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TECHNOLOGY SCAN FOR ELECTRONIC TOLL COLLECTION



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Technology Scan for Electronic Toll Collection

by

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and

The Federal Highway Administration

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16. Abstract The purpose of this project was to identify and assess available technologies and methodologies for electronic toll collection (ETC) and to develop recommendations for the best way(s) to implement toll collection in the Louisville metropolitan area. The intent was to determine which tolling mechanisms maximize efficiency and effectiveness of toll collection while minimizing traffic impacts. This report describes the advantages and disadvantages of tolling, current tolling technologies, the purpose of ETC, and the benefits and costs of ETC. Implementation issues for ETC are discussed, including the location of toll collection facilities, ETC methodologies, interoperability of ETC systems, how to handle vehicles not equipped for ETC, enforcement, pricing strategies, and congestion management. Case studies are presented for the Bay Area Bridges in San Francisco, Highway 407 in Toronto, and the Indiana Toll Road. The study concluded that ETC provides substantial advantages over manual toll collection; ETC technology is proven, accurate, and reliable; interoperability is an important consideration in choosing an ETC technology; the greatest benefits are achieved with open-road tolling; decisions must be made regarding how to deal with non-equipped, non-enrolled vehicles; and adequate enforcement will be critical to the success of any ETC implementation.			
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EXECUTIVE SUMMARY

Transportation facilities funded by user fees (i.e., tolls) are common throughout the United States and around the world. Kentucky has substantial experience with toll roads, having used this mechanism to fund the Parkway system across the Commonwealth. Tolls are currently being considered as a potential funding mechanism for the Louisville – Southern Indiana Ohio River Bridges Project. The purpose of this project was to identify and assess available technologies and methodologies for electronic toll collection (ETC) and to develop recommendations for the best way(s) to implement toll collection in the Louisville metropolitan area. The project included a literature review and case studies.

As a means of raising supplemental revenue, highway tolling offers numerous advantages, as well as some disadvantages. Advantages include the additional revenue generated by the tolls, the ability to assign charges directly to those actually using the facility, the public's willingness to pay direct user charges associated with a specific benefit, the ability to move projects forward more quickly, a continuing source of funds for operations and maintenance, the potential use of tolls to manage travel demand and congestion, and an enhanced opportunity for public-private and public-public partnerships. Disadvantages include the costs associated with collecting the tolls (both direct and indirect), the potential for tolls to be perceived as double taxation, and potential equity issues.

Current technologies for collecting tolls include manual collection, automated cash machines, dedicated short-range communications (DSRC) transponders, optical character recognition (OCR), and others. At one time, manual collection was the standard for all toll facilities. However, it is now viewed as impractical as a primary means of toll collection, principally due to its adverse impact on traffic flow and its high collection costs. Automated coin machines are only marginally better than manual collection in terms of traffic impact and collection costs.

DSRC technology, consisting of vehicle-mounted transponders and roadside readers, has been the predominant technology used for ETC for the past 20 years. It provides high traffic throughput, high accuracy, and low collection costs. A key issue in selecting a specific DSRC technology is interoperability with other systems. There are numerous ETC systems currently deployed in the United States, and these systems use several different DSRC technologies.

OCR technology uses camera systems and software to read motor vehicle license plates and to assign tolls to vehicles based on their license plate numbers. OCR-based systems can provide reasonable traffic throughput; however, accuracy tends to be low, and collection costs are quite high. As a result, OCR technology is typically used as a secondary collection method and/or an enforcement tool rather than as a primary collection method.

In addition to the “proven” technologies, there are other technologies being investigated and or pilot-tested. These include odometer-based tolling, cell-phone-based tolling, and satellite-based tolling.

When compared to manual toll collection, ETC has both economic and environmental benefits. These include: (1) reductions in transaction and waiting times, (2) faster commutes, (3) reduction in fuel consumption, (4) easing of traffic congestion, (5) reduction in air pollution, (6) reduction in cost of operations, and (7) improved identification of toll evaders.

When considering the implementation of tolls in the Louisville metropolitan area, it is important to consider the type of toll collection to be performed (traditional toll plaza, open-road tolling, or hybrid) and the best location for actually collecting the tolls. This report discusses advantages and disadvantages associated with different types of collection and different locations. It also discusses issues related to interoperability with other systems.

The primary challenge associated with any ETC deployment is this: How should the system deal with those vehicles that are not equipped and enrolled for ETC? The success of any ETC system will depend to a large extent on how well this challenge is addressed. If Kentucky decides to implement ETC, a key question will be whether or not to provide a manual payment option. This will affect the number and types of violators that will be encountered. Effective enforcement must be provided to discourage toll violations and to maintain public confidence in the system. The most common technology used in violation enforcement is automated license plate recognition (LPR) systems. These systems are used to identify violators so that appropriate enforcement actions can be taken.

When ETC systems are deployed, tolls can be varied by time of day in order to manage traffic flow and reduce congestion during peak periods. This report discusses several examples of variable-pricing strategies that have been implemented in various locations throughout the world.

The case studies described in this report are: (1) the Bay Area Bridges in San Francisco, California, (2) Highway 407 in Toronto, Ontario, Canada, and (3) the Indiana Toll Road. For each case study, information is presented on the types of toll collection conducted, the types of technology deployed, the toll rates and variations, violation enforcement, incentives for participating in ETC, collection rates and loss rates, technology reliability, operations and maintenance costs, marketing, and participation rates.

This study resulted in the following conclusions and recommendations: ETC provides substantial advantages over manual toll collection; the use of DSRC for ETC is proven, accurate, and reliable; Kentucky should strongly consider ETC versus manual collection for any proposed implementation of tolls; Kentucky should strongly consider selecting an ETC technology that is interoperable with the E-ZPass system; Kentucky should strongly consider implementing open-road tolling whenever possible; a major decision in implementing ETC is determining how to deal with non-equipped, non-enrolled vehicles; and adequate enforcement is critical to the success of any ETC implementation.

CHAPTER ONE: BACKGROUND AND OVERVIEW

Transportation facilities funded by user fees (i.e., tolls) are common throughout the United States and around the world. Kentucky has substantial experience with toll roads, having used this mechanism to fund the Parkway system across the Commonwealth. Tolls are currently being considered as a potential funding mechanism for the Louisville – Southern Indiana Ohio River Bridges Project. On a broader scale, tolls may be considered as an additional source of revenue for building, operating, and maintaining Kentucky’s highway infrastructure.

1.1 Project Purpose

The purpose of this project was to identify and assess available technologies and methodologies for electronic toll collection (ETC) and to develop recommendations for the best way(s) to implement toll collection in the Louisville metropolitan area. The intent of the project was to determine which tolling mechanisms maximize efficiency and effectiveness of toll collection while minimizing traffic impacts.

It is understood that there are regulations under the National Environmental Protection Act that would need to be considered in any implementation of tolls for the Louisville – Southern Indiana Ohio River Bridges Project. This study does not address those regulations, but is focused specifically on identifying and assessing available toll collection technologies.

1.2 Project Methodology

The process used to identify the best available technologies and methodologies for electronic toll collection in Kentucky included the following tasks.

Task 1: Literature Review

The available literature was reviewed to identify studies and evaluations of ETC technologies and approaches both nationally and internationally. Many different system studies and evaluations were reviewed to identify pros and cons of the various approaches and technologies used for ETC and to identify their potential applicability to Kentucky’s needs.

Task 2: Case Studies

The project staff selected three ETC systems for case studies: (1) the Bay Area Bridges in San Francisco, California; (2) Highway 407 in Toronto, Canada; and (3) the Indiana Toll Road. Each of these case studies provided a different perspective on the use of electronic tolling. A list of nine questions was developed for use in gathering information for the case studies.

Task 3: Assessing Available Approaches and Technologies and Developing Recommendations

The information gathered in Tasks 1 and 2 was used to develop recommendations, which are presented in Chapter 5 of this report.

1.3 Structure of the Report

The report is organized into five chapters. Chapter 1 outlines the background, purpose, and methodology of the project. Chapter 2 provides a general discussion of the various methods currently available for toll collection, with a particular emphasis on ETC. Chapter 3 discusses several of the key issues pertaining to the implementation of ETC, such as (1) tolling locations, (2) types of electronic collection, (3) interoperability with other systems, (4) tolling enforcement, and (5) pricing strategies. Chapter 4 presents three case studies of ETC implementations. Lastly, Chapter 5 presents conclusions and recommendations.

CHAPTER TWO: UNDERSTANDING TOLLING AND ELECTRONIC TOLL COLLECTION

2.1 Decisions Regarding Toll Collection

When considering tolls as a potential funding mechanism, the following questions must be addressed. These questions are discussed in the sections that follow.

- What are the advantages and disadvantages of tolling versus other funding mechanisms? (Section 2.2)
- If tolls are to be implemented, what technologies are available for toll collection? (Section 2.3)
- What are the benefits and costs of electronic tolling when compared to manual toll collection? (Section 2.5)
- Where (i.e., at what physical locations) should the tolling technologies be implemented? (Section 3.1)
- What implementation approaches are available (e.g., conventional toll plazas, open-road tolling, or hybrid systems)? (Section 3.2)
- How will the toll collection system deal with vehicles that are not equipped for electronic toll collection? (Section 3.4)

2.2 The Advantages and Disadvantages of Tolling

In June of 2005, the Kentucky Transportation Center completed a study of innovative financing options for enhancing Kentucky's transportation funding capacity. That study included an analysis of highway tolling as a means of raising supplemental revenue. The final report for that project listed several advantages and disadvantages associated with tolling (*1*).

Advantages of Tolls

- Tolls provide additional revenue that otherwise would not be available.
- Tolls provide a precise form of user charges, where the costs associated with a facility are borne by those actually using the facility.
- The public is generally willing to pay direct user charges. (The user is able to associate a direct benefit with the payment of the toll.)
- Tolls generally allow a project to be built sooner than would be possible without the tolls.
- Tolls provide a continuing source of funds for ongoing operations and maintenance.
- Tolls, once implemented, can provide a mechanism for managing travel demand and congestion.

