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I-5 Columbia River Crossing Partnership:
Traffic and Tolling Analysis

Evaluation of Toll System Options

Working Paper 7.1

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Date

October 8, 2004

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PURPOSE

The purpose of this working paper is to identify and evaluate toll system option concepts for further study in the I-5 Columbia River Crossing Study. This working paper will focus on various toll system options, reader system options, backroom systems, violation and enforcement systems, as well as manual and automatic toll collection options.

TAG SYSTEM OPTIONS

Tags provide automatic vehicle identification (AVI) in an electronic toll collection (ETC) system. Radio frequency (RF) tags are currently the most popular type of tags used for tolling purposes, primarily due to their accuracy, reliability in varying conditions, and flexibility for data storage. Other types of tags include laser or infrared (typically a window-mounted sticker with a bar code).

Tag Types

There are three types of RF tags that provide varying degrees of information, processing, and communication capabilities:

- Type I – These are "read-only" tags that contain basic information; such as toll agency, tag identification number, and vehicle classification. This information is read by the antennae/reader system, which is then processed along with other information (e.g. vehicle classification data) to identify the tag and corresponding account.
- Type II – These tags are read-write tags capable of storing extra information received from the reader. Certain fields are static (tag ID) while others can be updated, such as transaction data including time, plaza, and lane data. These tags provide more functionality and allow for instant verification of transaction communication.
- Type III – These tags are more commonly referred to as Smart Cards. They are typically made up of two components, including the card housing and actual smart card. The card is similar to a credit card with a magnetic strip used to encode information. The card housing communicates between the card and the antennae/reader. Similar to Type II tags, certain data are static and others can be updated. Because smart cards are typically used for multiple purposes (e.g. toll collection, transit fare payment, etc.), the account balance is maintained on the card. Patrons must remember to update their own accounts, as well as insert the smart card into the vehicle's card housing when traveling through toll plazas.

While ETC usage in the U.S. began with Type I tags in Texas, the Type II tags predominate, primarily to allow turnpikes, with interchange-to-interchange tolls to have a ready determination of the cost of the trip. The Tacoma Narrows project in Washington seems to be moving in the direction of a Type II tag.

Tag Power

Tags can be powered through either active or passive systems. Active tags are powered by an internal battery that is triggered by the antennae's interrogation signal. Passive tags do not have a power supply. There is a new round of passive Type I tags being tested in several states, which can be produced for an extremely low cost (roughly $1.00 to $2.00 per tag, versus the $20.00 to $30.00 for

an active tag). The signal from the antenna is modulated and reflected to the reader. For a system using passive tags, it is generally desirable for it to be compatible with other neighboring toll systems.

Based on geographic location, I-5 should be compatible with the Washington tag standard, which will most likely be a Type II active tag, although the distance between Tacoma and the Vancouver/Portland area indicates there will be minimal overlapping with the two systems.

Tag Mounting

Tags can be mounted in a variety of locations, including internal and external to the vehicle's passenger compartment. The location of the tag is directly related to the location and type of antennae being used. In-pavement antennae require externally mounted tags, typically located along the centerline underbody of the vehicle. Inherent problems with external tags include physical damage as well as inability to easily verify proper mounting. Antennae mounted to the roadside or side of the toll plaza lane work more effectively with tags mounted to the side of the front windshield. Overhead antennae require tags mounted in the center of the front windshield, typically behind the rearview mirror. Some vehicles with reflective windshields (e.g. metallic oxide) require an external tag, typically mounted to the front bumper.

The most commonly used system is the overhead antennae installation with tags mounted in the center of windshields.

READER SYSTEM OPTIONS

The reader, antennae, and tag are components to the overall AVI system. Several locations are possible for the reader antennae components of the system. These include overhead, roadside, and in-pavement systems. The overhead system is the most widely used system due to its accuracy, flexibility, and ease of maintenance.

