Conduent Public Sector
Public Transportation & Mobility

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The complete guide to tolling in the United States

What are mobility improvement programs?

- Construction of new roadways to improve or ease traffic congestions
- Restriction of movement in or out of a specific area such as an inner city
- Congestion management programs that use tolling to improve the mobility of commuters, the movement of freight, or a combination of the two.

Toll roads and bridges have been a tool to pay for transportation since ancient times. The practice of using tolls to pay for bridges grew out of the ferry business which had traditionally provided transport across rivers. Ferry operators created the practice of collecting fees for moving people, animals, and other goods across rivers extended this concept to bridges once they were constructed across rivers.

The practice was extended to toll roads as well. In the United States, the first toll road or turnpike was the Lancaster Turnpike which was built between Philadelphia and Lancaster in the 1790s. Users paid for the use of the road and it became one of the earliest methods to acquire funding for highways. The International Bridges, Tunnel, and Turnpike Association was founded in 1931, a full 25 years before the Eisenhower Interstate Highway System was begun in 1956, or the Federal Highway Administration was created in 1966.

When agencies decide to charge for the use of a roadway, the pricing scheme is likely part of budgetary planning for roadway maintenance, mobility improvement programs, or environmental conservation plans. Today's agencies are presented with political, monetary, and technical challenges. This paper will focus on the technical challenges and decisions that must be fully and carefully vetted to ensure program acceptance and adoption, as well as achieving mobility and monetary goals and objectives of the program.

Using tolls to pay for roads

Tolling and road use fees are becoming increasingly important to pay for the cost of new road construction and maintenance. Traditional methods of raising transportation maintenance funds are facing challenges as we move into the future. The gas tax or fuel excise tax are often used as a tool to generate funds, but there is little appetite to increase these taxes. The United States federal gas tax has been 18.4 cents since 1993, and states in America charge on average 30 cents per mile. This raises approximately $20 billion using the federal gas tax, and approximately $40 billion at the state level. The emerging issue is that the fleet is shifting to more fuel efficient vehicles (hybrids, plug-in electrics, more efficient engines), which will increase the miles per gallon (MPG) for vehicles from 35 MPG in 2016 to a federally-mandated 54.5 MPG in 2025. This will result in less money collected and available for new road construction and maintenance.

As a result, states and other entities are turning to tolls and other user fee arrangements that will not be susceptible to decreases in revenue as fuel efficiency improves. This takes several forms and names including toll roads, global navigation satellite system tolling, vehicle miles travelled, road use charging, and mileage-based user fees.

There is no right answer or perfect solution for everyone when it comes to deciding the toll collection technology and method to be implemented. The decision must be made after thorough consideration of many factors as stated above and including a balance approach that achieves the political, monetary, and mobility goals.

Establishing a toll rate

The tolling agency is responsible for setting the toll rates and schemes, as well as a proper and fair execution of any tolling policies. The agency is usually responsible for enforcement of the tolls. Often public agencies and private companies have entered into an agreement that gives the private company the right to operating the toll road or bridge on behalf of the government. This is considered a Private-Public Partnership, also known as a PPP or P3 agreement.

One of the initial policies that must be developed by the toll agency is the toll rates, the charge for each vehicle that would travel the roadway or bridge. Toll rates are usually based on the amount of usage or potential impact a vehicle could have on a roadway. This concept is considered when smaller vehicles pay a smaller fee and larger vehicles pay more. It's also seen as an equitable methodology, giving the public the sense that "everyone is paying their fair share".

The toll rate policy influences the technology that must be used to classify a vehicle. Classifying a vehicle is the process in which the technology implemented in the toll collection system will detect various aspects of the moving vehicles, such as number of axles, number of tires, height, width, length, speed, or even the weight of a vehicles. As one could imagine, some of these aspects present certain technological challenges to accurately and consistently detect these vehicle difference in moving traffic, harsh environments, vehicles changing lanes, or erratic driving.