- Tolls provide an enhanced opportunity for public-private and public-public partnerships.

Disadvantages of Tolls

- There are costs associated with collecting the tolls.
 - Direct costs for toll collection
 - Indirect costs due to interruptions in traffic flow
- Tolls may be perceived as double taxation.
- Tolls may create equity issues. Is everyone being treated fairly?
 - Rural versus urban travelers
 - In-state versus out-of-state travelers
 - Frequent versus occasional users

2.3 Current Tolling Technologies

There are several different technologies that can be used for toll collection: These include:

- Manual toll collection;
- Automated coin machines;
- Dedicated Short-Range Communications (DSRC) transponders;
- Optical character recognition (OCR); and
- Others (e.g., Odometer, Cell-phone, Satellite)

The following provides a brief discussion of each of the current tolling technologies.

Manual Collection

Manual toll collection typically consists of human operators stationed in toll booths to collect money from motorists, make change, and provide receipts. Prior to the advent of automated cash machines and electronic technology, manual toll collection was standard for all toll facilities. In today's environment, manual toll collection is typically viewed as impractical as a primary means of toll collection. The primary disadvantages of manual toll collection are traffic impact and cost of collection. Manual toll collection typically reduces lane capacity to less than 15 percent of free-flow capacity, and collection costs range from 35 to 45 cents per transaction (2).

The reduced lane capacity associated with manual toll collection has an adverse impact on traffic delays, fuel consumption, and vehicle emissions. It also necessitates a significantly enlarged "footprint" for toll collection plazas, since many additional lanes are necessary to accommodate the traffic flow.

Automated Coin Machines

Automated coin machines allow tolls to be collected (using coins or tokens) without the need for a human operator. In terms of traffic impact and cost of collection, automated coin machines are marginally better than manual toll collection. Automated coin machines reduce lane capacity to approximately 25-30 percent of free-flow capacity, and collection costs range from 28 to 35 cents per transaction (2).

As with manual toll collection, the use of automated coin machines has an adverse impact on delays, fuel consumption, and vehicle emissions, and it requires many additional lanes in the toll collection plaza to accommodate the traffic flow.

DSRC Transponders

DSRC technology consists of vehicle-mounted transponders and roadside readers, which communicate with each other using radio frequency transmissions. For the past 20 years, this has been the predominant technology used for ETC. All North American ETC systems (and nearly all such systems in the world) currently use this technology. It provides a high traffic throughput, high accuracy, and low collection costs. Depending on the specific approach selected, lane capacity can range from 50 to 100 percent of free-flow capacity, and collection costs can range from 7 to 19 cents per transaction. Typical system accuracy is greater than 99 percent (2).

A key issue in selecting a specific DSRC technology is interoperability with other systems. There are numerous ETC systems currently deployed in the United States (3). These systems use several different technologies, so it is currently impossible to get one transponder that works in all ETC systems. Table 1 shows examples of the different transponder technologies that are currently in operation in the U.S.

Table 1. Different transponder systems used for ETC in the U.S.

State	Acceptable Transponder Technologies
California	FasTrak
Florida	SunPass, EPass, OPass, and LeeWay
Maryland	E-ZPass
Massachusetts	Fast Lane and E-Zpass
Michigan	MDOT Pass
New Jersey	E-ZPass
New York	E-ZPass
Pennsylvania	E-ZPass
Indiana	E-ZPass, I-Zoom, and I-Pass
Illinois	I-Pass

Although there is no single transponder that will work in all systems, it is possible to select a DSRC technology that provides interoperability with some systems. So, a key question is, “With which other systems do we want to be interoperable?” Chapter 3 of this report contains a more detailed discussion of interoperability.

Optical Character Recognition

Optical Character Recognition (OCR) technology uses camera systems and software to read identifying information from a motor vehicle, such as the vehicle license plate. When this technology is used for ETC, the system assigns tolls to vehicles using their license plate numbers. OCR-based systems can provide reasonable throughput (typically 35 to 42 percent of free-flow capacity, ranging up to 100 percent for open-road tolling) (2). However, accuracy tends to be low (in the range of 85 percent, at best), and collection costs are quite high, at greater than \$2.00 per transaction. As a result, OCR technology is typically used as a secondary collection method and/or an enforcement tool rather than as a primary collection method.

Other Technologies

In addition to the “proven” technologies for toll collection, there are other technologies being investigated and/or pilot-tested. Some examples are listed here:

Odometer-based tolling – The Oregon Department of Transportation has a pilot project to test the concept of implementing a mileage-based fee in lieu of a fuel tax. Participants in the pilot project have their vehicles equipped with special technology. When they purchase fuel at a participating service station, the standard fuel tax is deducted from their bill and the per-mile fee is added (4).

Cell-phone-based tolling – This concept makes use of the fact that cell phones can be tracked as they move about. Tracking can be infrastructure-based, using cell phone towers to “triangulate” the position of the phone, or it can make use of the GPS capabilities built into many cell phones. With either approach, the cell phone is tracked and the customer is assessed a toll based on distance traveled and/or facilities used.

Satellite-based tolling – With this approach, technology on the vehicle (such as GPS) uses satellites to continuously determine the position of the vehicle. As the vehicle moves about, the system tracks those movements. The appropriate toll is then assessed based on the vehicle’s movements.

2.4 Purpose of Electronic Toll Collection

Electronic toll collection was created as an alternative to manual payment collection in toll plazas. One of the earliest implementations of ETC in the U.S. was on the Dallas North Tollway, where the tolling authority began supplementing manual lanes and coin machines with ETC lanes in 1989 (5). In 1990 and 1991, ETC was implemented in Oslo and Trondheim, Norway, making it the world’s first toll cordon to use automatic vehicle detecting and debiting in urban areas (6). Since then, numerous cities and states around the world have implemented ETC as a mechanism for increasing roadway revenues while also easing traffic congestion.

Jurisdictions choose to adopt ETC systems for various reasons, depending on what issues they hope to address through ETC. In San Francisco, California, the primary purpose of implementing ETC was to reduce the amount of time required for each toll transaction, thus reducing traffic backups behind toll plazas (7). In Oslo and Trondheim, Norway, ETC was implemented on roadways that previously had no tolling in order to generate revenues to fund new highway projects (6). Another possible reason for implementing ETC is to help alleviate congestion during certain peak periods. Both London and Singapore have used ETC systems as a tool to relieve congestion, by varying the amount of the toll by the time of day (8). This approach, often referred to as “congestion pricing,” is used to discourage motorists (by charging a higher fee) from traveling in congested areas during peak periods. When compared to manual toll collection, ETC systems have additional economic and environmental benefits, such as reducing air pollution, fuel consumption, and commuting times (7).

2.5 Benefits and Costs of Electronic Toll Collection (versus Manual Collection)

Benefits

When compared to manual toll collection, the implementation of ETC has both economic and environmental benefits. These have been documented to include: (1) reductions in transaction and waiting times, (2) faster commutes, (3) reduction in fuel consumption, (4) easing of traffic congestion, (5) reduction in air pollution, (6) reduction in cost of operations, and (7) improved identification of toll evaders. The following section provides a more in-depth discussion of each of these benefits.

Implementation of ETC provides a drastic reduction in transaction and waiting times in toll plazas. According to the U.S. Department of Transportation (USDOT), ETC increases toll lane capacity by 250 percent (5). Looking at specific examples of ETC installations, previous research found that a FasTrak lane in California can handle three times as many vehicles per hour (vph) as a manual collection lane. In Florida, a study conducted by the Transportation Research Board estimated that an E-Pass lane increases conventional plaza lane capacity by 50 to 160 percent (9). E-ZPass lanes in New York can accommodate 1000 vehicles per hour, compared to manual lanes’ 450 vehicles per hour (10). Moreover, a comparison of manual collection, coin baskets, and E-ZPass ETC shows that vehicle throughput is 400 vph for manned booths, 500 vph for lanes with coin baskets, 1000 vph for ETC with vehicle speed under 20mph, and 1500 vph for ETC using full-speed express lanes (11).

Figure 1 shows the Garden State Parkway with its conventional manual toll booths in the 1960s (12) Figure 2 is a picture of the current ETC set-up, with a combination of open-road tolling and toll booths (12).



Figure 1. Garden State Parkway Toll Collection (1960s)



Figure 2. Current ETC Set-Up in Garden State Parkway

With ETC, drivers have the benefit of faster commutes. In Nova Scotia, Canada, the net benefits of ETC were highly dependent on travel time savings (13). In Orange County, California, ETC saves motorists more than 6 million hours per year because of reduced congestion (14). In Washington State, ETC at highway speeds allows for a faster commute by driving in the express lanes with automatic toll collection (15). E-ZPass in New Jersey was estimated to have saved approximately 1.3 million hours per year for ETC users. Before ETC, New Jersey commuters wasted 2.4 million hours each year waiting to pay tolls (16).

Reduction in fuel consumption is another benefit of ETC. In a study of motorists on the New Jersey Turnpike, fuel savings were approximated at 1.2 million gallons annually after ETC

replaced manual toll collection (16). According to USDOT, ETC helped reduce fuel consumption by 6-12 percent (5).

ETC is also gaining popularity in major cities worldwide as a means to ease traffic congestion. The implementation of ETC allows for changes in toll fare based on congestion levels and/or time of day. Toll charges are set higher during congested peak hours. Variable pricing based on congestion levels may be referred to as value pricing, dynamic pricing, or congestion pricing. In Stockholm, Sweden, congestion pricing resulted in a 22 percent reduction in overall traffic levels, with approximately 100,000 fewer people traveling in and out of the zone each day (17).

