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16. Abstract

This research report focuses on the benefits and technology of electronic toll collection (ETC) systems. In addition, it reviews such issues as design and implementation of ETC systems, along with their operation and cost. Finally, this report reviews ETC system applications both within and outside the U.S.

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ELECTRONIC TOLL COLLECTION SYSTEMS

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Research Project 0-1322
An Evaluation of the Status, Effectiveness, and Future of Toll Roads in Texas

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
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THE UNIVERSITY OF TEXAS AT AUSTIN

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IMPLEMENTATION STATEMENT

This report, the second of three reports evaluating the future and effectiveness of toll roads for the state, identifies the issues associated with electronic toll collection (ETC) systems. Given their potential for reducing collection costs and improving traffic flows through toll collection plazas, ETC systems represent a critical element in the planning of future toll roads in Texas. In terms of implementation, the findings reported herein could prove useful to state transportation planners and policymakers.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

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SUMMARY

This research report focuses on the benefits and technology of electronic toll collection (ETC) systems. In addition, it reviews such issues as design and implementation of ETC systems, along with their operation and cost. Finally, it reviews ETC system applications both within and outside the U.S.

An in-state survey of attitudes towards tolling revealed that a large percentage of the respondents were concerned with delays at toll collection booths (see Report 1322-1 for a complete discussion of the survey). Traditional toll collection booths require a number of operations — stopping the vehicle, lowering the window, finding the correct coinage or valid card — before travelers can continue their journey. These labor-intensive, land-intensive, and time-consuming toll booths impede traffic flows on and off a toll road, resulting in congestion, higher vehicle operating costs, and increased pollutant emissions. To address these concerns, electronic toll collection (ETC) systems have been developed.

ETC systems are comprised of three functional elements: a vehicle-mounted transponder or tag; a roadside communication unit (RCU); and a computer system. Four different ETC technologies are used, including optical/infrared, inductive loop, radio frequency/microwave, and surface acoustic wave/complimentary metal oxide semiconductor systems, with radio frequency (RF) systems being the most popular. There are a number of technical and design issues to address when evaluating ETC technologies. Important technical issues include environmental conditions, recording accuracy, payment systems, and audit control. Design issues include security, communication between vehicle and roadside, equipment reliability, compatibility with other systems, system flexibility, and safety. In addition to these issues, the implementing agency must be aware of emerging standards for ETC, toll booth capacity or throughputs, user privacy issues, enforcement, maintenance, and staffing requirements.

ETC systems have been used successfully nationally and internationally. In addition to reducing bottlenecks at the toll booth, ETC systems also significantly reduce the cost of toll collection. Finally, because ETC systems can reduce the number of required lanes and booths to support throughput, they can significantly reduce labor costs.

CHAPTER 1. INTRODUCTION

Statistics place 60 percent of the nation's roads at substandard levels (Ref 2). This state of deteriorating infrastructure is created when facilities, many of which have exceeded their design lives, are subjected to weight overloading and inadequate maintenance. Simply put, many highway facilities now need major reconstruction.

Yet efforts to rebuild and maintain roadways are constrained by inadequate funding at the state level — that is, funds available from fuel taxes, registration fees, sales taxes, and other traditional sources are insufficient to finance such operations. And as underscored by Neil Schuster, executive director of the International Bridge, Tunnel, and Turnpike Association (IBTTA), "There's no such thing as a free road" (Ref 1). At the same time, the public is becoming frustrated with increased traffic congestion and poor roads. It is estimated that delays caused by congestion in urban areas cost users more than $30 billion annually (Ref 3). Public opinion may soon shift to a position that supports tolls or road pricing as an alternative to tax-based financing, a development that may lead to toll roads becoming popular again. There are three major reasons that toll roads are coming into their own: (1) an interest in new construction and maintenance revenue sources, (2) a movement toward privatization of some government activities, and (3) the new ability to mix funds from public/private, federal/state sources (Ref 2). The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, which encourages the development of modern, highly efficient toll facilities, allows localities to join with the private sector to finance and operate them.

There are 7,481.85 km (4,650 miles) of toll roads in the United States. This number is projected to double over the next 20 years. At present, toll roads represent only a small fraction of the United States highway network (about 8 percent of the total 68,096.10-km [42,322-mile] interstate system) (Ref 4).

1.1 COLLECTING TOLLS

Historically, tolling has been used for revenue collection on major high-capacity arterial highways (e.g., in France and Italy), on some interstate highways (turnpikes) in the United States, and for tunnels and bridges. Generally, toll revenues are used to maintain the highway and to recover the costs of construction. Revenue from tunnels and bridges usually can repay only a portion of the construction cost, being used first to finance necessary maintenance and operations (Ref 5).

At present, revenue collection procedures at most toll facilities require a driver to stop his/her car, open the window or door, and find correct coins or a valid card before continuing his/her journey. As the use of tolls becomes more widely accepted, the drawbacks of this conventional toll collection method will be emphasized. Tollbooths suffer from being land-intensive, labor-intensive (owing to the hiring of toll operators), and time-intensive. Electronic toll collection (ETC) systems are superior to manual methods from the perspective of both the toll agency and the user.

While paying tolls electronically is a relatively new idea, it is based on a well-established group of technologies known as automatic identification. Examples of everyday automatic identification applications include credit cards, automatic teller machine cards, bar codes on supermarket products, security badges or cards for access control, and remote radar aircraft identification (Ref 6). A branch of automatic identification technology includes automatic vehicle identification (AVI), which is defined as the process of identifying a vehicle by a unique identification code number as it passes a sensor. AVI has proved to be effective in transportation industries including railroad, shipping, and trucking.

1.2 ELECTRONIC TOLL COLLECTION (ETC)

One of the most promising applications for AVI lies within the toll industry in the form of electronic toll collection (ETC) systems. ETC can improve the efficiency of revenue collection for toll roads through automation. It will help alleviate congestion at toll plazas, reduce toll collection costs, increase toll booth capacity, enhance audit control, improve fuel conservation, contribute to cleaner air, and reduce driver frustration and time lost. These elements are particularly critical on urban toll facilities that must accommodate large commuter populations.

In many cases, ETC will allow toll agencies to delay or even eliminate physical toll plaza expansion, which translates into added savings and less traveler disruption and delay. ETC should revolutionize toll collection and help improve economic productivity and competitiveness. ETC systems combine computers, communications, and vehicle recognition technology to make toll payments more convenient for drivers and toll collection more efficient for the toll authority.

1.3 COMPONENTS OF ETC

Operationally, ETC consists of three functional elements: a transponder (known as a tag), which is an in-vehicle unit that stores a unique identification code; an interrogator/reader with its associated antennas, which reads a transponder and decodes its identification, also called the roadside communication unit (RCU); and a computer system, which transmits, processes, analyzes, and stores data.

There are additional components that a toll agency may use, such as a means to detect and classify vehicles, and a data processor equipped with an extensive database for calculating graduated tolls, receiving payment, debiting accounts, storing transaction data for audit, transferring funds, and maintaining invalid tag flags. Other elements include methods for providing feedback to patrons regarding account and transaction status, as well as its use as an enforcement strategy.

1.4 OWNERSHIP ARRANGEMENT OF ETC

There are many different ETC system ownership arrangements, including those in which the vendor owns and operates, those in which the agency owns and operates, and arrangements dividing responsibilities between the vendor and the agency. At present, most ETC vendors are flexible with respect to ownership and operation of ETC systems. Toll agencies typically incorporate desired administrative arrangements into their bid specifications.

In the vendor-own-and-operate plan, the toll authority hires an independent contractor to administer the ETC program, giving the contractor responsibility for equipment installation, operation, administration, and maintenance. There is usually an agreement (contract) between the company and the agency stating conditions, terms, and responsibilities.

In the agency-own-and-operate plan, the agency purchases an ETC system and operates the system independently. In this administrative arrangement, the toll agency has complete control over the ETC system, making it completely accountable for successes and failures.

Yet another administrative arrangement is a combination of the other two. The toll agency can lease the equipment with a maintenance contract provision, but handle all operations internally. A toll agency may retain control over whatever aspects it considers appropriate (Ref 7).

1.5 SUMMARY OF REPORT

This report is divided into ten chapters and an appendix. The second chapter discusses the benefits of an ETC system. Chapter 3 discusses available technologies, while design and technical issues are addressed in Chapter 4. Chapter 5 presents implementation issues. Other issues for ETC systems are discussed in Chapter 6, and toll station operations are considered in Chapter 7. Chapter 8 examines the cost of ETC systems, while Chapter 9 reflects on ETC system application. Finally, Chapter 10, the concluding chapter, restates ETC system advantages.

CHAPTER 2. BENEFITS TO AGENCIES AND USERS

This chapter will outline the benefits of electronic toll collection (ETC) systems, both for the toll agency and the toll road users. The ETC system benefits that accrue to each group are listed below.

2.1 ETC AND AGENCY BENEFITS

A toll agency can realize significant ETC benefits. The following is a partial list:

1. Automatic vehicle identification (AVI)/ETC will increase throughput at toll plazas and reduce delays through reduced transaction times. For example, it takes approximately 8 seconds for a person to drive up to a toll booth, lower his/her window, deposit the money or token in the tray, have the machine count it, and receive the green light to proceed (Ref 8). By contrast, a dedicated ETC lane can handle up to 1,200 vehicles per hour (vph), versus an automatic (coin) lane handling 500 vph. Therefore, the plaza experiences an increase in level of service and less congestion with ETC lanes. Moreover, the time savings is even greater when compared with person-operated toll booths.
2. ETC systems will allow toll agencies to delay or even eliminate physical toll plaza expansion, which translates into additional savings (construction, land acquisition, and equipment) and less disruption and traveler delay.
3. ETC allows significant opportunities for operating cost reduction through toll collection automation and staff reductions. It also improves security by eliminating physical money handling transactions in the toll lane, eliminating cash handling (sorting, counting, and transporting), fraud, and error; also, it improves accountability.
4. ETC systems can improve handling of commuter-discount programs. This means there are fewer opportunities for patron or staff abuse (e.g., pocketing funds). ETC systems are able to immediately identify a vehicle and verify its authority to continue traveling; and, with video cameras for enforcement, non-payment can be controlled.
5. Enhanced audit control is possible with AVI/ETC systems. Non-ETC systems tie vehicles, transactions, variances, and monies collected together through a long, tedious paperwork review. A sampling system is used for checks and balances. An integrated toll system can eliminate paper passes, most unusual-occurrence forms, and all transaction discrepancy reports through the use of collector-entered keyboard codings. Also, auditing programs will automatically notify staff of any unusual activities, and the system can include either a random or selected cash auditing method by sending all funds collected by an employee into a certain vault, no matter how many times an employee opens or closes a lane (Ref 9).
6. AVI/ETC systems allow for voluntary participation; therefore, the privacy issue should not be a factor. No AVI-based toll system will meet the needs of all toll facility users. Only such regular users as commuters and commercial fleets are likely to participate in ETC. This means retention of the conventional toll collection method. The number of

attended and/or automatic lanes needed will depend on the percentage of ETC toll users and the desire for dual-use lanes.