Established agencies are hindered in modifying the toll rate schedule due to the past sale of municipal bonds to pay for roadway improvement with a return to investors based on the projections of the amount of tolls collected. Newer agencies can establish toll rates that maximize the technology available to ensure high accuracy in data collection, and no loss of revenue or constituent displeasure due to inaccurate vehicle classification.

Most toll systems have very basic functions: detect, classify, identify and collect the fee, however, you would be very surprised to see the amount of technology required to perform these functions consistently and accurately.

Approaches to toll collection

Two different approaches have emerged for toll collection or road use charging. Those broad categories are cash collection and electronic toll collection.

Cash Collection

Collecting currency directly from the road user has been the primary way to collect tolls since the very beginning. Cash collection can take the form of human toll collectors receiving money from drivers or automatic coin systems which are designed to receive and count the money. Most cash collection systems use a barrier to prevent the driver from leaving the toll booth without paying. Typically, the human toll collector or the automated coin counter will not raise the barrier arm until the correct amount is received.

Cash collection has certain advantages. Users can remain anonymous when using cash lanes and there is no need for an electronic violation processing system; the barrier arm at the end of the toll plaza ensures that revenue is collected. The big disadvantage is that cash lanes tend to be slow, leading to congestion and traffic back-ups. As drivers search to find cash or coins to pay the toll, vehicles are queueing up behind them, leading to slow downs, loss of productivity, and irritated road users.

If an agency decides to implement cash collections, the technology today provides faster, more accurate collections than a decade ago. This includes the deployment of cash collection devices such as automatic toll payment machines (ATPM) or automatic coin machines (ACMs), or manual cash collections. The ATPM and ACM can be equipped with various devices such as credit card terminals, bill note receptors, change dispensers, and coin baskets operating completely unattended with little manual intervention required.

Cash collection is still in use in many locations but is giving way to electronic collection methods. Many agencies use a combination of electronic and cash collection lanes.

Electronic toll collection

In order to improve throughput on roadways, road operators and toll agencies have moved away from cash collection and towards technology-based solutions. Unlike 10 years ago, technology has enhanced motorist mobility and the speed of processing vehicles through the motorway. Many toll agencies are reducing cash collection and implementing electronic tolling solutions, to reduce fraud, loss through theft, or other possibility for leakage. That said, there are still many agencies—especially those in developing countries—that are implementing the tradition cash collection methods that are enhanced with today's technology for the reasons stated above.

The use of electronic collection methods requires the road user to establish an account so that there is a payment system in place which is linked to the user. Typically a user provides full demographics including name, address, and most importantly a payment instrument to prefund the account for future passage of the roadway without the need for stopping and paying with cash. The payment instrument is usually a credit card, but can be a debit card or a stored value card. With a stored value card approach, users can purchase cards using cash even if they do not hold a credit card or have a bank account. A stored value card can be purchased at retail outlets that the agency designates.

Image of gantry system.

In the United States, these are often convenience stores or money transfer facilities. That way, the underbanked users can also use a toll transponder

Once the account is established, as the user drives on the road, the technology links their account to the vehicle they are driving and road use is measured.

These solutions typically take one of three approaches to identify accounts. These systems can be used as stand-alone systems, or in combination to ensure that revenue is collected. Most agencies use some of the techniques while some use all three of the systems. The three approaches to electronic collection for road use are:

- Radio-frequency Identification (RFID) Transponders
- License Plate Based Systems
- Wide-Area Wireless Systems Augmented with Global Navigation Satellite Systems (GNSS) systems. (We will refer to this as GNSS-based solutions.)

