed with the capacity to process more toll transactions than the anticipated initial daily volume of 45,000 manual and electronic transactions. The system also has the ability for expansion to handle a higher volume of customers.

The toll collection system also was designed to accept toll transactions from remote toll collection points using a defined data format, and to transmit information on valid transponders to remote toll collection points. Accordingly, the toll collection system can accept toll transaction data from other facilities, post these transactions to a customer's account, and generate a consolidated statement for all of the customer's toll transactions. A toll transaction from another facility would be treated in the same way as a transaction from TNB.

Finally, according to current law, revenue generated at TNB and the associated cost of operations at TNB can only be applied to TNB-related requirements. Accordingly, the operational costs associated with any additional toll facility that uses the customer services and violation-processing services provided by TNB will be required to pay a proportional share of these operational costs.

Beyond the cost aspect is the customer service element. By having a single customer service center, WSDOT can be assured that customers will have a single, consistent point of contact regarding tolling issues. As the additional toll facilities are brought on-line in the State, it is important to provide a uniform, consistent interaction with the public. A single customer service center would provide this single point of contact.

Lessons Learned

Previous implementation of toll collection systems around the world offer valuable lessons for Washington State, including:

- **More Than Manual Toll Collection Is Required –** Manual toll collection alone cannot provide an acceptable solution for toll collection because of the traffic congestion and right-of-way requirements. The toll industry has embraced Electronic Toll Collection as a proven means to provide a better level of service to toll patrons and reduce congestion.

- **Electronic Toll Collection Works –** The deployment of electronic toll collection with the use of transponders has gained the public's acceptance in one toll authority after another.

- **The Public Expects Interoperability –** As more toll facilities implemented electronic toll collection, customer expect that their transponders will work on adjacent facilities.

- **Violation Enforcement Is Required –** There is a clear need for an enforcement program. While enforcement systems have mostly achieved the desired results, there is an operational cost associated with this success. Truly understanding the costs of lost revenue and enforcement actions is important to have a complete picture of the enforcement program. With the proper identification of both, an enforcement program can be tuned to mitigate the potential loss of revenue balanced against cost of enforcement.

- **ORT Is Required for Traffic Management –** The use of pricing to manage traffic congestion in urban areas can only be provided by ORT deployments and not stop-and-go manual toll collection.

- **ORT Presents Technical And Operational Challenges –** ORT represents a significant technical jump, compared with the traditional tolling systems. From an operational point of view, the handling of violators and the control of the operational costs also need to be carefully addressed. The reduction in labor costs for toll collectors might be somewhat offset by the increase in need for image-based transactions and violation processing.

- **Maximize Transponder Usage –** Costs associated with tolling operations are highly dependant on the level of nontransponder transactions (i.e., those processed using license plate images), as the processing costs of nontransponder transactions are significantly higher than for transponder transactions. There are several reasons for this:
  - Processing transponder data is easy:
    - Simple business rules;
    - No human intervention;
    - Few business interfaces; and
    - Limited customer contact.
  - Processing images is complex:
    - Complex business rules;
    - Multilevel human interventions;
    - Many business interfaces; and
    - Frequent customer contacts.

Assuming that all vehicles in the State would not be required to be equipped with transponders, 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 ORT system, its services, and its benefits;
- Providing incentives to encourage transponder use, such as issuing tags free of charge, post-payment for tolls charges incurred, and preferential rates for tag users; 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.

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 minimum 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.

- Minimizing of customer service center staff time through emphasis on "self-service" techniques, such as online account access and Interactive Voice Response.

- Integration of nonautomated 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 nonautomated channels and generating input necessary for activating back office interventions.

- 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.

Avoid Toll and Violation Processing Errors. Avoiding errors (such as sending an invoice to somebody who has never used the toll road) are of crucial importance, since such errors might induce negative reactions, which could be relayed and amplified by the media. Implementing multiple validations for selected sensitive operations should minimize these errors.

Manual Toll Collection Still Has a Place. Some potential toll facilities may still have a need for manual or self-service toll collection, depending upon the level of demand and characteristics of the users. Lower volume facilities that serve mostly infrequent users would be the best candidates, but in combination with other technologies. This will generally be the case for these specific situations until most vehicles are equipped with transponders.

Toll Collection Requires a Strong Audit Function. Toll collection requires that strong cross checks, using automatic vehicle classification technology, revenue reports, and audit trails are in place to ensure that internal fraud is deterred and identified.

■ Toll Technology to Support Traffic Management

The advent of electronic toll collection has provided new tools for the traffic management. Manual toll collection's inherent limitations did not provide the flexibility required to use pricing as a means to manage traffic.

Time-of-Day Tolling

With time-of-day tolling, the toll rate is set by a fixed time-of-day schedule. The typical motivation for this tolling strategy is to push traffic demand away from peak hours. Both the New Jersey Turnpike and the Port Authority of New York and New Jersey introduced time-of-day-based-toll price schedules during toll increases over the past several years. The Turnpike Authority reports that traffic growth during rush hours has flattened since it adopted the time-of-day-based toll schedule. Port Authority reports also suggest that relatively lower prices attract some motorists to off-peak driving times.