When compared to manual toll collection, ETC has a positive impact on the environment, through the reduction of air pollution. It reduces vehicle emissions resulting from idling, acceleration, and deceleration at toll plazas. In Central Florida, carbon monoxide (CO) emissions were reduced 7.29 percent overall after ETC implementation (18). The Federal Highway Administration (FHWA) noted the following decreases in emissions per mile where ETC was implemented: carbon monoxide (CO) was reduced by 72 percent, hydrocarbons (HC) by 83 percent, and nitrogen oxides (NOx) by 45 percent (19). Air quality benefits from implementing E-ZPass in the New Jersey Turnpike include reduced emissions of volatile organic carbon (VOC) and of NOx, by 0.35 tons and 0.056 tons per day, respectively (20). The USDOT credited ETC with a 45-80 percent reduction in vehicle emissions (5).

Lastly, the installation of ETC can also aid in identifying toll evaders. ETC systems typically include a video enforcement system that captures an image of the evader's vehicle and license plate, making it possible to track down the toll evader and provide proof of the offense. Of course, this benefit is not exclusively for ETC, since video enforcement can be installed for manual collection systems as well.

Costs

In addition to the benefits resulting from the implementation of electronic toll collection, there are also costs. The following discussion focuses on the tangible costs associated with electronic toll collection. The four primary costs that have been identified include (1) infrastructure costs, (2) transponder costs, (3) marketing costs, and (4) maintenance and labor costs.

Infrastructure Costs

There are various infrastructure costs that result when converting existing roadways and manual tolling facilities to ETC facilities. Clearly, converting and upgrading existing infrastructure is substantially cheaper than building an entirely new roadway. One study estimated that converting a traditional High Occupancy Vehicle (HOV) lane to a High Occupancy Toll (HOT) lane using ETC technologies would cost approximately \$120,000 per lane-mile (21). However, costs are substantially higher when the entire toll plazas must be converted for electronic tolling. Florida's Turnpike Enterprise has estimated conversion costs for four of their mainline toll plazas (to open road tolling), that range from \$15 to 63 million (refer to Table 2).

Table 2. Estimated Cost of Converting Mainline Toll Plaza to Open Road Tolling in Florida (22)

Mainline Toll Plaza	Conversion Cost (Millions)	Scheduled Completion
Bird Road and Homestead	15.3	Winter 2007
Sunrise (on Sawgrass Expressway)	26.2	Summer 2008
Deerfield (on Sawgrass Expressway)	39	Spring 2009
Okeechobee	63.4	Late 2009

Table 3 provides some preliminary cost estimates for tolling infrastructure that may be anticipated for a prototypical six to eight-mile simple managed lane operation with up to five tolling stations (23).

It should be noted that these generic cost estimates do not include any software modifications necessary to integrate sites into an existing system, nor do they include the cost of communications infrastructure to link the project to a remote site. No costs have been estimated for other instrumentation necessary to monitor traffic conditions or to provide video surveillance of the facility. No automatic vehicle classification (AVC) equipment is included.

As Table 3 suggests, the cost estimates are affected by the type of support and signage used. Full span structures cost more than the cantilever or the pole support.

Table 3. Preliminary Cost Estimates for ETC Infrastructure (23)

Description	Unit Price	Quantity	Extended Price
Typical Pole Mount – Dedicated Directional Single Lane Median Divider (covers 2 lanes)			
Lane Controller	\$10,000	1	\$10,000
ETC Reader	\$10,000	1	\$10,000
ETC Antenna	\$2,500	2	\$5,000
Enforcement Cameras	\$5,000	2	\$10,000
Pricing Signage (Type 1)	\$10,000	2	\$20,000
Pole Support	\$10,000	1	\$10,000
Communications Interface	\$5,000	1	\$5,000
Total			\$70,000
Typical Cantilever – Dedicated Directional Single Lane (covers 1 lane)			
Lane Controller	\$10,000	1	\$10,000
ETC Reader	\$10,000	1	\$10,000
ETC Antenna	\$2,500	1	\$2,500
Enforcement Cameras	\$5,000	2	\$10,000
Pricing Signage (Type 2)	\$40,000	1	\$40,000
Cantilever Support	\$20,000	1	\$20,000
Communications Interface	\$5,000	1	\$5,000
Total			\$97,500
Typical Full Span Structure – Dedicated Directional Single Lane (covers 1 lane)			
Lane Controller	\$10,000	1	\$10,000
ETC Reader	\$10,000	1	\$10,000
ETC Antenna	\$2,500	1	\$2,500
Enforcement Cameras	\$5,000	2	\$10,000
Pricing Signage (Type 3)	\$75,000	1	\$75,000
Full Span Support	\$50,000	1	\$50,000
Communications Interface	\$5,000	1	\$5,000
Total			\$162,500

Transponder Costs

ETC users are usually required to purchase, rent, or place a deposit on the in-vehicle equipment (24). Table 4 shows the advertised cost of transponders in various systems, ranging from \$12 to \$50. There are also agencies that do not charge for a transponder, but instead require a security deposit or a minimum balance to be maintained in the user’s account. For example, in the San Francisco Bay Area, all new users must make an initial deposit to their account to receive a FasTrak transponder. These deposits vary according to the type of account opened. An initial prepaid balance per transponder is charged to the account; \$40 for a credit card account and \$50 for a cash or check account (7).

Table 4. Advertised Cost of Transponders

State	Transponder	Advertised Cost
California	FasTrak	No fee or service charge, only initial prepaid balance of \$50 per toll tag
Delaware	E-ZPass	\$25 (one time fee)
Illinois	I-Pass	\$50 (\$52.90 at Jewel Osco) includes refundable deposit and an initial balance of prepaid tolls
Indiana	I-Zoom	\$50
Massachusetts	Fast Lane	\$20.95
New Jersey	E-ZPass	Tag deposit waived for credit card accounts, \$10 refundable deposit per tag is charged to cash and check customers. The basic plan is \$25.
Florida	LeeWay	\$25
Florida	O-Pass	\$25
Florida	SunPass	\$25
Washington State	Good To Go	\$12

In Canada, transponders are leased to Highway 407 Express Toll Route (ETR) customers for use on Highway 407. The nominal monthly charge (in Canadian dollars) is \$2.55/month or \$21.50 annually (25).

Marketing Costs

Marketing to potential users has proven to be at least as important as selecting the right system/technology in achieving overall system success (26). Most toll agencies that previously spent minimal funds on marketing are now engaged in aggressive marketing programs focusing on customer relations, communication, and advertising (18). Marketing strategies are developed to keep existing transponder-users and to convince non-users to accept and use the new toll collection system (27). The marketing strategy developed by Orlando-Orange County Expressway Authority (OOCEA) not only promoted the benefits of E-Pass but also enhanced the family-friendly image of OOCEA (18). They welcomed input from their customers and built a presence in the community to improve customer relations. California's FasTrak offered its users discounts to encourage cash-paying motorists to use transponders (7). In Florida, the SunPass system used an aggressive marketing campaign that included radio advertisements, traffic-report sponsorships, and highway billboards as well as offering its transponders at a large supermarket chain (28). These are only a few of the different marketing strategies being employed in the promotion of ETC usage.

The Illinois Tollway has become a model for innovation, particularly, in paying for marketing and advertising of the I-Pass ETC. The National Council for Public-Private Partnerships (NCPPT) highlighted the total value of the tollway's advertising and marketing campaign in relation to the actual budgeted amount. Although the Illinois Tollway only budgeted \$500,000 for the advertising and marketing of I-Pass ETC, the total value of the actual services they

received from their business partners exceeded \$7 Million (29). Table 5 shows the estimated marketing costs of the promotion of the I-Pass ETC, which includes advertising in retail stores, on-air commercials, post-card size handouts, and customer newsletters.

Table 5. Estimated Marketing Costs (29)

Partner	Service Provided	Estimated Cost
Jewel-Osco	Advertising and Sale of I-Pass Transponders (responsible for 80% of all I-Pass sales)	\$5.7 Million in commissions and
NBC Channel 5	Customer communications by providing real-time traffic updates and the latest information about I-Pass	\$2 Million
PACE Suburban Transit	Ads on the buses	\$50,000 per year
Oases Developers: Wilton Partners, tenants in Wilton's oases pavilions, and Exxon Mobil	Hand-outs and Newsletters promoting Illinois Tollway topics	\$20,000 for 50,000 pcs.

Employee Costs

The cost per transaction for ETC tends to be substantially cheaper than the corresponding costs for manual collection. The Pennsylvania Turnpike Authority estimated the cost of operating a full ETC interchange can be as little as one-quarter to one-fifth the cost of a conventional cash toll interchange. Clearly, a substantial part of the costs associated with manual collection efforts involves the number of employees that are required to collect the tolls. In the case of the Pennsylvania Turnpike, a conventional interchange with four toll booths requires 25 full-time employees at a cost of up to one-third of the toll collection revenue (30). As ETC has been implemented, the turnpike authority has seen a reduction in the number of toll collectors.

Other studies have demonstrated that the adoption of ETC does reduce the number of toll operators and thus the cost per transaction that is incurred to collect toll revenues. A study of FasTrak in the Bay Area reported a 35 percent reduction in number of toll operators when ETC was installed (7). In Florida, the Orlando-Orange County Expressway Authority (OOCEA) disclosed that before EPass was installed, the cost of toll collection was \$0.23 for each dollar collected. After EPass installation, the cost of toll collection dropped to only \$0.10 per dollar collected (9).

Table 6 shows toll volumes, the cost per transaction and the accuracy level for the various manual, automated, and ETC technologies.

Table 6. Current Toll Technology Costs and Accuracy Levels (2)

Toll Options	Toll Volumes (vph)	Cost per Transaction (\$)	Accuracy (%)
Manual	250-350	0.35-0.45	98
Automatic Coin Machine with Barrier (5 coins)	450-550	0.28-0.35	98.5
Automatic Coin Machine with Barrier (1 coin/token)	500-700	0.28-0.35	95
Voucher Script	500-900	0.37-0.48	98.5
Automatic Number Plate Recognition (ANPR)	600-1000	2.25	85
Smart Card	700-900	0.10-0.19	99.5
RFID: Dedicated Lane with Barrier	900-1100	0.10-0.19	99.96
RFID: Free Flow Lane	1800-2400	0.07-0.15	99.25

2.6 The Electronic Toll Collection System

The process of collecting tolls using ETC technology is illustrated in Figure 3.

