Module 8: Electronic Tolling and Pricing

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Purpose

Advanced technologies give us new options to manage transportation. Electronic toll collection (ETC) technologies offer the dual potential of supporting new management strategies and revenue generation to pay for transportation delivery and improvement. Consequently, an awareness and understanding of relevant technologies, applications, and strategies is extremely valuable to today's transportation practitioner.

This module has been designed to provide awareness and understanding of ETC, transportation payment systems applications, and pricing strategies. It also provides information on the benefits that can be delivered to customers as a result of the application of payment systems.

Note that a terminology section is provided at the end of the module to assist. It is advisable to review this section before proceeding with the others because the definitions will help in understanding the materials.

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Objectives

At the conclusion of this module, you should be able to:

- Understand the basic terminology of electronic payment systems applications and pricing strategies.
- Describe electronic payment technologies, applications, and strategies.
- Understand the application of electronic payment systems applications to transportation and intelligent transportation systems (ITS) and describe some challenges.
- Understand the costs and benefits associated with electronic payment systems applications and pricing.
- Define the role of the private sector in electronic payment systems applications.
- Describe some implementation examples and lessons learned.
- Know where to look for additional resources.

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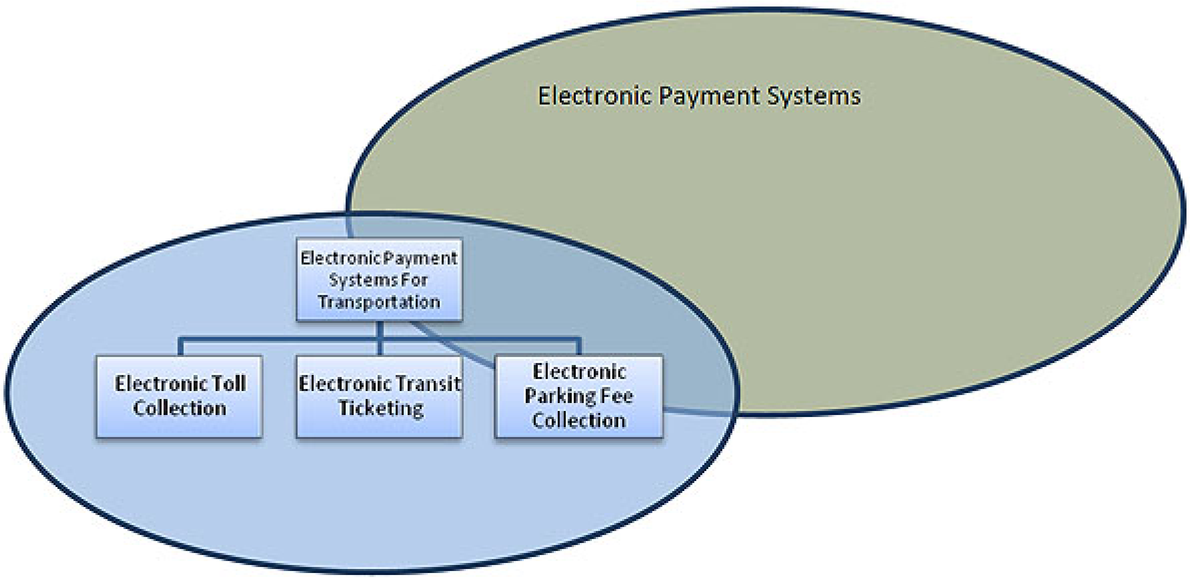
Introduction

In this module we will discuss electronic payment systems technologies, applications, and strategies. These terms are defined as follows:

Technologies— technologies and products that can be applied to meet transportation needs, issues, problems, and objectives such as contactless payment technologies.
Applications—specific technology implementations designed to address a set of needs such as an ETC system.
Strategies—ways in which technologies can be applied to achieve specific policy objectives such as congestion pricing.
ETC is a payment systems application that can move cash away from the point of sale for road, transit, and parking. Within the banking and financial industry, electronic payment systems applications are used to pay for goods, for services, and to support electronic financial transactions. In order to provide a complete context, transportation electronic payment systems applications and the wider world of payment systems are addressed in addition to ETC. Innovations in the banking and financial industry are moving into adoption by the transportation sector, although at a slower pace. This module discusses these technologies to provide the context for what lies ahead.

Figure 1. Electronic Payment Systems Applications for Transportation and Their Wider Context



(Extended Text Description: This diagram demonstrates aspects of electronic payment systems. There are two large overlapping ovals. The top oval (upper right side) is labeled Electronic Payment Systems. The lower oval (lower left side) has four sub-boxes, starting with Electronic Payment Systems for Transportation at the top, with lines leading down to the three lower boxes: Electronic Toll Collection, Electronic Transit Ticketing, and Electronic Parking Fee Collection.)
The module also provides information on the types of technology that are in use for payment systems. This is complemented by information on the applications and strategies that can be supported, with a particular emphasis on ETC. The intent is to provide the reader with a solid grounding in the capabilities and availability of electronic payment technologies and explain how to apply the technologies to achieve transportation policy objectives.

It is likely that in the future, ETC will be more closely integrated with all forms of electronic payment in a region. Such multimodal electronic payment systems applications will support payment for transit ticketing, for car parking, and for toll collection, as well as for non-transportation fee collection. They will do so by taking a multiple payment device, single account approach in which vehicle-based and personal payment devices are used for specific purposes. All devices will be linked to a single account enabling coordinated management of funds and transactions. For this reason we have taken the time to define electronic payment systems applications and set ETC within the wider context of payment systems transportation. Note that different devices are used for different applications.

Electronic Payment Systems Applications

These support electronic payment for a huge range of non-transportation items, from retail to airlines. In fact, many airlines will no longer accept cash for on-board purchases, requiring the use of a credit or debit card. This segment of the electronic payment market dwarfs the other transportation segments. Most of the innovation in the electronic payment systems applications domain happens in this segment, which includes electronic funds transfer, ecommerce, credit and debit cards and online banking services. An assessment of noncash financial transactions by regions of the world from 2001 to 2009 shows that approximately 260 billion transactions took place globally. The United States accounts for more than 40 percent of this market, with more than 104 billion transactions.[1]

Electronic Payment Systems Applications for Transportation

Electronic payment systems for transportation include ETC applications, transit ticketing applications, and car parking applications. An overview of each is provided in the following sections.

Electronic Toll Collection

Electronic toll collection, according to the MUTCD,[2] is defined as "a system for automated collection of tolls from moving or stopped vehicles through wireless technologies such as radio-frequency communication or optical scanning. ETC systems are classified as one of the following: (1) systems that require users to have registered toll accounts, with the use of equipment inside or on the exterior of vehicles, such as a transponder or barcode decal, that communicates with or is detected by roadside or overhead receiving equipment, or with the use of license plate optical scanning, to automatically deduct the toll from the registered user account, or (2) systems that do not require users to have registered toll accounts because vehicle license plates are optically scanned and invoices for the toll amount are sent through postal mail to the address of the vehicle owner."

The most common method of ETC involves the use of dedicated short-range communications technologies (microwave wireless) to support nonstop transaction processing between a suitably equipped vehicle and roadside equipment. As the vehicles pass through a toll zone, a transponder or tag fitted onto or inside the vehicle is read by roadside equipment. This identifies the vehicle and enables a toll amount to be deducted from a prepaid account. The transponder or tag sends a unique identification number to the roadside reader which, in turn, sends the information to a roadside computer. The roadside computer has data that links each identification number to a unique account number.

The identification of the vehicle can also be achieved through optical scanning and character recognition of the vehicle license plate. The identification data is transferred to a back office system, which deducts the appropriate toll from the account and adjusts account records accordingly. Because it supports nonstop operation, ETC also paves the way for the use of pricing techniques such as value pricing and congestion pricing. These techniques are described later in this module.

Electronic Transit Ticketing

According to the Smart Card Alliance,[3] there were 15 million smart cards and 20,000 smart card readers in use by U.S. transit agencies in 2006. These days electronic transit ticketing involves the use of a smart card to make payment for trips on a transit vehicle. The smart card can hold the balance available on the card itself or can simply be used as an account key to deduct money from a central account similar to toll collection. The user can add additional funds to the card at transit agency offices, participating retail outlets, and on the web by transferring money from a credit card. Transit passes can also be stored on the smart cards for specific trip quantities or unlimited rides. This application is also known as automated fare collection or electronic fare payment. Further information on these public transportation applications of electronic payment systems can be found in Module 7, "Public Transportation." Electronic Parking Fee Collection

According to the Smart Card Alliance,[3] public parking constituted an approximately $17 billion industry in 2006. This was composed of systems, equipment, facilities maintenance, and a variety of services, including revenue management. More than $1 billion was spent annually on parking revenue control systems, software, equipment, and related support services.

Both off-street and on-street parking applications can be supported by electronic fee collection. In the case of off-street parking, there are a number of access point technologies and pay-on-foot technologies that can be used. Similarly for on-street parking, smart parking meters and pay-on-foot parking kiosks can be utilized to allow drivers to pay using a smart card or a cell phone.

Regional Multimodal Electronic Payment Systems Applications

When all modes of transportation are addressed by one single payment system, this is known as a regional multimodal electronic payment system. It is worth noting that while there may be one single payment system, there may be different payment devices. For example, vehicle-based payment can be achieved by transponder or tag while personal-based payments such as ticketing for transit systems can be accomplished with a smart card. The same account can be used for both even if different payment devices are used. The advantage of a regional multimodal approach is that it offers more management solution possibilities after the system has been installed. For example, conditional discounts could be offered whereby users of the transit system on one particular day may be offered free parking downtown for another day when they decide to take their car. These systems have also been referred to as "universal transportation accounts."

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Contactless Payment Systems Technologies

The characteristics of the payment device can have an important bearing on how easy the system is to use. These days you can pay for calls, for transit, and for parking using a transponder or tag, a smart card, or a smartphone. The latest in smart card technologies allows the card to be held close to the reader or to a reading plate, with no contact required. The card does not need to be inserted into a slot. Short-range communication technologies allow data to be transferred from the smart card to the reader and vice versa. This avoids customer issues related to difficulties in inserting a card in a slot and makes the system mechanically more reliable. Needless to say, the wireless messages communicated are required to be secured through the use of encryption. The image below illustrates a smart card being used to make a payment using contactless technology.

Figure 2. Contactless Smart Card in Use for Transit in Finland[4]

(Extended Text Description: This photograph depicts a transit payment device from Finland using a contactless smart card. The device is located on a train in front of a set of train doors (a snowy railway scene with a train is in the background). The device has large sensors labeled 2, 2, 1, (last one blocked), a digital screen above the buttons ("EI SALLITTU") and three colored lights in its rounded top (red (lit), yellow, green). A person is holding a blue plastic card up in front of the transit payment device.)
Source: http://en.wikipedia.org/wiki/File:Matkakortti_ja_kortinlukija.jpg.

Near Field Communication (NFC)

Another technology development involves the use of near field communication (NFC). NFC enables you to use your phone to make payments just like a smart card. According to the NFC Forum, near field communications are defined as follows:[5]
"Near Field Communication (NFC) technology makes life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch. A standards-based connectivity technology, NFC harmonizes today's diverse contactless technologies, enabling current and future solutions in areas such as:

- Access control
- Consumer electronics
- Healthcare
- Information collection and exchange
- Loyalty and coupons
- Payments

- Transportation

Figure 3. Example of a Ticket-Stamping Machine of the Austrian Federal Railways that Can Be Used to Purchase Mobile Tickets[6]

Source: http://commons.wikimedia.org/wiki/File:NFC-Fahrscheinentwerter.jpg.

Smartphones

Several major airlines are piloting the use of smartphones for proof of payment purposes. Using this concept, the financial transaction is conducted elsewhere, that is, on a website, at the office, or at the ticketing desk.

Figure 4. Example of a Three-Dimensional Bar Code Displayed on a Smartphone[7]

Source: http://commons.wikimedia.org/wiki/File:Samsung_Focus_smartphone.jpg.

As proof of payment, an electronic symbol called a three-dimensional bar code is issued. The three-dimensional bar code can be displayed on the passenger's smartphone and then read by special readers at airport security facilities. Thus it is possible for the passenger to gain entry to the airport security zone and board the airplane without the use of a paper boarding pass.

The mobile boarding pass technology is part of the International Airline Transport Association (IATA) Bar Coded Boarding Passes (BCBP) initiative. At least 30 airlines use mobile BCBP. It is anticipated that at least 12 percent of airline passengers will use mobile BCBP in 2013.[8]

This technology may also be used in the future for electronic transit ticketing. The passenger would pay for transit fares at some other location such as a kiosk or a website. When the passenger wishes to use a transit vehicle, he or she displays the three-dimensional bar code on a smartphone and shows it to the special purpose bar code reader on the vehicle.

Figure 5. QR Code Billboard in Tokyo[9]

Source: http://commons.wikimedia.org/wiki/File:Japan-qr-code-billboard.jpg.

The figure above shows an example of a three-dimensional bar code being used on a billboard. The same three-dimensional bar code technology is used for an approach called QR codes. QR codes are found on print advertisements, billboards, and other locations where an advertiser wishes to advertise a product or service.

The print advertisement is designed to attract the attention of the target customer by providing an awareness of the advertised product or service. The QR code can then be used to enable the customer to request further detailed information. Most smartphones have an application that allows three-dimensional bar codes to be read by the camera built into the smartphone. When the QR code is read, the browser on the smartphone is automatically navigated to a predetermined web page where further information regarding the product or service can be found. This enables advertisers to raise awareness of the products and services using printed advertisements or billboards and then provide further information through the QR code channel. This is a very good approach to marketing because it allows the advertiser to raise awareness, generate interest, encourage a desire for the product or service, and then support the customer to take action.

Android Pay and Apple Pay

Both Google and Apple have introduced smart phone apps that can replace the functionality of a smartcard for electronic payment. Android Pay was introduced in 2015 and Apple Pay was introduced in 2014. Both of the apps make use of Near Field Communications and a technology known as Host Card Emulation (HCE). As the name suggests Host Card Emulation enables a smart phone to emulate a credit card and communicate with an appropriate Near Field Communication reader. The user enters credit card data into the smart phone where is stored securely. When the user pays for an item, the credit card data is encrypted or “tokenized”. This generates a one-time use temporary credit card number that is used to pay, thus protecting the user’s real credit card number.

The Android Pay approach makes use of a cloud-based store to retain these tokens, with a few tokens held securely on the smart phone to enable payment when there is no cell phone signal. The Apple Pay approach makes use of a special chip on board the phone to store the tokens. Both of these applications are already accepted by over 1 million merchants and it is expected that these methods will become the de facto way to pay electronically over the next couple of years. Similar electronic payment approaches are being introduced by a number of banks and also by Samsung, one of the major cell phone manufacturers.

Figure 6. Apple Pay being used to purchase a cup of coffee retrieved from Wikipedia on April 18 2016

Source: https://commons.wikimedia.org/wiki/File:Apple-payment-square.jpg

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Electronic Payment Systems Applications for Transportation

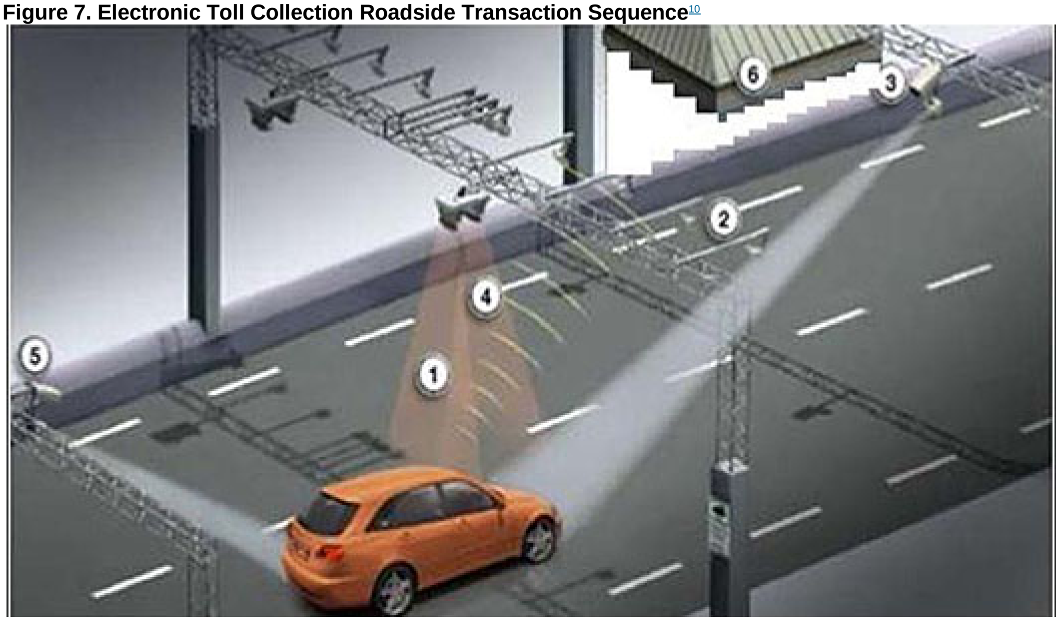
Electronic Toll Collection

ETC was developed from electronic identification technologies. These technologies were used for defense purposes or for tagging animals for farming purposes. The central principle is simple, but the technology can be complicated. It involves the installation of a tag into the vehicle. This tag can be read wirelessly at a distance from roadside readers set up either at an ETC toll plaza or, more typically these days, at an electronic toll zone for nonstop tolling. The telecommunication technology involved is known as dedicated short-range communications (DSRC). The "dedicated" part refers to the fact that the technology is dedicated to ETC and the "short-range communication" part refers to the fact that the wireless telecommunication technologies involved work only at relatively short ranges (up to 1,000 feet).