7. Toll projects with ETC lanes are more efficient and provide a greater service to the motoring public. When ETTM (Electronic Toll and Traffic Management) is incorporated into a total traffic management program, it will make toll financing a more attractive option. The implementation of comprehensive electronic traffic management is possible once the basic hardware is installed. All that is required is the addition of strategically placed reading locations and a supplementary computer system software package. This technology will allow toll agencies to improve traffic management, to measure traffic flow and density, to identify congestion, and to communicate this information to motorists in real-time. ETC systems should obtain greater motorist support of toll financing as a means to fund the construction, operation, and maintenance of new roads, bridges, and tunnels.
8. The ETC system will make it possible to eliminate less efficient subscriber systems (commuter coupons, windshield passes, etc.). These inferior toll payment systems can allow some users to avoid paying. This non-payment of tolls occurs at the indirect expense of other users. Also, the subscriber systems have poor statistics capabilities and enforcement measures.
9. Measurements of effectiveness for an ETC system include increased travel speeds; reduced travel time, delay, and stops; increased predictability of travel time (as measured by standard deviation of travel time); and a reduction in the number of toll collection personnel.
10. ETC systems reduce auto emissions at the toll plaza by reducing idling and minimizing stop-and-go movements; in addition, there will be increased user productivity, increased quality of life — i.e., more time at work/home and less aggravation, increased safety (less rear-end accidents), and less pavement damage at the toll plaza caused by vehicles stopping. As ETC systems are expected to increase toll plaza productivity by increasing vehicle throughput, there will be a corresponding reverse in vehicular emissions (Ref 10).
11. ETC systems experience 99.9 percent reliability and accuracy; and, because of its no-frills setup, an ETC system can achieve a relatively low toll collection cost. As ETC use increases, cost per transaction decreases.

2.2 BENEFITS OF ETC FOR THE TOLL ROAD USER

Toll road users also benefit from ETC in the following ways:

1. ETC users use less fuel because they are not required to stop and pay a toll.
2. ETC provides administrative and security benefits to the vehicle fleet operator because he/she does not have to deal with tickets or cash.
3. ETC systems can minimize congestion — especially during peak hours. With the implementation of ETC, the time required to process ETC-equipped vehicles at toll plazas decreases, which increases the throughput efficiency and toll lane capacity. Queuing times at toll plazas are reduced, and the total highway travel time is decreased

for both ETC users and non-users (Ref 11). Customer convenience is increased by reducing users' travel time, thus making the toll facility more acceptable to the public.

4. ETC is a user-friendly toll payment method. Drivers will have a number of options for paying tolls (such as sending a check through the mail, credit cards, electronic funds transfer, or cash). This eliminates the need for carrying exact change for toll transactions. No cash handling by drivers leads to increased convenience for the motorist and has possible safety benefits also (no weaving between payment lanes as a driver tries to find exact change).
5. ETC users will experience less difficulty in maintaining toll accounts (i.e., subscriber, monthly passes, or coupons) with the extended life cycle of transponder devices. Once an account is set up, all that is needed is for the account balance to be renewed periodically. There is no need for a change in the physical transponder device. Moreover, as stated before, accounts can be linked directly to credit cards for automatic balance renewal.
6. If an ETTM system is also installed with the ETC, motorists will receive additional benefits through traffic management and incident control.

2.3 SUMMARY

This chapter has shown how an ETC system will benefit both the toll agency and user. In the following chapter, different aspects of ETC systems are discussed, including how ETC systems work and the technological options available.

CHAPTER 3. ETC SYSTEMS

This chapter continues the technical discussion of ETC systems. ETC systems are comprised of three functional elements: a vehicle-mounted transponder (or tag), a roadside communication unit (RCU), and a computer system. A transponder is a vehicle tag that can be read by a roadside device. Transponders vary in type, capabilities, and power source. Four different technologies are used for ETC systems, including optical/infrared, inductive loop, radio frequency/microwave, and surface acoustic wave/complimentary metal oxide semiconductor systems. The most popular ETC systems are radio-frequency (RF) based.

3.1 EXECUTION OF ETC SYSTEMS

The central characteristic of ETC systems is a transponder that is read by the reader/interrogator. The transponder can be an optically read sticker or a sealed package ranging in size from a book to a thick credit card. The transponder package must survive water, vibration, and heat. The tag can be mounted behind a window, under or atop the vehicle, or integrated within the bumper or side molding.

Readers/interrogators used to capture transponder data are comprised of antennas and electronics available in a wide range of configurations (including portable versions). Interrogators normally cope with radio noise and other interference and perform error detection. They are sometimes multiplexed (i.e., several readers sharing one interrogator) in order to reduce costs where high throughput is not required. The interrogator can be mounted in the road, by the roadside, or on a structure over the road. The interrogator may perform several logic functions or serve as a minimal recognition device connected to a microprocessor. Each of these approaches has its own characteristics for performance, size, cost, and other attributes (Ref 12).

Readers come in many shapes and sizes depending on the application requirements. Readers vary from large inductance loops buried in the road to small heads measuring less than 5 cm (2 in.) across. Generally, the larger a reader is, the greater the distances and vehicle speeds handled.

ETC systems are triggered by a transponder-equipped vehicle passing a reader site. Coded data from the transponder are sent via a receiving antenna to the roadside reader unit. The data are checked for integrity before being sent to the computer for processing and storage. A complex system can transmit additional information or perform two-way communications (Ref 13).

3.2 TRANSPONDERS

There are three types of transponders: Type I (read-only), Type II (read/write), and Type III (read/write with an interface to an onboard computer or display device, also called a smart transponder). When a toll agency is choosing technology, the benefits of each transponder type and the underlying needs of the participants must be considered.

A read-only transponder (Type I) means the identification and other data are read from the tag. The tag's status (lost, valid, etc.) and other information are kept by the toll agency's computer, allowing the agency to maintain a complete audit trail. The read-only tag can, it is claimed, provide a secure method of toll payment. For barrier toll facilities, a read-only system works very effectively.

A read-write transponder (Type II) allows information to be retrieved from, or written onto, the tag (a multi-step process). A read-write tag can be useful in a tolling situation where the driver is charged according to distance traveled. When the vehicle enters the turnpike, the tag has the entrance point written onto it; then, when it exits, both the entrance point and vehicle identification information are read for an electronic toll ticket application.

Another use for a read-write transponder is to store a monetary value in the tag. Tolls are deducted directly from the tag balance instead of from the agency's computer account. This method is thought to be an avenue for fraud, theft, and other abuse, and the authority loses the ability to automatically renew credit card accounts. When deducting the toll directly from the tag, the agency will still want to compile data by tag identification for traffic management purposes and in order to recall toll information on demand to resolve questions concerning patron payments. Another possibility is to combine the use of read-only and read-write systems. Non-revenue vehicles (maintenance vehicles, authority fleet cars, police cruisers, etc.) do not usually need a read-write tag and can use a read-only tag.

Smart transponders (Type III) are capable of two-way communication between the on-board unit (OBU) and roadside antenna. The on-board unit consists of a smart card, a smart card reader, and a transponder. The smart card, which has a microprocessor chip embedded in the wafer-thin plastic, varies in memory size and computing power. All smart cards have the ability to process data and store information.

The smart card is a portable database that can remove transaction processing from the centralized financial computer system and place it in user hands (Ref 14). The Type III transponder enables high-speed, two-way communication that allows the transponder to maintain a toll account, automatically decrementing the account after each use. Toll authorities may be reluctant, however, to relinquish physical funds control (Ref 15).

The main problem of read-write tags is that the increased data rate requires additional power. For self-contained units, additional power consumption requires a larger battery and, hence, a larger tag (Ref 16).

Importantly, in the choice of a particular application, several specification areas should be defined and compared. Each system utilizes particular techniques to store information on the tag and to transfer it to and from the tag. Some areas to consider are data management (amount of data required to be stored in the tag), readability, programmability, range (reading distance), data transfer speed, durability, and packaging (Ref 17).

3.2.1 Transponder Power Supply

The transponder can be powered by the vehicle electrical system, by internal batteries, or by energy gained from the reader communication unit (RCU). There are three different approaches to the power source used by vehicle-mounted transponders: active, passive, and semi-active systems.

An active system receives power directly from the vehicle on which it is mounted, or from an internal battery. A battery tag is activated by a signal from the roadside antenna; however, those systems using vehicle power may transmit an identification code continuously. As the active system power supply is not significantly limited, the RCU can establish communications from a wide range of lateral roadway positions. Any externally powered transponder is vulnerable to power supply interruption and deliberate disablement. This source of unreliability make this type of active tag unacceptable for toll agency use (Ref 18).

Passive systems are energized by RCU-transmitted power; the transponders are sealed units with no power supply. When outside the field of the powering RCU, these tags are totally inactive. Passive systems are generally less vulnerable than active units to outside interference and damage, whether accidental or deliberate (Ref 13). On the negative side, the passive tag has a limited field length within which it can be triggered and operated.

Characteristics of active and passive tags are summarized in Table 3.1 (Ref 17). Note how active tags outperform passive tags.

Table 3.1. Relative Comparison of Active and Passive Tags

	Active	**Passive**
Readability		
- Orientation	Less critical	More critical
- Noise Immunity	Better	Worse
Programmability	Yes	Sometimes
Range	Longer	Shorter
Speed	Faster	Slower

Recently developed semi-active systems use an internal lithium battery (service life of about 10 years) to provide power to transmit the vehicle identification code when triggered. Because these totally sealed units require no external power supply, they are not susceptible to problems that plague externally powered active systems.

Semi-active systems have particular advantages in that the transponders are self-contained, are relatively interference secure, and avoid the need for high-power-level transmissions to energize the transponders, a problem with passive equipment (Ref 18). Although semi-active systems are still evolving, they offer a balance between passive and active tags (Ref 13).

3.2.2 Transponder Economics

As transponder memory capacity increases, the cost and function of the RCU also increases (because of the additional complexity and storage needs). The unit cost of transponders is influenced by the system design. Costs increase as memory is increased. Low-frequency tags are typically less than half the cost of high-frequency tags, and active tags cost 15 to 25 percent more than equivalent passive tags (Ref 17). With the current available technology, tag costs vary between $10 to $100.

Individual application characteristics will have a major impact on system costs. An economic analysis must include the total system and life-cycle costs. Estimating life-cycle costs is important in a consideration of alternative systems having different tag costs and durability (Ref 17).

3.3 TECHNOLOGICAL OPTIONS

There are several approaches to ETC that have been developed since the first investigations of automatic vehicle identification (AVI) were carried out in the 1960s. Recent advances in vehicle detection and data processing techniques have made the application of ETC systems both technically and economically feasible.

3.3.1 Optical and Infra-red Systems

Optical systems formed the basis of the earliest AVI technologies developed during the 1960s in the U.S. and in Europe. In the 1970s, infrared systems were substituted for the optical approaches. Both systems require clear visibility and lighting; their performance is seriously degraded by adverse weather (e.g., snow, rain, ice, and fog) and dirt. They are also sensitive to reader/tag misalignment, focusing problems, and depth-of-field limitations. Although improvements in performance have been achieved in recent years, the level of reliability is too low for most highway transportation applications (Ref 13); also, these systems are easily counterfeited.

Optical and infrared systems typically utilize a tag in the form of a coded label mounted on the outside of the vehicle. Vehicle identification is held in a series of lines of varying width or color, similar in appearance to a bar code. The information is extracted from the label by using a laser to analyze the unique patterns of reflected light (Ref 15).

Readings occur at traffic speeds as high as 88 km/h (55 mph), depending upon the size of the bar code; usually lower speeds are required to meet the exacting reading requirements. The scanning distance varies between 0.6 m (2 feet) minimum and 2.4-3.0 m (8-10 feet) maximum. This technology has a data processing rate of 2.5 milliseconds per character (Ref 7).

3.3.2 Inductive Loop Systems

Inductive (magnetic) loop systems use conventional traffic detection and counting loops in the highway pavement to detect signals from transponders mounted on the underside of vehicles (for a clear downward view to the road surface). The transponder must be located at least 15 cm (6 in.) from the ground (Ref 7). The system uses inductive coupling for data transmission and typically operates at frequencies of 50 to 500 kHz. It is considered a radio low-frequency system. The roadside reader units utilize conventional loops in the pavement as antennas for relaying signals to and from vehicles. Inductive transponders use a simple coil or ferrite rod antenna whose dimensions are a function of the communication carrier's wavelength (Ref 15).

The performance of inductive loop systems is adversely affected by steel-reinforced pavement (Ref 19). In-pavement loops generally cover a lateral span of up to 4.9 m (16 feet), and the reading can occur at speeds up to 161 km/h (100 mph) (Ref 7). The tag can be active, semi-active, or passive.