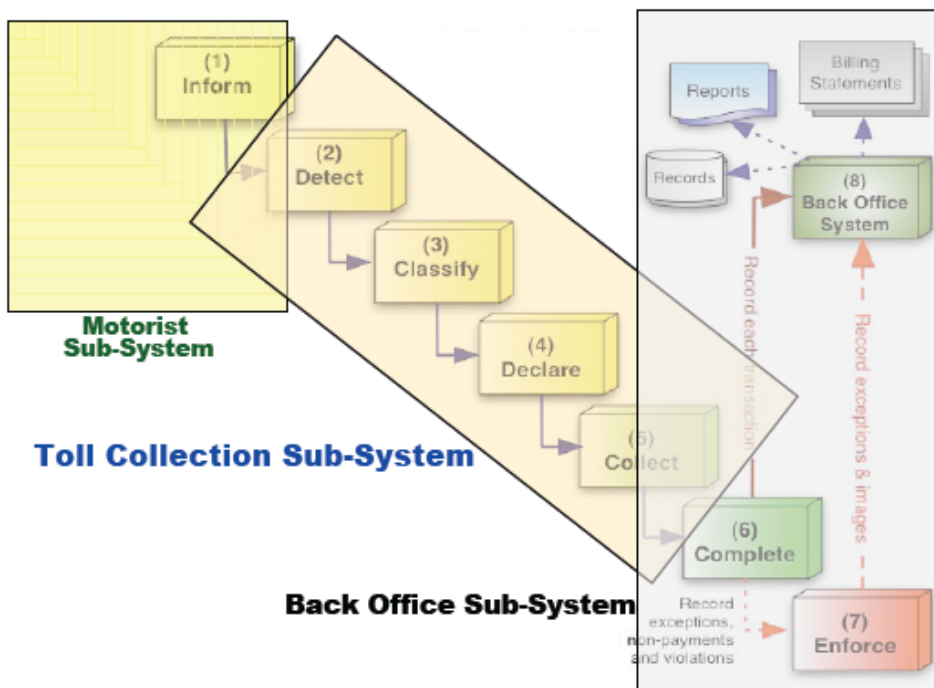


Figure 3. Toll Collection Process (2)

The motorist subsystem includes the vehicle and an on-board unit (OBU), which can be either a transponder or a radio-frequency identification (RFID) tag that automatically identifies the vehicle. The toll collection subsystem involves vehicle detection, vehicle classification, and toll collection. The back-office subsystem is where data storage, image processing, billing and accounting, violation enforcement, and customer servicing takes place.

A typical ETC system has four components: 1) automatic vehicle identification (AVI); 2) automatic vehicle classification (AVC); 3) transaction processing; and 4) violation enforcement (24). The AVI entails the use of vehicle-to-roadside communications to identify the vehicle. For AVC, vehicle class is determined by the vehicle's physical attributes, such as the number of axles. A higher toll is usually imposed on a vehicle with more axles. Thus, larger commercial trucks or cars pulling trailers would likely pay a higher toll (31). Treadles, light curtains, laser profilers, and inductive loop sensors are types of vehicle sensors used to classify vehicles. Transaction processing involves debiting the toll from the customer's account and addressing customer inquiries. Violation enforcement usually includes cameras that record a video or capture an image of license plates. Automatic license plate recognition (ALPR) technology is often used in violation enforcement.

CHAPTER THREE: IMPLEMENTING ELECTRONIC TOLL COLLECTION TECHNOLOGIES

3.1 Tolling Locations

When considering the implementation of tolls in the Louisville metropolitan area (or in any other part of the Commonwealth), it is important to consider the best location for actually collecting the tolls. For example, if a new bridge is constructed over the Ohio River, the tolls could be collected as vehicles cross the bridge. In this case, tolls could be collected in one direction only or in both directions. Alternatively, tolls could be collected at other locations, such as at a nearby junction or on major approaches to the downtown area.

The following discussion presents some pros and cons of collecting tolls on the bridge(s) versus some other location in the metro area.

Tolling on the Bridge(s)

Pros:

- This approach should generate higher level of user acceptance. The users will associate the tolls directly with a new facility and with the benefits generated by that facility.
- The toll collection infrastructure can be designed and built into the bridge construction project.
- The potential exists for having an ETC-only bridge, where only ETC participants are allowed to use the bridge. This would allow for highly-efficient, open-road tolling.

Cons:

- Would probably require revenues to be split with Indiana.
- Would be a dual-state project, thus adding complexity to all aspects of the project.
- For any type of toll-collection other than open-road tolling, the expanded footprint of the toll collection facility may require a larger bridge structure, thus increasing cost.

Tolling at another location in the Louisville Metro Area

Pros:

- The project could be managed and controlled by Kentucky.
- Revenues would stay in Kentucky.
- This could potentially allow the toll collection to take place at a less congested location, where additional right-of-way (if needed) could be more readily obtained.

Cons:

- There could be increased resistance from users due to placing tolls on an existing facility (which they have grown accustomed to using without a toll).
- The complexity of some alternative locations (such as interchanges) could make the tolling system more complex to design and install.
- There could be legal issues involved in placing tolls on an existing facility that was paid for with federal funds.

3.2 Electronic Toll Collection Implementation

Electronic toll collection can be implemented in several different ways. The traditional approach makes use of a toll plaza with individual lanes separated by barriers. As vehicles pass through the toll plaza, their transponders are read and the tolls are deducted from user accounts. The toll lanes may or may not have barriers installed to prevent vehicles from passing through if the toll has not been paid. With this approach, vehicle flow rates tend to be approximately one-half of free-flow capacity. These systems tend to be highly accurate, and they lend themselves well to violation enforcement. However, the reduced flow rate necessitates additional lanes and an expanded footprint.

An alternative approach, which has become increasingly common in recent years, is open-road tolling. This approach uses no barriers, and no toll booths. Overhead gantries are typically used for mounting the DSRC readers, cameras, lighting, and any other overhead equipment that may be needed. With this approach, there is no impediment to traffic, so lane volumes are equal to free-flow capacity. These systems provide high accuracy and highly efficient operations. However, they have no direct provision for dealing with non-equipped vehicles, and the open-road environment can make violation enforcement more difficult.

A third approach is called a hybrid implementation. Hybrid systems provide open-road tolling for those vehicles that are equipped and enrolled, and they also provide conventional toll booths (with manual collection and/or automated coin machines) for non-equipped vehicles. This approach provides many of the advantages of open-road tolling (unimpeded flow, high capacity, accuracy, and efficiency), while also accounting for the non-equipped vehicles and providing improved violation enforcement. The primary disadvantage of hybrid systems is the expanded footprint required for the toll plazas.

3.3 Interoperability

Interoperability is defined as “the ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together” (32). There are several issues to be addressed regarding interoperability of electronic toll collection systems. The challenges in obtaining interoperability, as seen by ITS experts, include: (33)

- Technical units must have a uniform means of communication

- Operators must establish and define how foreign clients can use their services still using their original subscription to the foreign service provider
- Service providers must legally agree on how to handle claims for payments

One of the substantial challenges to interoperability of ETC systems has been the establishment of proprietary DSRC technologies. Deployment of ETC systems in the U.S. began around 1990, in the absence of any North American or International standards for DSRC. The European Committee for Standardization (CEN) established standards in 1997. However, efforts to establish standards for DSRC technology in the U.S. were largely unsuccessful. Different DSRC technologies use different communication frequencies. In the U.S., most DSRC technologies operate in the 915 MHz frequency band. Outside North America, many systems use 5.8 GHz or 5.9 GHz. The Federal Communications Commission (FCC) has allocated spectrum in the 5.9 GHz band for DSRC in the U.S., but migration from 915 MHz to 5.9 GHz has not yet begun.

Currently, 5.9GHz microwave DSRC compliant systems are deployed in Austria, Switzerland, France, China, Japan, Australia, Malaysia, Norway, Denmark, Iceland, and Brazil.

Interoperability is essential in travel routes with toll roads run by different toll operators. Interoperability of tolling exists within the boundaries of California, Florida, and Texas. In California, anyone with a FasTrak transponder can use it to pay tolls on any California toll road or bridge using the system. In Florida, more than 90 percent of toll roads and bridges throughout the state are interoperable. Florida Turnpike Enterprise's SunPass transponders, OOCEA's E-Pass and Miami-Dade Expressway Authority's SunPass transponders are interoperable. On the east coast, there is interoperability of EZPass transponders in Virginia, Pennsylvania, New Jersey, New York, New Hampshire, and Maine. In Illinois, the I-Pass transponder can be used in the Chicago Skyway, Indiana toll road, and anywhere EZPass is accepted.

3.4 Vehicles Not Equipped For Electronic Toll Collection

Electronic toll collection technology is so well developed and well tested that there is little concern with being able to deploy technology that is accurate, reliable, and efficient. The primary challenge associated with any ETC deployment is this: How should the system deal with those vehicles that are not equipped and enrolled for ETC? Since we cannot assume that every vehicle will have the necessary onboard equipment (such as a valid ETC transponder) for our system, we must decide what to do with those vehicles that are not equipped. The success of any ETC system will depend to a large extent on how well this challenge is addressed. Here are some options for dealing with non-equipped vehicles:

- o Establish an ETC-only facility. Forbid non-equipped vehicles from using the facility.
- o Allow non-equipped vehicles to use the facility and provide a manual payment option (i.e., a hybrid system).
- o Allow non-equipped vehicles to use the facility and collect their tolls via an alternate method (such as collecting license plate information and sending invoices).