In the United States, wireless technologies that make use of the 900 to 919 MHz band are used for ETC. Frequencies in the 5.8 GHz band are also available and are dedicated to transportation use. There has also been widespread adoption of the so-called sticker tag. This is a radio frequency identification technology based on an ISO standard (ISO 18000 6C) originally designed for electronic article surveillance for retail stores. The technology has been adapted for longer range and to make use of the windshield as an antenna to magnify the signal. The advantage of the sticker tag is that it requires no batteries and instead uses power reflected from the roadside antenna. Sticker tags are also considerably cheaper than the transponder alternative. These tags are paper thin, and once affixed to the windshield cannot be removed without destroying the tag. The sticker tags have several operational benefits that reduce required functionality and operating costs.

The communication process between the roadside reader and the vehicle-based transponder or tag is illustrated in the following figure.

Figure 7. Electronic Toll Collection Roadside Transaction Sequence[10]



(Extended Text Description: This is a graphical illustration depicting electronic toll collection. There is a compact car on a two lane highway passing under the second of three overhead metal beams constructed over the highway. There are a series of lights and cameras and laser devices attached to the overhead beams. The illustration shows a white-shaded cone from the first overhead beam (under which the car has already passed) from the area of a camera on the beam to the car's back license plate. The illustration shows two orange-shaded cones from two laser devices overhead on the second beam down to the car's hood as the car is just beginning to pass under the second beam. There is another white-shaded cone from the third beam (under which the car has not yet passed) from a camera on the overhead beam to the front of the car. There is a building off the far side of the freeway.) Based on presentation titled "Stockholm Congestion Charging Scheme and Other Related Projects," by Naveen Lamba, IBM Global Business Services, October 18, 2006, to the National Surface Policy and Revenue Study Commission -U.S. Department of Transportation

An ETC system has two primary parts. In addition to the visible part involving the transponder or tag inside or on the vehicle and a roadside reader system, there is a considerable amount of equipment, technology, and resources working in the back office.

Let us start by defining what happens at the roadside. The figure above shows a typical example of a modern ETC system. Consider the path of the orange vehicle through the toll zone. As the vehicle enters the toll zone, it breaks the first laser beam (1), triggering the transceiver (2) to wake up. The transceiver then signals the vehicle's on-board transponder or tag requesting transmission of the time, date, and transponder or tag identity. At the same time as the transceiver operates, the camera (3) photographs the vehicle's front license plate.

As the vehicle progresses through the tolling zone, it breaks the second laser beam (4), triggering the second camera (5). The second camera photographs the rear license plate. This all happens without the vehicle slowing down. Throughout this entire process the vehicle is traveling at normal open road speeds. Payment is debited from the driver's prepaid account. Funds can be placed in the account via a website, at a bank, or at a retailer such as a convenience store chain.

This example was taken from the IBM-implemented electronic congestion charging project in Stockholm, Sweden. Note that the approach chosen in Stockholm is a completely open road electronic tolling system. This means that everyone using the system must have a suitably equipped vehicle and must pay using the ETC system. It should also be noted that this system is just an example to explain the various technologies involved. It is a proprietary system and represents only one of several detailed design choices for ETC. It is not the single solution for ETC. It does, however, explain the overall process between the transponder or tag inside or on the vehicle and the roadside reader.

In this example, lasers are used to detect the presence of the vehicle in the tolling zone and also to classify the vehicle according to size and shape. In other applications around the world and in the United States, light curtains, vehicle axle counters, stereoscopic cameras, microwave, inductive loop signal processing, magnetic sensors, and piezo sensors may all be used to detect and classify the vehicle. There are many technology choices and many design options.

In the United States, toll collection was introduced many years ago with large toll plazas that channelized vehicles toward a toll booth where cash payment could be made. Consequently, there has been a need to retrofit existing channelized toll plazas with nonstop ETC facilities. In situations where the existing channelized toll plazas are replaced with a nonstop ETC system on the main line toll road, a cash alternative has been preserved by providing tollbooths on slip roads adjacent to the open road tolling (ORT) zone. These are often referred to as express lanes because through traffic can pay using an express ETC approach, while cash customers are directed to a traditional toll plaza adjacent to the ETC through lanes.

These express lanes use what is referred to as an ORT type of operation, meaning that drivers of suitably equipped vehicles who have established prepaid accounts can pay tolls at normal high speeds of operation without stopping. When a toll road is converted to a totally electronic situation, it is known in the United States as an all electronic toll collection (AETC) operation.

Another variation on ETC is the use of video tolling. This involves the use of the video enforcement system that is used to capture images of license plates for all vehicles flowing through the toll system. It is possible to use these video images to identify the registered owner of the vehicle and send a toll bill to that person. This is sometimes offered as an alternative to the use of the transponder or tag. While this method avoids the use of cash at the roadside, it can be more expensive to administer than a transponder or tag reading approach. Consequently, the driver may be charged a higher toll for selecting this method of payment.

The use of video technology for toll-by-plate is a very effective method for addressing the needs of the casual road user. Infrequent use of the road provides no incentive to acquire a transponder or tag or identification device and toll-by-plate provides good customer service to this customer group. Toll-by-plate can be administered as either a preregistered or an ad hoc process. In the former, drivers are required to provide details in advance of using the road. In the latter, drivers do not provide advance information and the operator relies on the currency and accuracy of driver and vehicle licensing databases to identify the customer.

The prepaid account referred to in the example above is assumed to have been established previously by the driver in association with the agency operating the ETC. Many ETC systems' prepaid accounts are connected with a credit card account. Money is routinely transferred from a user's credit card to a prepaid toll account. Users can also elect not to use a credit card and can take cash to a customer service center to deposit it into the prepaid toll account.

Figure 8. Electronic Toll Collection System Options

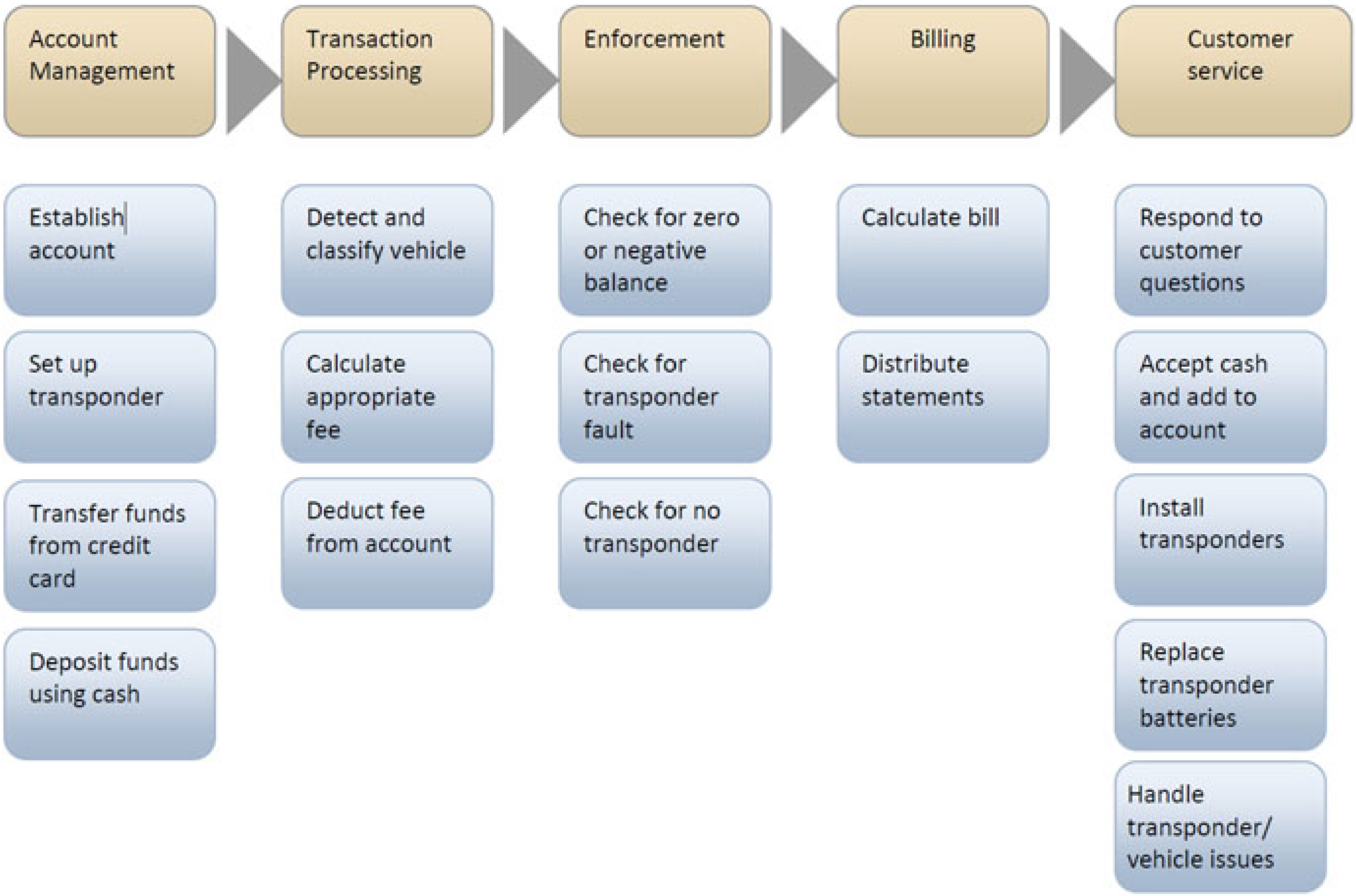
Open Road Tolling	The use of high speed telecommunications between the vehicle and the roadside to support nonstop toll collection in lanes that by-pass a conventional toll plaza where cash payments are also supported. In addition, video or pay-by-plate tolling is an integral part of most AETC operations, though a few do require vehicles to have a tag to access the facility as some bonding covenants require that a toll is collected at the time the trip is made.
All Electronic Toll Collection	Only vehicles equipped to pay using electronic toll collection are allowed to use the facility and no cash is accepted at the roadside.
Video or Toll by Plate Tolling	As an alternative to the use of a transponder or tag the customer can elect to pay by having the vehicle license plate read by an automated license plate reader system.

Electronic Toll Collection Business Process

ETC is more than just wireless communication between the vehicle and roadside. The wireless communication link must support a financial transaction where money is taken from the driver's account and transferred to the operator of the toll road. This is usually done by establishing a prepaid account into which the driver will place funds that are dedicated to toll payment. By law, almost all public toll operators in the United States are required to collect these funds before the driver uses the road since they prefer not to offer credit. This means that the prepaid toll account has to be established before the driver can use the road and typically the prepaid account is linked to the driver's credit card. Money is transferred from the credit card when the balance is low in the prepaid account. Each toll agency has different rules, but typically a balance of less than $30 will require that more money is taken from the credit card. A pre-agreed amount is taken from the credit card, and this typically varies from $10 to about $30 for each transfer. An exception to this happens when the driver pays for a high value transaction. If the value causes the prepaid account balance to be exceeded, the fee might be deducted from the credit card immediately.

It is important to realize that a considerable amount of back office processing is happening to support the roadside transaction. The best way to explain this is through a process diagram that provides a high level overview of the major steps in an ETC system business process. The figure below shows the business process. We will discuss each of the steps in the business process in turn.

Figure 9. Electronic Toll Collection High Level Business Process



(Extended Text Description: This text-box diagram depicts the electronic toll process. There are a series of five columns with a brown text box at the top of each column, and then various numbers of blue text boxes underneath. The first column text box (left) is labeled "Account Management" with a triangular arrow pointing to the second column. Under "Account Management" are the boxes (top to bottom): Establish account, Set up transponder, Transfer fund from credit card, and Deposit funds using cash. The second column text-box is labeled "Transaction processing" with an arrow pointing to the third column. Under "Transaction processing" are the text boxes: Detect and classify vehicle, Calculate appropriate fee, and Deduct fee from account. The third column text-box is labeled "Enforcement" with an arrow pointing to the next column. Under "Enforcement" are the text boxes: Check for zero or negative balance, Check for transponder fault, and Check for no transponder. The fourth column text-box is labeled "Billing" with an arrow pointing to the final column. Under "Billing" are the text boxes: Calculate bill, and Distribute statements. The final column is labeled "Customer service" with the text-boxes underneath: Respond to customer questions, Accept cash and add to account, Install transponders, Replace transponder batteries, and Handle transponder issues.)

Account Management

In this step in the business process, all activities related to the management of the prepaid account are handled. This includes the establishment of the account, linking the transponder or tag identification number to the account, and linking the driver's details, including the vehicle information, to the account. If any of these things change over time, the account management business process step will support the activity required to make the changes to the records.

Transaction Processing

As described earlier, this is the visible part of the ETC process. It takes place when a driver drives through a toll zone or a toll plaza with ETC. A sequence of activities take place involving roadside readers in the transponder or tag fitted inside the vehicle, as described previously. Enforcement

It is necessary to ensure that vehicles using the ETC system have valid transponders or tags and that the drivers have sufficient funds in their prepaid accounts. This step in the business process involves the capture and automated analysis of license plate images to enable enforcement. The license details captured are compared to a driver-and-vehicle-licensing database to determine ownership of the vehicle. Enforcement may also involve manual approaches involving local law enforcement, with the objective of ensuring that the probability of evasion is low and the consequences significant.

Billing

The accounts from which the tolls are deducted are prepaid and already have funds deposited by the driver. However, it is still necessary to prepare a statement showing how the funds were used. This step in the business process involves the preparation of statements based on transaction history and customer account details.

Customer Service

In this step in the business process, questions and service issues relating to the ETC system are handled over the phone, in person, or on a website.

The Value of Electronic Toll Collection Systems

The importance of ETC systems lies in the benefits that can be realized. These can be summarized under the following headings.

Safety

The primary safety effect of electronic toll collection lies in the avoidance of the need for vehicles to stop on high speed roads. This improves safety for staff working on toll collection and for drivers. The avoidance of a line of vehicles with drivers waiting to pay tolls with cash at the roadside prevents crashes at the back of the line. ORT also represents a step forward in safety as the removal of channelized toll plazas avoids weaving ahead of the plaza and removes the potential for collisions with the plaza infrastructure. Eliminating cash payment systems at the roadside, at the parking lot, and on a bus increases everyone's safety and has essentially eliminated "leakage" (loss from human error and theft) for these collection systems. In 2013, Florida's Turnpike Enterprise converted four toll plazas from manual toll collection to ORT. In the first three months of the conversion, accidents within a half mile of the Miramar, Okeechobee, Bird Road, and Homestead toll plazas dropped 76 percent compared to the previous year. In the first year, accidents declined 37 percent—40 crashes compared to an average of 63 in the same period during the three previous years.[11]

Efficiency

Efficiency gains are associated with the time saved not having to stop to pay the toll and not having to line up to pay the toll. There are also efficiency gains with respect to emissions because acceleration and deceleration are avoided in the toll zone. An electronic toll zone also requires less land than a conventional toll plaza. Note that the best manual toll collector can handle about 400 vehicles per hour with drivers paying by cash at the roadside, while an ORT system can handle about 2,000 vehicles per hour in the same lane. Therefore, an indirect efficiency gain provided by ETC is its ability to collect tolls, implement congestion pricing strategies, and manage demand better, using less land. Another valuable attribute of the ETC system is the inherent flexibility to change prices quickly and with little or no additional resources. This represents a substantial efficiency gain.

Customer Service

The customer service aspects relate to smoother trips with less stops and the convenience of not having to carry change for tolls. The customer also obtains a detailed record of use that can be used to manage vehicle-related expenses. In the United States, customer acceptance of ETC has been driven by the convenience provided by eliminating the need for cash and enabling faster trips. These benefits have allowed toll operators to overcome customer fears about data privacy, security of funds transfer, and possible speed enforcement through toll point information. It is important to frame the business case for electronic tolling in terms of the benefits to the end user rather than the implementing agency.

Electronic Transit Ticketing

Electronic transit ticketing follows similar principles to ETC. However, in this case the payment system is personal to the traveler and not associated with the vehicle. This requires that the payment device be something that the traveler can carry either in a credit card format, a key fob, or something that is attached to a cell phone. Just like ETC, a considerable back office effort is required to support the point of sale, point of payment, or point of service transaction. In the case of electronic ticketing, the payment device comes in the form of a smart card or some form of smart miniature transponder rather like the transponder or tag used in or on the vehicle for ETC. The most prevalent way to pay for transit fare today is to use a paper ticket. Many transit agencies, however, have migrated to magnetic stripe paper tickets, which allow the ticket to be read by machine. This supports features like free transfers between routes. Things are changing, however, and the industry is moving toward the use of electronic ticketing systems with contactless smart cards. The primary payment device is becoming the smart card. These small devices, which have the same size and shape format as a credit card, are defined by the ISO/IEC 14443 standard.