3.3.3 Radio Frequency and Microwave Systems

Radio frequency and microwave systems are the most popular type of ETC technology. The transponders can be read at speeds of up to 290 km/h (180 mph) and at distances of up to 72 m (235 feet) (Ref 7). These systems transmit and/or receive in a wide range of frequencies, including the kilohertz (kHz, 10^3), megahertz (MHz, 10^6) and gigahertz (GHz, 10^9) ranges. Transmission on reserved frequencies of 915 MHz or 2.45 GHz form the basis of several ETC systems available internationally (Ref 18). Systems utilizing in-pavement microwave antennas now being developed eliminate the problems of occlusion of the line-of-sight between the transponder and antennas (Ref 13). As with inductive loop systems, radio frequency and microwave technologies can be divided into active, semi-active, and passive systems.

One advantage of microwave systems over inductive loops is that they can transmit data at much higher rates and can handle a greater amount of information by performing at higher frequencies. Microwave transponders tend to be smaller than inductive loop transponders, as antenna dimensions are related to operating wavelengths (Ref 15). Passive microwave systems are not recommended for use because, in order to energize the tag, high power levels must be transmitted. Semi-active systems offer a satisfactory compromise using a sealed unit transponder with an internal battery. This allows radiated power levels to be greatly reduced while providing for a transponder design life of 10 years or longer (Ref 13).

Radio frequency (RF) systems can be read at greater distances and under much more difficult circumstances than bar codes, since the RF transponder can be read without being seen. Other key functional advantages of RF systems over bar code systems are the potentially greater tag data capacity, its re-programmability, and its ability to withstand harsh environments. Also, RF transponders can contain custom electronics and micro-codes for higher security. While RF transponders are normally more expensive than individual bar code labels, their cost is offset by higher capacity and longer life. Readers and interrogators can cost more or less than equivalent bar code systems, depending on the precise application requirements (Ref 17).

3.3.4 Surface Acoustic Wave and Complimentary Metal Oxide Semiconductor Systems

Surface acoustic wave (SAW) and complementary metal oxide semiconductor (CMOS) technologies are another recent ETC development. These systems are fixed-code (non-programmable), one-way vehicle transponders. Operating within the same frequency range as RF and microwave systems, these systems use a low-power radio frequency signal from the reader to energize the chip.

CMOS technology relies on integrated circuit chips, whereas SAW technology is based on a natural phenomenon associated with impurities implanted in lithium niobate crystals. These crystals reflect waves as a unique signal pattern by converting an electromagnetic wave into a surface acoustic wave (Ref 6).

Because SAW technology requires fewer electronic parts than radio frequency and microwave technologies, it is able to use smaller and less expensive transponders (Ref 7). The SAW system does not have a very high level of reliability (Ref 18), owing to the high number of transmission wave reflections to the antenna and to problems with high-speed reading. The transponder can be read at a distance of up to 4.6 m (15 feet) from the reader (Ref 7).

3.4 RADIO FREQUENCY

Of the previously discussed systems, RF is the most popular technology. There are many different RF systems that operate over a wide range of radio frequencies — from under 500 kHz to over 2 GHz. As a frame of reference, AM radio stations in the U.S. use the 560 to 1,600 kHz range, while television and FM radio stations use frequencies in the 80 to 500 MHz range.

High-frequency systems, which operate above 900 MHz, are frequently termed microwave systems. Microwave systems, which are characterized by faster communication speeds, can read or write more data more quickly (Ref 17). They feature smaller antennas focused on a specific read zone. Microwave systems, closer to the visible light portion of the spectrum, radiate energy in a beam, making orientation of the transponder and reader critical.

Microwave systems experience reflection from metal, which can complicate the differentiation between tags by sending the same signal along different routes to the scanner (multipathing) or by triggering two tags at once. Also, microwave energy is absorbed by water and grease.

Low-frequency systems, on the other hand, are less subject to reflection and have better penetration of obstacles between transponder and reader. Data transmission, however, is slower at lower frequencies. In some applications, this is an advantage, because confusion is avoided in the identification of objects close together. The tag and reader exchange data in a matter of milliseconds. Low-frequency systems also have a shorter range than high-frequency systems (Ref 6). It is important to remember that both speed and range are relative — low frequency systems can read at ranges of up to 1.2 m (4 feet) or more and at speeds in excess of 32 km/h (20 mph). Low-frequency radio fields operate under an inverse cube law, so interference from "distant" electrical noise is minimized. Moreover, antenna orientation is less critical because it is more omnidirectional (toroidal).

In practical terms, radio frequency systems appear to be in either the kHz range (40-500 kHz) or the MHz range (900-2,000 MHz and above). Low- and high-frequency system characteristics are summarized in Table 3.2 (Ref 17).

Table 3.2. Relative Comparison of Low and High Radio Frequency

	LOW (kHz)	**HIGH (MHz)**
Readability		
- Orientation	Less critical	More critical
- Noise Immunity	Generally better	Generally worse
- Penetration	Better penetration	More directional
Range	Shorter	Longer
Speed	Slower	Faster

3.5 SUMMARY

This chapter has examined the execution and technological options of ETC systems. Since radio frequency is the most popular ETC technology, a section has been dedicated exclusively to that technology. The following chapter discusses ETC system design and technical issues.

CHAPTER 4. DESIGN AND TECHNICAL ISSUES

This chapter discusses electronic toll collection (ETC) system design and technology. Design issues include security, communication, reliability, compatibility, flexibility, and safety issues as they relate to ETC system placement. Technical issues, which deal with how the ETC system works, is divided into the following sections: environmental conditions, accuracy, payment systems, and audit control.

4.1 DESIGN ISSUES

There are many factors to consider in the design of an ETC system. These factors include security, communication, reliability, compatibility, flexibility, and safety.

4.1.1 Security

Security has to be built into the system. Once the tag is delivered to the user, the authority has lost control over the unit. Accordingly, the device must be designed to prevent tampering. There are microprocessors available that can perform crypto-functions needed for safe payment. Messages are encrypted with secret keys and with algorithms to prevent misuse. Before any function is performed with the processor, the tag will be checked for proper encoded authorization (Ref 20).

The toll plaza and external equipment are all subject to vandalism, theft, accidents, and intentional destruction. Security at these locations is necessary for the preservation of property, personnel and motorists' safety, and revenue protection. One way to increase security is to require that all staff and visitors use identification badges.

4.1.2 Communication

Communication between vehicle and roadside is one of the crucial system elements. There are other communication links: between toll lane and toll plaza, between toll plazas, and between toll plaza and central computer. The communication link must be secure, adaptable, and dependable. This link needs to utilize easy-to-install equipment that functions in all vehicles and under all weather conditions. The mode of communication must also be considered. For example, communications between tags and readers can be carried out by radio frequency, optical/infrared, inductive loop, or by surface acoustical wave; links elsewhere can be by hardwire, dial-up telephone lines, and/or fiber optical cable.

4.1.3 Reliability

Reliable equipment is important to toll agencies, since it is through the ETC system's equipment that these agencies receive revenues. Electronic systems are more reliable (especially when redundancy is built into the system) than coin machines, since there are no moving parts. The ETC system can be designed to degrade gradually, regardless of the failure conditions encountered. This means that there is a minimal loss of operating capability and no loss of data.

Even a massive communications or central computer failure can be overcome by the ability to download data directly from each toll lane into a portable computer.

Dial-up capabilities serve as a backup to link failures, and, since uninterruptible power supplies are preferable, portable generators need to be on hand. Actual or impending malfunctions can be noted by the ETC system to inform maintenance and operations supervisors in real-time (Ref 9).

4.1.4 Compatibility

An agency should consider three different compatibility types. The first type is compatibility of the equipment manufactured by different companies. To integrate the equipment into a complete system, the equipment must be adaptable. Compatibility requires the development of a standard for the communication link between the transponder and the roadside. The second type is future-focused, unless the agency already has an agreement to be concordant with other toll systems. Readers and tags should permit cross-agency use. The third type is the additional use of equipment for other intelligent transportation system (ITS) functions; such equipment can be used to obtain route guidance and other information, and can assist in the operation of an automatic parking management system. Equipment use for ITS purposes may increase costs; for example, while the toll agency requires a read-only system, ITS functions need read-write capabilities.

4.1.5 Flexibility

A system design needs to be flexible so it can expand, change, improve, and include additional services. Flexibility can also include variable payment methods and tag use.

The system's design needs to include procedures to handle a failure, an accident, or a disabled vehicle that requires lane closure. Lanes are to be designed for two payment modes so that, if a lane is closed, vehicles can be re-routed to an adjacent mixed-mode lane.

4.1.6 Safety

Safety is a very important issue. An evaluation of motorist and employee safety must be performed before electronic toll systems are introduced. Retrofitting existing facilities, where electronic and manual toll payment are to be placed contiguously, is usually more difficult, safety-wise, than building a new facility that separates the two different payment modes.

4.2 TECHNICAL ISSUES

Technical issues must also be considered in any evaluation of an ETC system. These technical issues include the environment as well as the system's accuracy, payment scheme, and audit controls.

4.2.1 Environmental Conditions

Environmental conditions should be considered when evaluating system placement. Vehicles travel in an environment full of dirt, wind, humidity, oil, snow, water, ice, de-icing chemicals, and spilt commodities. Temperature extremes for equipment operation range from over 38° C (100° F) in the summer to below -18° C (0° F) in the winter. Some video enforcement systems are sensitive to extreme cold, and vehicle classification systems that use vertical sound waves may be distorted by strong wind. There has been very little unbiased documentation on ETC equipment for weather conditions (Ref 11).

4.2.2 Accuracy

An ETC system's accuracy is important for its credibility and for its revenues. If the system is perceived as inaccurate, then the percentage of ETC users may decrease. Patrons do not want to be overcharged or receive enforcement notices when they are following the rules. Vehicle classification is an area that needs to be improved (average accuracy level is 95 percent). The vehicle classification system can fail to classify or can misclassify vehicles. Also, the system must be able to detect fraudulent use of tags — for example, the placement of a two-axle tag on a multi-axle vehicle (Ref 21).

Before an ETC system is chosen, the level of accuracy must be determined. If an accuracy rate of 99.95 percent (considered a low percentage for peak periods) is desired, then a test of 40,000 to 50,000 observations is required (Ref 11) to achieve a statistically valid test. Note that, for an accuracy rate of 99.95 percent, the system can malfunction only once per 2,000 observations. This means the individual systems (reader, vehicle classification, enforcement, etc.) of the ETC system must attain a greater accuracy rate.

4.2.3 Payment Systems

Payment systems should be designed to meet both the authority's and the user's needs. Because most authorities do not extend credit to customers (post-payment system via conventional monthly billing statements), a pre-payment method is required. Pre-payment systems include cash, check, credit card, and electronic funds transfer (EFT). A credit card or EFT allows for the automatic replenishment of a prepaid toll account. Also, pre-payment benefits the agency in time-value of money by allowing it to invest in other projects, earn interest, or increase its cash flow flexibility.

When a motorist is using the ETC lane, the account status for that tag will be checked. The account status can be defined as unused, open and valid, requires funds, and opened but blocked. ETC usage would be blocked when a motorist's pre-payment has been deleted. This is why the automated payment process is preferred to depending on a motorist's deliberate act of sending a check or going to an authorized representative to add money to his/her account.

Another payment system is the joint clearing-house approach. The clearing-house concept uses a reimbursement system that allows toll-paying customers to maintain only one account for all participating agencies.

4.2.4 Audit Control

Audit control is defined as having all individual transactions classified correctly, with collected money reconciled to transactions and totals (Ref 21). In an ETC system, the audit control is done automatically, since vehicle classification, vehicle separation, vehicle payment, and video enforcement are all integrated into the system. During audit control, irregular or unusual transactions appear concerning invalid accounts, unread/misread tags, class discrepancies, vehicles being towed, etc. The last example is interesting, since the tag reading can be unreliable — i.e., a vehicle's "on-hook" tag would be read but a vehicle on a flatbed wrecker would not be read (Ref 22).