A key question here is whether or not Kentucky should provide a manual payment option. This will affect the number and types of violators that will be encountered. Reported violation rates

for hybrid ETC systems are generally four percent or less (34). For such a system, with a manual payment option provided, violators should fall into the following categories:

- The intentional violator — chooses to drive on the facility and not pay.
 - Might be a non-equipped vehicle using the ETC-only lanes.
 - Might simply drive through the manual lanes without paying.
- The accidental violator — intended to pay but did not.
 - Driver of non-equipped vehicle wasn't paying attention and got in ETC-only lanes.
 - Driver of non-equipped vehicle got on facility and had no cash. Unable to pay.
 - Driver of enrolled vehicle unaware that account has zero balance and needs to be replenished.
 - Enrolled vehicle whose onboard device malfunctions.

If no manual payment option is provided, then an additional category of violators is created, with a corresponding increase in the number of violators. These additional violators are the occasional or one-time users of the facility who are quite willing to pay the toll but have no way to do so.

The design of the ETC system must consider how violation enforcement should be conducted. It could be argued that violation enforcement is expensive and does not generate a high return on investment. From a strictly economic standpoint, it may be more cost-effective to just accept a certain level of violators rather than investing in expensive enforcement measures. However, a lack of adequate enforcement would create anger and resentment among those users who do pay the toll. It is important for users to perceive that enforcement is present and violators are caught and prosecuted. This is essential in order to maintain user confidence in the system.

3.5 Toll Enforcement

The most commonly used technology in violation enforcement is an array of cameras which use automatic license plate recognition (ALPR) capabilities (e.g., London, Sweden, Maryland, Canada). To reduce the variability of system performance with time of day and lighting conditions, the ALPR systems typically use infrared lighting. The most common current practice in violation enforcement involves taking pictures of license plates of violators and sending out written notices (and possibly citations) for each violation. A fine may also be imposed on violators, on top of the toll charge and administrative fee. Fines are typically imposed only for repeat offenders and delinquent accounts. Table 7 provides information on revenue losses due to toll evasion for three U.S. ETC systems.

Table 7. Revenue Losses Due to Toll Evaders

State	Year	% of Evaders	Lost Revenue (per year)	Source(s)
Virginia	2005	1-2	\$1.4M	Virginia DOT
Florida	2005 2006	4	\$20-25M	Florida Turnpike Enterprise
Maryland	2007	(not reported)	\$2.5M	Maryland DOT

Any electronic toll collection system--whether open-road or hybrid--will need to be backed up by a well-designed and well-operated enforcement capability. The enforcement system should have the following attributes:

- A license plate reader system should record photographs and license plate numbers of all violators. Human review and correction will be needed to improve the accuracy of the license plate reading.
- The system must have the capability to generate invoices (and/or citations) for violators. An appropriate threshold level can be selected, so that one-time violations or infrequent violations can be overlooked.
- Violators will help to bear the cost of the enforcement effort by paying higher tolls, processing charges, and/or fines.
- Persistent violators will be targeted for enforcement action. This can involve immediate notification of police when a persistent violator is detected on the facility (for an immediate traffic stop). It can also involve citations and/or arrest warrants for the owner of the vehicle (similar to how unpaid parking citations are handled).
- Cooperation should be sought with neighboring states to deal with persistent violators licensed outside Kentucky.

3.6 Pricing Strategies / Congestion Management

For most ETC systems currently in operation, toll charges are based on vehicle class, time of day, day of week, distance traveled, and use of transponders. Charges are typically lower for passenger cars and other four-tire single-unit vehicles and higher for trucks and buses. Some ETC systems vary tolls by time of day (or by congestion levels) to aid in the management of traffic flow. Table 8 provides examples of this variable pricing strategy.

Table 8. Toll Pricing Strategies

Location	Toll Pricing Strategy	Toll Charges
I-394 Minnesota	Dynamic Pricing	Based on change in traffic density
I-25 Denver, Colorado	Hourly Block Pricing	
I-15 San Diego, California	Value Pricing	Per-trip fee varies in response to real-time traffic volumes on the express lanes
Orange County, California	Peak Pricing	Pre-set toll schedule with different rates for most daylight hours and differences among days of the week
Lee County, Florida	Value Pricing	Discounted tolls apply at the following times: 6:30-7AM, 9-11AM, 2-4PM, and 6:30-7PM
New Jersey Turnpike	Variable Toll	12% higher tolls during peak traffic hours than during off-peak periods
Bridges and Tunnels Crossing Hudson River in New York and New Jersey	Variable Toll	20% discount for off-peak tolls Peak toll rates are effective on weekdays from 6-9AM and 4-7PM
London, England	Congestion Pricing	Three toll charge rates (based on time of day) per crossing made between 6:30AM-6:30PM
Melbourne City Link, Australia	Zonal Billing	Based on number of zones traveled

Some states have high-occupancy toll (HOT) lanes. HOT lanes allow single-occupant vehicles to pay for the privilege of driving in high-occupancy vehicle (HOV) lanes (when there is available capacity in those lanes). As the traffic volume in the HOV lane increases, the toll is raised accordingly. The concept for HOT lanes developed when toll agencies in California observed that HOV lanes were being underutilized and decided to sell the excess capacity to those willing to pay a market price for a faster trip. Rush-hour tolls vary from 50 cents to \$4.00, depending on how much traffic is using the HOT lanes (35). In addition to California, there are now HOT lanes operational in Colorado, Minnesota, Texas, and Utah, with toll rates changing to reflect periods of higher and lower demand.

For many ETC systems, the use of transponders not only gives the benefit of reduced waiting and transaction times, but it also provides discounts to its users. Some toll agencies give tag or transponder users a percentage reduction from the regular toll charge.

CHAPTER FOUR: CASE STUDIES

Over the last 20 years, numerous cities and states in the U.S. and around the world have implemented ETC technology. This study identified three cases where a further evaluation of these ETC systems could provide valuable insights into the various processes necessary for the implementation, marketing, management and maintenance of ETC systems. The three cases selected for further review are (1) the Bay Area Bridges in San Francisco, California, (2) Highway 407 in Toronto, Canada, and (3) the Indiana Toll Road.

4.1 Bay Area Bridges: San Francisco, California

In 1997, the California Legislature created the Bay Area Toll Authority (BATA) to administer tolls on the seven San Francisco Bay state-owned toll bridges. BATA is responsible for the administration, programming, and allocation of toll revenues for the California Department of Transportation (Caltrans). BATA is also responsible for day-to-day operations, facilities maintenance, administration, and long-term capital improvement projects (36). In 2004, BATA assumed responsibility for the collection of tolls paid electronically through the FasTrak system.

4.1.1: Types of Toll Collection

Currently, tolls are collected on the Bay Area Bridges using ETC transponders and manual cash collection. In February 2008, BATA commissioned a study to determine the feasibility and assess the operational and financial impacts of implementing a video toll system to collect the tolls from drivers who currently pay cash (37). The video tolling system would provide the capability to assess tolls by reading the license plate images of non-transponder-equipped vehicles (38). If implemented, the video toll system would supplement the ETC automated toll collection system and completely replace the manual cash collection of tolls.

4.1.2: Types of Technology

As mentioned in the previous section, tolls on the Bay Area bridges are collected electronically and manually. The electronic toll collection system utilized by the Bay Area bridges is FasTrak. The FasTrak system allows drivers to prepay bridge tolls, thus eliminating the need to stop at the toll plaza. The FasTrak system has three components: (1) a transponder placed inside the vehicle, (2) an overhead antenna at the toll plaza that reads the transponder and deducts the toll from the prepaid account, and (3) video cameras to identify toll evaders (36). FasTrak is also interoperable with Golden Gate Bridge, allowing motorists to pass through all eight of the Bay Area bridges with a single transponder.

4.1.3: Toll Variation

The toll rates for the seven Bay Area bridges are depicted in Table 9

Table 9. 2008 Toll Rates for the Bay Area Bridges (36)

Number of Axles	Toll Rate
2 Axles	\$4.00
3 Axles	\$6.00
4 Axles	\$8.25
5 Axles	\$11.25
6 Axles	\$12.00
7 or More Axles	\$13.50

Currently, there are no discount rates for motorists that utilize the FasTrak system verses those that choose the cash option. Toll rates remain static regardless of the time of day or day of the week.

4.1.4: Violation Enforcement

If a vehicle passes through a FasTrak only lane and does not have a valid transponder, an image of the vehicle is recorded (including the license plate) and a violation notice is sent to the vehicle's registered owner at the address on file with the California Department of Motor Vehicles. The violation notice requires the owner of the car to pay the toll and a \$25 violation fee. If the violation notice is not paid, an additional fee of \$45 is assessed and a hold is placed on the vehicle's DMV registration (36). This process is also used for vehicles that pass through the manual collection lanes and do not have sufficient funds to pay the toll. However, the \$25 violation fee is waved if the violator then signs up for the FasTrak service.

In order to enforce violations, vehicle license plates must be displayed and readable. However, some drivers cover their license plates or display temporary tags to avoid receiving violation notices (37). In an effort to reduce the number of toll evaders, the California Highway Patrol has begun pulling over motorists who attempt to cheat the FasTrak system. It is unclear what effect this enforcement presence will have on toll evaders, as this mechanism of violation enforcement has just recently been implemented.

4.1.5: Incentives for participating in ETC

There were several reasons for implementing the FasTrak system of toll collection on the Bay Area bridges. One reason was to reduce the time required for each toll transaction. In addition to easing congestion, keeping motorists moving has also led to a reduction in both air pollution and fuel consumption. BATA has estimated that each dedicated FasTrak lane is able to handle almost three times as many vehicles per hour as a manual collection lane (36).

Implementation of the FasTrak system has also provided financial benefits for BATA. All new users must make an initial deposit into their account to receive a transponder, and users are

required to maintain a certain minimum balance (7). The state can then earn interest on these funds, creating an additional revenue stream for the state.