Radio-frequency identification (RFID) transponders

RFID transponders are used for gantry-based tolling solutions. In an RFID system, the vehicle passes under a gantry which includes a toll reader; the transponder and toll reader exchange information which identifies the account of the vehicle passing under the gantry. RFID is a short-range communications protocol (less than 100 meters) and as the vehicle passes under the gantry, the tolling system and its components recognize the transponder and the associated account. The user's account is then charged. Some systems use a more sophisticated approach which involves trip construction, a technique we will explain further below.

License plate based systems

Another technique which is employed for road use collection is license plate recognition (LPR). Using this approach, the vehicle drives under a gantry (or some similar structure, possibly a cantilever) and the vehicles front license plate and rear license plate are captured.

The license plate images are then reviewed by manual image reviewers who determine the license plate number and the associated vehicle by referring to license plate databases. These databases may be the toll agencies account database or the license plate database at the Department of Motor Vehicles.

An automated approach for license plate recognition has been adopted by many agencies which is typically more efficient. Under automated license plate recognition (ALPR), the cameras on the gantry capture the license plate and then typically perform an Optical Character Recognition on the image to determine the license plate number. Using ALPR, once the license plate number is identified, it can be linked to an account or vehicle. The system then uses this information to charge the user's account or send an invoice to the vehicle owner.

License plate recognition systems can be used as a standalone for road charging but are typically used as a back up to RFID-transponder-based solutions. There may be vehicles which pass under the gantry which do not have a transponder, the battery of the transponder has gone dead, or the transponder is not properly mounted. In these instances, the system will attempt to identify the account or vehicle using the license plate recognition system.

GNSS tolling or road charging systems

In addition to gantry-based solutions such as RFID transponder systems and license plate recognition, a new approach has emerged that uses a global navigation satellite system connected to a commercial wireless network. By sending GNSS location data over the air to the tolling back office, this system is able to calculate where the vehicle has traveled.

The ability to send GNSS location over a wireless network can be used for tolling in two ways:

1. Virtual gantries: Smartphone tolling approaches use GNSS location data on the phone to determine where a "virtual gantry" is located. This is done by downloading geofence data to the phone so that the phone knows where the virtual tolling gantries are. When the phone detects that it is in a toll location, it sends a toll declaration message to the back office. This approach works very similar to RFID-based tolling, except it does not require readers and transponders. The phone and the wireless network establish the location of the phone, and send the information.

   In this scenario, the smartphone and the smartphone application effectively become the transponder. There are many experiments with this approach underway in the US, but this is not accepted as the primary method for toll collection by any agency. Even under a system using smartphone tolling with geofencing, the agency will probably still want to put up gantries with license plate cameras to identify the users whose smartphones are turned off, out of battery, or otherwise unavailable.

2. Kilometer/mileage based tolling: under this approach the on-board unit (OBU) includes a GNSS element and a wireless data transceiver. The OBU effectively replaces the transponder described above. The wireless data transceiver is typically capable of sending 4G-LTE data. Under this configuration, the system establishes a "bread crumb" trail for where the vehicle is located and where it has been. Location messages are sent periodically from the OBU to the back office that become toll declarations. The toll declarations are established based upon distance travelled. Under this system, any road can become a chargeable road since the system does not depend upon the vehicle passing under a toll gantry.

   This approach is used for commercial vehicle truck tolling in Europe. The heavy truck operator is charged based upon the number of kilometers driven. Many countries in Europe utilize this approach including Germany, Czech Republic, Poland, Austria, and Belgium. The kilometer-based tolling approach in Belgium combines all three elements described thus far:

- GNSS tolling as the primary transaction tool
- Gantry based RFID transponders placed at strategic locations throughout the country for the purposes of auditing.
- Automated license plate recognition located on the gantries for the purposes of identifying trucks that do not have an OBU or whose OBU is not broadcasting.