One of the interesting aspects of the smart card payment device is that it has the ability not just to store electronic money but also to conduct limited processing on board the card. You can think of the smart card as a very small computer with no keyboard and no display. This makes it possible for the payment device to calculate eligibility for discounts and to be able to store data regarding location of boarding and alighting of transit vehicles. Such devices can log where the passenger got on and off the transit, making it possible to conduct distance-based charging. It is also possible to track the holder of the smart card, enabling trip pattern information to be gathered regarding how travelers are using the transit system. The keyboard and display functions are provided by the terminal that the smart card interacts with through short-range communications. Since money is effectively being transferred between the card and the reader, the communications between the card and the reader must be secure.

Note that there is also the possibility of coordinating the storage of benefit information from human service agencies on the same smart card. This is the long-term vision of Mobility Services for All Americans (MSAA) and is a good example of the multiple uses that the smart card technology platform can support.

Electronic Parking Fee Collection

Electronic parking fee collection can involve either off-street or on-street applications. In the case of off-street applications, entry and exit to the parking structure is controlled by a payment system. In the case of on-street applications, fees are collected either with parking meters or by a pay-on-foot system. Parking meters are assigned to each individual parking bay while the pay-on-foot systems involve the use of a single ticket-issuing machine to serve a number of parking bays. Electronic parking fee collection is very different from ETC. A parking transaction is one that occurs in a stopped position where many types of electronics might be appropriate. A roadway ETC application requires the transaction to take place in a matter of milliseconds at highway speeds.

Electronic parking fee collection, like electronic ticketing systems for transit, has great similarities to ETC. The overall objective is to replace the use of cash at the roadside or in the parking structure with the use of electronic payment devices. Systems in use today use a number of different technology approaches. Some of these approaches are described in the following sections.

Off-street Car Parking

There are a few different approaches to electronic fee collection for car parking in off-street parking structures. One approach is related to entry and exit payment and the other approach is related to payment on foot. Considering the entry and exit payment approach first, a typical ETC system for off- street car parking involves channelized entry to the parking structure. As the vehicle enters the parking structure, a barrier prevents access until the ticket is obtained from the parking access machine at the entrance. The ticket issued to the driver has the time of entry recorded to it, either by printing it on the ticket or entering data onto the magnetic stripe on the ticket. When the driver leaves the parking facility, the time of arrival is read from the ticket and the appropriate fee for the duration of the parking is calculated. The system supports a feature called anti-passback. This means that when a driver leaves the facility it is not possible to transfer the paper ticket to another driver, as the system will only accept the paid ticket for exit on one occasion.

Consider the second approach, which is the pay- on-foot method. Entry and exit access to the parking structure is open and there are no barriers. After the driver has parked the vehicle, he or she is required to go to a kiosk or parking ticket machine and obtain a ticket to be displayed in the vehicle. Parking enforcement officials are employed to check every vehicle in the parking structure to ensure that a valid ticket is being displayed. Vehicles that have no valid ticket or that have an expired ticket (parking beyond the duration paid) are issued a parking fine ticket, and the driver is required to pay the parking fee plus a penalty.

Another variation on the pay-on-foot approach involves the collection of a parking ticket as the driver enters the parking structure. On exit from the structure, the driver is expected to go to a pay-on-foot machine and have the ticket converted to an exit ticket after payment of the appropriate fee. In most cases, drivers have the option to pay on foot or pay the fee at the exit lane from the parking structure. The pay-on-foot option helps to reduce waiting times for exit from the structure.

Another approach to electronic parking fee collection for payment structures involves the use of an ETC approach. This approach involves the use of a transponder or tag. In fact, the transponder or tag may have been issued to the driver for use on the regional ETC system. As the driver enters the parking structure, he or she utilizes a special purpose lane that has been equipped with transponder or tag reading equipment that identifies the vehicle and communicates with the toll systems' back office to determine the time and date of entry. When the driver exits the parking structure, a similar dedicated payment lane is utilized. As the vehicle leaves the structure, the transponder or tag is again read and the transponder or tag and vehicle are identified. The appropriate parking fee is calculated based on entry and exit time and date, and is then deducted from the associated prepaid account.

A variation of the above would be the use of an electronic, transit ticketing smart card for entry and access to the parking. On entry to the system, the driver would touch the smart card on a special keypad fitted to the entry system. This would open the barrier to let the driver access the parking structure. The driver would again touch the card on a similar keypad to exit the system, and the appropriate amount would be deducted from a prepaid account

On-street Parking

For on-street parking, ETC is achieved through either individual parking meters serving each parking bay or through a pay-on-foot electronic payment kiosk. In either case, the system can be made more user friendly through the use of either smart card or smartphone technologies. For example, parking meters can be fitted with a contactless smart card reader enabling payment to be made using the same smart card being utilized for transit fare collection. Another option would be to place an 800 phone number on the parking meter to enable drivers to pay by calling a number and then having the parking fee included on their next cell phone bill. Both of these techniques can also be used for the pay-on-foot payment kiosks.

Electronic fee collection is one of a number of technology-based management strategies available for on-street parking. The following video provides an example of the smart car parking system being implemented in San Francisco. http://sfpark.org/resources/sfparkoverviewvideo/.

Electronic Payment Systems Applications Security

In many cases, it is necessary to phase in the introduction of a system over a number of years due to funding constraints and other local challenges. This requires that each stand-alone project is capable of independent operation and that the sum of the parts adds up to the whole required. Good project and program planning is vital to the success of each stage. It is also worth noting that the needs of the traveler/driver, the transit passenger, and the car park user must be taken into account when designing a phased approach. It is useful to consider the geographic spread of the services to be delivered, the quality of those services, and the time over which the services will evolve. This requires a cost-benefit analysis to show how much benefit is being derived for the investment in the project. The security of data contained in and used by each stage of the deployment must be considered. In this respect, the payment systems industry has developed its own standard for security. This is known as the PCI or Payment Card Industry standard. This standard was originally developed and adopted by the credit card industry; however, many U.S. toll systems comply with PCI standards for data security. The following is a definition of the PCI standard.

"The Payment Card Industry Data Security Standard (PCI DSS) is a proprietary information security standard for organizations that handle cardholder information for the major debit, credit, pre-paid, ePurse, ATM, and POS cards. Defined by the Payment Card Industry Security Standards Council, the standard was created to increase controls around cardholder data to reduce credit card fraud via its exposure. Validation of compliance is done annually—by an external Qualified Security Assessor (QSA) that creates a Report on Compliance (ROC) for organizations handling large volumes of transactions, or by [a] Self-Assessment Questionnaire (SAQ) for companies handling smaller volumes."[12]
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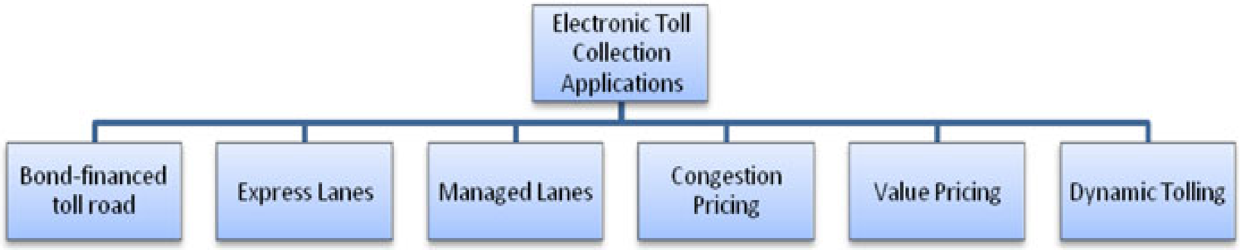
Pricing Strategies

ETC technologies can support a number of different approaches, as shown in the figure below. An overview of each strategy is provided.

Figure 10. Pricing Strategies



Bond-financed Toll Roads

Bond-financed toll roads are either publicly or privately owned and operated highway facilities. The money to plan, design, build, and operate such roads is raised from the private sector on the commercial bond market. This approach places an emphasis on maximizing throughput and revenue while delivering the highest possible levels of safety, efficiency, and customer service. The United States has a considerable number of toll roads where a flat fee is collected for the trip between toll plazas, using a fixed or static approach. These agencies operate what could be known as a flat fee at a point tolling strategy. What this means is that as the vehicle crosses an imaginary line in the road, a fee is levied. Traffic engineers and transportation planners would refer to this as a screen line. The imaginary line can be drawn at the toll plaza, which is more likely these days to be an electronic tolling zone in an ORT system. The fee to be charged as the vehicle crosses the imaginary line has no relation to the entry point of the vehicle, the exit point of the vehicle, or the distance traveled in the toll road. Due to the cost of constructing toll plazas, the implementation of this approach can also involve gaps in the collection coverage, in which one or more movements on and off the toll road are not charged. It is possible, using this approach, to approximate the distance-based charge by relating the fee levied as the vehicle crosses the imaginary line to the distance between toll plazas.

Express Lanes

The express lanes term is reserved for those lanes where the user pays a variable or fixed toll in return for use of a special purpose facility that typically operates in parallel with general purpose lanes that are not tolled. This offers the driver a choice to pay or not to pay.

Managed Lanes

The managed lanes term is reserved for a highway lane or set of lanes, or a highway facility, for which variable operational strategies such as direction of travel, tolling, pricing, and/or vehicle type or occupancy requirements are implemented and managed in real time in response to changing conditions. Managed lanes are typically buffer or barrier-separated lanes parallel to the general purpose lanes of a highway, in which access is restricted to designated locations. There are also some highways on which all lanes are managed.

Congestion Pricing

Congestion pricing is used to manage the demand for travel by varying the cost of travel through a fee. The economic principles that underpin this strategy are described later in the module.

Value Pricing

This is an operating strategy, in which the price to use the facility is varied according to the value being delivered. The value can be defined in terms of trip time, average speed, or trip time reliability. This can be achieved through the use of time-of-day pricing according to a pre-published schedule, or by adjusting the toll rates in near real time using dynamic tolling techniques as defined in the next section.

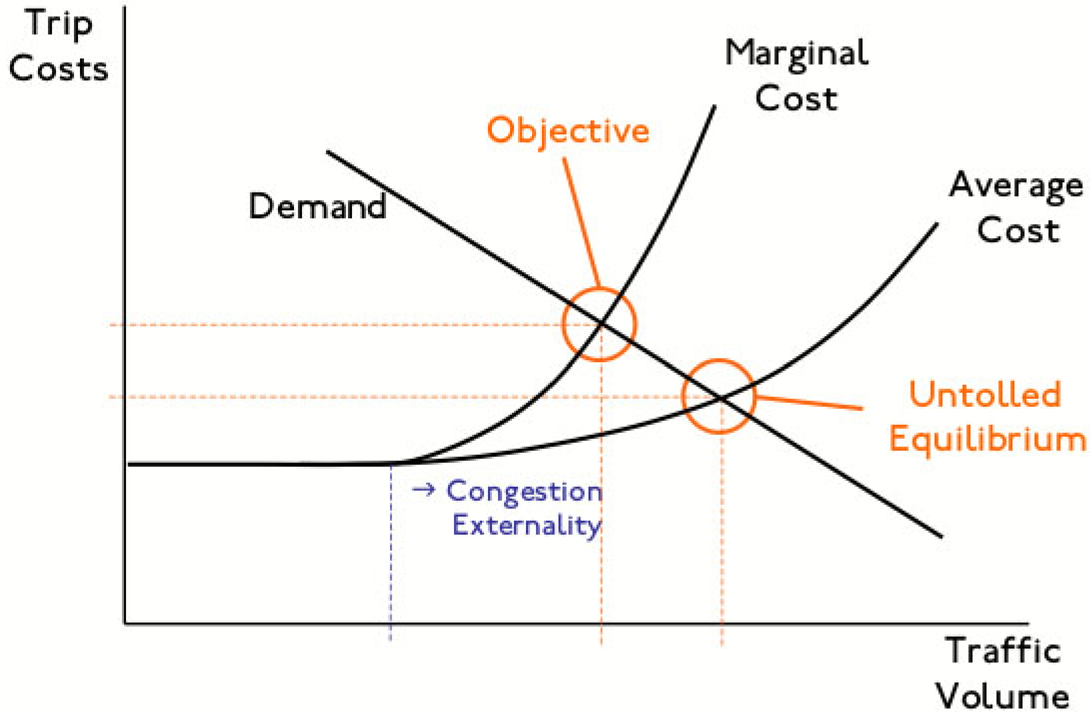
Dynamic Tolling

Dynamic tolling varies toll rates for each time period and each road segment to achieve predefined service level objectives. Sensor data is used to calculate new toll rates at regular intervals, and these are communicated to drivers using dynamic message signs.

Basic Economic Principles

The basic economic principles behind each of these strategies are the same and are illustrated in the following figure.

Figure 11. Economic Principles of Pricing Strategies[13]



(Extended Text Description: This is a line graph depicting the basic economic principles of pricing. The x-axis is Traffic Volume and the y-axis is Trip Costs. Demand is shown as a descending diagonal straight line (moving upper left down toward lower right). Marginal cost is shown as a line that starts horizontal (about 1/4th of the way up the y-axis) and then curves steeply upward. The intersection between the Demand line and the curving Marginal Cost line is circled and labeled in orange as "Objective." The Average Cost line is shown as a line exactly overlapping the Marginal Cost line until the point of upward curve – the Average Cost line does not curve as steeply up as the Marginal Cost line. The intersection between the Demand line and the Average Cost line (which occurs more to the right and slightly lower than the Marginal Cost intersection) is circled and labeled in orange as "Untolled Equilibrium." Under the initial point of curving of the Marginal and Average Costs lines is a small arrow pointing to the right labeled "Congestion Externality.")
The principle is simple: the volume or the demand for travel is reduced as the cost of the trip is increased. For example, in the figure, as trip cost is increased from average cost to marginal cost by imposing a toll or user fee, traffic volume drops from the un-tolled equilibrium to the objective traffic volume. The relationship between volume and price with respect to pricing and tolling for congestion is referred to as elasticity. In economic terms, elasticity is defined as change in demand or volume divided by the change in price. Elasticity can also be defined as the slope of the straight line shown in the diagram above.

An interesting thing about pricing is that pricing is enabled by open road ETC technologies. We now have the ability we never had in the past to actually implement a pricing strategy based on the theory explained in the figure. Pricing has moved from being discussed as an economic theory to actual implementation.

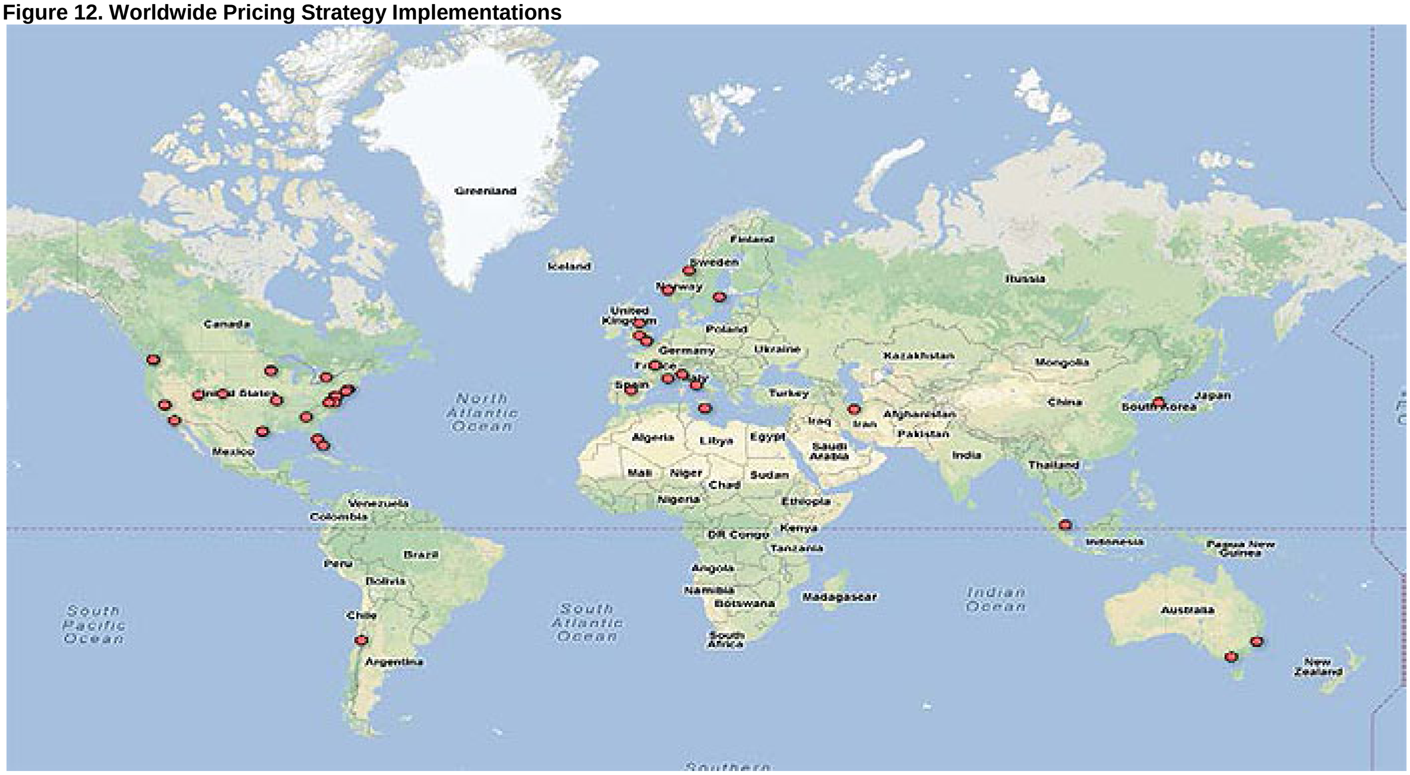
The history of pricing theory is quite interesting. In 1920, a British economist by the name of Arthur Cecil Pigou described the use of congestion pricing for a congested highway. He was, in fact, trying to illuminate how social welfare would operate and was merely using a congested road as an example or analogy. The true father of congestion pricing theory is probably the Nobel Economics prizewinner William Vickrey. He was the first to propose a system of electronic tolling for congestion pricing purposes. He described a process in which each car in the Metropolitan Washington area would be equipped with a suitable transponder or tag as follows:

The transponder's personalized signal would be picked up when the car passed through an intersection, and then relayed to a central computer which would calculate the charge according to the intersection and the time of day and add it to the car's bill.[14]

A considerable time elapsed before Vickrey's theory was implemented in practice, mainly because of the lack of practical ETC technologies. The first "citywide" congestion pricing project was launched in Singapore in 1975, followed by the London system in 2001, and then the Stockholm system in 2008.