4.3 SUMMARY

This chapter has examined ETC design and technology. Issues included security, communication, reliability, compatibility, flexibility, safety, environmental conditions, accuracy, payment systems, and audit control. Each of these issues should be studied before an ETC system is planned. In Chapter 5, implementation issues are further discussed in sections on standards, capacities, system requirements, and system operation performance.

CHAPTER 5. IMPLEMENTATION ISSUES

This chapter discusses electronic toll collection (ETC) implementation issues. These issues include standards, capacities, system requirements, and system operation performance. Each of these areas requires in-depth study before an ETC system is installed.

5.1 STANDARDS

In the implementation of an ETC system, standards are an important issue. Standards lead to lower costs because they allow different companies to compete by producing compatible equipment. Standards also result in greater efficiencies and reduced complexities for the user.

5.1.1 System Standards

The desire to create standards for automatic vehicle identification (AVI) is not new. Public officials are attempting to avoid the situation of a traveler needing multiple transponders. Standards imply compatibility among all system types that are standards-compliant. Toll authorities will then be able to choose systems or system components from different vendors.

One view is that the ETC industry should allow the marketplace to determine its own de facto standards. Since the industry is relatively young and competitive, it is argued that imposing standards too soon could hamper the development and evolution of AVI systems (Ref 23).

Another view is that future standardization is essential for network interconnection. Although there is tremendous growth in competing electronic toll systems, incompatibility between these proprietary systems threatens to compromise the convenience gains made by the technology. There have been well-documented pitfalls that state (Florida) and regional (E-ZPass Interagency Group) officials have encountered in trying to establish ETC standards; such experiences underscore the complexity of the issues involved. The establishment of regional — not to mention national — standards has proved to be a daunting task.

Many patents have already been granted relating to such proprietary equipment as tags, readers, and antennas. The companies owning these rights will fight in court to protect them. Some of these technologies are mutually exclusive. For example, readers can be linked to different computer systems, but the tags made by one manufacturer cannot be read by another manufacturer's equipment. If two tags are attached to one vehicle, one tag may cause interference when the other tag is being read. A solution to this problem would be the development of an industry standards for tags, like the Universal Product Code (UPC) used in supermarkets and retail stores. A major obstacle is that manufacturers have patents for related technologies that they are not ready to share. Another solution might be to require that all tags built be Brand X-compatible, as is requisite in IBM-compatible personal computers. This is not yet possible, since improvements to the technology are occurring daily and no one (manufacturers or toll companies) is ready to lock into a specific software or hardware solution. Another approach that will probably be used in the near future is to have a region coordinate specification and purchasing so that the products are compatible or at least do not cause interference with each other (Ref 6).

As articulated at a November 1991 meeting, ITS America is focusing on the possibility of adopting a common set of standards. During that meeting, agencies attending decided that adopting a common set of standards would be impractical because of time constraints. The agencies instead decided to develop a common set of standards for the next generation of ETC installations. These standards would attempt to address the following areas: tag data content, operating frequency, power density, and antenna placement. The agencies expressed hope that standards within the competitive marketplace would foster cost-effective solutions (Ref 24).

There are many groups that have taken up the challenge of developing an ETC/Electronic Toll and Traffic Management (ETTM) system standard. The following is a list of known standards-making bodies:

- ITS America
- Intelligent Transportation System (ITS) Group E.17.51 of American Society of Testing and Materials (ASTM)
- Transportation Research Board (TRB) through A3A01 Communication Task Force
- Society of Automotive Engineers (SAE), the Secretariate for the International Organization for Standardization (ISO) TC-204 (looking at AVI standard issues from an international perspective)
- Institute of Electrical and Electronics Engineers (IEEE)
- ISO TC 204 (Road Transport Informatics, i.e., RTI)
- Federal Highway Administration (FHWA)
- American National Standard Institute (ANSI) X3T6
- Mitre (a firm under contract to FHWA to provide consulting assistance in various ITS areas)
- State Departments of Transportation

While there is substantial overlap occurring in these organizations, they seem to be making progress (Ref 25).

ITS America's Standards and Protocols Committee, through its Communications Subcommittee, has worked for nearly two years trying to define the problem in terms of a matrix that defines applications and their attributes. It is to be a living document that can change as new applications arise and circumstances warrant. A scale of values from 1 to 5 was developed. It rates the importance of a particular attribute to an application, with 5 being very important, 4 being important, 3 being moderately important, 2 being rarely important, and 1 being unimportant.

Still, when standards for systems are approached, care must taken to protect against premature obsolescence of equipment purchases, owing to unplanned and uncontrollable shifts in approach or style. System architecture should provide systems with the attributes of reliability, upgradability, fail-safes, ease of installation and use, and broad compatibility from the end user's point of view. There should be provisions so that problems can be diagnosed and repaired easily, and the system should be cost-effective both for initial deployment and operation (Ref 26).

5.1.2 France's System Standard

The French toll agency association USAP (Union des Sociétés Francais d'Autoroutes à Péage) agreed in 1993 to implement a standardized ETC system nationwide. However, two of the eight toll authorities included in USAP amended the agreement to allow non-conforming ETC equipment in urban areas. These two agencies are COFIROUTE (Compagnie Financiére et Industrielle des Autoroutes) and SAPN (Société des Autoroutes Paris-Normandie). The other six toll agencies in USAP are SARR (Société des Autoroutes Paris-Rhine-Rhöne), AREA (Autoroutes Rhöne et Alpes), ASF (Autoroutes du Sud de la France), SANEF (Société Autoroutes du Nord et l'Est de la France), ACOBA (Société Autoroute de la CÔte Basque), and ESCOTA (Société Autoroute Esterel-CÔte d'Azur).

The name of the standard system, dubbed TIS (Telepéage Inter Société), is to be gradually implemented over the next 5 years. This permits toll road operators to totally depreciate the existing toll systems. If the joint USAP procurement holds together, industry observers expect that most existing equipment would be replaced by the TIS hardware, even though there are several ETC systems already operating or being tested in France, including equipment from Amtech, Saab-Scania Combitech, and CGA (Compagnie Générale d'Automatisme). At this point, it is unclear what effect the urban area exemption will have on the proliferation of the TIS system, with up to 800 toll plazas throughout the country fitted with the standardized ETC reader. In addition to standardizing within the borders of France, the toll agency is trying to set up ETC networks in Spain and Italy.

USAP is planning to select as the TIS standard one of two prototype systems being developed by two consortia teams. Early in 1993, USAP awarded contracts worth French franc 11 million (about $2.6 million U.S.) to the two consortia that had emerged from a field of six bidders. They were CGA, with smart card manufacturer Gem-plus Card International, and CSEE (Compagnie des Signaux et Equipments Electroniques) with Saab-Scania Combitech and Compagnie Grenobloise. Prototypes from these two companies are expected to be completed in the spring of 1994, when several months of field testing is scheduled to begin. Only one of the two remaining teams will be awarded a contract to develop a production version of the system, which is slated for completion in early 1995.

A USAP procurement committee has established the functional and technical specifications for the TIS system. USAP is calling for a read-write radio-frequency-based ETC system incorporating smart cards. The system would operate at 5.8 GHz.

Toll facilities on the verge of implementing ETC technology in the Paris area are not waiting for the TIS procurement to be completed. In seeking exemptions from using TIS in urban areas, SAPN and COFIROUTE identified two main concerns about the jointly procured system: price (TIS system could be more expensive to operate than other ETC options, namely read-only) and its ability to handle high traffic volumes (Ref 27).

5.1.3 Japan's System Standard

In Japan, the standardization of identification (ID) tags for automotive use has been investigated as one of the programs in the IMS (Intelligent Manufacturing System) project. IMS is a 10-year international (U.S., Europe, Canada, and Australia) effort to develop and standardize manufacturing technology. The standardization program was started at the end of 1991 by Japan's Ministry of International Trade and Industry. Designers, users, and research institutions with interests in ID-tag equipment are taking part in this program (Ref 16).

5.1.4 Radio Frequency Standards

If internal and external system compatibility is a priority for industry and toll agencies, then radio frequency (RF) compatibility and selection represent major challenges. Although there is much concern for radio frequency standards, this should not preclude investigating other non-RF-based technology solutions.

Which radio frequencies are chosen will likely have a tremendous impact on the reliability, flexibility, capacity, throughput, and a host of related characteristics that will define the extent and quality of technological advances in ETC design and use. ETC systems that are in production or being designed vary widely in frequency selection from 120 kHz to 5.7 GHz — that is, across the entire radio spectrum (Ref 28).

Although much of the current focus has been on short-range, unlicensed radio operation, it is not premature to discuss long-term, higher-power RF operations. It is apparent that as ETC technology grows and matures, higher-powered, licensed radio transmitters will be associated with ETC systems.

The transition from unlicensed to licensed operations will provide additional protection by locking in an ETC user frequency range. Federal Communications Commission (FCC) rules require operators of unlicensed radio frequency devices to operate at sufferance to all other users, including other unlicensed users. Therefore, in practical terms, the only method of protecting the industry's use of the radio spectrum for ETC operations is to concentrate on a certain radio spectrum and obtain a licensed radio range. The history of telecommunications has demonstrated that great inventions in RF technology have failed because users could not qualify for FCC licensing (Ref 29).

The results of an International Bridge, Tunnel and Turnpike Association (IBTTA) survey (spring 1992) of manufacturers and developers of ETC equipment showed that equipment was being designed to operate within the 902-928 MHz band (Ref 30). In spring of 1993, the FCC proposed rules regarding use of this band. The proposal drew more than 1,200 pages of comments. Responses came from amateur radio operators, vendors of spread spectrum devices, users of radio-location systems, and developers of ETC systems; respondents debated how the spectrum should be assigned and whether parts of it should, or could, be shared.

The FCC has proposed that radio-location systems (which it terms "wideband" services) and AVI systems (which it terms "narrowband" systems) should no longer share frequencies within the band. Narrowband systems should be licensed at 902-904 MHz, 912-918 MHz, and

926-928 MHz. Wideband systems would continue to operate at 904-912 MHz, and 918-926 MHz. Within those two 8-MHz bands reserved for wideband systems, different radio-location vendors could receive licenses to operate on the same frequencies. The FCC does have an alternative proposal on this matter if the industry persuades them that the first proposal is not feasible.

Vendors of systems used in ETC and other short-range applications are divided over the proposal to separate from location services. ETC vendors have chosen sides depending on how well their systems operate within the proposed FCC limits. Some ETC and radio-location vendors are debating whether the two types of systems could share the same channels without causing harmful interference (Ref 31).

The European Commission has proposed a set of community-wide frequency bands for use by RTI/ITS applications. Although existing commercial products are unlikely to be modified in the short term, once the directive is in place, new products can be designed to meet the standards. A bandwidth of about 10 MHz has been identified as a general requirement, with up to a 20-MHz band needed in multi-lane applications.

For automatic tolling applications, and for early RTI application, the European Radio Communications Committee has identified the 5.795 to 5.805 GHz range (with a possible extension to 5.815 GHz). For future applications, including radars used in collision avoidance, the bands 63 to 64 GHz and 76 to 77 GHz have been proposed. Because these allocations fall within a band identified for industrial, scientific, and medical applications, careful design will be required to avoid interference. This directive to member states will be in force by the end of 1993 (Ref 32). The Japanese RF standard for AVI is in the 2.45-GHz band (microwave frequency), and the power is no greater than 300mW (Ref 16).

5.2 CAPACITIES

Operations of toll plazas have been studied for many years to determine the optimal number of booths. With the use of ETC systems, there is an opportunity to increase the toll processing capabilities at plazas. This can reduce the number of toll booths and, in addition, would allow existing plazas to increase throughput despite the constraints of economics and geography. Prior to ETC implementation, planners should evaluate the technology and assess its effect on the toll plaza.