Mileage Based Road Charging is also being evaluated in the United States. As states see their collections drop due to fuel taxes being threatened by improving gas mileage on all- electric and hybrid vehicles, states are considering use of GNSS solutions to implement Mileage Based Tolling. These solutions are very similar to GNSS solutions in Europe. The two states looking to implement GNSS for Road Use Charging are Oregon and California. Oregon has limited production system in place involving 5,000 vehicles and California conducted a limited trial on early 2017. California will decide if they want to move to Mileage Based Tolling in 2018/2019 after the trial is concluded. California is often at the forefront of new approaches; if California adopts Mileage Based Tolling, other states are likely to follow. Today California collects approximately $5.5 billion in gas tax revenue. Vehicles with improved gas mileage will reduce collections making a Mileage Based approach more viable.

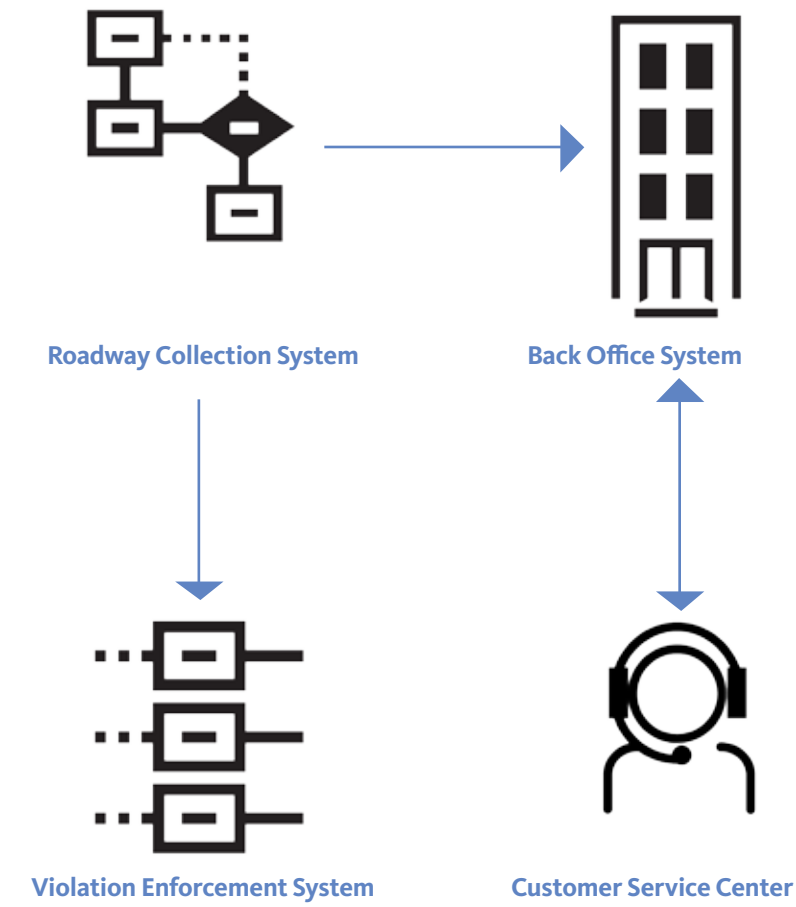
One key difference between the California and Oregon programs versus European Truck Tolling is that in Europe, the truck is tracked every few seconds, while in California and Oregon, the states permit an option where the vehicle's location is not known by the back office. Under this scenario, the OBU only sends odometer mileage. The user may end up paying for road miles driven outside the state since they are paying for the total mileage on their vehicle in a given year. However, some users prefer this approach as it protects their privacy and does not disclose their location.

The components of a tolling system

A road use charging system typically requires four parts:

- Roadway collection system
- Back office system
- Customer service center or customer care system
- Violation enforcement system

There are pieces that create the tolling system but these elements break down into these four building blocks.



Roadway collection system

Generally the roadway collection system is built upon the technologies described earlier in this paper. In the United States, the typical all electronic tolling roadway collection system is a gantry-based solution that contains automated vehicle identification and vehicle detection and classification.

In a gantry based solution, the lane system needs to perform three key functions: detect the approach of the vehicle, classify the vehicle, and identify the account holder or vehicle owner.