- Overhead – These systems can be mounted on plaza canopies or gantries in the case of open-road or high-speed lanes. They are mounted in the center of the lane and provide a large "read zone" allowing accurate reads at high speeds. Furthermore, by placing antennae in each lane, the system is able to correctly locate the vehicle and determine its lane, which allows for accurate correlation to the audit system (AVC data).
- Roadside – These antennae are located along the side of the toll plaza, toll lane, or open highway. They are prone to interference from adjacent vehicles, structures, and weather. They are less capable of determining lane location and correlation to AVC data.
- In-Pavement – These antennae are typically embedded in the roadbed similar to loop detectors. A saw-cut is made, the antennae is then inserted and covered with epoxy. This system requires an external tag. Drawbacks to this system include installation and maintenance difficulties, poor performance in some environments (snow, salt), as well as inherent problems with external tags.

Other Reader Systems

There are a few examples of Optical Character Recognition (OCR) systems (or License Plate readers) that are in use. The most well known example is the Toronto 407 system, which is all electronic. Either the customer has a transponder (Toronto 407 uses Type II transponders) or the system reads the license plate and sends a bill for the trip to the owner of the vehicle, with an accompanying administration fee ($3.35 Canadian).

BACKROOM SYSTEMS–THE CUSTOMER SERVICE CENTER

Backroom systems, typically administered by the Customer Service Center (CSC) can include a variety of subsystems. These subsystems can generally be broken down into the toll transaction system, toll audit system, maintenance and operating system, administration system, and customer service system. The backroom system can handle all of these functions, or a subset of these functions. Typically, the backroom or host handles all functions for smaller toll facilities, while the system is broken into two major components (i.e., Host and CSC) for larger toll facilities. When broken into two components, the CSC system typically handles account maintenance and violation enforcement functions.

There are infinite combinations of functionality for the various subsystems, and decisions made for one system often directly affect other parts of the overall system. Many of the general parameters affecting backroom systems are summarized in Working Paper 5.3. Vollmer's experience has shown that trying to develop a custom set of functionality is counter-productive. Most vendors provide basic backroom functionality that adheres to general accounting principles and have adapted to the most popular custom functions specified by existing toll systems. Other influencing factors to various subsystems include interoperability with other toll facilities as well as other systems such as Commercial Vehicle Operations, such as HELP (Heavy Vehicle Electronic License Plate, Inc). HELP is a system that allows pre-registered trucks to pass efficiently through weigh stations, among other benefits. For more information on HELP, visit the following website:

http://www.prepass.com/help.htm#heavy

VIOLATION AND ENFORCEMENT SYSTEMS

This section presents a brief discussion of violation enforcement for ETC systems. This analysis forms a basis for discussion and policy development with regards to Violation Enforcement Systems (VES) going forward in the project.

Prior to special legislation in many states, a toll violation was treated as a violation by the operator of the vehicle. As such, enforcement required a visual identification of the violating driver. In practice, this method served more as deterrence with occasional sting operations designed to show the willingness to enforce tolls. With the introduction of ETC, the perception has been that non-stop toll collection will increase the occurrences of individuals avoiding payment of tolls. New technology makes it possible to identify the vehicle, but would still require human observance to identify the violating motorist. Most states with operating ETC systems have secured legislation that establishes toll violation as an administrative offense on the offending vehicle similar to that of a parking ticket. As a result, images of license plates can be used to administratively fine toll violators. The opposition

to this type of legislation is usually based on the big brother principle and has been mitigated by language in the legislation specifically prohibiting the use of images for anything but toll violation. In a system with Open Road Tolling and staffed lanes, we recommend deterrence with legislation as an effective VES.

In addition, policy needs to be determined about which violations are going to be enforced. The following sections define violation types and enforcement methodologies, providing examples and relative costs associated with the different levels of enforcement.

In general, toll systems have violation rates of low single digits, typically 2% to 5%. In most cases, system administrators informally set their goals and then change their enforcement levels to meet their expectations. There are many cases of low-traffic, unattended ramps with much higher rates, but these are usually evaluated in context of the entire system

Violation Definitions

There are several different types of violations that the toll system can be designed to detect. Each violation type represents a series of costs and benefits that can be derived from their implementation. Below is a list of different types of violations that may occur in a toll system.