Under this approach, the toll rates are fixed by time of day and day of week, usually at one-hour intervals. Peak prices on weekdays are generally highest, and pricing is adjusted typically every few weeks based on hourly volumes. Setting price based on time of day is relatively simple to implement from a technology perspective. TNB has this feature included in its toll collection system.

This approach is easy for the driving public to understand, but it does not support more frequent updates to pricing, as rate schedules are generally published. Public outreach efforts are made to publicize the schedule. The concept is relatively easy to convey to the public, and has achieved the desired impact.

Dynamic Pricing

Advances in tolling, traffic management, and traffic sensor systems over the last decade have significantly increased the number of options available in terms of setting the price of using a toll facility. Dynamic pricing adds a level of traffic management sophistication over time-of-day pricing. With dynamic pricing, tolls are based on actual traffic conditions, changing to maximize some specific objective. Typical traffic management objectives are:

- **Speeds –** A classic measurement of the conditions on a facility, is easily collected using available sensor technologies, and is easily understood by the public. It also allows for frequent pricing adjustments based on changing conditions. However, speeds can vary greatly across a facility, particularly between differing sensor sites, and are not always an effective measurement of true level of service. Speeds are generally best used in conjunction with volume and/or occupancy to allow more accurate setting of prices.

- **Volumes –** Can be averaged over time to support less frequent pricing changes, or they can be used together with speeds to set prices on a more frequent basis. Volumes can be relatively accurately measured with existing sensor technologies.

- **Traffic Density –** A measure of speed and volume over a set period of time, and is considered a very accurate measure of actual level of service. Use of traffic density has been proposed for several High-Occupancy Toll (HOT) lane facilities. Its disadvantages include that it requires greater sensor accuracy and reliability, and it is difficult for the driving public to understand when compared with other measures.

- **Travel Time –** Perhaps the truest measure of value to drivers, travel time also can be the most difficult to measure. Travel times can be collected from transponder-equipped vehicles by matching transponder identification numbers at two points. However, this results in a lag in time for availability of the measurement based on the time that it takes a transponder-equipped vehicle to travel the distance. It may be necessary to estimate travel times based on speed/volume sensors placed at regular intervals along the facility with calibration based on less frequent RF tag reads.

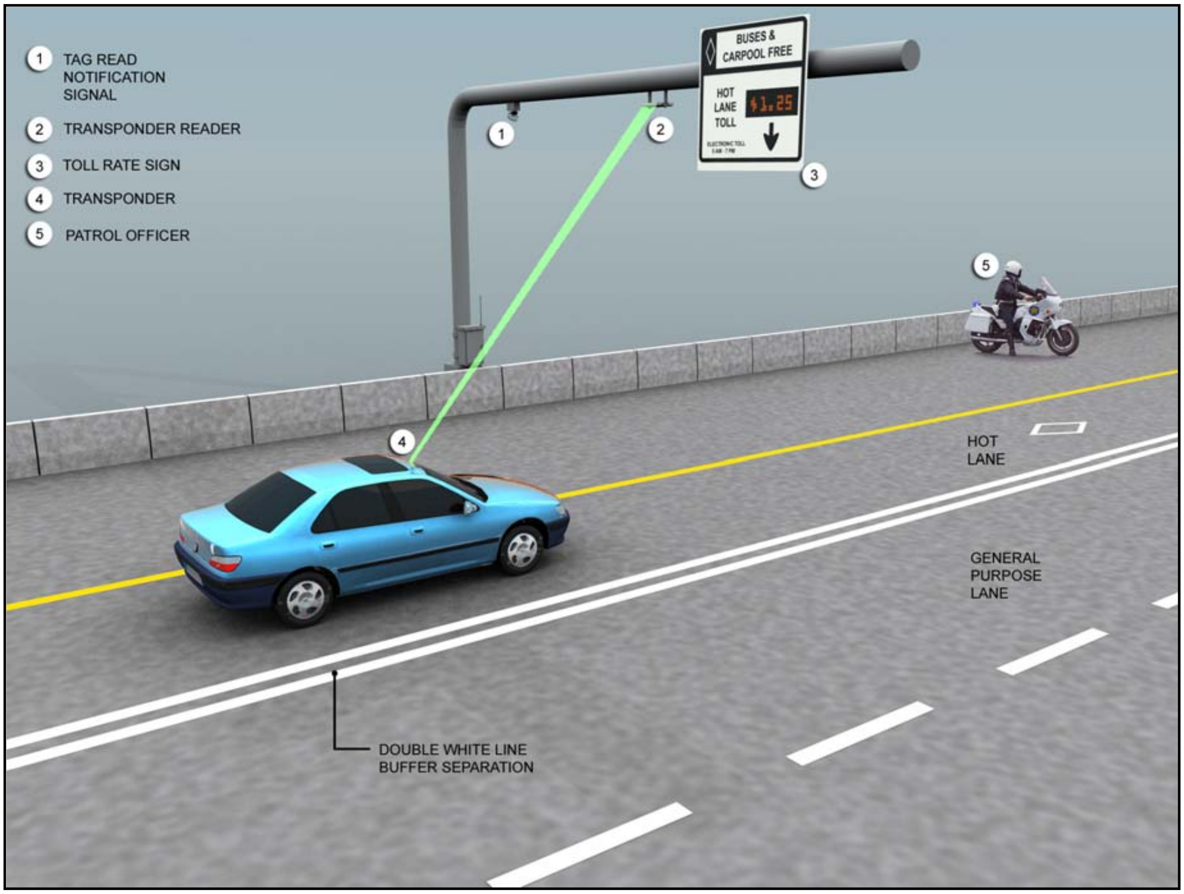
Regardless of the measure used, high levels of accuracy are crucial. Generally, existing field traffic sensor infrastructure needs to be updated to properly support dynamic pricing. Existing infrastructure has generally been deployed for traffic management and monitoring purposes where occasional failure of individual sensors does not drastically impact the overall effectiveness of the system. However, with toll systems, high accuracy and reliabilities of greater than 99 percent are necessary to ensure accurate toll rates and to maintain public confidence. The tighter the frequency or greater the number of segments, the more important accuracy and reliability becomes.