Toll operations that affect the motorists can be discussed in terms of time requirements for processing and interacting. Processing time is the time required to decelerate into and accelerate from the lane, basically defined as the amount of time that a vehicle occupies a toll lane. The interacting time is the time needed by a vehicle operator for payment (by cash or other method). An ETC vehicle has a transaction time of about 0.1 seconds (the time the ETC reader needs to read the vehicle's transponder) (Ref 33).

In determining the ideal lane configuration for toll barriers, planners must consider three basic characteristics: capacity, speed-capacity relationship, and anticipated ETC participation levels. These characteristics are discussed below.

5.2.1 Capacity of Toll Lanes

There are five basic types of toll plaza lanes: staffed, automatic, mixed-mode, dedicated ETC (within a conventional toll plaza), and express ETC. Staffed lanes are manned lanes that handle all toll transactions through a human operator. Automatic lanes collect tolls by coin machines. Mixed-mode lanes combine ETC with either staffed or automatic toll collection. Dedicated ETC lanes are lanes within the conventional toll plaza that process only ETC patrons. Express ETC lanes are physically separated from all other types, permitting free traffic flow (88 km/h [55 mph] or greater). On the average, normal capacities are reduced by about 10 to 20 percent when gates are used on automatic lanes (these numbers include gates). It is unknown whether the capacity of a lane would be affected by increased gate sensitivity (Ref 34).

Table 5.1 shows the capacity or throughput of seven different types of toll lanes. Notice how the capacities increase when the payment process is simplified. This table shows the potential to increase conventional plaza lane capacity by 50 to 160 percent with the inclusion of ETC, depending on plaza lane configuration. Figure 5.1. shows the average capacity of toll lanes by type.

Table 5.1. Lane Types and Capacities (Ref 11)

Lane Type (with description)	**Capacity in veh/hr**
1. Staffed (with change-making transactions, receipt issuing, etc.)	350
2. Staffed (only distributing commuter tickets and such)	500
3. Automatic Coin Machine (only coins — no tokens)	500
4. Automatic Coin Machine (receiving primarily tokens — few coins)	650
5. Mixed-Mode (includes any of types 1 - 4 as well as ETC in the same lane)	700
6. ETC (dedicated ETC lanes in a conventional plaza with barriers)	1,200
7. Express ETC (dedicated ETC lanes in a highway speed pass-through)	1,800

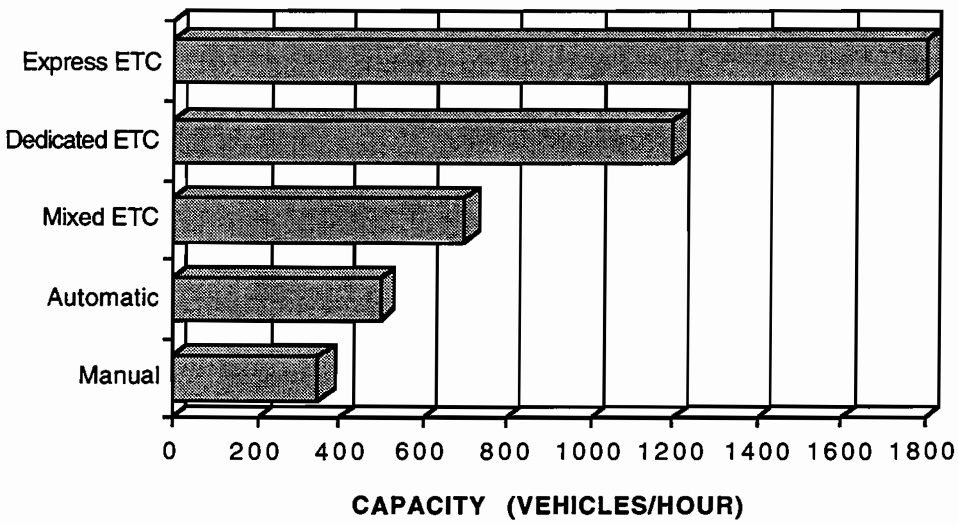

Figure 5.1. Average Capacity of Toll Lanes by Type

5.2.2 Speed-Capacity Relationship

It stands to reason that the faster vehicles travel through toll collection lanes, the more cars can be processed. Through established traffic engineering theory and observations, safe and reasonable vehicle spacing has been determined for various speeds. For example, the typical spacing for 16 km/h (10 mph) is 16.8 m (55 feet). The density would be 59 veh/km (95 vehicles per mile) or 960 vehicles per hour (vph), which is the corresponding volume passing a fixed point in an hour. At 88 km/h (55 mph) the average spacing is 48.8 m (160 feet), which translates into a density of 21 veh/km (33 vehicles per mile) or 1,815 vph.

By using the respective throughput capacities of toll lane types, the average speeds of the lanes have been determined (see Table 5.2). Speed is based on volume divided by density. For illustration, back-calculating the 88 km/h (55 mph) example, 1,815 vph divided by 21 veh/km (33 vehicles/mile) equals 88 km/h (55 mph). So density decreases (or spacing between vehicles increases) as the speeds become greater (Ref 34).

Table 5.2. Average Speed for Toll Plaza Lane Types

Staffed	4 km/h (2.5 mph)
Automatic	8 km/h (5 mph)
Mixed-Mode	11 km/h (7 mph)
Dedicated ETC	24 km/h (15 mph)
Express ETC	88 km/h (55 mph)

In Table 5.2, we see that the average running speed (the speed maintained once a vehicle slows down while approaching the toll lane queue through the point of being processed) for a staffed lane is about 4 km/h (2.5 mph). When compared with the express ETC lane of 88 km/h (55 mph), the higher ETC average speeds translate into greater lane capacity.

5.2.3 Anticipating Levels of ETC Participation

Actual patronage levels for ETC are extremely difficult to estimate. If lanes are dedicated to ETC use, and only a small proportion of the motorists use ETC, then the capacity of the toll plaza may actually decrease. An authority wants to use all its toll lanes effectively, obtaining the maximum throughput with minimum queues in order to minimize toll plaza congestion.

To illustrate this point, consider a three-lane toll plaza currently operating one manual lane (350 vph capacity) and two automatic lanes (650 vph capacity). Its plaza capacity would be (350x1)+(650x2) or 1,650 vph. Assume that one automatic lane is replaced with a dedicated ETC lane (1,200 vph capacity). This toll configuration would increase the capacity of the plaza to 2,200 vph [(350x1)+(650x1)+(1,200x1)], or 650 vph more than the original configuration.

The throughput of the plaza will depend on the ETC lane market share. For example, if the ETC lane has a market share of zero (that is, no one is using the ETC lane), then the throughput of the plaza would actually decrease to 1,000 vph if a lane was dedicated to ETC [(350x1)+(650x1)+(1,200x1x0%)]. At the other extreme, if all vehicles wish to use ETC and they must use the single ETC lane, the throughput would be (1,200x1x100%) or 1,200 vph.

From these calculations it can be seen that careful evaluation of the possible ETC market share is essential when planning an ETC system. At low levels of market penetration, non-dedicated ETC lanes are a better choice (Ref 35).

5.2.4 Other Concerns

There are other ETC lane capacity concerns. Some professionals would argue against dedicating an ETC lane unless the proportion of those using ETC would match the proportion of the lanes dedicated to them. If there is a four-lane highway and 25 percent of the customers use ETC, then one lane dedicated to ETC would be justified. On the other hand, some professionals would argue that an initial dedicated ETC lane is required even if the proportion of users does not justify it. This is because users would enjoy the time savings in toll payment; it would also show others the actual benefits of ETC, thereby encouraging more participation (Ref 11).

Another concern is that the ETC benefits may not be realized. If the road system is already experiencing total congestion and cannot absorb any additional volume, then the use of ETC will generate limited gains. These limited user gains include less money handling and fewer windows to roll down (Ref 6).

A final capacity issue occurs where facilities are linked closely together. Different toll facilities share overlapping markets, and, if all of them implemented compatible electronic tolls at once, the area might obtain congestion relief and an increase in ETC market share. In contrast, if only one facility implements ETC, the benefits will be constrained by the physical toll facilities' limitations (Ref 6).

5.3 SYSTEM REQUIREMENTS

For a toll agency to design and choose equipment for its ETC system, system requirements must be defined. These general requirements include procedures, equipment, and toll plaza needs. Since every ETC system has different accuracy, reliability, cost, complexity, equipment, and/or operation design, the agency needs to define the desired system requirements. Planners should consider the following system requirements:

1. The system should be able to function accurately and reliably in all ambient climatic and man-made (de-icing materials) conditions.
2. The system should be able to function reliably and accurately with a variety of highway pavement conditions (reinforced concrete, concrete, asphalt, etc.).
3. The system should be able to function in the presence of dirt, spilled commodities, inoperative vehicles, and other unforseeable toll plaza conditions.
4. The system should be able to distinguish separate vehicles, even ones following closely.
5. The system should have a sealed unit tag, one that is resistant to unauthorized tampering, moisture incursion, vibration, and other environmental effects.
6. A decision should be made as to where to locate the tag.
7. The agency needs to determine the antenna configuration to use: in-pavement, distributed overhead, or focused beam.
8. The equipment used should be compact and visually unobtrusive and capable of adaptation to other functions.
9. The effects of equipment on the health of users and staff (for example, radiation levels) should be minimal.
10. A decision on tag coding requirements (security, identification of system and vehicle, etc.), data capacity, read-only versus read-write systems, and power supply for the tag (dependent or independent of vehicle) must be made.
11. The acceptable error rates and protocols for correcting errors on equipment and functions must be determined, along with the reasonable costs to obtain hem.
12. Audit control functions need to be defined with its equipment requirements.
13. A decision must be made on how to design the toll plaza to incorporate an ETC system (stop, non-stop, free flow) in a safe manner and to enable the best use of equipment, costs, maintenance, and other items.
14. Determine payment structure for the system (pre-pay, post-payment, electronic funds transfer) and whether the system will incorporate variable pricing and discounts.
15. Need to decide types of enforcement to be used and the enforcement levels for untagged vehicles, poorly performing tag, and low fund accounts.
16. The agency should determine the system fault tolerance and maintenance response and whether to use autonomous operation of a lane or redundancy of readers in a lane.

17. The agency should determine how it is going to handle privacy issues.
18. A decision on the capacity of the system to monitor multi-lane highways and transaction capacity.
19. A decision on how the ETC system should structure vehicle classification and what method to use to check classification.
20. The system should reliably read tags at vehicle speeds of at least 113 veh/km (70 mph) in a free-flow situation.

5.4 SYSTEM OPERATION PERFORMANCE

There are several different technologies incorporated by manufacturers into products being supplied for ETC systems. Even when the same technology is used by different manufacturers, their execution varies significantly. A system's performance can be evaluated in many different ways — such as the percent of tag passes read by a single reader or in a lane with two readers; percent of undesired reads that report long-range, cross-long, or double reads; percent of tags working properly upon installation and/or after several years; and percent of tag reads where the wrong number is reported.

Other possible performance guides are the effects of radio signals and noise interference, the reader mean time between failure (MTBF), the mean time to repair (MTTR), the reader availability percentage, and the reliability of the reader to the host communication. It is important that the system is operating correctly so that detecting and reporting of various reader equipment malfunctions in real-time is possible (Ref 35).

The impact of ETC system failures must be considered in relation to the steps required for restoring equipment and lane operation. These steps include detecting the problem, resolving the situation, and certifying proper operation after repair. Each step requires time and resources that will affect the ETC process. When determining the equipment reliability, testing methods and diagnostic data can greatly influence the results. Means to independently audit equipment performance should be an integral feature.

The ETC system can verify the account balance and status information before signaling the driver to proceed through the toll booth. For accounts having insufficient funds or inoperative tags, the driver is signaled to stop and pay the toll by another means. Accounting has system performance parameters, including percent of tagged vehicles identified and properly billed, percent vehicles evading tolls (which could include non-tagged vehicles), percent tagged vehicles improperly billed, percent ETC accounts with an error in the billing host database (error could be in balance, billing information, or tag number), percent customers having success on first tag use, and percent customers improperly billed during a month.