- True Toll Violation – A true toll violation is one where a driver deliberately fails to pay a toll on a regular basis. This group is often referred to as the core violators. Detection requires cameras and or human observation.

- Inadvertent Toll Violation – An inadvertent violation is one by a driver that is unfamiliar with the new type of toll collection. This type of violation occurs most frequently when ETC systems first open. The size of this group tends to diminish over time. A second group of inadvertent violators are called "one-timers." One-timers are those users who seldom use the facility and will inadvertently end up in the dedicated ETC lane. These violations tend to remain constant over time. Detection requires cameras and or human observers.
- ETC Failed Read Toll Violation – A failed read violation refers to a failed read of a ETC customer's transponder. Reasons for the failed read include improperly mounted tags, weak batteries, true miss by the reader, and customers forgetting to mount their transponder. This type of violation results in non-collection of the toll by the facility despite the user's intention to pay the toll. Violators of this type are customers of the toll facility. Detection requires cameras, or human observation and a link to the CSC.
- ETC Class Mismatch Toll Violation – This type of violation occurs when a transponder-equipped vehicle has a transponder of a lower vehicle class than the class of the vehicle being operated. In this case, the toll collected electronically is less than the toll that should have been collected for the passing vehicle. Violators of this type are customers of the toll facility. Detection requires AVC, a link to the CSC, and may require cameras to document the offending vehicle.
- ETC Toll Speeder – A toll speeder is a customer of the toll facility who exceeds the allowable speed limit in the toll lane (dedicated or mixed) when paying by transponder. Detection requires speed detection, a link to CSC, and may use cameras to document the offending vehicle.

- ETC Toll Discount Program Abuser – At many facilities there are special discounts available. An example of a discount program may allow free passage at one location, but requires a payment of a toll at second location. A discount program abuser would be a tag holder who has free passage at the first location, but travels through the second location with no funds available to cover the toll. The abuser is like a toll violator, but is a known customer. Detection requires a link to the CSR and may use cameras to document.
- Toll Collector Errors – Regardless of the toll system installed, there will always be human error as well as opportunities for toll collectors to conduct fraudulent activities in the toll lane. Detection of fraudulent activities includes detailed audit reports from the host system. Another effective method for correcting toll collection errors, which can also be used for training and system debugging, utilizes lane controller data overlaid on video images of the toll lanes. This detection method combines the data with a visual picture of what happened.

In the business of toll collection, violation rates and enforcement information is proprietary and held in strict confidence, so that is it difficult to generalize about the frequency of occurrence of the various types of violators. As noted previously, the overall rates tend to be in the 2 % to 5% range, and it would be expected that each category of violation would be at most 1% or 2% of total traffic.

Definitions of Possible Enforcement Methods

There are many ways to deter violations, some of which are very expensive. However, doing nothing to assure compliance will increase violations and can be more costly in the long run. The following list defines the various methods, describes the associated relative costs, and provides examples (where available) for each type of enforcement:

- Do Nothing – This is the lowest-cost alternative, but for practical purposes is not viable. Vollmer is not aware of any ETC facility that has no evader enforcement policies, though some may not pursue any enforcement actions at select remote, un-staffed ramp locations.
- Spot Police Enforcement – Currently, some facilities practice spot enforcement by occasionally setting up operations with the state police to identify and apprehend toll violators. At a sample location, this method resulted in a toll violation rate of approximately 1.6% in the existing lanes and less than 1 % overall. In an ETC-based system, this method would require little additional equipment or staff.
- Gate Enforcement – For tolls collected at the MTA Bridges and Tunnels facilities in New York, electronic toll, manual, and automatic coin machine lanes are enforced by using gated toll lanes. Enforcement is accomplished by a gate remaining closed for a toll-violating vehicle. The MTA has no speed violations and handles class mismatch violations administratively at the CSC. The Peace Bridge is planning to deploy ETC using the same approach.
- Enforce Existing ETC Customer Violations – With the exception of the missed read transaction, equipment can be placed in the lane (automatic vehicle classification [AVC] and speed detection) to identify each of the customer violations. Enforcement actions and communications can be made through the CSC or through some type of DOT operated violations processing center that communicates with the CSC. Cameras can be added to supplement the in-lane equipment used for customer enforcement. We are not currently aware of any facility applying this approach to enforcement.