HOT Lanes

Characteristics

HOT lane facilities charge Single-Occupant Vehicles (SOV) for the use of a High-Occupancy Vehicle (HOV) lane. Access into the HOT lane remains free for transit, vanpools, and carpools. The toll charged for SOVs is dynamically adjusted to ensure traffic congestion does not exceed an established threshold for all vehicles in the HOV lanes. Toll collection is done electronically to provide nonstop toll collection. Tolls are charged at fixed points along the facility. The SR 167 HOT Lane Pilot Project will be such an implementation (see Exhibit 8.7). Selected considerations when implementing HOT facilities are discussed next and are under consideration for the SR 167 project.

Exhibit 8.7 SR 167 HOT Lane



Technical Considerations

Pricing for HOT Lane Capacity Versus Corridor Throughput

The first consideration is what will drive the calculations that determine the toll rate at any point in time or along the facility (i.e., pricing algorithm)? With HOT lanes, there are two basic approaches:

1. **Maximize efficient throughput of the HOT lane alone.** Under this pricing philosophy, the goal is to maintain acceptable operations (e.g., level of service (LOS) C, speed or traffic density) on the HOT lanes, regardless of the level of operations on the adjoining general-purpose lanes.

2. **Maximize efficient throughput of the entire corridor.** This pricing philosophy is quite different from the first approach; in that, traffic conditions on the general-purpose lanes more directly influence pricing on the HOT lanes. The overall goal is to

maximize the throughput of the entire corridor (HOT and general-purpose lanes), while maintaining acceptable operations on the HOT lanes. In actual operations, the key difference here is that, if congestion levels are heavy on the general-purpose lanes, prices on the HOT lanes may actually be lowered to try and attract more drivers until such time that the HOT lanes are near-capacity.

It is important to understand that this decision drives the larger pricing concept for the facility, and can result in drastically different toll rates and schedules. The first approach is relatively simple to implement, while the second approach is significantly more complex.

Frequency and Segmentation of Pricing Adjustments

Once a basic pricing approach has been selected, a determination needs to be made regarding how often prices will be adjusted, and whether or not prices will be set for the entire facility or on a segment by segment basis.

- **Frequency of Price Adjustment** – Frequencies for toll rate adjustments can vary greatly from facility to facility. Some set prices based on average volumes across several weeks and establish a time-of-day toll schedule. Some adjust prices every few minutes. As a general rule, allowing frequent price changes can be considered too confusing to drivers. However, frequency can be a key factor in how much the toll rate can influence the amount of SOV traffic that enters the HOT lane. While infrequent price changes can reflect seasonal and growth trends, they do not allow for reactions to abnormal conditions that may occur within any single peak period or day. Increased frequencies also increase the complexity of the required pricing algorithm and the supporting systems (such as traffic sensors and variable toll rate signs).

- **Corridor Segmentation** – Many HOT lane facilities set different toll rates for separate segments of a corridor, as well as the distance or number of segments crossed by drivers. Segmenting facilities allows dynamic pricing to reflect different conditions along the facility. As with frequency, tighter segmentation provides for more control, but segmentation also increases complexity and cost of the supporting systems. Excessive segmentation of a facility can create a confusing pricing scheme that is difficult for drivers to understand, and it also becomes more difficult to provide adequate signage.

Recent deployments of HOT lanes (including the MnPass program in Minnesota) have dynamically set the toll rate based on near real-time traffic conditions.