Detection and classification

The process of detecting and determining the class or category of vehicles enables the system to apply the appropriate toll rate based on various aspects of the vehicle and establish the rate to be collected from the registered owner. The Transportation Ministry or Department of Transportation should implement a scheme that is:

- Technologically feasible to achieve with the given available technology
- Can accomplish the revenue generation goals that have been established
- Does not present an unsafe environment for Ministry or DOT resources
- Is easy to operate and maintain for the long-term at a reasonable cost

1. One technique is the use of loops buried in the pavement. The loops detect the approach of the vehicle and are able to count the number of axles, establishing what type of vehicle passed over. This data is used to set the toll rate as passenger cars generally pay less than commercial trucks.

2. Another technique for detection and classification is the use of lasers. The laser will detect the approach of the vehicle and then based upon volumetric data assign a classification to the vehicle. This approach is gaining popularity but is not as accurate as loops in establishing how many axles a commercial truck has.

The automated vehicle identification system in the gantry-based toll system generally uses two elements:

1. Reader: the RFID transponder is read and the account associated with transponder and vehicle is charged for the toll. RFID transponders utilize a variety of protocols, but the US Tolling Industry is looking to move to a National Tolling Protocol (NTP). The NTP is expected to be chosen from the E-ZPass protocol, the SeGo protocol, or the 6c protocol.

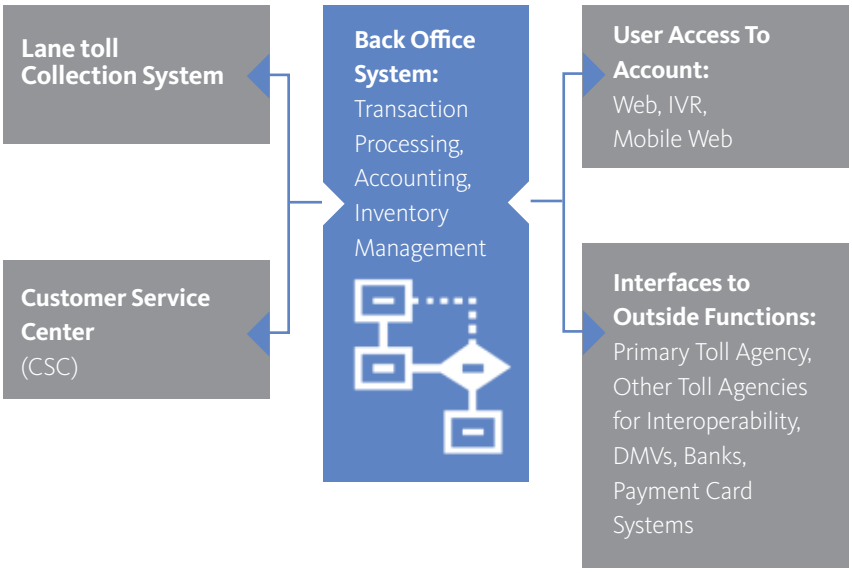
2.LPR: In the event the RFID Transponder cannot be read, License Plate Recognition cameras capture the license plates. This will always include the Rear License Plate, and in many instances, the Front License Plate as well. The License Plate is then matched to a Toll Account Holder in the Toll Agency database or to a Vehicle Owner in the Department of Motor Vehicles (DMV) database.

In the event the License Plate number cannot be determined by the Automated License Plate Recognition system, the license plate images are sent to a manual Image Reviewer who will attempt to ascertain the license plate number

Once the lane system has classified and identified the vehicles, the information is sent to the back office system where the transaction is received and processed. The transaction is posted to the customer account and will be included in the customer's next bill.

Back office systems

The Back Office System (BOS) is the nerve center of the tolling system. The back office system is responsible for keeping track of transponder inventory, creating new accounts, generating invoices for customers, maintaining records of transactions, and supporting the accounting functions of the agency. The BOS performs all of these functions and more.