Today there are almost 50 projects worldwide involving some form of pricing strategy. These are depicted on the figure below. These projects represent a combination of toll roads, urban congestion pricing, value pricing, managed lanes, and express lanes strategy implementations.

Figure 12. Worldwide Pricing Strategy Implementations



(Extended Text Description: The following descriptive notes are from the author. This figure is for general illustrative purposes only. This is a world map depicting worldwide pricing projects. There are a series of approximately 34 red dots placed approximately in the following locations: United States/North America - Seattle, San Francisco, Los Angeles, Salt Lake City, Denver, Minneapolis, St. Louis, Houston, Atlanta, Toronto and many along the Eastern Seaboard; South America – Chile; Europe – Spain, United Kingdom, France, Norway, Sweden, Italy; Middle East/Asia: Iran, Indonesia, South Korea, Australia. This map depicts the almost 50 projects worldwide that involve some form of pricing strategy. Note that there are not fifty dots on the map as some cities have more than one project. The map shows that interest in the application of pricing is spread widely across the globe, indicating that the use of pricing strategies has become a mature activity.)

Dynamic Tolling Projects in the United States

The figure below shows the 11 projects that are conducting dynamic tolling currently in the United States. Dynamic tolling can be viewed as a subset of managed lanes or express lanes as they are operated under variable tolling regimes in order to achieve specific traffic condition objectives.

Figure 13. Dynamic Tolling Projects in the United States

(Extended Text Description: The following descriptive notes are from the author. This figure is for general illustrative purposes only. This is a map of the United States/North America depicting dynamic tolling projects in the USA. There are approximately 10 red dots in the following locations: Seattle, San Francisco, San Diego, Salt Lake City, Minneapolis, Atlanta, Orlando, Miami, DC. This map depicts the 11 projects within the USA that are currently using dynamic tolling techniques. Note that some cities have more than one project so there are not 11 dots. Dynamic tolling can be considered as one form of pricing technique. The map clearly shows widespread application of dynamic tolling techniques in US cities.)

Here in the United States the approach tends more toward a higher fee in return for a value rather than a mandatory congestion charge. The 11 dynamic tolling projects shown in the preceding figure use a combination of fully dynamic or time-of-day tolling techniques.

The figure below shows the types of variable and dynamic tolling approaches that have been implemented in the United States.

Figure 14. Variable and Dynamic Tolling Techniques

Variable tolling	Pre-published schedules
	For each segment
	Vehicle classification
	Time of day
	Day of week
Dynamic tolling	For each segment
	Level of service based
	Value of time saved based
	Combination of level of service and value of time

As noted in the figure, variable tolling techniques can simply involve the use of a pre-published schedule of toll rates updated at 3-to-6-month intervals based on traffic counts. When a pricing schedule approach is adopted, the tolling is not really conducted in a truly dynamic fashion. A schedule of rates for each vehicle type for each segment of highway is made available to drivers both on the web and at the roadside. Drivers are then empowered to make a decision to use the facility or not. You can think of the refresh rate (the rate at which the toll is updated) as 3 to 6 months for this type of project. This approach takes advantage of the flexibility of electronic toll systems to make pricing changes rapidly and with minimum expense.

On the other hand, dynamic tolling makes use of sensors in the roadway that are used to continuously monitor traffic flow. Incremental adjustments of the toll are then made to correspond to changes in the traffic flow. One approach is to install sensors in the express lanes and adjust the toll in order to preserve a specific level of service on those lanes.

Another approach involves the installation of sensors on both the express lanes and parallel general purpose lanes. Travel times on both facilities are then computed, and the toll charged on the basis of the travel time savings experienced by drivers on the express lanes. In practice, a combination of both of these approaches has been used with some success. Even when the level of service on the express lanes is the only consideration, sensors are typically placed on the general purpose lanes for flow monitoring purposes. Dynamic tolling approaches make use of a special purpose algorithm that takes traffic data as input and varies one or more of the following key parameters to achieve a traffic performance objective:

- Speed (miles per hour)
- Flow (vehicles per hour)
- Flow Density (vehicles per mile per lane)
- Headway (feet)
- Elasticity of demand (ratio)
- Toll adjustment interval (minutes)
- Toll adjustment increment (cents)
- Minimum toll (dollars)
- Maximum toll (dollars)

Many dynamic tolling implementations attempt to preserve a level of service on managed or express lanes. The level of service can be defined as an average speed on the express lanes or as a level of service (LOS) as defined by *The Highway Capacity Manual* and the American Association of State Highway and Transportation Officials (AASHTO) *Geometric Design of Highways and Streets* (often referred to as the Green Book). Levels of service are defined in the figure on the next page.

Figure 15. Level of Service Definitions

Level of Service (LOS)	Description	Detailed Traffic Conditions
A	Free flow	Traffic flows at or above the posted speed limit and all motorists have complete mobility between lanes. The average spacing between vehicles is about 550 ft. (167 m) or 27 car lengths. Motorists have a high level of physical and psychological comfort. The effects of incidents or point breakdowns are easily absorbed. An example of LOS A occurs late at night in urban areas, frequently in rural areas, and generally in car advertisements.
B	Reasonably free flow	Free flow (LOS A) speeds are maintained, maneuverability within the traffic stream is slightly restricted. The lowest average vehicle spacing is about 330 ft. (100 m) or 16 car lengths. Motorists still have a high level of physical and psychological comfort.
C	Stable flow	Ability to maneuver through lanes is noticeably restricted and lane changes require more driver awareness. Minimum vehicle spacing is about 220 ft. (67 m) or 11 car lengths. At LOS C most experienced drivers are comfortable, roads remain safely below but efficiently close to capacity, and posted speed is maintained. Minor incidents may still have no effect but localized service will have noticeable effects and traffic delays will form behind the incident. This is the targeted LOS for some urban and most rural highways.
D	Approaching unstable flow	Speeds slightly decrease as the traffic volume slightly increases. Freedom to maneuver within the traffic stream is much more limited and driver comfort levels decrease. Vehicles are spaced about 160 ft. (50 m) or 8 car lengths. Minor incidents are expected to create delays. Example of LOS D is perhaps the level of service of a busy shopping corridor in the middle of a weekday, or a functional urban highway during commuting hours. It is a common goal for urban streets during peak hours, as attaining LOS C would require a prohibitive cost and societal impact in bypass roads and lane additions.
E	Unstable flow	Flow becomes irregular and speed varies rapidly because there are virtually no usable gaps to maneuver in the traffic stream and speeds rarely reach the posted limit. Vehicle spacing is about 6 car lengths; however, speeds are still at or above 50 mi/h (80 km/h). Any disruption to traffic flow, such as merging ramp traffic or lane changes, will create a shock wave affecting traffic upstream. Any incident will create serious delays. Driver's level of comfort becomes poor. LOS E is a common standard in larger urban areas, where some roadway congestion is inevitable.
F	Forced or breakdown flow	Flow is forced; every vehicle moves in lockstep with the vehicle in front of it, with frequent slowing required. Technically, a road in a constant traffic jam would be at LOS F. This is because LOS does not describe an instant state, but rather an average or typical service. For example, a highway might operate at LOS D for the AM peak hour, but have traffic consistent with LOS C some days, LOS E or F others, and come to a halt once every few weeks. However, LOS F describes a road for which the travel time cannot be predicted. Facilities operating at LOS F generally have more demand than capacity.

Through empirical observation, the different levels of service are linked to different toll levels. The elasticity parameter discussed previously can be used to relate traffic flow or flow density to price. The variable tolling calculation makes use of traffic data sensors on the express lanes to provide data regarding the prevailing traffic conditions. Then the special purpose algorithm is used to determine how the tolls must be raised or lowered to maintain the target level of service on the express lanes. In some cases, traffic sensors are also placed in the general purpose lanes alongside the express lanes. The travel time difference between the express lanes and the general purpose lanes is then taken into account in determining the current toll. The rate at which tolls are altered is usually constrained by the minimum and maximum toll increment in order to ensure stable pricing and smooth transitions between tolls. The figure below shows dynamic message signs displaying the current toll rate for the next segment of the express lanes.

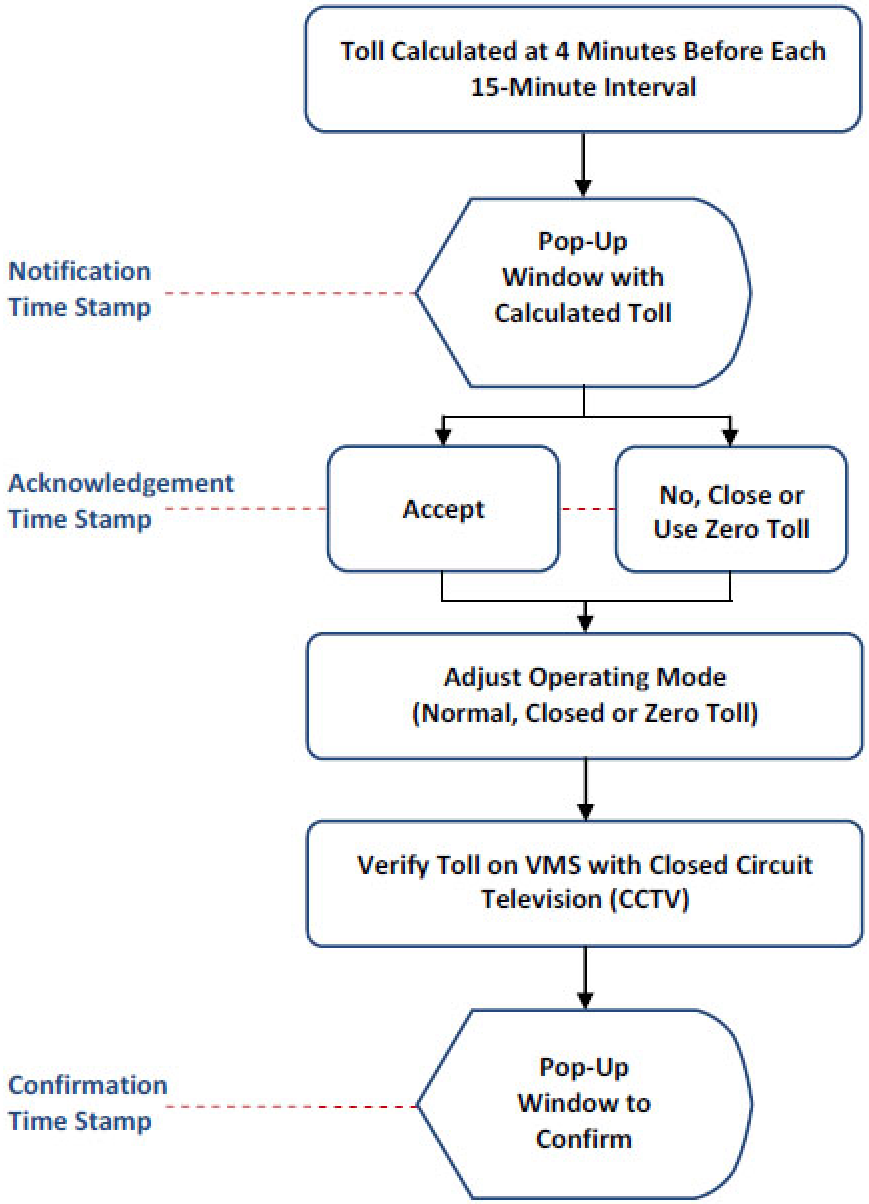
Figure 16. Dynamic Message Signs Used for Dynamic Tolling in the Metropolitan Washington Area[15]

Source: https://www.495expresslanes.com/signage.

(Extended Text Description: This is the image of dynamic message signs used for dynamic tolling in the Metropolitan Washington Area. The top portion of the sign is white with the purple E-ZPass logo and the word, Express. The second portion is green with the Interstate 495 logo and the word, South. The next portion is digital with the words Westpark $1.00 I-66 $2.00 I-395/I-95 $3.00. The last portion of the sign is yellow and says 1 Mile.)

The figure on the next page shows the overall flow for a typical pricing algorithm using the express lanes level of service approach.

Figure 17. Dynamic Tolling Algorithm Flow Diagram Example[16]



(Extended Text Description: This is a flowchart depicting the typical dynamic tolling algorithm. At the top is a text-box "Toll Calculated at 4 Minutes Before Each 15-Minute Interval" with an arrow pointing below to the second text-box "Pop-Up Window with Calculated Toll." There is a dotted line leading to the left to the words "Notification Time Stamp." The second text box has two arrows pointing to the two side-by-side text boxes below it: "Accept" (left) with a dotted line to the left with words "Acknowledgement Time Stamp" and "No, Close or Use Zero Toll" (right). There is a dotted line between these two text-boxes. They both have an arrow pointing to the lower text-box "Adjust Operating Mode (Normal, Closed or Zero Toll)" with an arrow pointing below to the next text-box "Verify Toll on VMS with Closed Circuit Television (CCTV)" with an arrow pointing down to final text-box at the bottom of the flowchart "Pop-Up Window to Confirm." There is a dotted line to the left with words "Confirmation Time Stamp.")
For this implementation, the toll is calculated at 15-minute intervals. The toll calculation is initiated 4 minutes before each 15-minute interval begins to allow time for the new toll to be calculated, the operator to validate the new toll, and the new toll to be communicated to drivers via dynamic message signs. The system also has "closed" and "zero toll" modes. These are used when an incident requires that express lanes be closed to traffic (closed mode) or when an evacuation scenario requires the toll to be removed completely for a period of time to facilitate evacuation (zero toll mode).

This diagram also brings to light another interesting challenge for prospective dynamic tolling operations. At the entry points to the express lanes, drivers are informed of the current charge for the express lanes through the use of dynamic message signs. It is necessary to be able to confirm that these dynamic message signs display the correct toll. This is achieved through the use of closed circuit TV (CCTV) cameras trained on the dynamic message signs so that the toll operator can verify the correct toll is being displayed. Images from the CCTV system are recorded on a digital video recorder (DVR) system, enabling historic records to be retrieved if a particular toll is questioned. If for some reason an incorrect toll is displayed, the pricing operator has the ability to retroactively alter the toll.

Why is Pricing a Valuable Tool?

Pricing is a valuable tool because of its ability to allow us to manage demand. The economic theory linking the price of a commodity to the use of a commodity, or to the demand for the commodity, can now become implemented through ETC technologies. In addition to the demand management capability, pricing allows us to raise additional revenue that can be reinvested into more transportation improvements, including better transit, more general purpose lanes, and improved operational management of the transportation infrastructure.

At a time when the U.S. Highway Trust Fund is suffering from a lack of money due to difficulties with fuel-based taxation, distance-based taxation is a viable alternative. At this time, we have more options driven by information technology and more management solutions than ever before. This provides us with the flexibility to address policy objectives while avoiding undesirable side effects.