For single-lane HOT lane implementation, frequent price changes based on actual conditions are probably the only way to reliably kept traffic flowing at some guaranteed performance level. For two-lane HOT lanes, time-of-day pricing based on historical patterns may be possible, since there is more capacity, and hence, more room for demand fluctuations.

Enforcement

One of the challenges for a HOT lane implementation is enforcement. Besides addressing toll evasion, the enforcement of HOV regulations also is required. An SOV must pay to be in the HOT lane. The enforcement official must be able to verify that a transponder has been read and the toll paid. This requirement leads to a two-step process – the enforcement officer visually identifies the SOV, and then verification of payment is determined. This enforcement action must be conducted along the side of the roadway and is a manual process. This manual enforcement requires the deployment of enforcement officers at additional cost to ensure compliance with HOT lane regulations.

Unfortunately at this time, there is not a fully operational mechanism to electronically determine the number of persons in a vehicle. Promising methodologies are being field tested and do offer some potential for automated HOV enforcement in the future.

The second complication is making sure that a transponder-equipped vehicle that is an HOV and can use the HOT for free is not charged. Accordingly, a means to prevent a transponder from being read is required. These operational issues are being addressed as part of the SR 167 HOT Lanes Pilot Project.

Express Toll Lanes

Express lane tolling is just like the HOT approach, but for all vehicles not just SOVs. With an express lanes tolling scheme, tolls are charged to all vehicles using the express lanes. The other vehicles not willing to pay a toll can use an untolled, usually parallel facility. Express toll lanes are designed to guarantee performance on a managed facility. Tolls are collected either by manned tollbooths or ORT.

The SR 91 express lanes in California implement a combined HOT and express toll lanes scheme. During most hours of the day, high-occupancy tolls are charged only to operators of SOVs using the lanes. But during peak commute hours, the lanes turn into a full toll road, charging all users. Projects are under consideration in Maryland and Minnesota.

HOT or Express Lane Systems

Characteristics

The next logical step is the combination of individual HOT or Express lane corridors into a regional system of roadways. As expected, this would add another level of complexity. This complicates the development of pricing algorithms; in that, there is the potential to optimize for the entire network, and not just the corridor. Once the price is set, the next challenge will be to inform the driver of what they are paying. As a driver moves along the network, the price may change. The difficulty is determining when to inform them in a manner that allows for a timely decision. These issues and others are being explored as the San Francisco Bay Area, San Diego County, Texas, and Minnesota consider systems of HOT lanes.

Technical Considerations

Dynamically priced toll facilities implemented to date have been relatively simple, using only one or two tolling zones. As WSDOT looks to potential networks of managed facilities, the technology challenges multiply. The main challenges are to set rates and communicate the price information to the traveling public so that the system is managed to its optimum flow.

Since traffic levels and available capacity might vary over the network, prices should ideally be set by segment. The network could be divided into logical travel segments with prices set based upon maintaining an acceptable level of traffic flow. Before the start of each new segment, travelers could be presented with information on the current toll rate for the next segment. The roadway design would need to allow drivers adequate time to make a decision whether to continue on the tolled portion or move to the free portion of the facility.

The question is: how far in advance can you guarantee a price to the customer for a portion of the network, and how does this uncertainty affect the ability to maintain traffic flowing at the optimum rate? This is a problem that has not yet been solved in the industry, and will require additional research and experimentation.

Pricing All Roads

Characteristics

In response to increasing concerns about the ability of the fuel tax to remain a reliable source of revenue into the future, the idea of pricing all roads, potentially through some kind of fee on vehicle miles, is being discussed in some places. Pricing all roads also raises the opportunity to apply pricing techniques to traffic management problems.

One way to accomplish pricing on all roads involves the installation of GPS in a vehicle to locate itself within a charge area or along the highway network. The on-board unit will contain the appropriate charge structure, as well as information concerning when the vehicle should be charged. Charges are applied using the position information provided by the GPS system. The charge can either be deducted directly from a smart card located in the on-board unit, or stored for later uploading to be charged against the customers account. The charging scheme can be based on location, time of day, distance traveled, type of vehicle, emissions, or any combination.

The charging of drivers based upon vehicle miles traveled has been implemented for commercial vehicles in both the United States and Europe. Some states have added commercial vehicle characteristics, generally weight, to the fee calculations. With weight-distance truck tolling, freight carriers are charged a fee for use of the road system that depends on weight and total distance traveled over a given period. The usual motive for such fees is to recover fully the costs associated with the operation of heavy vehicles on the road network.

Technical Considerations

Pricing all roads would require charging different fees based upon distance traveled on defined categories of road (such as freeways or major arterials) at certain times of day (some roads may only be tolled during peak hours). A means of accurately determining the distance traveled and identifying the class of road is a fundamental requirement of the system. Distance traveled can obviously be measured by a simple odometer reading; however, this does not provide the location information needed to assess a toll for only those miles traveled within the tolled network or the date/time data that is needed to determine miles traveled during peak hours. Additional issues arise about ensuring the accuracy of the data, ensuring that user privacy is not compromised, and communicating the data to a central system for calculating the toll amount due.