The fundamental purpose of the BOS is to receive toll transactions from the lane toll collection system or the GNSS toll system, process these transactions and make them available to customers and customer service representatives to view and then translate these transactions into funds received by the toll agency.

The back office also allows customers to access their account in a variety of ways, including interactive voice response phone systems, web access, or by speaking to a representative.

In addition, the BOS provides accounting and general ledger information to the primary toll agency and also provides transactions to other toll agencies whose customers may have driven onto the primary agency's road system. Furthermore, the BOS connects to other government agencies including Departments of Motor Vehicles, state enforcement agencies, and the court systems. The back office also provides the interface to banks, payment cards and other financial institutions.

This description is based upon a view of the functional elements that comprise the BOS, however, there is a significant Information Technology (IT) underpinning to the BOS. This includes hosted data centers with significant amounts of storage and storage management in addition to systems that support disaster recovery and business continuity.

Our BOS is constructed upon commercial off-the-shelf software to perform these functions. These key elements include operating systems, customer relationship management tools, and database management software. We constantly evaluate the best value approach for selecting the right information technology going forward whether it be via hosted data centers, cloud-based, or some new technology.

Customer service center

A key element in the toll system management is the Customer Service Center (CSC). The CSC is the front line for toll road users seeking to manage their toll account. Among the major activities that the CSC supports are:

- Account initiation and creation including gathering payment information, name, address, and other customer identifying data
- Issue transponder/on-board unit to customer
- Updating account information from the customer such as new credit card information, credit card expiration dates and other data that changes over time
- Answer queries about transactions or road use
- Manage returns of defective transponders/OBUs
- Issue correspondence to the customer as needed. This can take the form of violations notices, collection notices, and other forms of correspondence
- Receive payments from the customer
- Other customer related activities

We deliver these functions by combining the back office with interactive voice response systems (IVR) and via computer telephony integration. The IVR system is designed to answer most customer inquiries prior to speaking with a live customer service representative. Many questions are routine such as where to send payments, what is the address of the customer service facilities, what is the customer's account balance, and other related queries.

If the customer needs to speak to a representative, the computer telephony integration links the customer's phone number (using Caller ID) to the customer's toll account so that the representative is ready to answer questions related to the customer's account.

We've built state-of-the-art processes for managing customer service centers (CSC) in an efficient fashion and provide these centers for major toll agencies in the United States including New Jersey, New York, San Francisco Bay Area. We are currently deploying one of the largest Tolling CSC installations for the state of Florida.

Violation enforcement and processing system

One of the hottest topics in every tolling operation is revenue leakage and enforcement. Leakage is a transaction that was either not detected, or where the violator could not be identified. The moment a violator can be identified it becomes an enforcement or collection issue. Enforcement is the process you need to identify and prosecute violators. If this is not done properly, agencies bear the burden of losing revenue.

A lot of older toll roads in the US are still barrier based. As long as these structures use a direct form of payment like cash or a credit/debit card, there is hardly any revenue leakage and no additional enforcement needed. The enforcement is more or less built into the system.

The only worldwide accepted reliable approach of enabling an enforcement process is the use of license plate recognition to identify a violator. Each agency chooses their own enforcement rules of either a video or violation toll, for cases where a vehicle is not equipped with an electronic transponder, a transponder is not read, or the account is in an inactive state. These transactions can be divided into tagged (transponder detected) and untagged (transponder undetected).

Tagged Violations can occur when an account has a prepaid toll balance that is overdrawn or a tag is suspended, but the tag is still associated with the user's account. In these cases, the violation can be sent to the customer.

An untagged violation occurs when a transponder is not detected in a vehicle and the driver is not attempting to pay by other means. Untagged violations can occur for both electronic toll collection (ETC) and non-ETC customers.