- Enforce Existing Customer Violations and Perform Spot Deterrence for Violators – Essentially, this is a combination of the two types of enforcement discussed above. It may or may not include cameras. The West Virginia Turnpike is employing this approach to violations. Their system detects toll violators, speeders, class mismatches, and discount program abusers.
- Enforce All Toll Violations – By definition, this level of enforcement requires that all types of violations will be detected and pursued. This approach requires all in-lane equipment including the cameras. OCR is usually included as a means of reducing staffing requirements. Business rules are usually established to screen out inadvertent violators. This type of effort generally features high levels of staffing. The best example of this is the failed enforcement program for the Regional Consortium in New Jersey and Delaware. The violation enforcement system was viewed as a revenue stream to offset the costs of implementing ETC. This approach has been abandoned because the costs were greater than the return in fines, there were political problems in developing and monitoring the system, and a more conventional approach is being pursued.
- Monitor Toll Collectors – Toll collector enforcement can be conducted independent of or in combination with any of the above enforcement approaches utilizing the equipment discussed above.

Enforcement operations can either be located at each plaza as spot enforcement, or centrally located. They can be operated by the tolling agency, a vendor, or by the CSC provider.

Enforcement System accuracy

There are many issues associated with the accuracy of VES. One of the more common problems is correctly identifying the violating vehicle. In a mixed-mode AVI/ACM, it is common for a cash-paying vehicle to beat the green light. Most systems would detect that vehicle as a violator even though the vehicle had not violated. Sometime later, a true violator could pass on the first vehicles' payment thus would not be detected as a violator. A gate can mitigate some of those problems. Another example would be in heavy traffic when a violating vehicle is mixed with transponder-equipped paying vehicles. The video equipment frequently can not properly pick it out. It is also sometimes difficult to read license plates in the image or to find the vehicle owner once the plate is identified—it is a policy decision as to what course to pursue. Mitigation of the risks is based on balancing policy and cost. In application, enforcement ranges from simple deterrence to a revenue source used to guarantee bonds.

Cost/Benefit Approach for Selecting Enforcement Options

Video enforcement is expensive, requiring large numbers of staff and expenditures of capital. Spot enforcement is deterrence using the same tools for reducing violations, but on a limited basis. In the absence of financial penalties for toll violations, high levels of enforcement generally result in reduced net revenues (it costs more to chase a violator than the value of the lost toll). The decision on how to proceed requires a business analysis to select the appropriate levels of activity.

The following discussion relates the cost of enforcing violations to the net revenue achieved at various levels of enforcement.

- **Violation Rate**. The violation rate is the percentage of total passages through the toll plaza that do not have tolls collected or recorded for them.
- **Toll Revenue**. Toll revenue is the total toll revenue collected for all passages of vehicles through the toll plaza.
- **Enforcement Level**. The enforcement level refers to the effort expended by the DOT to pursue violators. Various levels of enforcement were discussed in the previous section.
- **Violators Processed.** Not all of the violators can be identified or fall into a category that is considered a violator. For example, policy is usually set not to pursue inadvertent violators. Also, not all violating vehicles can be identified for a variety of reasons such as obstructed license plates, or out of country registrations.
- **Fine Revenue**. Many VES programs include fine revenues that can be used to offset the costs of collecting from violators. Fines are usually set at some level sufficient to deter toll violations.
- **Net Revenue**. The net revenue is the total net revenue when all of the toll income, fine income, and violation processing costs are considered.