Using the last category as an example, one can determine the percent customers improperly billed during a month. Assume a read rate of 99.5 percent for each tag pass and 30 trips per tag during the month. This means that there is a possibility that nearly 14 percent of the customers could be misbilled during a month. The general formula is:

100(Trips) / (1-(read rate)) = missed monthly %,

assuming independent read failures. This calculation translates to the following table of possible missed monthly percentages for various read rates:

Table 5.3. Comparison of Read Rates to Trips per Month

		Trips per Month		
Read Rate	**Missing (1 in __)**	**20**	**30**	**40**
0.99	100	18.2%	26.0%	33.1%
0.995	200	9.5%	14.0%	18.2%
0.999	1,000	2.0%	3.0%	3.9%
0.999	52,0000	0.995%	1.49%	1.98%
0.9999	10,0000	0.1998%	0.3000%	0.3992%

Note that total independence is not likely due to the same tag being read on the same vehicle in the same lane; therefore the actual values may not reach the above levels. However, this analysis does show that high levels of performance required of both the equipment and the billing system (Ref 36).

5.5 SUMMARY

This chapter discussed implementation issues concerning standards, capacities, and system performance requirements. Chapter 6 will explore other issues that have not been covered by Chapters 4 and 5.

CHAPTER 6. OTHER ISSUES

This chapter will discuss additional issues not covered in Chapters 4 and 5. These issues include privacy, results of surveys, using a testing period, customer relations, regional electronic toll collection (ETC) systems, and the effects of lawsuits.

6.1 PRIVACY

The privacy of the ETC user is a frequently stated automatic vehicle identification (AVI) concern. Authorities think customers will not accept an ETC system if the system is rumored to operate as "big brother," the all-seeing, omniscient government. People perceive that ETC systems threaten their individual freedom of movement, since travel information may be recorded.

User's privacy may be invaded through maintaining toll records for billing and audit purposes and through video/picture enforcement. Users are concerned that the system may capture the "errant spouse" (someone being somewhere they are not supposed to be), personal use of a company vehicle, travel movements of a driver who borrows a transponder-equipped vehicle, or the for-hire individual who does not want others to know his/hers trips.

Most of these concerns can be addressed by authorities. First, the basic practice is to make participation voluntary. If the ETC system is accepted voluntarily by users, then the user has made the choice to accept whatever loss of privacy may occur. Second, anonymous pre-paid accounts can be established; however, if the transponder is lost or stolen, the account balance is lost. Third, the toll authority maintains user privacy by separating accounting from transponder identification from personal identification functions. This separation allows traffic management to use transponders to monitor traffic without any personal monitoring (Ref 36). Fourth, the authority maintains non-ETC lanes that permit users to have non-ETC trips.

Other ways to ensure privacy require new legislation. The laws cover the deletion of travel records within 24 hours (billing shows number of trips, not when/where information), the requirement to keep trip information and records private, and the limiting of enforcement photographs to only that purpose.

When performing customer relations, the privacy issue should be addressed. ETC users need to know how the system works, what information is stored and for how long, and any supplementary transponder uses.

6.2 RESULTS OF SURVEYS

Surveys are an important tool for assessing public opinion. Typically, results are reviewed prior to making changes in the system, and a follow-up survey is performed to compare attitudinal changes.

6.2.1 Urban Transportation Monitor Survey

In 1988, the *Urban Transportation Monitor* executed a survey to determine how motorists feel about toll roads. They found that 48 percent of the respondents felt negatively about toll roads;

but when asked if automatic tolls would improve their attitudes, 85 percent of those surveyed said yes (Ref 4).

6.2.2 AT/Comm, Inc., Survey

Another more in-depth survey was conducted between October 1989 and May 1990 by AT/Comm, Inc. (Ref 37). It was a marketing research project to help determine system design, market statistics, and pricing structures. The research was divided into three individual exercises. First, agencies were surveyed: 54 in the U.S. and 2 in Europe. The surveys were distributed to agency personnel working in finance, operations, toll management, enforcement, and the commission level. Second, a motorist survey consisting of 12,000 handouts was performed at the Lincoln Tunnel, Goethals Bridge, George Washington Bridge, and the Holland Tunnel. Third, a telephone survey of 600 commuters in the New York metropolitan area was executed.

The results from the agency survey on barriers to implementation revealed the following ranked priorities: (1) safety concerns; (2) lack of standard in the industry; (3) cost to consumer; (4) lack of universal transponders; (5) requires the toll agency to maintain individual accounts; (6) requires new toll agency accounting systems; and (7) cost to the toll road.

From the motorist survey, respondents perceived the benefits of ETC as saved time (50 percent) and needed no cash (40 percent). Motorists were willing to pay one month (61.0 percent) to three months (25.7 percent) in advance tolls. An acceptable minimum balance (deposit) to maintain by a motorist was $20 (42 percent) and $10 (36 percent). Motorists would like to pay for their advanced tolls by check (58 percent) and credit card (27 percent), and with toll credit purchased by mail (49 percent) and over the telephone (20 percent).

6.2.3 ITS Survey

In 1990, the Institute of Transportation Studies (ITS) of the University of California at Berkeley, in association with GLS Research, conducted several surveys of toll bridge users in the San Francisco Bay area. The study was supported by the California Department of Transportation (Caltrans).

According to the surveys, over 82 percent of the toll bridge users in the Bay area were interested in using the ETC system; but when asked about permanently attached tags versus transferable, the interest dropped to 70 percent. Inside the windshield was the preferred tag mounting location for transferable tags, and the underside of the car for permanently mounted tags. Mounting the tag on the outside of the windshield was the least desired because of the risk of vandalism and because such placement was not aesthetically pleasing. Acceptable to the vast majority of toll bridge patrons was a $30 tag deposit, with a $40 minimum to open an account.

ETC was perceived as a way of reducing toll gate traffic congestion and improving air quality. The survey respondents were not concerned with tagged vehicles being more easily located by police. They also did not believe ETC might encourage an increased use of toll bridges.

Commercial users were more price sensitive to ETC operational issues than motorists. The interest in ETC by commercial users was highly elastic with respect to the cost of the tag deposit and payment method. The tag cost for commercial users should be kept as low as possible to allow the largest number of trailers to be tagged (Ref 38).

6.3 TESTS

Most of the operational systems in the United States started with a testing program. Testing is used to find faults in a system prior to full-scale operation. A faulty system can cause lost revenue, increased congestion, and public dissatisfaction. The testing time is considered part of a start-up period for choosing applicable technology, validating system reliability, determining maintenance requirements, monitoring sensitivity to climate, measuring background RF environment, and verifying operating requirements and standards. Finally, the testing period can demonstrate system benefits to the public and give guidance in the creation of tag distribution, database management, and system failure contingencies.

Appropriate procedures for testing and evaluating equipment must be provided. Note also that a comprehensive test takes 9 to 12 months (Ref 11). Tests are performed to verify manufacturer claims and to confirm specifications in hardware, software, and operation. Some items tested are listed below; these tests can be performed either in the laboratory or in the field (Ref 18).

1. Height tests (reading range between tags and readers)
2. Offset tests (offset distance from the center of the reader)
3. Temperature tests (the temperature extremes)
4. Speed tests (the range of speeds)
5. Multi-lane tests (tagged vehicles simultaneously in adjacent lanes)
6. Multi-tag tests (closely spaced tags passing reader)
7. Accuracy and reliability tests
8. Durability tests
9. Interference tests (electrical noise and radio transmissions)
10. System recovery tests (recovering from power cuts)

6.4 CUSTOMER RELATIONS

Customer relations play a big part in how an ETC system will be accepted by the traveling public. It is important to have a marketing department in place to give current and correct public information. Early incorrect knowledge is very hard to overcome, as demonstrated in Oslo, Norway: The newspapers debated whether a new tollway should have a toll ring when the decision had already been made; the public was outraged at this revelation(Ref 39).

Community issues is another area that deserves attention. Society has become well informed and will not tolerate technology if it goes against basic beliefs, values of fairness, and individual freedoms. An example of fairness is when the user gets the benefit of the doubt in a system failure situation. Implementation and operating schemes dealing with society values need to be carefully considered and explained (Ref 40).

6.4.1 Marketing

Marketing is one way to attract participants to the new ETC technology. The initial challenge is to find, with minimal effort, motorists who will participate. By dividing motorists into two categories — users with a distinct mission and the motoring public — promising markets can be identified.

Trucks (commercial transport), taxis and limousines, bus/vans (public and private transport), public vehicular use (police, etc.), and commercial enterprises (rental cars, etc.) are examples of users with a mission. It is possible to make contact with trade organizations to encourage these groups to participate. The other category, the motoring public, is a difficult group to identify, find, and reach. Although some members can be reached through a number of representative agencies (e.g., commuter groups, private car associations, and representative government bodies), the effort required for contacting is greater than the first category.

6.4.2 Advertising

Advertising can be done on- and off-site. On-site advertising, on or near the toll booth, is that presented to a captive audience waiting to pay tolls while ETC users pass through. Large signs near toll booths inform motorists of the transponder purchasing process. Of course, the best form of advertisement is the ETC system success.

Off-site advertising is useful in informing the public of the ETC benefits. Direct mailings are targeted to certain user groups. Signs, posters, and pamphlets can be placed at the Registry of Motor Vehicles and gas stations. Major newspapers and user group publications (such as newsletters) are examples of printed media that can be used to get information into motorist hands (Ref 41).

6.5 REGIONAL ETC SYSTEMS

The establishment of regional ETC systems has received much attention. The idea is to have within a region compatible systems that provide customer convenience for all vehicle types, congestion relief with improved mobility, more efficient handling of revenues, and enhanced traffic management opportunities. Before a regional ETC system is possible, studies must be performed on compatibility questions, standards for non-interfering systems, performance specifications (Ref 11), and cost effectiveness. Also, an agreement between agencies must be made concerning legal issues, operational coordination, customer procedures, and distribution of toll payments.

The advantages of a regional system having several different toll facilities using one tag are many. First, the percentage of motorists using the ETC system will rise because of the increased ease of movement in the region. Second, motorists will probably increase the number of trips they make on a monthly basis, causing a higher trip utilization rate that results in lower processing cost per transaction. Third, there will be a reduction in traffic congestion at toll plazas throughout the region; fourth, it may be possible to negate future toll plaza reconstruction activities (Ref 42).

There are two disadvantages (or barriers to implementation) of a regional system. First, independent toll agencies will no longer have complete control over the revenue and will have to place a certain amount of common trust in the regional group. Also, when participating in a regional system, an individual agency may not be able to continue special programs. Second, some toll agencies have specific Trust Indenture requirements that must legally be followed. These requirements may be tied to bond payments that must be made unless the Trust Indenture can be revised (Ref 42).

There is a need for a regional ETC system because multiple tags per vehicle generate negative public reactions. Additional tags are expensive for the motorist when he/she has to pay for each tag and maintain minimal account balances. Also, multiple tags can create interference problems because these devices need to be physically separated from one another to guarantee operation. Also, when operating separate ETC systems in the same region, there is duplication of effect, equipment, installation and maintenance costs. There is non-uniformity of system upgrading and difficulty in coordinating a traffic management system.

Regional systems are difficult to coordinate and require a tremendous lead-time to get all toll agencies to agree to system design. Since ETC systems are now off-the-shelf technology, individual agencies will not wait for regionally designed systems. Many agencies want to get a system in place and become comfortable with it before interconnection with other agencies, although compatibility will probably be emphasized when systems are upgraded (Ref 43).

6.6 EFFECTS OF LAWSUITS

Around the beginning of 1993, lawsuits in the electronic toll and traffic management (ETTM) field started to proliferate. These lawsuits affect the placement of ETC systems by causing toll agencies to freeze purchases until a company and/or its equipment listed in the lawsuit is cleared. Toll agencies do not want to invest time and money in a system if it is possible that a lawsuit will cause equipment to be removed.