- **On-board Equipment Cost** – While the proliferation of vehicles with integrated on-board GPS makes vehicle location data somewhat more available, not all vehicles are equipped. The current cost of on-board units remains expensive and requires custom installation.

- **Accuracy of Location Data** – Highly accurate GPS location data is needed to ensure that drivers cease to be charged once they have left the toll network. This location accuracy requirement is particularly important when considering a roadway that may be tolled in one direction during peak periods, but not in the other, or discerning one lane over another.

- **Informing the Driver of Charges** – Drivers will make cost-effective decisions for travel if they have the cost data required to make these decisions in a timely manner. Providing dynamic pricing information to a moving car before a driver reaches an appropriate decision point presents series of technical and human factor issues. The GPS device only knows where the vehicle is and not where it is going. So providing toll rate information in the vehicle would not work for this purpose. Another approach is to set up a schedule by time of day and route, but this approach is contrary to the desire to provide dynamic pricing.

- **User Privacy** – While privacy laws vary from region to region, many users are not comfortable with the idea of their vehicles' location data being shared with a government agency; and in fact, toll authorities may not wish to have this information due to the liabilities involved. Privacy concerns may be addressed by configuring the system so that no vehicle location data is stored by or transmitted to the authority, and the only information received by the authority is the total miles traveled within a certain pricing zone.

- **Data Communications** – At some point, vehicle use data must be transmitted to a central system for the calculation of the applicable user fees. Cellular networks and DSRC are potential options.

- **System Updates –** Every software application requires periodic updating and refreshing. The task of ensuring timely updates of the software contained in the on-board units presents a technical challenge.

Enforcement

The need for an enforcement infrastructure is common to all road user charging systems – independent of charging policy or the approach used for charging. Although there have been numerous strategies proposed to prevent toll evasion, they can generally be grouped into two categories: 1) designing the On-Board Unit (OBU) that tracks the vehicle's road usage in such a manner as to prevent tampering or disabling, and 2) observing the vehicle from fixed or mobile check points to ensure that charges are being recorded. The two are not mutually exclusive, however, and can be employed in parallel for the sake of redundancy.

Strategies proposed to prevent tampering with the OBU include the following:

- Disabling the engine unless the OBU also is activated;
- Ensuring that the components of the OBU can be accessed only by certified professionals; and
- Checking the OBU's distance monitoring records against the odometer reading each time the unit is turned on, and flagging any discrepancies.

Strategies for observing the vehicle from fixed or mobile checkpoints include:

- Using roadside readers to transmit queries to passing vehicles to ensure that their OBUs are in fact operating as intended.
- Using video cameras to capture images of vehicles that have passed a given check point; this information can later be crossed-referenced against billing records to ensure all identified vehicles did in fact pay the corresponding tolls.

Example Projects and Programs

Two all-road pricing pilot projects currently are underway in Washington and Oregon. The PSRC's Traffic Choices Study investigates whether participants might opt to change their travel patterns (such as opting to telecommute, take transit, or travel during off-peak hours) if they are charged a fee for travel on all freeways and major arterials in the Puget Sound area with higher fees during peak hours. An OBU is installed in each participating vehicle and provides a running tally of the user's assessed cost per trip. This amount is then debited from a prepaid account (funded by the study). At the conclusion of the study, participants will get to keep any money not used in the account. The system architecture uses cellular communications to transmit data from the OBU to the central system for processing. Participants may log on to the project web site to view their "account activity" online.

The Oregon DOT's Road User Fee Pilot investigates the potential for Road User Charging to replace the state gas tax. Participants are assessed a per-mile charge based on miles driven in Oregon by zone. Participating vehicles will be equipped with an OBU that tracks the vehicle's mileage traveled in each zone. This data will be downloaded wirelessly at the gas pump when the vehicle stops to refuel. The usage fee is then added to the total due, while the gas tax is credited. Both amounts are shown on the user's receipt. By collecting the fee at the gas pump, Oregon could continue to charge a gas tax to non-equipped vehicles.

While both ODOT and PSRC are installing a vendor-provided OBU in each vehicle participating in the pilot projects, it is anticipated that the technology provided by the OBU will eventually be standard equipment in all new cars. By continuing to collect the gas tax from non-equipped vehicles, ODOT leaves the door open to implement Road User Pricing without waiting for the majority of citizens to purchase new cars.

Other examples of international implementations include the following:

- **Heavy Vehicle Fee (HVF) or LSVA System in Switzerland –** Switzerland introduced a toll system for trucks over 3.5 tons in January 2001. The supporting technology includes an OBU (mandatory for all Swiss vehicles and optional, though encouraged, for foreign vehicles) featuring GPS and DSRC, as well as a connection to the vehicle's tachometer (including odometer information).