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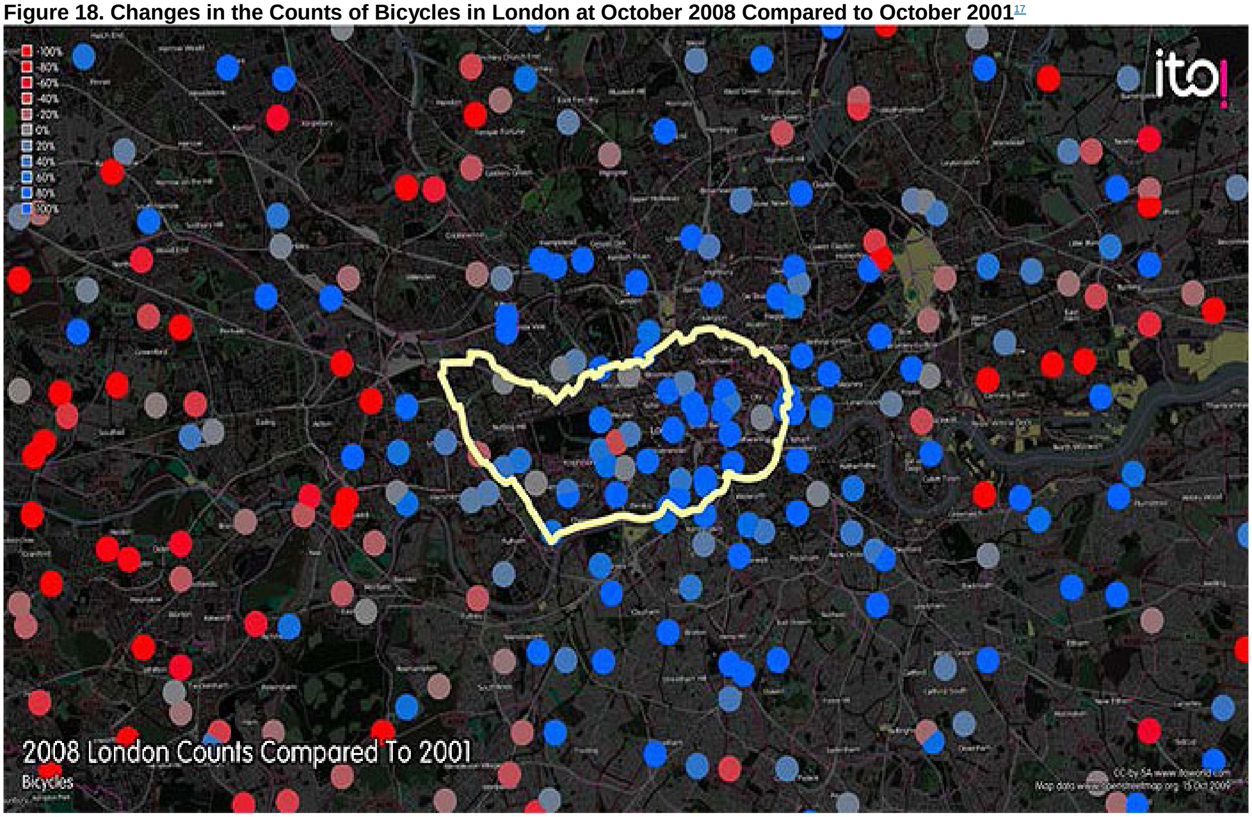
Defining Strategic Objectives for Pricing

The strategic objectives for pricing projects can vary considerably, and it is important to define objectives before launching the planning, design, and cost estimation of projects. The following sections describe some possible strategic objectives for pricing projects.

Congestion Reduction

Both the London and Stockholm projects have the primary objective of congestion reduction. This was achieved by imposing a mandatory charge for travel into downtown congested areas during the daytime. The objective is to deflect a portion of the traffic to other modes of transportation or to travel at different times of the day. The reduction congestion objective can also address emissions management objectives through modal shift and congestion reduction. The modal shift effects of the London congestion pricing project is shown in the figure below. The blue dots show an increase in the number of bicycles counted during traffic counting. The red dots show a decrease. The gray dots indicate "no change" in traffic flows and the yellow line represents the boundary of the congestion charging zone.

Figure 18. Changes in the Counts of Bicycles in London at October 2008 Compared to October 2001[17]



(Extended Text Description: The following descriptive notes are from the author. This figure is for general illustrative purposes only. The image is a large aerial map (dark in color) showing lines for roadways around London. There are many dots covering the map,

with a slight concentration at the center of the map. The center maps has mainly blue and light blue/gray dots. Farther to the outside of the map, there are more red and light pink/gray dots. There is a key scale in the upper left corner with a series of color boxes (dark red to light red/gray and light blue/gray to dark blue) with percentages listed beside each color block. There is a yellow irregular shaped outline overlaid the center area of the map. The London project also had modal shift effects as illustrated the figure, which illustrates an increase in the use of bicycles. The blue dots show an increase in the number of bicycles counted during traffic counting. The red dots show a decrease. The gray dots show no change. The figure clearly demonstrates that there was an increase in the use of bicycles within the congestion pricing zone (shown in yellow).)
It is interesting to note that the London congestion charge is defined as a user fee for presence inside the pricing zone during defined time periods. The Stockholm congestion charge has been defined as a tax, enabling existing tax regulations to be applied to enforce the charge.

Peak Spreading

In some cases, the objective is not to divert traffic away from the road, especially if it is a toll road, but to encourage drivers to advance or delay their trips to avoid the peak period. This strategy is known as peak spreading as the intent is to spread the peak period traffic over a longer period by toll increases during the very peak period.

Modal Shift

When the objective is to divert traffic to another mode of transportation, such as transit, bicycle, or pedestrian modes, the strategy to be applied is known as modal shift. This requires that viable alternative modes are available and that good traveler information can be delivered to make drivers aware of the choices.

Revenue Generation

The revenue generated from a pricing project can be reinvested into transportation infrastructure in the region. It may also be used to accelerate the development and construction of infrastructure by funding availability payments or some other form of public-private partnership. Note that revenue generation as a strategy can be implemented in tandem with the other strategies above, with the exception of modal shift.

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Multimodal Integrated Payment Systems

Multimodal integrated payment systems for a region can be viewed as the ultimate goal or pinnacle of electronic payment systems applications for transportation. This involves the implementation of an ETC system, transit ticketing, parking fee collection, and the support of payment for other government services. The regional system combines vehicle-based transponders or tags with personal, portable smart cards, within a single back office or accounting structure. This enables regional residents to pay for all forms of transportation from a single account. The ultimate system could also include non-transportation fee collection for relatively low value transactions. The system can make use of multiple payment devices, but a single back office accounting structure is applied.

At the present time there is no single implementation of a multimodal integrated payment system anywhere in the United States. Many agencies have developed partial systems that support both transit ticketing and other applications, while many other agencies have developed toll collection systems for toll roads and express lanes that also support car parking fee payment. The ideal regional electronic payment system would include regional settlement and clearing. This would enable multiple service providers to use the system to pay for their goods and services. The settlement process would ensure that each service provider receives the money due them.

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Challenges Associated with Electronic Payment Systems

Requirements Definition

It would be fair to say that most challenges and issues associated with ETC and pricing projects relate to people. The progress of technology is such that if a group can define what is required from a proposed system, the technology will be available to make that system work. Over the course of many projects, systems engineers have realized that requirements analysis and agreement of objectives are a crucial part of a successful ETC and pricing project. The definition of what the system is needed to do and how the system should do it requires the efficient use of specialist resources to enable the job to be done properly. Requirements gathering and agreement is a project stage that is often overlooked or under-resourced in the haste to implement quickly. That can lead to dramatic consequences in the later stages of a project.

The lesson is simple—ambiguity costs money. Ambiguity appears in systems requirements due to lack of formal agreement on what the system is designed to do and lack of definition on specific requirements. Boehm demonstrated through his study of a number of large-scale systems development projects that failure to remove ambiguity will cost an increasing amount of resources through the different stages of the project.[18] Research has shown that the cost of ambiguity rises dramatically as the project progresses. As a rule, it will cost approximately $1,000 to correct problems during the deployment stage, while that same problem could have been dealt with during the requirements gathering stage for approximately $1. That is why it is worthwhile investing heavily in initial requirements analysis and objectives agreement.

There is another reason why this investment is so valuable. This relates to the partnership needs of projects like ETC and pricing. Many asphalt, concrete, and steel projects have one major sponsor and require little by way of local regional partnership. The nature of electronic payment systems applications is such that the best results are usually achieved when the project is shared by multiple organizations and multiple agencies. This enables risk sharing, cost sharing, and the integrated operation of the system for the full benefit of the residents in the region. The early definitions of what the system is required to do also provide an opportunity to harness the full power and motivation of the private sector.

As noted earlier, there is a great deal of overlap between the directions taken by the private sector and the desires of the public sector. There is a huge amount of activity in the private sector with regard to financial transactions, banking credit cards, and support for multiple small value transactions that are not related to transportation. These enterprises have considerable resources, skills, and talent that, if applied creatively to the public sector objectives, could produce dramatic results.

Proprietary Technologies

On the negative side, engaging the private sector is a concern regarding the use of proprietary technology. There is considerable discussion today about use of open standards, open architecture, and systems that allow plug and play of key elements from multiple vendors. There is a great attraction in avoiding being locked into using a single vendor over a number of years. There is also value in knowing that decisions made now do not commit users to a long-term future with unforeseen consequences.

From the private sector perspective, considerable resources may have already been invested in developing the tools, the technologies, and the approaches that they have to offer and they want to bring to the table. This tends to make them protective, leading to the use of proprietary technologies to defend their position and ensure that they get a return for the resources invested. Evolution to open standards and architecture appears to be a trend in technology markets. As markets mature and sales volumes get larger, vendors realize that they are actually fighting for the same "slice of the pie" or market share. They come to realize that the best way to make the pie or overall market bigger is to cooperate, lower the shields, and dispense with proprietary technology. This leads to adoption of open standards, which leads to larger sales volumes, enabling each vendor to have a larger market share. Proprietary technologies could have an edge when it comes to systems security because their lack of openness could make them more difficult to penetrate.

Funding and Financing

Another major challenge facing an agency embarking on an ETC and pricing project is what could be referred to as "the second question." Assuming that the first question that an agency would ask relates to what the system does and the value it will deliver, the second question relates to the means of funding and financing the project.

In a traditional public approach, a considerable sum of capital is required to be able to design, build, acquire, install, and operate an ETC and pricing system. However, large capital sums are not always available and alternatives must be considered. These include financing, leasing, availability payments, public-private partnerships, and many other ways to spread the payment required to acquire the infrastructure and services. Later in the module we will discuss some of the ways in which an ETC and pricing system can be financed and funded. ETC systems have relatively low capital expenditures as well as operating expenditures when compared to manual toll collection. ETC capital expenditures are also very low compared to the costs of the facilities for which they collect revenue to pay off the bonds.

Future Proofing

Another challenge that electronic pricing and payment systems implementers face is the relatively long time span for the completion of major projects. For example, the construction of a 20-mile corridor to include new express lanes as well as new general purpose lanes can involve the reconstruction and replacement of a considerable number of structures, the acquisition of a large amount of right-of-way, and a significant construction effort to build a new facility. Such endeavors can take 6 to 10 years to build. This means that the technology choice in the planning for the use of electronic toll systems technologies is being made well in advance of the actual opening of the system.

The challenge is that when the system actually opens for use, several years after the design work, the technology may have evolved, making the system outmoded before use. Here again system planning is required. A well-crafted systems engineering management plan and a structured systems approach to the development and planning of the technology will allow future flexibility and will also take into account every development that can be seen in the foreseeable future. This is also a good reason for the adoption of local, national, or international standards for technology where available.

Privacy and Anonymity

One of the challenges associated with electronic payment systems applications is around privacy and anonymity of the user. While these are legitimate concerns, there is clear documentation that the user of an electronic payment system is prepared to trade privacy in return for a value or a service. An interesting example of this is the SmarTrip electronic transit ticketing system implemented by WMATA in the Metropolitan Washington area. WMATA had a strong desire to harness the full power of electronic payment systems applications to enable it to gather trip pattern and service demand information. WMATA was also cognizant of the need to respect privacy and the rights of the individual using the system. The solution was to offer users of the system two options. For the first option, users were issued a smart card with no registration required and no information collected from the user. The user was totally anonymous and it was not possible to track the movements of the individual. For the second option, the user was asked to voluntarily agree to be tracked and to provide registration information to WMATA. In the former case, where no registration information was provided, a lost or stolen card had the same effect as lost cash. There was no ability to replace the smart card balance and the user lost any money that was placed on the smart card. In the case of the latter option, because the user had agreed to be recognized, tracked, and registered, WMATA was able to offer a balance recovery feature. This meant that if the card was lost or stolen, WMATA was able to recover the balance and give the user a new card with exactly the same balance that was on it when it was lost or stolen.

Interestingly, when offered these two choices, approximately 98 percent of system users elected to be registered. They traded a loss in anonymity with a gain in service features that they found to be desirable. Privacy and autonomy are apparently not major issues.

Regardless of the fact that users may trade privacy in return for a particular service or benefit, it is essential that any electronic payment system provide the relevant level of data security to preserve the privacy of the individual and enable anonymous operation if that is the choice of the user. It may also be the case that an electronic toll system for a pricing system for managed lanes may be subject to existing "sunshine" laws. These require that the public agencies within the State publish all information regarding the activities of the agency. This could involve information regarding the use of the ETC system. This might include trip information regarding the origin and destination of a particular vehicle, which would be an undesirable intrusion into the privacy of the user. In most cases, this can be addressed by seeking a waiver or exceptions to the prevailing sunshine laws.

Fairness and Equity

Fairness of, and the perceived equity of, the system are important considerations. As mentioned earlier, some toll collection approaches involve "leakage." What this means is that some people are getting a free ride while those who do pay may have to pay more to compensate for the loss of revenue as the cost of the system must be covered. Fairness and equity are particularly important when implementing congestion pricing and dynamic tolling strategies. In most implementations, there will be both winners and losers. It is important to identify both groups, determine the likely impact, and seek ways to mitigate or avoid undesirable side effects. This issue also has an influence on the required accuracy and reliability of the electronic toll technologies to be employed. The accuracy and reliability must be high enough to support a public perception of fairness and equity, with all users being charged as appropriate and low levels of leakage. Leakage losses from cash toll/parking systems have sometimes been estimated in excess of 30 percent of revenue collected.

Fitting Within the Wider Context

As described earlier, one of the commercial challenges associated with transportation electronic payment systems applications relates to ensuring that full account is taken of the wider context of electronic payment systems applications. It is important to avoid the risk of reinventing the wheel, assuming that everything has to be acquired and managed in house. It is also possible to develop an extreme focus on the special needs of the project and the region while not taking into account the capabilities that have been developed in the wider industry beyond transportation.

There are often opportunities to take advantage of previous private sector investment by making minor changes to project requirements. Some industry sectors attract a higher level of investment due to larger market sizes. It is often the case that the private sector can bring significant resources and motivation to the table. This can include substantial prior investment in products and services. For example, both MasterCard and Visa have extremely sophisticated and well-developed electronic payment systems applications. It may be possible to adopt one of these private sector services and fine-tune it to transportation rather than develop a customized public sector alternative.

Harnessing Regional Partners

Many aspects of electronic payment systems applications lend themselves to cost sharing and risk sharing. When attempting to identify the resources required to achieving objectives, it is a valuable exercise to look around and see if other public agencies have similar or compatible objectives. This could form the basis for a regional partnership under which objectives are achieved in a common way by sharing resources and sharing risks associated with the project. An example of this could be a regional electronic payment system that enables the local transit agency to support electronic ticketing and allows the local toll operator to conduct ETC. Sharing the planning, design, and implementation costs could be an important way to make the project viable.

This leads to another interesting dimension in regional partnerships. Quite a bit of effort is placed in quantifying the cost and benefits of electronic payment systems applications project. We will cover this in some detail later in the module. In order to support effective partnership establishment, it is important to not only quantify the benefits of the project but also to identify the beneficiary. Knowing who is going to benefit from the project could give a clear indication of potential partnership candidates.

Finding the Best Business Model

A business model defines a way of doing business. It describes how the project is going to be funded and how it is going to be operated from a commercial perspective. This involves the definition of who will invest in the project and who will be the beneficiary of any rewards generated. The business model also defines roles and responsibilities for operational management and the operation of the project. A number of business models can be applied to electronic payment systems applications. These can also be referred to as procurement mechanisms.

Business Models

Design, Bid, Build, Operate, and Maintain

This could be described as a traditional approach to a public sector transportation project. It involves a sequence within which the project is planned and designed before services and products are procured under the auspices of an open competitive procurement. The design and bid steps in the sequence are usually supported by the public agency, with support from private consulting resources. At the end of the bid step, the project is handed over to the private sector to build and implement. During the operations and maintenance step, the project can be returned to public sector control but, alternatively, the private sector can continue to operate and maintain the project, receiving suitable compensation.

This approach requires significant resources on behalf of the public sector. In many cases, during the design and bid activities the public sector will draw on expertise and resources from private sector consultants. This approach can also introduce delays in the project between the completion of the design activities, the procurement activities, and the beginning of the implementation step. A large-scale public procurement may take many months and be very complicated. The development of procurement documents to capture the precise detail regarding what the bidding organizations have to provide can take a significant amount of resources.