6.6.1 Amtech Corp. vs. ISTHA

The Amtech Corporation filed suit against the Illinois State Toll Highway Authority (ISTHA) over ISTHA's awarding San Diego-based Science Applications International Corporation (SAIC) a contract to provide ETC equipment from AT/Comm, Inc. in Marblehead, Mass. Amtech, the subcontractor on one of the losing bids, claimed the Authority broke state law by conducting a sole-source procurement using specifications that only AT/Comm's system could meet. The suit said that the Authority did not allow for competitive bids that would ensure the lowest possible cost (Reported February 1993) (Ref 44).

By mid-April a state judge in Illinois dismissed the lawsuit on a procedural technicality. The judge ruled that, because Amtech was a subcontractor to Motorola, it had no legal standing to file suit against the agency (Ref 45).

6.6.2 Amtech Corp. vs. AT/Comm Inc.

In another lawsuit that was independent and unrelated to the Illinois suit, Amtech moved to sue AT/Comm for making false statements that were having a detrimental effect on Amtech's business. AT/Comm is counter-suing, claiming tortuous interference (February 1993) (Ref 44).

6.6.3 AT/Comm, Inc. vs. Amtech Corp. and Mark IV

On February 19, 1993, AT/Comm filed suit in U.S. District Court in Boston against two of its competitors for patent infringement. The company alleges that read/write automatic toll collection system marketed by Amtech Corporation and Mark IV violate AT/Comm's rights under several patents. AT/Comm charges that Amtech has violated its Patent No. 4,303,904, entitled "Universally Applicable, In-Motion and Automatic Toll Paying System Using Microwaves," and Patent No. 4,104,630, "Vehicle Identification System, Using Microwaves." Mark IV, AT/Comm says, violated the '904 patent, plus Patents No. 5,086,389 ("Automatic Toll Processing Apparatus") and 5,144,553 ("Electronic Vehicle Toll Collection System and Method"). Damages were not specified in the suits.

In a press release issued February 19, 1993, AT/Comm said that actions leading to the suits were triggered by a press release from Dallas-based Amtech, which described a test installation of its IntelliTag system on the Tobin Memorial Bridge in Boston. Amtec's release was dated February 3, the day MassPort conducted a public demonstration of IntelliTag. Immediately upon reading Amtech's release, AT/Comm commissioned the Cambridge, Mass., consulting firm, Arthur D. Little, to review various ETC systems to determine whether any of them were infringing on AT/Comm's claims. The decision to proceed with court action was based, in part, on the Arthur D. Little report.

Amtech denies that the IntelliTag system infringes on AT/Comm's patents. Amtech says its systems are different in design and operational characteristics, and that they hold patents on the technology used in the IntelliTag system (Ref 46).

AT/Comm has named the MassPort as a defendant in its suit against Amtech: MassPort, a Boston agency, installed Amtech's read/write IntelliTag system on the Tobin Memorial Bridge for a 90-day test. AT/Comm might sue other customers if they install read/write systems from either Amtech or Mark IV, although they might not file further suits against customers until after a judge decides in AT/Comm's favor. Because patent infringement suits typically take years to settle, Amtech and Mark IV will probably continue to provide their products while the suit is in progress, unless the court issues an injunction (Ref 47).

Relating to this lawsuit, near the end of March 1993 Amtech lost its attempt to obtain a temporary restraining order preventing the AT/Comm patent suit to be decided in Massachusetts. The restraining order ruling pertains to Amtech's desire to litigate the patent infringement suit in Texas instead of in Boston (Ref 45).

6.6.4 Lockheed Information Management vs. Metro Dade County

In June 1992, the Metro Dade County, Fla., Department of Public Works announced it planned to award a contract to SAIC. The $2.5 million contract was for an ETC system with automatic vehicle identification (AVI) on the Venetian and Richenbacker Causeways. SAIC, which was the low bidder, proposed using read-only AVI systems from either Amtech Corp. or Mark IV Industries' ITS Division. The Department planned to use the Amtech equipment because it was the lower-priced option.

After the Department announced its intentions, two of the losing bidders, Lockheed Information Management and Cubic Toll Systems, filed protests with Dade County. The county rejected the protests in summer 1992. Lockheed then brought suit against the county and SAIC questioning the procurement procedure. They also sought an injunction against the contract award. Lockheed was the second lowest bidder.

The court ruled against Lockheed in December 1992. The contract was offered to the lowest bidder, SAIC, which elected not to sign the contract. SAIC stated that while the contract had been held up for six months, their resources had been allocated elsewhere and, because of the 210 day schedule, could not sign the contract in good faith.

Rather than extend the project schedule, the Public Works Department is going to re-issue requests for proposals. The new proposal will be the same as the original one (Ref 48).

6.6.5 Cubic Toll Systems vs. VDOT

Virginia Department of Transportation (VDOT) posted an intent on January 4, 1993, to award a contract for an integrated toll collection system, including automatic vehicle identification (AVI) to MFS Network Technologies. The toll location was the Dulles Toll Road outside Washington, D.C., named the Fastoll Project, and the contract was estimated to be worth $12 million.

Cubic Toll Systems and Science Applications International Corp. (SAIC) both lodged protests shortly after the intent announcement. The VDOT denied the protest and SAIC chose not to appeal. Cubic, however, took the complaint to court. The complaint was that the AVI system from Texas Instruments (TI) that MFS proposed did not meet specifications in the RFP (Ref 49).

VDOT canceled its notice of intent to award the Fastoll contract to MFS Network Technologies on June 11, 1993. The trial, which had been postponed several times, was scheduled to begin on June 14, 1993. VDOT withdrew its intent to award because they discovered that MFS had erred in the information they supplied about the coin machines. Because the lawsuit was dropped, no ruling was made on the original question as to whether Texas Instruments' AVI system met VDOT's specifications (Ref 50).

6.6.6 Teamsters Local 72 vs. NYSTA

The New York State Thruway ETC opened on August 2, 1993, as scheduled. A ruling by the New York State Supreme Court stopped the New York State Thruway Authority (NYSTA) from operating lanes that allow patrons with AVI transponders to pay their tolls without stopping.

NYSTA had planned to operate two mixed-mode lanes and one dedicated ETC lane in each direction at the Spring Valley plaza near New York City, the first location to begin operating the E-ZPass System. But a suit filed by Teamsters Local 72, representing NYSTA's toll collectors, claimed that the dedicated ETC lanes would pose a danger to toll collectors who needed to cross the lanes to reach other plaza areas. NYSTA planned to post a 5 mph speed limit at the dedicated lanes, although it is common knowledge that most drivers exceed posted limits.

The court ruled that NYSTA can operate only mixed-mode and cash-only lanes until the grievance is resolved. Arbitration began on August 17, 1993. As a result of the injunction, the plaza operates two mixed-mode lanes and one cash-only lane in each direction.

An article in the August 2, 1993, *New York Times* alluded to the possibility that NYSTA's toll collectors are really concerned that the introduction of unattended ETC lanes threatens jobs. The article states that the union has a no-layoff contract, but quotes a NYSTA official who said that if the electronic system works well, the authority might reduce the number of toll collection jobs through attrition (Ref 51).

6.7 SUMMARY

This chapter discussed items other than technical implementation issues. The subjects included privacy, surveys, tests, customer relations, regional ETC systems, and lawsuits. The following chapter, Chapter 7, will discuss toll station operations.

CHAPTER 7. OPERATIONS AT TOLL STATIONS

This chapter discusses functions required for the operation of electronic toll collection (ETC) at toll stations. These functions include enforcement, maintenance, staffing, traffic operation, and vehicle classification.

7.1 ENFORCEMENT

Some form of enforcement at toll plazas is required, given that there are some motorists who will not pay tolls. This non-payment endangers the authority's toll revenue stream and causes honest motorists to pay higher charges.

In order for enforcement to be effective, communication, detection and localization are needed. Communication between the vehicle and toll agency is required in receiving payment. Detection is required to determine whether vehicles are tagged. Finally, localization determines which vehicle requires enforcement measures. Localization involves photographing only the non-paying vehicle.

In some cases, the travel lane has no barriers to enforce toll payment. Therefore, ETC equipment needs to be able to deal with vehicles speeds up to 160 km/h (100 mph). There are basically two toll payment lane types: stop and non-stop lanes.

7.1.1 Stop Lanes

Stop lanes occur in a toll plaza setting. For stopped lane toll payment, the lane may or may not have a gate. If gates are used, additional enforcement may not be necessary. Gates decrease the lane's throughput and create longer customer delays by not lifting until toll payment. Some gates are poorly located, allowing room for a noncompliant vehicle to squeeze past. This problem is solved by placing the gate closer to the pay location. If there are no gates, enforcement measures are needed to ensure payment.

7.1.2 Non-Stop Lanes

There are three types of dedicated ETC non-stop lanes: barrier lanes, special separate advanced lanes, and free flow lanes.

The first lane type is retrofitted into an existing toll plaza by dedicating an ETC lane. This lane coexists in the toll plaza with other payment methods limiting vehicle speed. This lane placement in the barrier toll plaza allows equipment placement to validate and inform the driver of the transaction and account balance.

The second non-stop lane type is configured for 25 mph about 115 m (380 feet) in advance of the toll plaza. This special separate lane has ETC equipment that validates the payment before reaching the toll plaza (Ref 52). (Note: A variable entry sign is not shown, since it is placed far in advance of the lane.) If the tag is not valid, the vehicle is directed by gates or lights to the toll plaza. A valid tagged vehicle continues past the toll plaza in its separate lane without stopping. This type of lane requires video/photo enforcement.

The third type of lane is free flowing, which means there are no barriers or impediments, as shown in Figure 7.1. Here ETC equipment is placed either above or adjacent to the lane. In this situation, there are no external indications given to a driver about their passage or the validity of their tag, although an internal indication of toll payment can be given by a light or sound through an in-vehicle unit (IVU). Here effective enforcement measures are required to control non-payment either by using enforcement vehicles or photos.

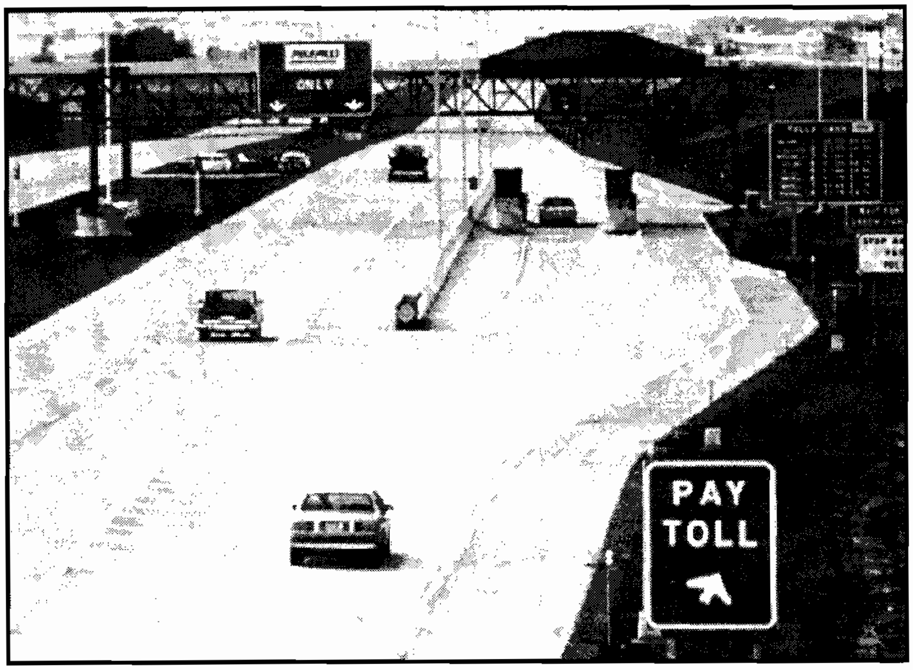

Figure 7.1. An Example of Free Flowing Lanes (from "The PIKEPASS Connection Oklahoma Motorists Avoid Tollbooths." Government Technology, August 1992)

7.1.3 Types of Non-Payments

There are four different sets of circumstances for non-payment that must be treated individually, owing to customer relations. Violations are divided into untagged vehicles, inoperative transponders, insufficient account funds, and invalid technology for toll payment (fraud).