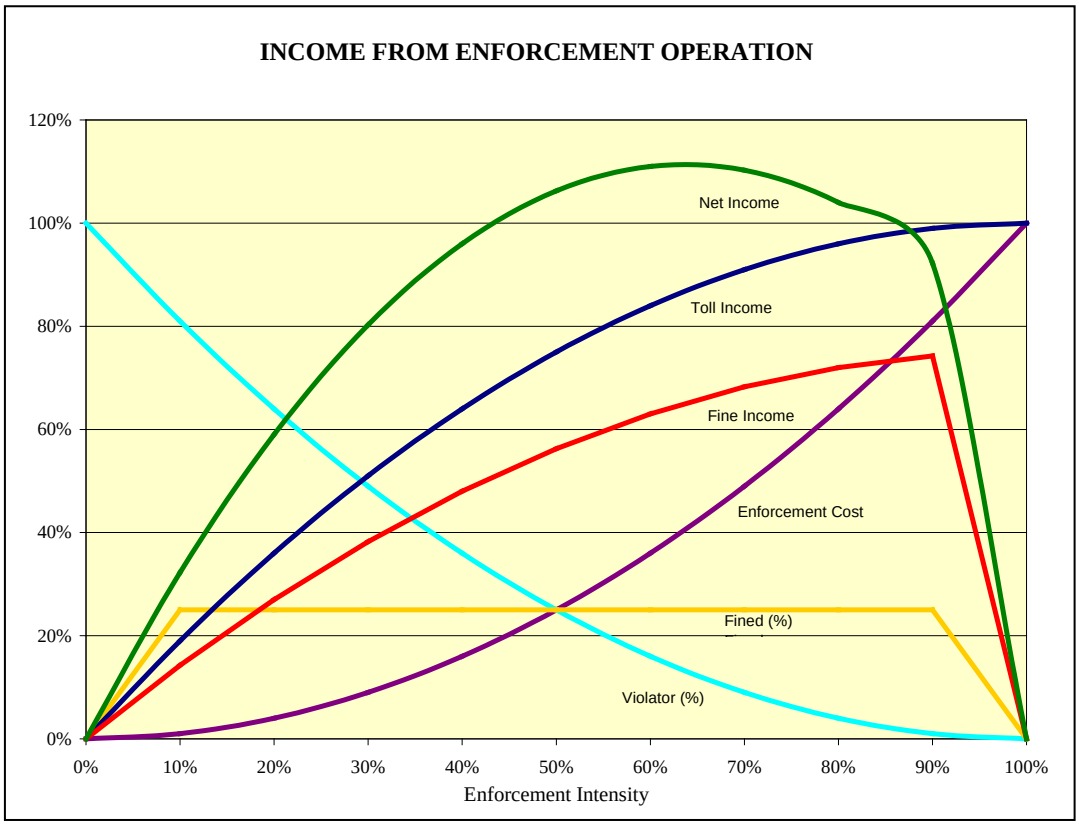

Figure 1. Income from Enforcement Operation

Figure 1 is a graphic representation of the relationships between the various components of enforcement. It is meant to be illustrative of the relative value of each element of enforcement. A

more precise set of curves can be determined once violation enforcement policies are determined. Most operating systems have violation rates under 10 percent.

It is unlikely that a 100% violation rate would occur. As can be seen in the figure, there is an optimum level of enforcement that produces the highest amount of net revenue. The point of highest net revenue does not necessarily match the highest level of enforcement. Parameters relative to this facility will be applied to the basic curves to help determine the best policy to apply to the specifications.

Possible Scenarios

In this section, we have prepared a table that shows the process of developing policy on violation enforcement. It follows the example presented above and makes some initial assumptions on typical activities occurring.