4.1.6: Collection Rates/Loss Rates

Since 2004, revenue collections from FasTrak have continually increased. The bar graph below (Figure 4) provides a three-year comparison of the total number of paid vehicles utilizing the Bay Area bridges and the total number of tolls paid through the FasTrak system.

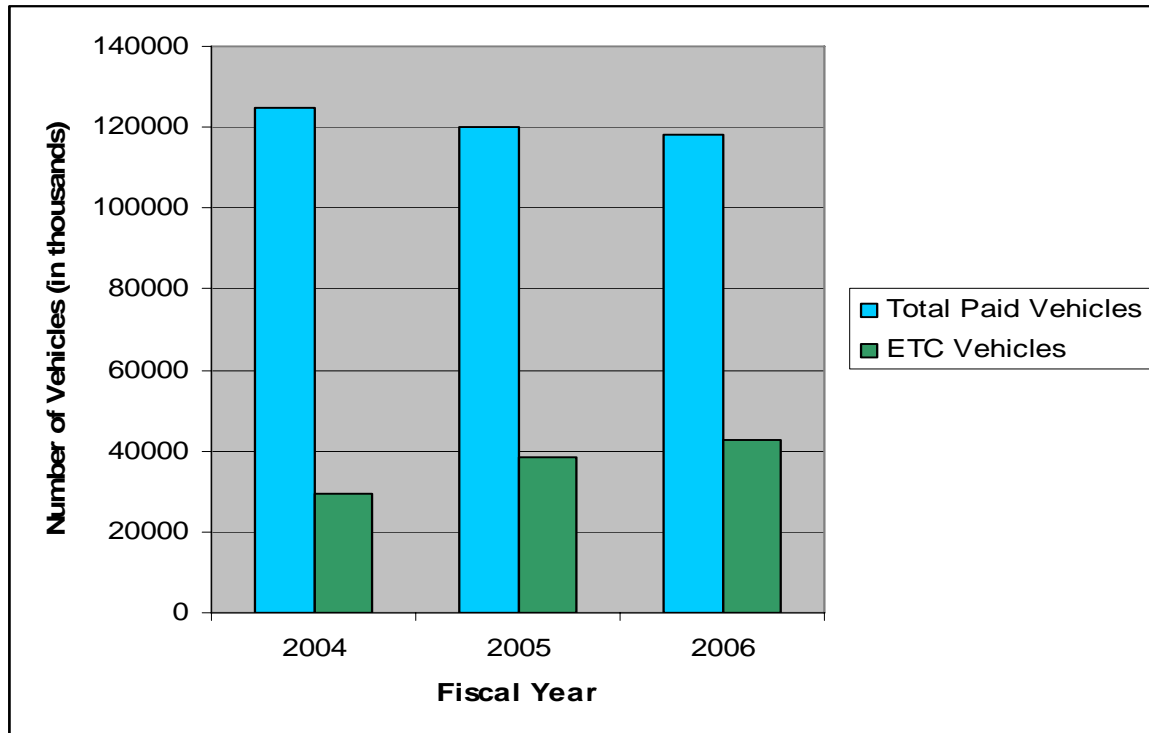


Figure 4. Electronic Toll Collection Rates by Fiscal Year (39).

During fiscal year 2003-2004, electronic toll revenue comprised 23.5 percent of the total toll revenues. In fiscal year 2004-2005, the percentage of tolls paid electronically increased to 32.1 percent. Fiscal year 2005-2006 saw an additional increase, as 36.3 percent of the total tolls collected were paid using the FasTrak system. Figure 6 also shows that despite the decrease in the total number of vehicles paying tolls on the Bay Area bridges, the use of electronic toll collection has continued to rise.

In 2003, Traffic Technologies, Inc. estimated that the violation rates for the Bay Area bridges averaged approximately 1.3 percent for all lanes of traffic. Their study suggests that ETC violation rates were consistent with the violation rates in other ETC-enabled facilities in the U.S. (40). However, it seems that violation/loss rates may have increased since that 2003 study. In February 2008, BATA approved a 7.5 million dollar contract with TRMI Systems Integration to design, install, and maintain a new violation enforcement system on the state-owned bridges (38). According to BATA, a new camera system is needed because the existing cameras are obsolete, are difficult to maintain, and do not consistently generate quality images. The installation of the new cameras began in June 2008 and will be complete by Spring 2009.

4.1.7: Technology Reliability

Information on the reliability of this system is not available from the current literature, and numerous calls to FasTrak and BATA have not been returned.

4.1.8: Operations/Maintenance Costs

For fiscal year 2003-2004, the total toll revenue for the Bay Area Bridges was \$158,583,010. The total operating expense for both manual and electronic toll collection was \$41,398,252, where \$2,483,982 was spent for toll facility maintenance. The operating expense for electronic toll collection operations only was \$10,498,447.

For fiscal year 2004-2005, the toll revenues for the Bay Area bridges increased significantly due to a \$1.00 increase in tolls. The total toll revenue for 2004-2005 was \$285,812,299. The total operating expense for both manual and electronic toll collection was \$39,441,274, a slight decrease from the previous year. The operating expense for electronic toll collection operations only was \$11,357,003.

4.1.9: ETC Marketing and Participation Rates

When BATA began managing the FasTrak system, they launched an online enrollment website through the state's 511 program. However, monthly enrollments in FasTrak were relatively low when compared to ETC usage in other metropolitan areas (7). In July 2004, BATA offered a temporary toll discount rate for drivers using the FasTrak system. Enrollment in the FasTrak system jumped approximately 40 percent, adding 80,000 more users (41).

Since 2004, FasTrak ETC usage continued to increase. In the spring of 2006, BATA began promoting FasTrak with TV and radio spots designed to boost enrollment. At the same time, BATA conducted several contests where new FasTrak customers were eligible to win several thousand dollars in free tolls. In October 2006, BATA also reduced the minimum initial prepaid balance from \$40 to \$25. By July 2007, BATA estimated that approximately 43 percent of all tolls were being collected electronically (for those toll plazas equipped for ETC). During peak traffic periods, the share of vehicles using ETC jumps to approximately 50 percent.

Currently, drivers interested in enrolling in the FasTrak system have several convenient options. Transponders can now be purchased and accounts opened at Costco and Safeway stores, as well as at the FasTrak Customer Service Center. Online enrollment is also available.

4.2 Highway 407 Express Toll Route: Toronto, Canada

Highway 407 Express Toll Route (ETR) in Toronto, Canada, was the world's first all-electronic, open-access toll highway. The design and construction process for Highway 407 began in 1994, with tolling operations commencing on October 14, 1997. Highway 407 extends 108 kilometers east-west, from Pickering to Burlington, just north of metropolitan Toronto. The purpose of Highway 407 is to provide a fast, safe, and reliable express route for motorists. It is an alternative route for motorists traveling in and around Toronto. There are no toll booths or toll plazas located along the roadway, and use of the roadway does not require a transponder or a prearranged user account. The highway includes six freeway-to-freeway interchanges: 401, 403, 410, 427, 400, and 404. Figure 5 provides a map of Highway 407.



Figure 5. Map of Highway 407 (42).

The operator and manager of Highway 407 is the 407 ETR Concession Company Limited (42). The sole shareholder of 407 ETR Concession Company Limited is a consortium comprised of Cintra Concesiones de Infraestructuras de Transporte, Macquarie Infrastructure Group, and SNC-Lavalin.

4.2.1: Types of Toll Collection

When vehicles enter and exit Highway 407, they drive under overhead gantries, which automatically record the beginning and end of a trip. There are 197 gantry sites on Highway 407. At the end of each monthly billing cycle, the all-electronic system calculates all tolls, fees, and interest, and bills are sent (25).

4.2.2: Types of Technology

Roadside equipment provides transponder data, vehicle classifications, and video images to the Toll Transaction Processor (TTP). For those vehicles not equipped with a transponder, a picture

is taken of the vehicle's license plate. The license plate images are sent to the operations center, where the TTP associates individual transactions into trips and provides automatic data extraction from the license plate images. Figure 6 provides a diagram of the technologies utilized on Highway 407.

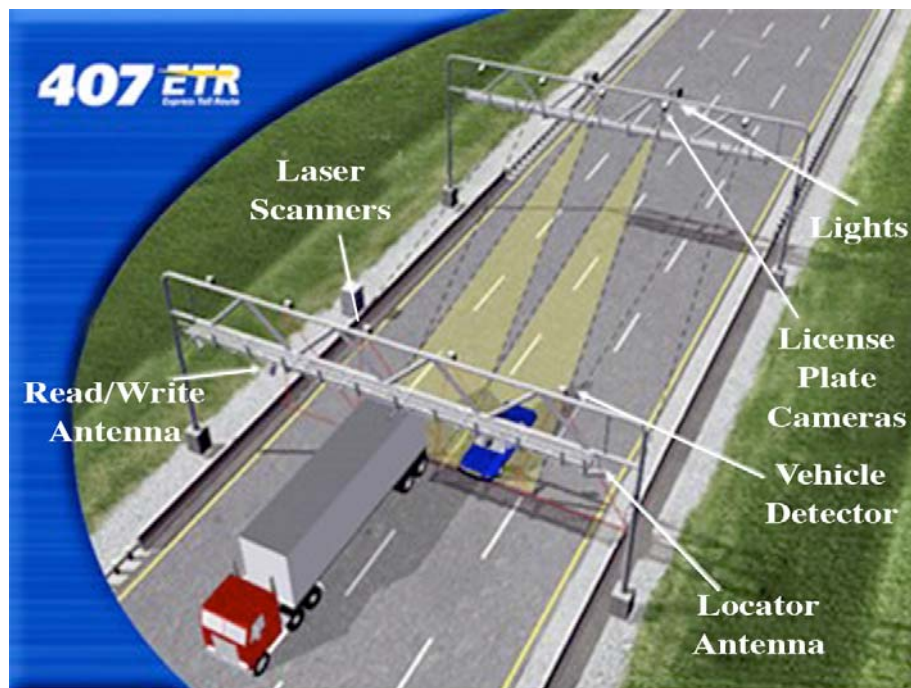


Figure 6. Various technologies in use on Highway 407 (42).