- **"GO" Weight-Distance Truck Toll Program (LKW) in Austria –** Austria introduced an electronic toll collection system for trucks over 3.5 tons in January 2004, based on DSRC microwave technology.

- **"Toll Collect" Weight-Distance-emissions Truck Toll Program in Germany –** Germany followed suit with some delay through technical problems on January 1, 2005. The German Toll Collect system is based on a GPS technology; truck operators may choose to either install OBUs for automated tracking of movements, or to book their route in advance using the Internet or computerized booking terminals.

Toll Technology Considerations, Opportunities, and Risks

The deployment of toll collection technology to meet the operational requirements of the various types of toll collection approaches described above comes with a wide range of potential challenges, issues, opportunities, and risks. Understanding the factors and their implications is required when selecting an overall approach to tolling within the State of Washington. Policy and toll project decisions will influence the technology choices, but technology also will have an impact on policies and projects. The remainder of this section identifies specific areas to be considered and their potential implications.

Toll Collection Methods

State of the Practice

The choice of toll collection method should be based on the operational requirements of the individual toll project, recognizing the need for interoperability with other systems around the State. The following types of systems currently are available:

- **Manual Toll Collection** – This traditional approach has been around for centuries. A driver stops at a tollbooth and pays the required toll directly to a toll collector. Cash and agency issued payment cards are generally accepted modes of payment, and some systems now accept third-party credit or debit cards, though this is rare in the U.S. Toll plazas can be located on highway mainlines or at entrances or exits to the facility. Manual toll collection can accommodate up to 400 vehicles per hour in a pure-cash environment. Credit transactions reduce this rate considerably. Typically, tollbooths are provided in a ratio of three or four for every lane of through travel, which requires considerable right-of-way.

- **Unattended Toll Collection –** An early step in automation was the introduction of automatic coin machines, where drivers placed the required toll payment in a basket and the machine counted the amount. While coin machines have become less popular with toll agencies because of high maintenance requirements and the introduction of ETC, a related approach is still being used at locations and times of low-traffic volume. A self-service machine – similar to parking pay and display machines – is used to allow the driver to pay the toll with currency or credit card when a toll collector is not present. The need for right-of-way remains, but staffing costs are reduced. This practice is used for low-volume facilities and during late night hours at many facilities.

- **ETC** – This method uses automatic vehicle identification technology that identifies a toll customer while the vehicle passes through a toll plaza, sometimes at highway speeds. Customers need to have an identification tag, usually an electronic transponder that is linked to the customer's account, which is automatically debited for the amount of the toll. ETC may be used in dedicated lanes, or combined with manual toll collection. Cameras are used to identify violators.

- **Open Road Tolling (ORT) –** This is a form of electronic toll collection without tollbooths. Customers pass through a highway toll collection zone at full highway speed, and capacities over 2,000 vehicles per hour. Most deployments require vehicles to be equipped with transponders for the payment of tolls, and cameras are used to capture the images of violators. Some installations now allow drivers without transponders to "pay by plate," which allows customers to register their vehicle with the toll authority and pay the applicable toll either before or after they access the facility via telephone or Internet. If customers do not register, their name and address is obtained via the license plate, and they are sent a payment notice.

- **Global Positioning System (GPS) Tolling –** Under this approach, a GPS unit and wireless communication link are installed in a vehicle to track its location within a charge area or network. The OBU will contain the appropriate charge structure, as well as information concerning when the vehicle should be charged. Charges are applied using the position information provided by the GPS system. PSRC is conducting a demonstration of value pricing using this approach, and a countrywide installation of GPS tolling was recently introduced for tolling trucks in Germany.

Methods To Be Used in Washington State

The TNB toll collection system currently under construction will have three ORT lanes for patrons with transponders, and six manual toll lanes for customers using cash. Vehicles without transponders that use the ORT lanes will be treated as violators. Pay by plate will not be allowed, although this approach may be considered in the future based upon operational experience. The SR 167 HOT Lane pilot project will use ORT to allow for dynamic pricing, and to avoid the need for space-consuming toll plazas. HOT lane toll facilities are only being developed as strictly open-road tolling systems.

Interoperability

Washington is moving toward a consolidated operations model for interoperability under which customers will have a single account, transponder and phone number to call. WSDOT has selected a common transponder technology to be utilized at all future toll facilities. The customer service center and related back office system for the TNB will most likely serve as the customer service center for the SR 167 HOT Lanes Demonstration Project. Transaction data from SR 167 will need to be transmitted to the TNB back office system for processing. In turn, transponder status information will be made available at the lane level for SR 167.

An additional complicating factor is that revenue collected at the Tacoma Narrows Bridge (minus operational and maintenance costs) is legally designated to pay back the motor vehicle fund which financed the bridge construction (RCW 47.46.140). Therefore, the costs for providing services to other facilities as part of a statewide interoperable able toll collection system must be fully accounted for.

The consolidated approach is what customers expect. However, as toll facilities outside of the Puget Sound Region develop, there may be a need to consider regional customer service operations. The potential new crossing of the Columbia River in the Vancouver/Portland region is one such example.