- **Violation Rate**. The violation rate is the percentage of total passages through the toll plaza that do not have tolls collected or recorded for them. For this example, we will assume that 2% would be the maximum violation rate. This includes some 0.4% for inadvertent violators in the ETC system. We have also assumed a minimum rate of 0.1% when full enforcement is in place.
- **Toll Revenue**. Toll revenue is the total toll revenue collected for all passages of vehicles through the toll plaza. In Table 1, toll revenue is presented as "Lost Toll Revenue" from a case where all tolls are collected. With a 2% violation rate, this is represented as 2% of toll income.
- **Enforcement Level**. The enforcement level refers to the effort expended by the DOT to pursue violators. 100% enforcement assumes a cost of $7.00 to pursue each of the initial 2% initial violators. In this example, full enforcement requires almost 20% of gross toll revenues.
- **Violators Processed**. Not all of the violators can be identified or fall into a category that is considered a violator. It is not likely that an inadvertent violator would be treated as a violator and have a fine assigned with it. Not all vehicles can be identified for a variety of reasons such as obstructed license plates, or out of country registrations. When deterrence is used, not all violators are even collected. Based on these parameters, the percentage of violators that are processed through to collecting a fine increase from 0% to a maximum of 33% at full enforcement.
- **Fine Revenue**. Many VES programs include fine revenues that can be used to offset the costs of collecting from violators. For this example we assumed the DOT legal right to assess and collect a fine and set a value of $25.00 to each fine collected.
- **Net Revenue**. The net revenue is the total net revenue when all of the toll income, fine income, and violation processing costs are considered. In this example, net revenue is shown as a change in the net revenue from the baseline current level of enforcement case.

Based on the values assigned in this example to each category, Table 1 suggests the optimum balance between net revenue and gross revenue (capital costs are not included). Enforcement level is about 20% to 30% of the maximum enforcement level, but this will vary based upon the definition of the enforcement parameters and the legal support for them. Again, this is just an example of the

methodology used by various agencies to arrive at the level of effort each employs in pursuing toll violators and would need to be refined as actual policy is developed.

Table 1. Enforcement and Revenue Balance

Enforce Level	Enforce Cost	Violation Rate	Violators Fined	Lost Toll Revenue	Fine Revenue	Change to Net Income
0%	0.2%	2.00%	0.0%	-2.0%	0.0%	-0.4%
10%	0.4%	1.36%	0.3%	-1.4%	0.1%	0.2%
20%	0.8%	1.10%	1.3%	-1.1%	0.5%	0.4%
30%	1.6%	0.87%	3.0%	-0.9%	0.9%	0.2%
40%	2.6%	0.67%	5.3%	-0.7%	1.2%	-0.3%
50%	4.0%	0.50%	8.3%	-0.5%	1.4%	-1.3%
60%	5.6%	0.36%	11.9%	-0.4%	1.4%	-2.7%
70%	7.6%	0.26%	16.2%	-0.3%	1.4%	-4.6%
80%	9.8%	0.18%	21.1%	-0.2%	1.3%	-6.9%
90%	12.4%	0.14%	26.7%	-0.1%	1.2%	-9.5%
100%	18.7%	0.10%	33.0%	-0.1%	1.1%	-15.9%

NON-ELECTRONIC LANE SYSTEM OPTIONS

The two primary methods of non-ETC are manual and automatic collection. For this study, it has been determined that the toll collected will most likely be in the range between $1.00 and $10.00, and therefore, automatic toll collection will not be a feasible option because the toll amount is not easily paid using coins. Manual collection was the original technique for collecting tolls, while automatic coin machines (or "honor baskets" as they were once known) only moved into significant usage in the late 1950s. Most new toll roads, especially those with higher tolls, have combinations of ETC and manual lanes, and occasionally use automatic coin machines at low-volume, low-toll rate ramps. The European toll roads have developed very sophisticated automatic machines with coin, bill, and credit card capability. There are many drawbacks to this option since there is a high cost associated with the equipment, and the processing time associated with each transaction is slow, creating a low throughput number for that lane.

Manual collection is a straightforward, common non-ETC method. Staffing costs are predictable and security and reliability issues are addressed in the design of the toll plaza. Videotape and audits are used for security.

RECOMMENDATIONS

Vollmer has been recommending to its clients to focus on deterrence, rather than a high level of enforcement. We would suggest administrative fees and fines to deal legally with repeat offenders, and would expect with such a system that the revenues received by the VES would at least equal the losses in revenues due to violations.

Regarding the types of systems, tags, readers and the like, it is too early in this work effort and too early in planning for tolls to focus on such items yet, as these will be more pertinent when the planning for tolls becomes a design for tolls.