Public-Private Partnership
This business model requires the sharing of risk, resources, and rewards by both the public and private sectors. For example, in an ETC public-private partnership, the private sector may well be asked to invest the money required to build the facility. In return, the public sector will agree to issue a franchise or concession that endures for a number of years. During the concession period, the private sector partner is entitled to recoup investment and a suitable return on investment, including payment for interest, by receiving the tolls.
At the end of the concession period, the private sector agrees to return the facility and all related infrastructure to the public sector. This particular business model also involves the transfer of risk from the public sector to the private sector. The private sector takes the risk that traffic forecasts will be accurate and that the tolls collected over the concession period will be sufficient to cover the investment plus a return on investment.

A variation of this public-private partnership model would be a design, build, operate, and maintain model. Under the auspices of this model, the private sector would invest the money required to build the facility. The private sector would then operate the facility in return for regular availability payments from the public sector over a predefined concession period. At the end of the concession period, the facility would be returned to public ownership. This approach retains the risk with the public sector. Note that the design, build, operate, and maintain approach described in the preceding section could also be achieved through a public-private partnership.

Outsourcing
This approach involves developing a package of products and services that will be procured by the public sector. Rather than simply buying products and services, this approach involves the purchase of services for operations management and maintenance. This approach could be used to procure operational management services separately from the infrastructure construction. Outsourcing projects requires the development of a concise level of service agreement that specifies the services to be provided and the level of quality to which those services should be provided in order to meet the terms of the service level agreement.

Public-Public Partnership
A public-public partnership involves two or more public agencies agreeing to work together in a partnership to deliver the project. The public-public partnership could be an equal partnership where resource responsibilities are split evenly between the two agencies. The public-public partnership could also take the form of a senior partner/junior partner relationship, in which one agency has additional responsibilities for procurement and management.
Note that it is possible to use a combination of the above and adopt a hybrid approach to business models. In addition to the options explained above, it is advisable that the business policies and practices proposed for the operation of the toll system are captured in a set of formal, structured business rules. Such rules can enforce business policy, make a decision, or infer new data from existing data.

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Understanding the Relationship to Transportation and ITS Application

ETC and pricing can be considered a subset of ITS. While there are undoubtedly separate communities that have formed around each application area, at the end of the day the technologies being applied are similar. Additionally, many ITS applications are extremely complementary to ETC and pricing systems. Consider the case of a toll agency operating an express lane facility in a major urban area. One of the most important success factors in systems operation lies in effective marketing to tell the drivers how to use the facility, how much it is going to cost them, and how they should go about preparing themselves to use the system. In short, there is a need for traveler information.

In many major metropolitan areas, travel information systems have already been deployed. These typically collect data from multiple sources, process the data into information, then deliver the information over a range of established information delivery channels. It would make sense for the ETC and pricing agency to make use of the existing traveler information system to convey information to the driver regarding the use of the system. One way to address travel might simply be the development of a user manual for the system being deployed. For the driver to get the best experience, a manual should be provided explaining the best use of the system.

ETC and pricing may also be set within a wider context of performance management. The region involved may already have a significant performance management system involving sensors, telecommunications, processing, visualization, and report delivery. Here again a smart approach to ETC and pricing would fully utilize these existing services in an integrated way with existing applications. The Federal Highway Administration recognized the need for integration of ITS applications a number of years ago and launched a program called the National ITS Architecture Development Program. This multiyear, multimillion dollar program resulted in the definition of architecture and systems engineering approaches to ensure that new applications fit with existing ones and that we make maximum use of synergies that are available at the technical, commercial, and institutional levels.

Electronic payment systems applications such as ETC, pricing, transit ticketing, and parking fee collection systems collect a significant amount of data. By definition, if you need to charge people the appropriate fee, then you need to know about their use of the facility.

Electronic payment systems applications can be much more than a vehicle for paying for service. They can also be powerful collectors of data for performance management. Here again a smart approach to electronic payment systems applications would be to recognize this in the planning, design, and operation of the electronic payment system. The electronic payment system would be closely coordinated with regional performance management. Of course the performance of the electronic payment system itself is an interesting subject. One would expect that features would be built into the design of the system to enable performance management to be conducted by the system, as well as to provide data for other performance management applications.

Electronic payment systems applications fit with ITS and transportation management through the delivery of more efficient means to collect money and to manage demand. The flexibility of electronic systems to adjust payment levels at short notice with minimum resources also provides us with demand management possibilities.

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The Role of the Private Sector in Electronic Payment Systems Applications

There are many roles the private sector can play in electronic payment systems applications. In fact, it may be argued that the private sector was instrumental in the creation of the current ETC industry. Some of the potential roles have been described above. It is valuable, however, to take a more detailed look at the specific roles that the private sector could play in electronic payment systems applications.

Providing Technology Products and Services

The private sector may have already developed a number of technologies, products, and services that are available off-the-shelf. Adapting the design of the project to take advantage of these commercial off-the-shelf elements could have substantial cost reduction consequences. It should also be recognized that commercial off-the-shelf products have been developed on the basis of an understanding of the business process for previous initiatives. It may be valuable to consider the nature of these prior business processes before embarking on a complete redesign of the business process for your project.

Providing Expertise and Experience

In some cases, the private sector has particular expertise and experience not found in public sector organizations. This is especially true when the private sector resources are drawn from areas beyond transportation. A private sector organization may also have had the opportunity to gain experience over a number of regions and a number of projects. This experience would be very complementary to the public sector agency experience, which offers greater detail for a single region. The specialist resources could be particularly important in both the planning and design stages of a project. In many cases, private sector organizations have specialist expertise in operations, maintenance, and management. In addition to providing expertise, the private sector may also be able to deliver the resources required to help plan, design, build, operate, maintain, and manage the project. Not every public agency has the in-depth operational experience or expertise required to successfully execute an electronic payment systems payment project.

Providing Finance

In today's economic conditions, the public sector may not always have the resources required to fund the project. It may be possible that the private sector could provide financing for a project if a suitable compensation mechanism can be defined. Electronic payment systems are particularly suitable for this approach because they have an inherent charging mechanism. For example, a fee could be applied to every transaction to compensate the private sector for financing resources invested in the project. Experience has shown that this approach requires careful structuring of the business model and contractual agreements.

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Illustrative Examples of Electronic Payment Systems

Based on research into a number of leading electronic payment systems, the following illustrative examples have been identified. These examples provide information on the nature of each project, the partners involved, the technologies utilized, and the overall benefits achieved through the implementation of the project. The following figure provides a brief description of each example and the web reference for detailed information.

Figure 19. Illustrative Examples Summary

Name of Project	Description	Web Link
ORCA Card	Implemented a single smart card for bus, rail and ferry services in the Seattle Metro area. Single card, multiple modes, multiple service providers	www.orcacard.com
New Jersey Transit Google Wallet trial	Trial of smart-phone technology to pay for transit fares in New Jersey with Google Wallet	www.reuters.com/article/2010/09/21/usvisamobileidUSTRE68K2DG20100921on February 2 2013
New York and New Jersey NFC payment trial	Trial involving MasterCard and Visa on the use of smart-phones with NFC technology for transit fare payment	www.reuters.com/article/2010/09/21/usvisamobileidUSTRE68K2DG20100921
Houston Katy Freeway Express Lanes	Dynamic tolling on express lanes retrofitted in the median of major freeway	www.hctra.org/katymanagedlanes/how_it_works.html on January 31 2013
WMATA Washington, DC – SmarTrip	Smart card system for paying bus and Metro fares in Washington, DC	www.wmata.com/fares/smartrip/
CTA Chicago Card	Smart card system for paying bus and Metro fares across multiple operators in the Chicago Metropolitan Area	www.chicagocard.com/ccplus/firsttime.aspx
I-15 FasTrak Tolls San Diego	First implementation of dynamic tolling on express lanes in the USA	www.sandag.org/uploads/publicationid/publicationid_6_1065.pdf
E-ZPass Group	Coalition of agencies in the North East sharing interoperable electronic toll collection system and central clearing/settlement	www.ezpassiag.com/aboutus/overview
Oregon Mileage based Road User Fees	Pilot projects and legislation development to replace fuel based taxation with distance based	www.oregon.gov/ODOT/HWY/RUFPP/pages/rucpp.aspx

We will discuss two of these examples in more detail in the following sections.

I-15 FasTrak Tolls San Diego

This project was conducted by the San Diego Association of Governments and features express lanes on I- 15 from State Route 163 to State Route 78. The project features a movable barrier that enables the number of lanes in each direction to be changed for both morning and evening peak hours. Use of the express lanes is free for carpools, vanpools, and transit vehicles. Solo drivers are charged a fee on a per mile basis. The fee is varied according to traffic conditions along the corridor. Traffic sensors along the corridor provide data regarding current traffic flow conditions and this data is fed into a specially developed algorithm that determines the appropriate level of fee. This was the first example in the United States of dynamic tolling applied to manage congestion.

E-ZPass Group

The E-ZPass program is the largest, most successful, interoperable toll collection program anywhere in the world, consisting of 25 agencies in 15 States, servicing more than 14 million accounts, 24 million tags, and the collection of more than $6 billion dollars in electronic toll revenues. The group started in 1987, when several toll agencies along the northeast corridor began to explore potential regional application of ETC. In 1997, toll facilities joined to form an alliance known as the E-ZPass interagency group (IAG). The group strives for interoperability among all the member agencies. This includes sharing business rules, file specifications, documents, plans, and other interoperability information. The group conducts collective procurement and makes use of single standard technology across all members.

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Lessons Learned

A series of interviews with the Transport for London staff responsible for the London Congestion Charging Project provides the following summary of challenges and issues for the successful implementation of ETC. The lessons learned were summarized as "the 7 Ps": politics, power, problem, program, procurement, project management, and performance. Each lesson is described in the following sections.

Politics

This encompasses the ability to gain and retain political support for the project by communicating the value of the services to be delivered. This requires a structured outreach program to initially communicate the value and benefits of the program to political decision makers. The outreach must then continue to ensure the political support gained during the initial communications is maintained throughout the life of project implementation. It should be noted that additional policy requirements can drive up the cost of the project.

Power

It is necessary to ensure that any legislation or lawmaking required to allow the project to be implemented has been addressed at an early stage. In London, the requirements were defined, debated, and passed into law several years before it was decided to go ahead with a congestion pricing implementation.[19] This provided Transport for London the advantage of public debate well ahead of any implementation decision supporting rational, non-emotional discussion of the subject.

Problem

It is essential to develop a clear, concise definition of the problem in terms of the needs, issues, problems, and objectives to be addressed. This includes the definition of the value proposition for the end user. The preparation of a structured problem statement is of significant value in this respect.

Program

This includes the definition of a structured program to implement the project. A series of projects may be defined, phased, and linked together to achieve the overall objective.

This requires a clear understanding of technology capabilities and the selection of a business model to ensure that technology capabilities are matched to the selected business model. This also requires effective communications and planning, strong institutional cooperation, a complete economic and financial analysis, and a detailed effects analysis.

Procurement

The procurement approach should be selected on the basis of minimizing life-cycle costs and risks. It should incorporate clearly defined requirements and seek simple, well-understood solutions. As discussed earlier, requirements should be as free from ambiguity as possible. The objective of procurement should be to try to acquire products and services that are flexible, scalable, and preferably feature the use of open standards and architecture. An early interactive dialogue with potential product and service providers through the use of a request for information process can be very enlightening. This provides information on current technology capabilities and limitations and will also help to define service and product provider's capabilities and constraints. This can ensure that the requirements and the procurement documents are realistic and practical.

Project Management

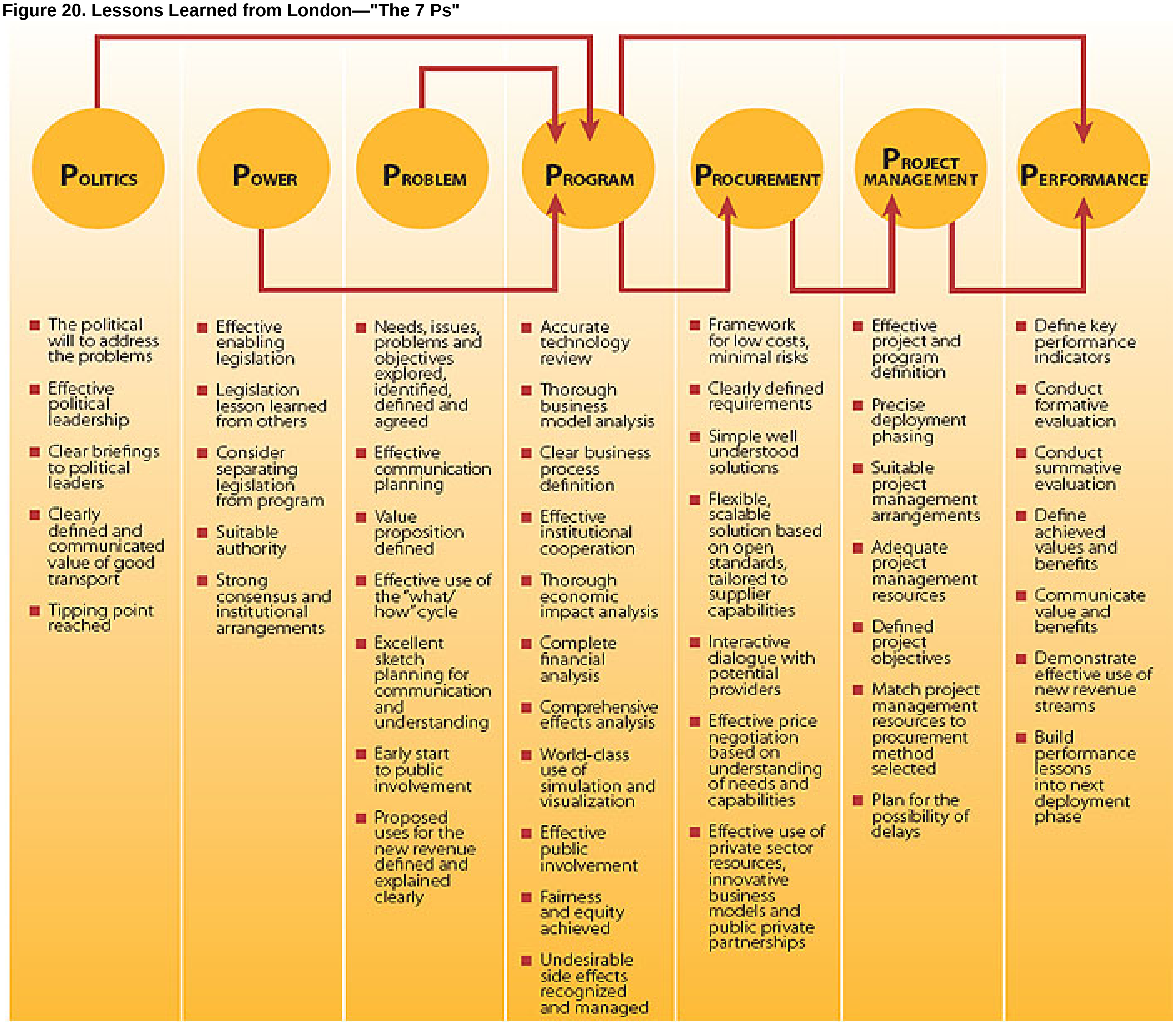
Project and program definition includes the use of best practices for deployment planning and phasing. This ensures that sufficient project management resources are made available on both the public and private sector sides. This also requires a clear definition of project objectives and the definition of a contingency plan for possible delays. New public agencies have the in-house expertise to plan, procure, manage the deployment, and implement a modern ETC system. In many cases, specialized assistance is required.

Performance

Performance management for ETC projects supports both summative and formative approaches. The summative approach would incorporate lessons learned at the end of the project and provide information to guide subsequent projects. The formative approach would provide information that can be used to guide the project in real time and to keep the project on course. In the ETC industry, performance is a term often used to gauge the efficiency of system operation. It is a metric used to verify the system does what it is supposed to do. Performance metrics are also established to monitor and manage operations.

These important lessons learned are detailed further in the following figure.