Toll Collection Without Toll Booths

Modern technology has eliminated one of the main complaints about toll facilities: stopping to pay the toll. Nonstop toll collection is enabled by either vehicle-mounted transponders or devices to automatically read license plates. In an urban setting with a primarily local population, projects being developed today can safely do away with manual toll collection, since the majority of the customers can be encouraged to get transponders. Those that choose not to get transponders can have tolls collected through the automated license plate recognition systems. ORT requires less right-of-way, no toll collectors, and no stopping for toll patrons. It is possible that, if the TNB were being designed today, there would be no manual tollbooths.

On the flip side, ORT means that operational costs are shifted to customer service and violation enforcement activities. Violation enforcement activities can be time-consuming, because they rely on people reading license plate images captured by potential violators, and a sometimes cumbersome process to verify, process, and collect tolls and fines. It is still unclear whether current operations that are 100 percent ORT have lower operational costs than manual operations.

As Washington looks forward to projects beyond TNB, it should actively consider whether any manual toll collection should be provided. In the immediate term, 100 percent ORT should be actively considered for all new toll facilities, especially for high volume, urban settings with limited right-of-way, and all HOT lane implementations. The combined manual/ORT configuration might best be used in lower volume locations with a lower percentage of repeat customers. Over time, this conclusion might change, as national standards emerge for built-in in-vehicle transponder technology.

Third-Party Service Providers

Looking towards the future, many auto manufacturers will be installing transponders as factory equipment in new cars, once the national roadside to vehicle communications protocol has been firmly established. These transponders will go far beyond toll payment to potentially include a wide variety of retail (such as using the transponder account to pay for drive-through restaurant service), traveler information, and road safety applications. Essentially, these transponders would function as an in-vehicle credit card, with the likely expectation from the customer that they will receive a single invoice for all of their in-vehicle transactions. In this scenario, the government tolling authority would interface with a third-party service provider to bill each customer's account. The means to securely activate this on-board interface will need to be determined.

Setting the Toll Rate

Traditionally, the toll rate for a facility has been set to pay for the capital, operating, and maintenance costs of the facility or authority. This toll rate has generally been fixed based upon the classification of a vehicle, with heavy commercial vehicles paying more than passenger cars. However, charging drivers a fee that varies with the level of traffic on a congested roadway can allocate roadway space in a more economically efficient manner. Toll rates for individual vehicles can be determined in the following manner:

- **Fixed Toll Rates** – The most common practice is to set a fixed toll rate based upon vehicle characteristics such as the number of axles.

- **Time of Day –** Because travel demand varies based upon the time of day, toll rates can be set based upon historic traffic levels. SR 91 Express Lanes in Orange County, California use a time-of-day schedule. The public generally easily understands time-of-day schedules.

- **Dynamic or Traffic Conditions-based Pricing** – Time-of-day pricing is based upon historical information and does not account for actual conditions each day. By using traffic sensor information, real-time traffic conditions can be determined and used to update prices as conditions change. When developing dynamic pricing algorithms, the balance between revenue generation and mobility will need to be determined. To ensure that a driver is charged the correct toll under a dynamic pricing approach presents a technical challenge. The driver must be informed of the price of the trip, and the price must remain constant for the duration of the trip. This is more easily done for a corridor with limited access points than an entire network of roadways.

Enforcement

Since the first construction of toll facilities, users have attempted to avoid payment of the required toll. The introduction of ETC without gates and toll collectors has resulted in the deployment of technology to automatically identify toll evaders and demand the payment of the required tolls. The primary goal of enforcement is to ensure that there is an acceptable level of compliance, and enforcement efforts are considered to be fair and consistent. The changing attitude in the toll industry is to treat violators first as potential new customers, and secondly as violators. The enforcement program will need strike a balance with the desire to bring more travelers into compliance.

The second aspect of enforcement is the acceptance that not all tolls will be collected. Like any business, this potential loss must be identified, quantified, and mitigated in a cost-effective manner.

Out-of-State Drivers

Infrequent users of a toll facility will have little incentive to enroll as ETC customers and obtain transponders. For tolling projects without manual toll collection, images of their license plates will be captured for further processing. If a pay-by-plate options exists for the facility, the driver may register their vehicle and pay over the telephone, Internet, or upon receipt of a notice. If no payment were received, they would become a violator.

Acquiring information on the registered owner of a vehicle from out of state is a common practice. Within the United States, most state DMVs will accept requests from other states for no or little costs. Once an address is obtained, a demand letter can be sent.

Unfortunately, enforcement mechanisms available against in-state vehicle owners cannot be brought to bear against out-of-state owners (e.g., registration hold, notice of infraction, etc.). The cost to collect these tolls from out-of-state residents will be higher. Particular attention will be required in establishing the bi-state toll enforcement requirements for the potential new Columbia River crossing between Washington and Oregon.