Although a transponder is not necessary to drive on Highway 407, it is cheaper to use the transponder system. Vehicles equipped with a transponder pay a reduced rate as compared to those who pay using the license plate images (407 ETR 2008—Tolls Explained). There are two types of transponders in use on Highway 407—one for regular vehicles and one for vehicles weighing over five tons (43). As of 2005, approximately 77 percent of the transactions on Highway 407 were conducted by transponder.

The use of the transponder system has steadily increased over the last eight years. Figure 7 shows the total number of transponders in circulation for 1999 through 2007. Between 1999 and 2007, the total number of transponders in circulation grew 148 percent. On average, the yearly growth rate from 1999-2007 was approximately 18 percent.

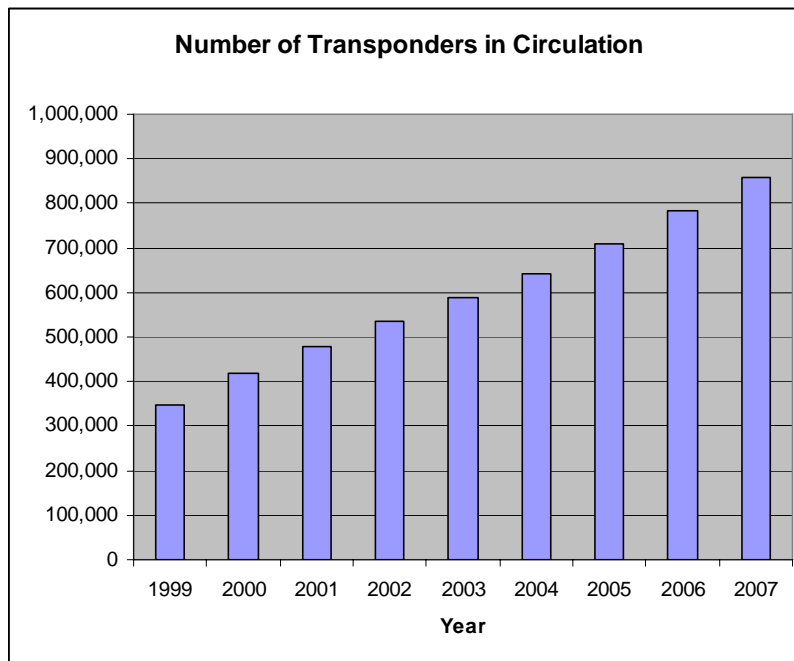


Figure 7. Total number of transponders in circulation on Highway 407

4.2.3: Toll Variation

The cost of a trip along Highway 407 depends on factors such as: (1) the time of day a car enters the highway, (2) vehicle class, (3) distance and section(s) traveled, and (4) the correct mounting and use of a valid transponder. Beginning in February 2008, the program began charging different rates during peak periods based on the section or zone of the highway travelled (42). Table 10 provides the current rate schedule for Highway 407.

Table 10. 2008 Toll Rates for Highway 407 (Prices are in Canadian Cents per Kilometer) (25)

Vehicle Class	Peak Rate Regular Zone	Peak Rate in Light Zone	Off-Peak and Night Hours
Light Vehicles (Cars, Minivans, and SUVs)	19.25	19.0	18.0
Heavy Vehicles (Large Trucks)	38.50	38.0	36.0
Heavy Multiple Vehicles (Tractor trailers)	57.75	57.0	54.0

Note: Peak hours are weekdays between 6:00 am and 10:00 am and between 3:00 pm and 7:00 pm. Off-peak hours are all other times during the day, weekends, and holidays.

In addition to the toll rates shown in Table 10, there is an additional video toll charge for users that do not have a transponder. The current video toll charge for light vehicles is \$3.60, while the video toll charge for heavy vehicles is \$15.00. For example, if a tourist with no transponder were to travel the entire length of Highway 407 during off-peak hours, the cost would be approximately \$23.04.

Over the eight-year time period that Highway 407 has been in operation, the total number of trips per year has steadily increased at an average annual rate of 5.41 percent. Figure 8 presents the total number of trips per year along Highway 407.

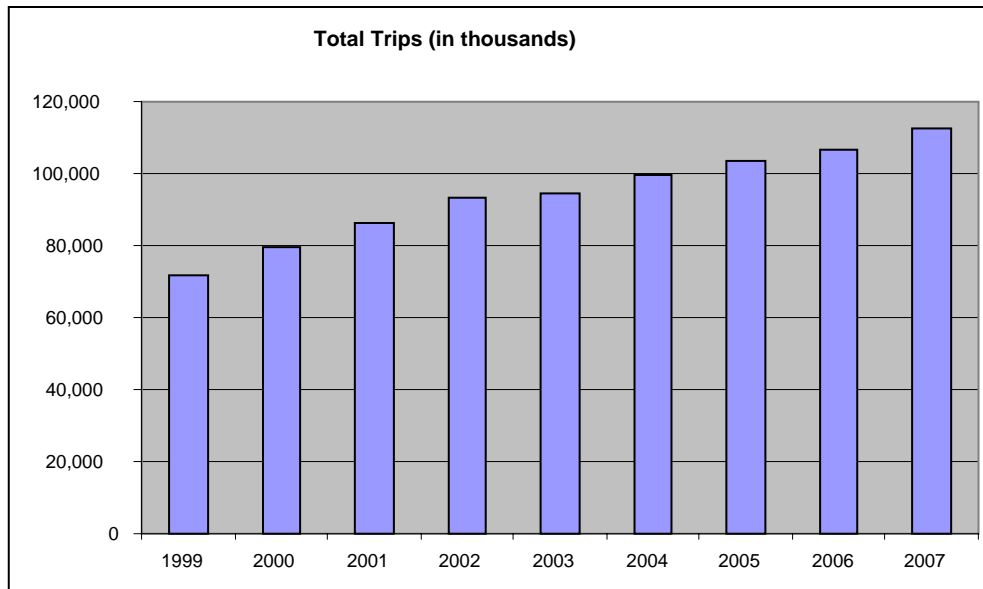


Figure 8. Total trips per year on Highway 407.

4.2.4: Violation Enforcement

As previously mentioned, any vehicle that enters Highway 407 automatically receives a bill for the distance traveled along the toll road. Therefore, it is not necessary to ‘enforce’ toll violations on Highway 407. However, 407 ETR did need a way to ensure that motorists that were sent a bill would have an incentive to pay. In November 2005, the Ontario Divisional Court issued a ruling that ordered the Ontario Registrar of Motor Vehicles to deny vehicle permits to individuals who refuse to pay their 407 ETR tolls. Essentially, individuals that have not paid their tolls are denied the issuance and renewal of vehicle plate permits.

4.2.5: Incentives for participating in ETC

407 ETR offers a 30 percent discount on the transponder lease fee to those customers who choose an annual lease rather than a monthly lease (42). This discount affects over 800,000 transponder customers.

In February 2007, 407 ETR also announced the “ETR Rewards” program, which is a tiered rewards program that provides customers with free 407 ETR kilometers and instant savings on their gasoline purchases at Petro-Canada sites. The most frequent users of Highway 407 can potentially save between 10 and 15 percent of their overall monthly travel bill. Essentially, every month, eligible customers can receive up to 140 free kilometers on Saturdays and Sundays, and will instantly save 9 cents per liter on their gasoline purchases. To be eligible for the program, customers must have at least one light-vehicle transponder with no outstanding balance on their account, and they must travel more than 400 kilometers per month for six months (44). After the first five months of the program, 407 ETR announced that it had extended over \$4

million in benefits to qualifying customers. By February 2008, 407 ETR had extended over \$10 million in benefits during the first year of operation, to over 140,000 users.

In an effort to improve traffic flows during peak periods, 407 ETR also offers a rewards program for heavy vehicles. Heavy vehicles can receive a substantial discount if they are willing to travel at night, on weekends, or during off-peak hours. 407 ETR has estimated that tens of thousands of trucks can potentially benefit from this program, while greatly reducing traffic congestion during peak travel periods.

4.2.6: Collection Rates/Loss Rates

Previous research concluded that approximately 6 percent of the non-transponder-equipped vehicles utilizing Highway 407 would not receive a bill for their usage. This can occur when the technology or human employee is not able to read the vehicle's license plate. It can also occur when there is no extradition agreement with the vehicle owner's home province or U.S. state (45). Later research showed that by 2004 the number of "unbillables" had decreased to 3.1 percent, after a multi-faceted effort (43).

4.2.7: Technology Reliability

The automated license plate recognition system is able to identify approximately 80 percent of the vehicles not equipped with transponders on Highway 407. For the other 20 percent, the digital images are reviewed by employees in an effort to identify vehicles for billing (45).

4.2.8: Operations Costs and Revenues

Operational costs for Highway 407 have changed from year to year. This is illustrated in Figure 9. These changes are primarily due to the expansion of Highway 407 in terms of total mileage and number of lanes. 407 ETR has also continued to upgrade the ETC equipment along the highway.