A violation can occur when a vehicle passes through a dedicated lane or mixed-mode lane without paying the toll. Non-payment could have one of many reasons including:

- Tolls not paid
- No transponder
- Transponder not read
- Account has negative status
- Transponder has been reported as lost, stolen, or revoked
- Transponder registered with another tolling jurisdiction
- Vehicle classification mismatch (using a tag on a different class vehicle than what it was issued for)

When a transponder is not detected, most lanes immediately capture an image of the license plate and a video transaction record is created. Depending on the program there could be multiple images associated to the transaction. These captured images, are sent to the system image server. The transaction record includes information regarding the location, lane, time, date, violation type, agency, and image file name. Transaction records and images are matched after they have been received from the roadside equipment. The matched transactions are processed through the automated system or further processed via manual review.

Once the plate number is determined, it is checked against the known user accounts within the back office system, matched to the correct account, and the fare amount is deducted from the prefunded balance. An invoice can be sent to those user accounts without a prepaid balance or an insufficient balance.

If the plate number information does not match an existing account, a request for the name and address of the vehicle's registered owner is made to the Department of Motor Vehicles (DMV).

We have direct interfaces for real-time processing to DMV that supports violation processing. It can also have the capability for out-of-state DMV lookups sourced through DMV direct agreements, or services such as Polk Directories and National Law Enforcement Telecommunications System. To obtain the correct registered owner of vehicle, some states require the license plate type be provided in addition to the license plate numbers/letters and jurisdiction of issuance.

When toll transactions remain unpaid, there can be several levels of notifications and escalations attempting to collect the unpaid amount. Tolling agencies with the best results in collecting unpaid toll amounts are those who implement strong regulatory infractions or penalties, such as vehicle registration holds or withholding registration renewals. Vehicle owners are not allowed to renew their vehicle registration until all outstanding toll amounts are paid in full.

Multi-agency support

Many US agencies seek to combine their back-office system (BOS) into a single operation for multiple agencies. For instance, Florida is seeking to provide toll road users in the state of Florida with a seamless experience. That is, drivers who travel from Miami to Orlando to Tampa have an expectation that their toll transponder will work on the various roadways and that a single toll account can be used.

Florida is addressing this challenge by building a consolidated customer service system (CCSS) that will support Florida Turnpike Enterprise, Tampa-Hillsborough Expressway Authority, and Miami-Dade Expressway.

The implementation process uses a single BOS and customer service center to manage all toll accounts on these roadways. The various toll agencies often have different business rules and different price structures so the CCSS must accommodate the needs of the disparate toll agencies while providing service to the toll road user. When a toll road user accesses their account, the system will provide the necessary information as to where the customer is located.

In addition, the BOS must manage financial disbursements to the various agencies and reconcile the transactions. For instance, a Miami-Dade Expressway Customer may have used the Tampa-Hillsborough Expressway meaning that a funds transfer will occur from one agency to another. Managing this financial reconciliation process while making the customer experience seamless and avoiding revenue leakage is a key challenge in a multi-agency environment. We have successfully built systems to deliver this functionality.

Conclusion

Designing, deploying and operating a complete tolling system is a complex undertaking. We bring decades of expertise in all phases and elements of system design, management, and operation. Whether designing a system that employs an all-electronic, open road, GNSS, or license plate tolling system—or even a combination of these options—we have deployed roadway collection systems, back office systems, customer service centers, and violation enforcement systems for agencies.

Selecting a partner that can deliver both the right scope and is capable of scaling the system as the agency grows is a key consideration. We process over 50% of the toll transactions in the United States annually, which is more than $5.0 billion of revenue collected on behalf of agencies.

We also manages over 15 million transponders, processes over 60 million images for tolling annually, and generate over 17 million violation notices each year. The experience and expertise that we've acquired in these key areas makes us a partner that can help design the approach, deliver the system, and enable the agency to expand the system as the agency's business grows.

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