Figure 20. Lessons Learned from London—"The 7 Ps"



(Extended Text Description: This diagram shows the lessons learned from the London and Stockholm congestion charging projects. At the top of the diagram of a series of seven text ovals with a column of notes under each. The ovals have arrows pointing to various other ovals, showing a relationship between certain categories. From left to right: The first column has a text oval "Politics" with an arrow pointing to the middle text oval "Program." Under "Politics" are the following bullet points: The political will to address the problems; Effective political leadership; Clear briefings to political leaders; Tipping point reached. The second column is headed by the text oval "Power" which has an arrow pointing to the "Program" oval. Under "Power" are the following bullet points: Effective enabling legislation; Legislation lesson learned from others; Consider separating legislation from program; Suitable authority; Strong

consensus and institutional arrangements. The third column is headed by the text oval "Problem" with an arrow pointing to the "Program" oval. Under "Problem" are the following bulleted points: Needs, issues, problems and objectives explored, identified, defined and agreed; Effective communication planning; Value proposition defined; Effective use of the "what/how" cycle; Excellent sketch planning for communication and understanding; Early start to public involvement; Proposed uses for the new revenue defined and explained clearly. The fourth (middle) column is headed by the "Program" oval. It has two arrows, one pointing to the "Procurement" oval and one to the "Performance" oval. Under "Program" are the following bullet points: Accurate technology review; Thorough business model analysis; Clear business process definition; Effective institutional cooperation; Thorough economic impact analysis; Complete financial analysis; Comprehensive effects analysis; World-class use of simulation and visualization; Effective public involvement; Fairness and equity achieved; Undesirable side effects recognized and managed. The fifth column is headed by the "Procurement" oval with an arrow pointing to the "Project Management" oval. Under "Procurement" are the following bullet points: Framework for low costs, minimal risks; Clearly defined requirements; Simple well understood solutions; Flexible scalable solution based on open standards, tailored to supplier capabilities; Interactive dialogue with potential providers; Effective price negotiation based on understanding of needs and capabilities; Effective use of private sector resources, innovative business models and public private partnerships. The sixth column is headed by the oval "Project Management" with an arrow pointing to "Performance." Under "Project Management" are the following bulleted points: Effective project and program definition; Precise deployment phasing; Suitable project management arrangement; Adequate project management resources; Defined project objectives; Match project management resources to procurement method selected; Plan for the possibility of delays. The final column is headed by the oval "Performance" with the following bullet points underneath: Define key performance indicators; Conduct formative evaluation; Conduct summative evaluation; Define achieved values and benefits; Communicate value and benefits; Demonstrate effective use of new revenue streams; Build performance lessons into next deployment phase.)

Matching the Business Model to the Capabilities and Constraints of the Technology

There are many significant examples of the use of ETC technologies in Stockholm, Sweden and in London, United Kingdom. Considering the London example, it was decided to make use of license plate readers rather than using an in-vehicle transponder or tag because this is a less invasive way to conduct ETC. This also enabled Transport for London to avoid a large-scale exercise in acquiring transponders or tags and installing them in vehicles, thus reducing the initial cost of the project. It was decided that transponders or tags could be used in later stages of the project as necessary.

The technology for license plate recognition using video cameras and image processing is not as accurate as transponders or tags. Transport for London understood the constraints associated with the technology choice. At the time the system was implemented in 2003, license plate recognition could produce a sustainable accuracy of around 75 percent. This is low compared to transponder or tag-based systems that can deliver an accuracy of 99.99 percent, but the system was made viable by the choice of an appropriate business model. Transport for London had two major choices when it came to the policy regarding charging. Choice number one was a cordon crossing-based system, in which drivers would be charged for crossing an imaginary line in the road drawn around the pricing zone.

Choice number two was for drivers to pay for being present inside the zone. The latter business model was selected because it fits best with the technology constraints of the license plate reading system. This business model enables multiple locations for license plate recognition to be integrated into the design for the system. Retrospective analysis using the system indicates that there are at least 11 possible opportunities to detect a vehicle inside the charging zone. This allows probability multiplication, meaning that the probability of a vehicle having been detected inside the charging zone rises to more than 95 percent. Because it was well matched to the technology, the business model allowed for a viable solution at the desired price point.

Another way the business model was fine-tuned to the technologies related to the adoption of multiple payment channels. When the system was launched, drivers had the choice to pay by telephone, by web, or at a retail outlet. Transport for London monitored the number of drivers choosing each option. They also monitored the cost of operating each option and targeted their marketing effort to encourage drivers to use lower cost payment channels. This minimized the cost of operation of the system and maximized the revenue that would be returned to the transportation network for improvements.

Understanding the Marketing Resources Required

An ETC and pricing system requires the establishment of a close customer relationship. It is not a case of building a facility and then having minimal contact with the user afterward. A strong relationship between the operating agency and the customer takes the form of a customer service relationship and a billing and invoicing relationship. Customers also feel more directly connected when they pay as close as possible to the point of service. These considerations increase the need for world-class customer relationships and increased marketing resources.

One of the major lessons of electronic payment systems implementation is that these projects require a higher percentage of marketing resources than most asphalt, concrete, and steel projects. Electronic payment systems applications are complicated and there is an important need to engage the customer. The customer is part of an ongoing dialogue with the operating agency. Under the circumstances, marketing resources are required at a much higher level. For example, in the London congestion pricing system, approximately 10 percent of the total project budget was set aside for marketing. This is very high compared to the typical asphalt, concrete, and steel projects in the United States. The commitment of significant resources also means that there should be a coordinated marketing plan and the marketing planning should be well defined, clear, and concise. It should be noted that the London implementation introduced a mandatory charge for vehicle presence inside a zone and required a considerable amount of marketing and outreach resources. In the context of toll roads, express lanes, managed lanes, and value pricing in the United States, effort can be focused on public relations in lieu of marketing and utilizing press releases and other means to get existing media channels to inform the public about the project and how best to take advantage of it. If one is particularly astute, these public service announcements can gain marketing advantage at little or no cost.

Avoiding Technology Lock In

ETC and pricing systems should be designed with maximum flexibility in mind. System designers should strive for device interoperability, enabling elements from one vendor to be replaced with elements from another vendor with no disruption to the operations of the system. Systems should support back office interoperability, in which one ETC back office can talk to another to exchange information regarding tolls for managed lanes, tolls for toll roads, ticketing for transit fee collection for parking, and non-transportation small-volume transactions.

Avoiding Operations Lock In

Another thing to consider is what could be referred to as operations lock in. It is like technology lock in, in which a public agency finds it difficult to change vendors. In this case, the vendor is providing operations resources rather than products. This can happen when a particular vendor is offered a long-term contract to operate and manage an ETC and pricing system. The organizational arrangements, the technical arrangements for project administration, and the overall design of the system may be such that the incumbent operator is locked in and it becomes very difficult for the client to replace the vendor if necessary. One important way to mitigate this effect is to ensure that transitional arrangements are defined in the initial service contract. It is essential to look beyond the end of the operating period and consider what the "get out" approach will be. How will the incumbent operator be gracefully phased out of the project and the new operator phased in? This includes handover arrangements for hardware, software, data, people, and management.

One of the major lessons learned with modern ETC systems (ORT and AETC) is the need for a violation enforcement and collections function supported by the ETC, as well as enough teeth in local legislation to enable the toll operator to impose and collect penalties from those who choose to defraud the system. Lack of accuracy and latency in DMV databases is also an increasing problem in this regard.

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Benefits and Costs

Benefits

A summary of the benefits that have been experienced through the implementation of the various types of transportation electronic payment systems[20] is provided in the following figure. Where possible, quantified benefit information has been provided. When this information is not available, then a description of the benefit has been provided.

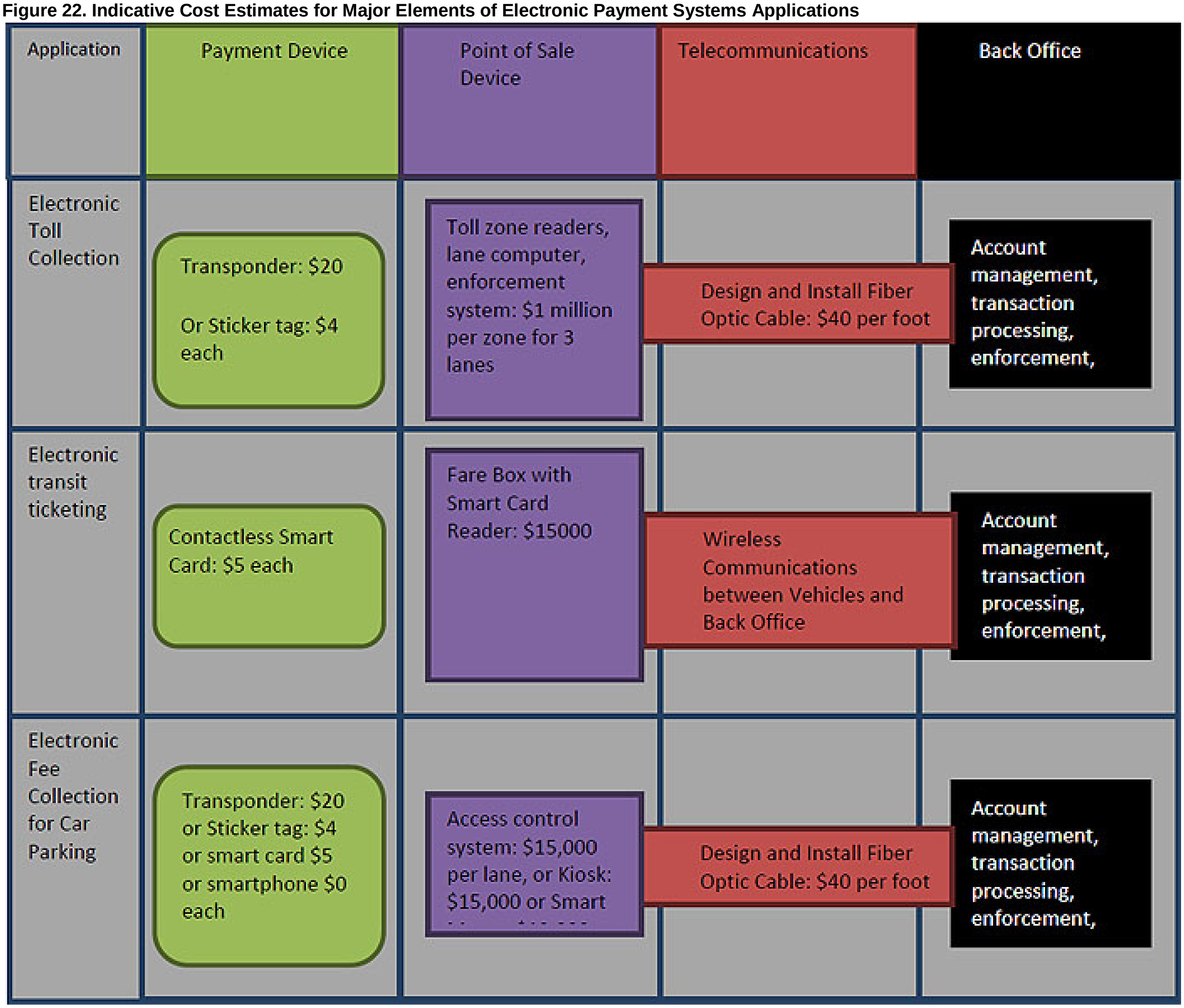
Figure 21. Benefits of Electronic Payment Systems

Application	Benefits Experienced		
	Safety	**Efficiency**	**Customer Service**
Electronic toll collection	In Florida, the addition of open road tolling (ORT) to an existing electronic toll collection (ETC) mainline toll plaza decreased crashes by an estimated 22 to 26%.	In Florida, the addition of ORT to an existing ETC mainline toll plaza decreased delay by 50% for manual cash customers and by 55% for automatic coin machine customers, and increased speed by 57% in the express lanes.	In Japan, a field test found that conventional toll collection takes an average of 14 seconds per car, while ETC takes only 3 seconds per car.
	In Europe, evaluation reports show that ETC can decrease traffic volumes by up to 17%.	The E-ZPass electronic toll collection system on the New Jersey Turnpike reduced delay for all vehicles by 85%, saving an estimated 1.2 million gallons of fuel each year and eliminating approximately 0.35 tons of VOC and 0.056 tons NOx per weekday.	In California, electronic toll collection on the Carquinez Bridge saved 25,193 hours per year by improving traffic movement through the toll facility and reducing the time required to process transactions.
Dynamic tolling and pricing	The same benefits as electronic toll collection with the addition of congestion reduction benefits.		During the planned expansion of the I-15 HOT lanes in San Diego a survey of facility users found that 71% considered the extension fair with few differences based on ethnicity or income.
Electronic transit ticketing	The removal of cash from the point-of-sale (farebox) of the transit system increases the safety of both passengers and operators.	In Manchester, UK, transit smart cards that improve data accuracy and reduce data collection costs saved $1.5 million.	Fare collection systems that use electronic tickets or passes can reduce passenger boarding times by 13% compared to driver operated systems that require exact change.
			Proof of payment systems that use ticket vending/validating machines can reduce boarding times by up to 38%.
		A Bay Area Rapid Transit (BART) smart parking system encouraged 30% of surveyed travelers to use transit instead of driving alone to their place of work.	In Chicago, a CTA survey of smart card users found that features related to convenience, rail use, and speed were most liked by program participants; 21% rated convenience over the magnetic stripe card as their single favorite feature of the system. The most desired features were the multiuse functions and ability to recharge the smartcard via the internet and credit card.
Electronic parking fee collection	The removal of cash from the point-of-sale in the parking system increases the safety of both parking users and operators. Balance recovery also improves personal safety	Implementation of ITS with AVI, real-time passenger information, and electronic fare media in a midsized transit system resulted in a minimum 3.9:1 benefit/cost ratio.	Survey data indicates the most popular reason commuters use smart parking is that a parking spot will be available when they need it.

Costs

Capital cost estimates based on experience from previous implementations[20] have been developed for each type of payment system and for each element. They are depicted in the following figure. Note that these are indicative estimates for planning purposes only, because detailed costs can only be established after a detailed design has been completed. There are multiple design choices and local factors that influence the cost of a project, including the quantities of devices and point-of-sale devices acquired, the size of the transit fleet to be equipped, telecommunications systems bandwidth needs, and existing infrastructure. The financial gain in forming partnerships and integrating systems is also obvious. For example, the same transponder or tag could be shared between ETC and electronic fee payment for car parking. All three applications could share a single back office with appropriate operations staff cross training.

Figure 22. Indicative Cost Estimates for Major Elements of Electronic Payment Systems Applications



(Extended Text Description: This chart organizes the typical cost elements. The top row (left to right) reads "Application," "Payment Device" (green), "Point of Sale Device" (purple), "Telecommunications" (red), "Back Office" (black). The second row reads (left to right): "Electronic Toll Collection," "Transponder: $20 Or Sticker tag: $4 each" (green), "Toll zone readers, lane computer, enforcement system: $1 million per zone for 3 lanes" (purple), "Design and Install Fiber Optic Cable: $40 per foot" (red), "Account management, transaction processing, enforcement, billing and customer service hardware, software: $400,000" (black). The third row reads (left to right): "Electronic transit ticketing," "Contactless Smart Card: $5 each" (green), "Fare Box with Smart Card Reader: $15000" (purple), "Wireless Communications between Vehicles and Back Office" (red), "Account management, transaction processing, enforcement, billing and customer service hardware, software: $400,000" (black). The fourth row reads (left to right): "Electronic Fee Collection for Car Parking," "Transponder: $20 or Sticker tag: $4 or smart card $5 or smartphone $0 each" (green), "Access control system: $15,000 per lane, or Kiosk: $15,000 or Smart Meter: $10,000" (purple), "Design and Install Fiber Optic

Cable: $40 per foot" (red), "Account management, transaction processing, enforcement, billing and customer service hardware, software: $400,000" (black).)
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Summary

The main focus of this module is to introduce you to ETC and congestion pricing. Most ETC systems are connected with a credit card account. Money is routinely transferred from a user's credit card to a prepaid toll account. It is expected that, in the future, ETC will be more closely integrated with all forms of electronic payment in a region. As such, multimodal electronic payment systems applications will support payment for transit ticketing, for car parking, and for toll collection, as well as non-transportation fee collection. For this reason, we have taken the time to define electronic payment systems applications and set ETC within the wider context of payment systems for transportation. Electronic payment systems applications are described in the following sections.

Electronic Payment Systems Applications

These support electronic payment for a huge range of non-transportation items, from retail to airlines. In fact, many airlines will no longer accept cash for on-board purchases, requiring the use of a credit or debit card. This segment of the electronic payment market dwarfs the transportation segment, and most of the innovation in the electronic payment systems applications domain happens in this segment. This includes electronic funds transfer (EFT), ecommerce, and online banking services. EFT accounts for a large part of the value transferred as transactions tend to be very large.

Electronic Payment Systems Applications for Transportation

Electronic payment systems applications for transportation include transit ticketing applications, car parking applications, and ETC applications.

Electronic Toll Collection

ETC involves the use of dedicated short-range communications technologies to support nonstop transaction processing between a suitably equipped vehicle and roadside equipment. As the vehicles pass through a toll zone, a transponder or tag fitted to the vehicle is read by roadside equipment. This identifies the vehicle and enables a toll amount to be deducted from a prepaid account. The transponder or tag sends a unique identification number to the roadside reader which, in turn, sends the information to a roadside computer. The roadside computer has data that links each identification number to a unique account number. This data is transferred to a back office system, which deducts the appropriate toll from the account and adjusts account records accordingly. Because it supports nonstop operation, ETC also paves the way for the use of pricing techniques such as value pricing and congestion pricing.

Electronic Transit Ticketing

According to the Smart Card Alliance,[3] there were 15 million smart cards and 20,000 smart card readers in use by U.S. transit agencies in 2006. These days electronic transit ticketing involves the use of a smart card to make payment for trips on a transit vehicle. The smart card can hold the balance available on the card itself or can simply be used as an account key to deduct money from a central account, similar to toll collection. The user can add additional funds to the card at transit agency offices, at participating retail outlets, and on the web by transferring money from a credit card.