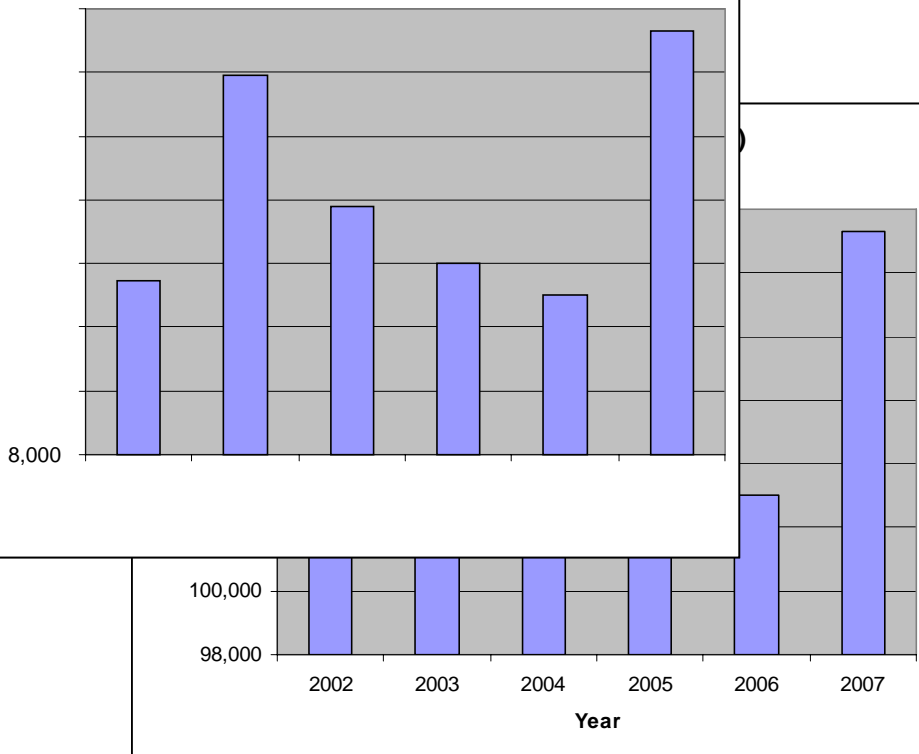


Figure 9. Operating expenditures for Highway 407, 2002-2007.

Revenues grew 363 percent between 1999 and 2008. However, it wasn't until 2006 that the net yearly income for Highway 407 was positive, once all the various costs were taken into account. Figure 10 shows the yearly net income for Highway 407, from 1999 to 2007.

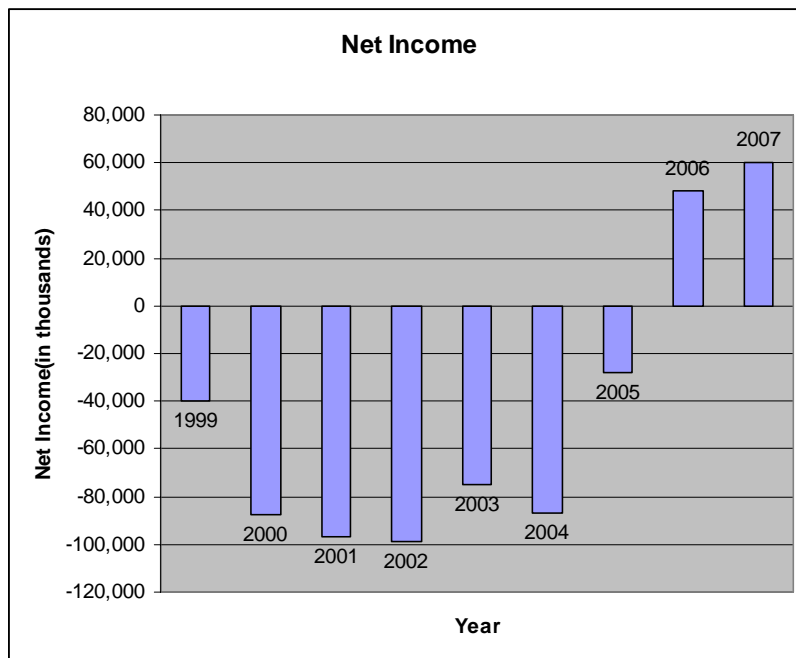


Figure 10. Net Income for Highway 407, 1999-2007.

4.2.9: ETC Marketing and Participation Rates

Since 1997, over six million customer accounts have been established and over 850,000 transponders have been issued to customers. As mentioned in previous sections, the total number of trips taken per year has grown at a steady rate as have the number of transponders issues to motorists.

4.3 Indiana Toll Road: I-80

The Indiana Toll Road stretches approximately 157 miles across northern Indiana, from the Ohio border to the Illinois border. Built in 1956, the Indiana Toll Road has served to link the largest cities on the Great Lakes with the Eastern Seaboard (46). The Indiana Toll Road also provides the primary connection to the Chicago Skyway and downtown Chicago as well as connections with I-65 and I-69.

Historically, the Indiana Toll Road has been operated by the Indiana Department of Transportation. However, in 2005, the Indiana Finance Authority (IFA) was charged with the responsibility of exploring the feasibility of leasing the Toll Road to an entity in the private sector. Once it was determined that leasing was feasible and would be beneficial to the state, the Indiana Finance Authority released a request for lease concession proposals. The lease concession was awarded to ITR Concession Company LLC (ITR). By April 2006, the IFA and ITR executed a 75-year lease for \$3.8 billion. The ITR formally assumed operational responsibility for the Toll Road on June 29, 2006 (46).

4.3.1: Types of Toll Collection

Prior to the lease of the Indiana Toll Road to ITR, all tolls on the roadway were collected manually. However, a key part of the lease concession between IFA and ITR was to install electronic tolling (47). The lease concession included a clause that requires ITR to install and operate ETC along the entire highway by June 28, 2008.

4.3.2: Types of Technology

With the implementation of ETC, tolls will be collected both manually and through the use of transponders. Currently, the Indiana Toll Road accepts I-Zoom, E-ZPass, and I-PASS transponders. I-Zoom is the transponder sold to travelers along the Toll Road or through the Indiana Toll Road website.

All lanes at all toll plazas along the Indiana Toll Road are gated, and cameras with optical character recognition (OCR) have been installed to process unpaid tolls in both cash and unmanned ETC lanes (48). There are also several manual toll lanes in each plaza, where an attendant can take cash payments for tolls.

4.3.3: Toll Variation

Tolls along the Indiana Toll Road vary depending on the size of the vehicle and whether or not the motorist uses transponder technology. For two-axle vehicles, motorists choosing to pay tolls manually are charged a higher toll. For vehicles with more than two axles, the toll is the same regardless of whether a transponder is used. Table 11 provides the toll rates for the Indiana Toll Road. These rates assume that a motorist is traveling the entire 157-mile stretch of the roadway.

Table 11. 2008 Toll Rates for the Indiana Toll Road (49)

Number of Axles	Toll Rate
2 Axles (with ETC transponder)	\$4.65
2 Axles (without ETC transponder)	\$8.00
3 Axles	\$10.75
4 Axles	\$21.00
5 Axles	\$27.25
6 Axles	\$32.00
7 Axles	\$59.60

4.3.4: Violation Enforcement

Although the Indiana Toll Road has been leased to a private entity, the Indiana State Police still provide enforcement along the roadway. However, the purpose of the Indiana State Police is primarily for speed enforcement—not stopping toll violators. The lease concession between ITR and IFA does permit ITR to hire private security services to catch toll violators. They also have the option to contract this service out the Indiana State Police for an additional fee.

4.3.5: Incentives for participating in ETC

The primary incentive for motorists to participate in ETC is the cost difference between using a transponder and paying cash. For example, motorists with transponders pay \$.50 at the Westpoint barrier plaza, whereas motorists paying cash pay \$1.25. The lease concession between IRT and IFA states that for the next 10 years there is a “freeze” on toll rates that are collected electronically. However, there is no such requirement for tolls that are collected manually. Therefore, cash toll rates can continue to rise, while electronically collected tolls will remain at the current price.

4.3.6: Collection Rates/Loss Rates

As ETC is still in the process of being implemented, collection rates are not currently available.

4.3.7: Technology Reliability

Although ETC has not been fully implemented along the Indiana Toll Road, preliminary tests have demonstrated that the ETC system is reading over 99 percent of transponders (48).

4.3.8: Operations/Maintenance Costs

Estimates of the operations and maintenance costs for the Indiana Toll road are currently unavailable, as ITR is still in the process of installing, constructing, and upgrading several portions of the toll road.

4.3.9: ETC Marketing and Participation Rates

In July 2007, approximately 30 percent of motorists traveling along the Indiana Toll Road utilized one of the transponders recognized by the system. By January 2008, almost 40 percent of motorists were using transponders to pay tolls, with some locations experiencing over 50 percent usage during peak hours of travel.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations have been drawn from the information gathered for this project:

- Electronic toll collection (ETC) provides substantial advantages over manual toll collection, including reductions in transaction times, waiting times, fuel consumption, traffic congestion, air pollution, and operations costs. In terms of the cost per transaction for collecting tolls, ETC is one-half to one-sixth the cost of manual toll collection.
- The use of dedicated short-range communications (DSRC) technology (i.e., vehicle-mounted transponders and fixed readers) for ETC is proven, accurate, and reliable. It has been in use for nearly 20 years, and it is widely deployed, both in the United States and around the world.
- Based on the substantial advantages and proven performance of ETC, Kentucky should give strong consideration to the use of ETC versus manual collection, if the decision is made to implement tolling in Kentucky
- Not all ETC systems in the United States are interoperable. The selection of a specific ETC technology for Kentucky would need to take into account the other regional systems for which interoperability is desired. Kentucky should give strong consideration to selecting a technology that is interoperable with the E-ZPass system.
- The greatest benefits from ETC are achieved with open-road tolling. This type of toll collection minimizes traffic impact, minimizes the “footprint” of the toll-collection facility, and maximizes the benefits described above. Kentucky should give strong consideration to implementing open-road tolling whenever possible.
- A major decision in implementing ETC is determining how to deal with vehicles that are not equipped/enrolled for ETC. Options for dealing with these vehicles include:
 - Prohibiting them from using the facility;
 - Providing a cash payment option (i.e., a hybrid toll collection system); or
 - Using an alternative method (such as license plate readers) to collect the tolls from the non-equipped vehicles.

Adequate enforcement is critical to the success of any ETC implementation. Even if the direct return from enforcement activities does not seem to justify the investment, the enforcement is critical to maintaining public confidence in the system.

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