Unfortunately, the ability to obtain names and addresses for the owners of vehicles registered in Canada currently is not available. British Columbia and other provinces are unwilling to share private information on their citizens that would be stored in databases in other countries. Enforcement of violators from Canada will require further attention.

HOT Lanes – Operational Considerations

HOT lanes have specific functional requirements to be considered. Because the concept is to "sell" excess capacity of the HOV lanes, traffic conditions must be monitored in real time to ensure that there is excess capacity available to sell at a given time of day. This information is used to dynamically set the toll rate for SOV drivers who wish to use the HOV lanes. This concept of operations leads to a set of requirements that include:

- **ETC Only** – Stopping traffic to collect tolls is antithetical to the idea of providing a higher level of service for a fee. The HOT lane concept implies that toll collection must be electronic to provide for nonstop toll collection. However, the operational difficulty lies in not charging an HOV vehicle that also happens to be equipped with a transponder for using the HOT lanes. While this issue can be successfully resolved with technology, customer service and driver education issues will need to be addressed.

- **Manual Enforcement** – For now, all HOV enforcement requires a police officer to verify on the spot that the vehicle is an HOV. This places the operational burden of providing enforcement on the Washington State Patrol. This additional duty will require funding and additional staff beyond currently available resources.

- **Notification of Toll Rates –** SOV drivers will need to be notified of the toll rate at a point before they enter the HOT lanes, and be assured that the posted rate is the rate they will be charged. For a corridor, this can be addressed even with multiple access points. For a network of HOT lanes across the region, it will present additional challenges.

Public-Private Partnerships

Under the Transportation Innovative Partnerships Program, Washington State is reviewing and updated its approach to Public-Private Partnerships (PPP) for transportation projects. It is anticipated that some of the potential projects under this program would include a tolling component. The tolling technology and operational aspects of these projects must be coordinated with the overall WSDOT tolling program. Issues to be coordinated will include toll setting authority, interoperability, customer service, enforcement policy and procedures, cost allocation, and technology upgrades. The first four items are the most critical from a customer perspective.

Proprietary Technology

Currently, there is not a national standard for the sharing of information between the transponder in a vehicle and the roadside transponder reader. There are regional and programmatic standards with a small number of suppliers. The national standard is under development and should be on the market within the next several years. It is anticipated that manufacturers will install transponders that are compliant with the new national standard in new vehicles.

WSDOT has selected as its primary transponder one that is proprietary to a single supplier. This selection was made to provide a shorter-term, cost-effective solution to fill the gap between current technology and the new standard. WSDOT policy is, and should remain, to move to national technology standards in an orderly fashion as they are adopted. In this way, multiple suppliers will become available, and use of proprietary technology can be minimized over time.

Technology Refresh

Within less than 10 years, a technology investment has generally reached the end of its economic life, especially with the rapid advancement of technology. The same is true for ETC systems. The State and any potential private partners should consider this lifespan and be ready to upgrade relevant components of the ETC system at all levels. Flexibility will be required as the technology marketplace moves the toll industry in directions that have not been anticipated.

The State should actively monitor the progress of developing a national standard for transponders and consider becoming a test bed for early deployment of this standard. This would provide an opportunity to fully test the standard and integrate it into toll and other applications. The toll collection system should be reviewed on a two-year cycle to determine its overall performance against current toll technology and operational benchmarks.

Privacy

To date, participation in electronic toll collection programs by equipping a vehicle with a transponder has been voluntary. Any toll system that requires the use of electronic toll collection will mandate the identification of individual vehicles, which in theory could be used to record time, location, and speed of travel. At least some segment of the population will oppose any new technology that may enable the government to monitor their movements.

Current Washington State law provides ETC account protection, which prohibits the release of information to third parties. However, pressure remains to allow the release of individual travel records to third parties. For example, current law allows media access to transit smart card information. Once ORT, which will enable toll collection without transponders, is deployed, the same safeguards provided to ETC accounts should be extended to the patrons without transponders.

Project Cost Allocation

WSDOT is primarily organized to deliver a completed highway project. If more than one toll project is implemented and customer service functions are shared, then a means for the proper allocation of operational and capital costs among the various projects will need to be developed. Many toll projects are financed under strict bonding covenants and enabling legislation that restricts how toll revenue can be spent. TNB is one such example for which revenues and costs cannot be shared with other projects. If the TNB customer service center is used for projects beyond TNB, then a means to quantify and charge other projects for services will be required. This requirement for project cost accounting also implies that an internal means to track operational costs for providing services must exist, in order to provide a basis for the allocation of costs.

Routine Operations and Maintenance

Toll collection programs require a level of overall system and operational availability not generally demanded by most business and government activities. If the components of the toll collection system and operations are not working, then customers are not being served adequately and revenue can be lost. Trained staff provided at adequate levels is required to maintain and operate enterprises of this extent.

Background paper prepared by the IBI Group, with assistance from Cambridge Systematics, Inc.in January 2006.