Electronic Parking Fee Collection

According to the Smart Card Alliance,[3] public parking constituted an approximately $17 billion industry in 2006. This was composed of systems, equipment, facilities maintenance, and a variety of services, including revenue management. More than $1 billion was spent annually on parking revenue control systems, software, equipment, and related support services.
Both off-street and on-street parking applications can be supported by electronic fee collection. In the case of off-street parking, there are a number of access point technologies and pay-on-foot technologies that can be used. Similarly for on-street parking, smart parking meters and pay-on-foot parking kiosks can be utilized to allow drivers to pay without cash either using a smart card or a cell phone.

Regional Multimodal Electronic Payment Systems Applications

When all modes of transportation are addressed by one single payment system, this is known as a regional multimodal electronic payment system. It is worth noting that while there may be one single payment system, there may be different payment devices. For example, vehicle-based payment can be achieved by transponder or tag while personal-based payments such as ticketing for transit systems can be accomplished with a smart card. The same account can be used for both even if different payment devices are used. The advantage of a regional multimodal approach is that it offers more management solution possibilities after the system has been installed. For example, conditional discounts could be offered whereby users of the transit system on one particular day may be offered free parking downtown for another day when they decide to take their car.

A considerable amount of implementation experience has been gained. Based on the results of that experience, a number of lessons learned and practical insights have been defined. Practical experience has provided a rich vein of information on how best to plan, design, operate, and manage electronic payment systems applications for transportation. This includes lessons in legislation, harnessing the power of the private sector, and the identification of challenges that need to be addressed. Over the past few years the focus seems to have shifted. From a fascination with the implementation of technology we have moved to a new emphasis on defining the management solutions that can be supported and employed once we have the technology in place. As a result of the availability of proven technologies, transportation professionals have more management solution options for demand management and operational efficiency than ever before. It is a great time to be transportation professionals.

Turning our gaze from the past to the future, there are some great opportunities and a few challenges on the horizon. Our management solutions portfolio could become significantly larger as new technologies are introduced. For example, there has been considerable progress made in improving the accuracy of the Global Positioning System (GPS). There are already serious discussions regarding the use of a higher accuracy GPS for tolling purposes. This would give transportation professionals further options and considerable flexibility in imposing dynamic tolling across wider networks. It would be possible to implement not just the distance-based fee system but the fee system that William Vickrey envisioned in 1959, in which the toll is proportional to road use, the class of the vehicle, the time of travel, and the location. Such technology would also support any political aspirations to "charge anything that moves" and use the revenue generated for wider purposes beyond transportation.

We are also seeing the embryonic stages of regional, multimodal electronic payment systems applications. As these continue to develop, we should see very sophisticated systems that take full advantage of cost sharing and deliver a range of services, including transportation payment. Such systems could deliver a wide spectrum of transportation performance management data and offer the flexibility to apply management solutions that are not currently feasible; for example, the ability to offer a transportation user a conditional discount for good traveler behavior. This discount could come in the form of free or reduced cost parking on another occasion. There are already private sector programs to link customer loyalty to transportation. These programs allow shoppers in participating grocery stores to accumulate discounts that can be used to reduce the cost of gas. The advent of fully functional regional multimodal transportation payment systems could herald the dawn of a new set of management solutions for demand management. An intriguing possibility is the use of the congestion avoidance rewards approach to reverse the current psychology and reward travelers for good travel behavior.

The implementations in Stockholm and London, along with a large number of pricing implementations in the United States, provide a strong platform for learning practical lessons. As these programs develop, we are likely to see the evolution of a new breed of transportation professional with customer relationship management and management solutions skills. As we migrate from an intense focus on how to implement the current systems, we will move to a new emphasis on how to make the best use of the new capabilities that are provided. A new era awaits us; it is going to be an even better time to be a transportation professional.

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Additional Resources

The following additional resources can be used to gather more information and practical insight into electronic payment systems applications, ETC, and pricing:

- For ETC: The International Bridge Tunnel and Turnpike Association. Website: www.Ibtta.org
- For electronic ticketing systems for transit: Intelligent Transportation Society of America. Website: www.itsa.org and the American Public Transportation Association. website: www.apta.com
- For pricing: Federal Highway Administration Value Pricing Program Website: www.ops.fhwa.dot.gov/tolling_pricing/value_pricing/ and Federal Highway Administration Technologies That Enable Congestion Pricing—a Primer. Website: http://ops.fhwa.dot.gov/publications/fhwahop08042/cp_prim2_05.htm
- For electronic fee collection for car parking: The Smart Card Alliance. Website: www.smartcardalliance.org

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Terminology

The following list provides definitions for all essential terminology used in this module.

All Electronic Toll Collection (AETC)	The operation of a highway facility where there is no cash option to pay for the use of the facility and tolls are collected by transponder or tag based electronic toll collection or by video tolling
American Association of State Highway Officials (AASHTO)	An association of leaders in highways and transportation from each State in the USA
Anti pass back	A feature of electronic fee collection for car parking systems and some transit ticketing systems that prevents a proof of payment to be transferred and used again by the next customer
Average trip cost	The cost of the trip before value or congestion pricing. Can include delay time and the cost of operating the vehicle
Bar Coded Boarding Pass Initiative	An initiative of the International Airline Transport Association (IATA) to use bar codes on paper boarding passes to speed processing and to use three-dimensional bar codes for mobile boarding passes on smart phones, avoiding the need for a paper pass
Business Process	The definition of the activities and work products required to accomplish a task or run a business operation
Channelized Toll Plaza	A toll facility where traffic is channeled past a number of toll booths or payment points requiring that vehicle slow down. Some facilities also have barriers across the lanes that are raised after payment
Closed Circuit Television Camera (CCTV Camera)	Camera that is connected to copper or fiber optic telecommunications network that is dedicated to the specific purpose. The term closed circuit refers to the fact that the images

	from the camera are relayed along a closed circuit and not broadcast like commercial television
Congestion Pricing	Variable tolling implemented to achieve a level of service objectives by taking advantage of the relationship between trip cost and traffic volume
Contactless Payment Systems Technology	Payment devices and mechanisms that require no physical contact between a payment device and the associated reader or acceptor
Credit Card	Payment device made of plastic with magnetic stripe or smart chip memory with an embossed account number and accent holder name. The card carried identification information that acts like a key to an online account. Users swipe that card or quote the card number in order to pay for goods and services in person, on the web and over the telephone. The funds are added to the account balance which has a pre-agreed monthly credit limit. The user settles the bill at the end of each month.
Debit Card	Like a credit card but has no credit line. The card is linked to a bank account and funds for purchases are deducted from the account immediately.
Dedicated Short Range Communications (DSRC)	Relatively short range communications in the 914 MHz or 5.8 GHz band range used to communicate between the vehicle and roadside equipment for Electronic Toll Collection
Digital Video Recorder (DVR)	A device that stores video images in digital form on either a hard disk or solid-state memory. It also has an operating system that allows the storage of the images to be managed and selected images retrieved as required. For dynamic tolling applications this device would be integrated into a larger system
Dynamic Message Sign (DMS)	Often referred to as variable message signs or changeable message signs. These are roadside devices that display configurable messages to drivers. They are typically connected to a fiber optic telecommunications network to a traffic management center. An operator at the traffic management center can input the message and have it displayed on one or more roadside dynamic message signs. For dynamic tolling purposes this technology is used to communicate the prevailing toll for each segment of road to the drivers. They are typically placed sufficiently far in advance of the decision point in the network that the driver can see the message and then take a decision on the basis of the tolling information
Dynamic Pricing	A pricing structure in which charges are regularly adjusted according to traffic conditions to maintain a free flowing level of traffic, increasing when the lanes are relatively full and decreasing when the lanes have extra capacity. Traffic sensors on the road facility being managed and sometime on parallel routes are used to continually monitor the traffic conditions

Dynamic Tolling	Use of traffic sensors and electronic toll collection technology (open road) to vary the price for using a road facility at regular intervals
Elasticity of demand	The change in demand divided by the change in price for a commodity
electronic payment system	A system that has been designed and implemented to enable cash free payment for good s and services using payment device, reader, telecommunications and back office technologies
Electronic Toll Collection (ETC)	Electronic systems that collect tolls, eliminating the need for tollbooths and for vehicles to stop to make payment.
Express Bus Service	Bus service with a limited number of stops, usually at a higher speed; when in a dedicated right-of-way, it is sometimes referred to as Bus Rapid Transit (BRT). Typically the vehicles used are of a higher standard to encourage use of the BRT as an alternative to a private car commute. BRT services gain important journey time reliability when operated on express lane facilities
Express Lane	A limited access road facility where users pay a fee for the use of the facility or qualify for free use due to the number of occupants in the vehicle
FeliCa	A smart card for transportation standard developed by Sony
Fiber Optic Communications	The transmission of voice video and data as pulses of light along very thin glass strands. Equipment of the ends of each fiber cable converts electronic pulses to light pulses. This telecommunications technique is capable of transmitting very high volumes of data over large distances. The fiber optic cables can be installed in conduits and buried underground, or can be attached to poles as an aerial installation
General Purpose Lanes	Limited access lanes on which no toll or fee is charged. These are usually operated in parallel with express, high occupancy toll or managed lanes
Headway	This is the distance from the back of one vehicle to the front of the next, typically measured in feet
High Occupancy Toll Lane	A high occupancy vehicle lane in which vehicles that do not meet the occupancy requirements are permitted to use the facility in return for the payment of a toll. This enables the use of excess capacity on high occupancy vehicle facilities.
High Occupancy Vehicle Lane	A road facility that is dedicated to those vehicles that meet a predefined occupancy standard. For example, high occupancy vehicle 2 facilities allow vehicles that have 2 or more occupants to use the facility. Transit vehicles, emergency vehicles and motorcycles are also permitted to use the facility.

Highway Trust Fund	The United States Highway Trust Fund is a transportation fund which receives money from a Federal fuel tax of 18.3 cents per gallon on gasoline and 24.4 cents per gallon of diesel fuel and related excise taxes. It currently has three accounts, the Highway Account which funds road construction, a smaller 'Mass Transit Account' which supports mass transit and also a 'Leaking Underground Storage Tank Trust Fund'. It was established 1956 to finance the United States Interstate Highway System and certain other roads. The Mass Transit Fund was created in 1982. The Federal tax on motor fuels yielded $28.2 billion in 2006.] In 2008 the fund required an additional $8 billion from general taxation due to reduced receipts from fuel tax in order to meet its obligations.
Institute of Transportation Engineers	An institute for the promotion of transportation engineering in the USA.
Intelligent Transportation Systems Society of America (ITSA)	A society that promotes the advancement of Intelligent Transportation Systems application and adoption in the USA. This includes the exchange of information
International Bridge Tunnel and Turnpike Association (IBTTA)	A society that promotes the interests of toll operators, suppliers and consultants worldwide. This includes the exchange of information
Leakage	A term used to describe the loss of revenue in an electronic payment system. With regard to electronic toll collection it can refer to certain traffic movements that are not charged on a toll system as there are insufficient toll zones or toll plazas to address every entrance and exit. In electronic toll collection, electronic transit ticketing, and electronic fee collection for car parking, leakage is also used to describe losses of revenue due to fraud or errors in accounting
Level of Service	This is a measure of traffic conditions specified in the Highway Capacity Manual and in the AASHTO green book
Limited Access Highway	A limited access road known by various terms worldwide, including limited access highway, dual carriageway and expressway, is a highway or arterial road for high-speed traffic which has many or most characteristics of a controlled access highway (freeway or motorway), including limited or no access to adjacent property, some degree of separation of opposing traffic flow, use of grade separated interchanges to some extent, prohibition of some modes of transport such as bicycles or horses and very few or no intersecting cross streets
Managed Lane(s)	A lane or lanes that are used to increase roadway efficiency through management of operations and access.
Margin al trip cost	The cost of making a trip once a congestion for value pricing fee has been superimposed on the average trip cost
Maximum toll	This is a maximum amount in dollars or cents that will be charged for a trip along the variable tolling facility. It is often specified in terms of a Per mile charge. For example One dollar per mile

Minimum toll	This is a minimum amount in dollars or cents that will be charged for a trip along the variable tolling facility. It is often specified in terms of a Per mile charge. For example $.25 per mile
Modal shift	I dynamic tolling of pricing techniques the objective of reducing the volume of traffic by encouraging some drivers to use an alternative mode of transportation
Near Field Communications (NFC)	Communications standard that enables one smart phone to exchange data with another one. Data can also be exchanged with a payment system allowing contactless payment operation
Noncash transactions	Payment for goods or services by means other than cash. Such as credit cards, debit cards, PayPal or special purpose payment systems for transportation
Nonstop tolling	The collection of tolls or fees at normal road operating speeds
Objective point	The point on the demand curve where marginal trip cost and the target traffic volume meet
Open Road Tolling (Open Road Tolling)	Electronic toll collection using overhead gantries and no traffic channelization
Pay on foot	Payment kiosks that require the driver to walk from his vehicle and make a payment for car parking either before or after parking
Payment Cards Industry Standard (PCI)	A data security standard for payment systems data developed by the credit card industry
Peak spreading	I dynamic tolling or pricing technique with the objective of spreading the same volume of traffic over a longer time.
Personal Based Payments	Payments that relate to personal use of goods or services rather than those related to a vehicle
Pre-paid Toll Account	A special purpose account that contains funds that are deducted to paying tolls. Funds are paid in by cash at a service center or transferred from the drivers credit card
Republished toll schedule	A schedule of toll rates that specifies the toll for a specific day, time of day, segment of Highway and class of vehicle
QR Code	A three dimensional bar code data standard
Regional Multi-modal Electronic Payment System	A single payment system capable of handling payments for multiple modes of transportation utilizing several payment devices and a unitary back office structure

Revenue generation	A dynamic tolling of pricing technique while the specific objective is to maximize the amount of revenue being collected by the tolling system. This money is reinvested into transportation network
Smart Card	A credit card sized payment device that can store and process data and communicate with special readers at the point of sale. Transportation smart cards are defined in the ISO/IEC 14443 standard
Smart Card Alliance	A society dedicated to the promotion and advancement of the use of smart car d technologies
Smart parking meter	A parking mater that can accept cash and noncash methods of payment. Some smart meters are also connected to each other and to a back office via a communications network
Smart phone	A cell phone that has memory, processing power, an operating system , a keyboard and a display
Speed	This is the average velocity of a sample of vehicles passing a specified point in the highway. It would be more accurately described as time mean speed
Tag	An ISO 18000 6C standard paper tag used for vehicle identification in Electronic Toll Collection
Three-dimensional bar code	An extension of two-dimensional bar coding that features a square array of black and white areas, arranged in a pattern. A scanner or smart phone can capture the image and turn the pattern into data for proof of payment
Time of Day Pricing	Facility charges that vary by time of day, with charges generally higher during peak periods and lower other times.
Toll adjustment interval	In variable tolling and you toll rate is calculated at regular intervals based on traffic conditions. The toll adjustment interval is the time in minutes between each toll calculation
Toll by Plate or Video Tolling	The use of CCTV cameras and advanced image processing to read vehicle license plates, match the license number to a driver and vehicle licensing database and deduct a toll from a pre=paid account or automatically send a bill
Toll Operating Mode	Variable tolling systems May required to work in more than one toll operating mode. For example there may be three possible operating modes for a variable tolling system. The first mode would be normal routine operation. The second mode would be for evacuation management in which case the tolls on the whole facility would be reduced to zero for a specified period of time. The third mode would be for incident management where the toll is removed because the express lanes facility is blocked or partially blocked because of a traffic incident

Traffic flow density	The number of vehicles present at any given time within a specific period of road. This could be measured as vehicles per kilometer or vehicles per lane per kilometer.
Traffic sensor	A roadside device that is capable of measuring one or more parameters associated with the traffic passing the device location. These parameters could include vehicle speed, headway, and vehicle classification. There are several alternative technologies that can be used for these sensors. These include microwave, inductive loop and video image processing
Traffic volume or flow	The number of vehicles passing a given point in the highway over a specified period of time. Often measured in vehicles per hour
Transaction	The process s through which goods and services are paid for by an exchange of funds from buyer to seller.
Transponder	An electronic tag mounted on a license plate, built into a vehicle, mounted on the vehicle, placed on the windshield or dashboard by which vehicles can be identified at prevailing highway speeds
Trip costs	The total cost of the trip including the cost of operating the vehicle, the drivers time and any tolls paid
Un-tolled equilibrium point	The point on the demand curve where average trip cost and un-tolled traffic volume meet
Value Pricing	Adoption of market principles routinely used in the private sector to bring transportation supply and demand into balance. An example is a system of fees or tolls paid by drivers to gain access to certain roadway facilities providing consistent, free flowing service compared to the alternative toll-free facilities.
Variable tolling algorithm	This is a process that is conducted to calculate toll amounts related to varying traffic conditions. It is often used to describe the software program used to do the toll calculations, but more accurately it refers to the defined process which the software executes
Wi-Fi	Wireless data communications complying with the IEEE 802.11 standards family for local area networking
WMATA	The Washington Metropolitan. Area Transportation Authority. Responsible for operating bus services and Metro services in the capital region