With untagged vehicles, it is the driver's responsibility to leave an ETC dedicated lane when indicated. If the driver does not leave the lane, it is assumed that he/she is making a deliberate effort to avoid paying the toll. Because enforcement may not be visible, the driver may assume a no-penalty free ride. Most authorities establish an enforcement grace period when starting a dedicated ETC lane; this grace period allows law-abiding motorists to become familiar with the concept.

In the case of inoperative transponders, the driver may not realize there is a problem and should be given the benefit of the doubt. To inform the driver of a problem, in-lane indications on the status of ETC toll payments can be set up. An inoperative transponder can be the result of a poorly placed tag or of an improper vehicle class tag (Ref 36).

For insufficient account funds, the motorist is informed that there is a problem either internally or externally. If the motorist ignores the indication, he/she should receive notification of the problem and be given the opportunity to pay without being ticketed. If the problem is recurring, then additional enforcement and penalties are needed.

The fraudulent use of technology to avoid payment is serious. The authority needs to detect and eliminate this threat quickly, since it will cause a higher unit charge for honest users (Ref 40).

7.1.4 Video Enforcement Legislation

Some states do not currently allow toll violations to be issued on the basis of picture/video evidence, requiring instead observation by a law enforcement officer. This is a regulatory issue of ticketing the owner of the vehicle instead of the actual driver. The photography-based method of enforcement is already being used for speed-limit and traffic-light violations (Ref 20).

In 1991, New York state law did not permit the fining of motorists based on photographic evidence. Legislation has since been passed to allow enforcement to include photographs. The following are key points in New York's state law:

- The vehicle's owner can receive a civil penalty for toll evasion with photomonitoring evidence and information.
- The notice of liability must be mailed first class within 30-days after the violation.
- The penalties for the violation increase as the number of offenses increase: First offense = the greater of $50 or 2 times the toll; second offense = the greater of $100 or 5 times the toll; third and subsequent offenses within 18 months = the greater of $150 or 10 times the toll.
- The imposition of liability is based on the evidence.
- The conviction of the toll violation is not conviction of the operator and is not recorded on their motor vehicle operating record.
- Exceptions to liability: if the vehicle was properly reported stolen, if the lessor of the vehicle provides the court with the lessee's name and address, and if owner indemnification is in place against vehicle operator.
- Conviction requires a certified copy of the photo delivered to the court.
- Guidelines on account delinquency must be adopted and notice of delinquency must be mailed before holding liable for violation.
- The photos may not be used for any other purpose.
- Failure to appear in court or to pay fines on five or more violations issued within 18 months will lead to a suspension of vehicle registration or, for out-of-state residents, suspension of operating privileges in New York.

In order to obtain passage of this toll law, authorities claimed that the law provided confidence in revenue protection for the public and bondholder. They used legislator education, compromise, emphasis on deterrence, protection of confidentiality, appropriate limitations on liability, and persuasion to get the bill passed (Ref 53).

7.1.5 Toll Evasion Violation Enforcement Systems

This section discusses toll evasion violation enforcement systems. The subsections include examining basic technical approaches, obtaining clear images, obtaining the correct image, and identifying license plate numbers.

7.1.5.1. Basic Technical Approaches: There are four technical approaches to toll enforcement. They include law enforcement officer, photographic systems, time lapse systems, and frame capture systems. The first technical method involves having law enforcement personnel issue tickets to toll evaders. While the visible presence of law enforcement officers and their vehicles can reduce toll violations, such 24-hour surveillance is also expensive and impractical; moreover, pulling over toll evaders disrupts traffic.

The second basic approach is through the use of photographic systems. These systems were used before the widespread acceptance of closed circuit television (CCTV) systems, time lapse recorders, and frame capture systems. Few photographic systems are still in place. Photographic systems consist of an electronic alarm trigger attached to a photographic camera having a large capacity film canister. The system's high resolution allows for license plate reading. The picture also includes more information in the field of view, such as traffic lights, the vehicle, patron toll display, and vehicle driver. The reasons for the decline of this method include the high cost of the systems, limited suppliers, high cost of film media and subsequent processing, and inconvenience of handling photographic media.

The third method is the time-lapse system. This basic system has a CCTV camera, a time-lapse recorder, and an alarm detection device. The time-lapse recorder annotates the image with the date, time, and alarm indication. The recorder continuously records at a very long duration (examples include the 24-hour mode used by the Illinois State Toll Highway system and the 720-hour mode used by the Oklahoma tollway) and changes to the 2-hour recording mode under alarm conditions (Ref 54). This continuous recording in the 24-hour mode can show (e.g, in court) the transaction before and after the violation, thereby demonstrating the equipment was operating correctly. The system can be set up to automatically search for alarms on the editing/playback workstation. These systems provide good, usable results at a reasonable cost.

Fourth, the frame capture system obtains an electronic image (a digital "snapshot") captured from an electronic CCTV system. This image can be stored on removable memory cartridges, floptical disks, and on optical disks. This single image can be transmitted from a remote toll location to a centralized storage and processing facility. The resolution of the image is limited by the magnetic properties of the video tape, and by physical recording head limitations.

The frame capture system can provide two services. First, it can be a deterrent to toll evasion and, second, it can record "unusual occurrences" for further analysis. These unusual occurrence images are time/date annotated and are combined with a toll transaction log. The review of the data and image allows personnel to determine if a toll evasion incident actually occurred.

The frame capture system usually provides a resolution higher than that captured through time-lapse recorders. This is an advantage when attempting an automatic license plate reading (meaning the reading is being performed by a computer versus an employee). System limitations include only the camera or the frame-capture equipment.

7.1.5.2. Obtaining Clear Images: To obtain a clear image of the license plate, the position of the camera for the field of view, the shutter speed of the CCTV camera, and the maintenance of the equipment are all important. The field of view needs to be set no larger than necessary to maintain a readable license plate image (though it needs to take into account the placement of license plates, either to the left or right of the vehicle's centerline for trucks and vans). The usual size employed for the best readability is approximately 0.9 m x 1.2 m (3 feet high by 4 feet wide).

To obtain clear, sharp images of moving vehicles, it is very important that the shutter speed of the CCTV camera be correctly set. Most modern CCTV cameras have an adjustable shutter speed feature that operates automatically. In this automatic shutter mode, the camera adjusts the shutter speed according to the light level present. The minimum shutter speed is based on the speed of the vehicle, the angle of the camera with respect to the traffic flow, the resolution of the system, the camera field of view, and the sensitivity or Lux rating of the camera. Auxiliary lighting to supplement the ambient light at the toll lane may be required. Types of additional lighting can include incandescent, fluorescent, strobe (usually for frame capture systems), or infrared.

Maintaining the equipment is essential in receiving a sharp image. The equipment is in a dirty environment, with grime settling on the housings and optics. This dirt reduces image contrast, making it more difficult to read license plates. When cleaning the housing windows and camera lenses, extra care must be taken to avoid scratching the optics.

7.1.5.3. Obtaining the Correct Image: The following factors affect the equipment's ability to obtain a clear image: the robustness of the toll processing algorithms, physical lane layout, position of the camera, and the vehicle separation sensors. First, the processing algorithms need to consider all possible occurrences. The issuance of unwarranted citations can lead to a loss of public support and can jeopardize warranted citations that are taken to court. This is why time-lapse recorders prove more valuable in court than a single snap-shot image.

Second, the physical layout of the lane should be designed to minimize unusual occurrences—for example, when two vehicles can fit between the reader and the gate or treadle at the exit point.

Third, the positioning and placement of the camera is important in obtaining a clear image. The camera is usually mounted 30 degrees or less in both the horizontal and vertical directions to the side of the roadway; the camera can also be mounted overhead. There is no perfect placement or angle for the camera, given that interference can come from tailgating vehicles or from a recessed vehicle body.

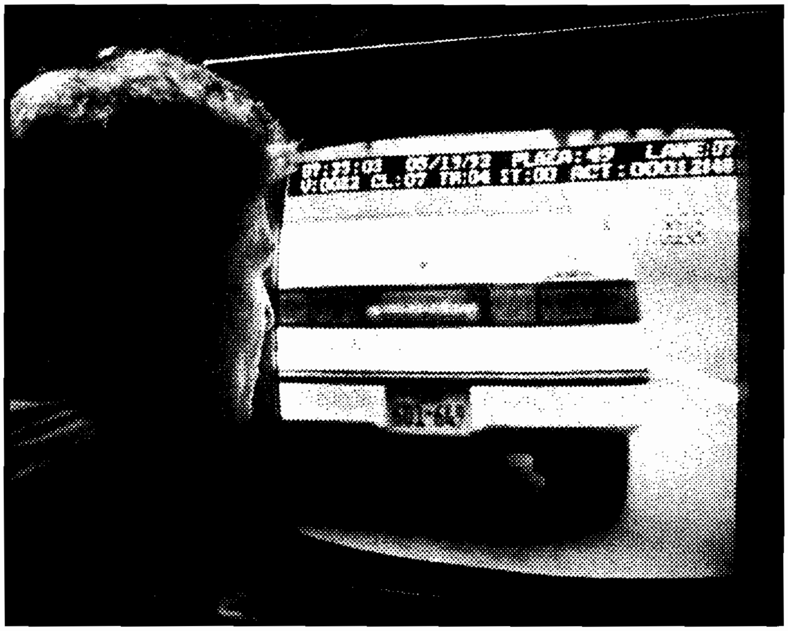

Figure 7.2. An Example of Video License Plate Enforcement (from Cubic Toll Systems)

Fourth, since vehicles are not always ideally spaced in the traffic stream, vehicle separation sensors need to be adequate to allow the correct vehicle to be detected. The traditional sensors (loop sensors, photo-optic sensors, and treadles) may have difficulty in separating two closely spaced vehicles. A more sensitive device (e.g., a photo-electric beam) is a possible alternative.

7.1.5.4. Identifying License Plate Numbers: After images have been captured, there is additional processing. The vehicle's license must be read, either manually or by a machine, and the violation frequency must be determined for the vehicle; the Department of Motor Vehicles' (DMV) database must then be cross referenced to obtain the owner's name and address.

It is estimated that 5 percent of all license plate images cannot be read automatically. While automatically reading the license plate is a highly cost effective alternative to manually reading the numbers, computer reader accuracy is only 70 to 85 percent. Reasons for reduced accuracy include interference caused by trailer hitches, bumper damage, mud, ice, snow, photographing wrong vehicle, view obscured by a tailgating vehicle, difficulty in determining the vehicle's state, lighting (glare, too little or too much light), poor contrast in the license plate, and license plate damage (Ref 54).

7.1.5.5. Conclusion on Violation Enforcement Systems: For effective enforcement, the probability of a violating vehicle being photographed must be very high and the license plate reading must be extremely accurate. It is desirable that the violation image show both the vehicle and the license plate. This combined image is required in order for it to represent evidence of the vehicle's violation. There are quantitative problems to this enforcement method that have to do with storage, transport, processing, and billing. While adequate, it is not a perfect system (Ref 20).

7.2 MAINTENANCE

An ETC system can be programmed to perform automatic notification of maintenance needs. Event monitoring and predictive diagnostic hardware and software are available. The mean times between failures can be tracked and used to help determine the spare parts inventory to ensure minimal down time. The system equipment can be designed with ease of access, so that component replacement is quick and non-hazardous. An integrated system (one having manual and coin machine lanes) can coordinate lane controller diagnostic information and can provide the status of in-lane devices to the toll host computer for maintenance scheduling. The system can be designed to offer histories and feedback on parts usage, failure histories, warranty repair, and work scheduling. In addition, for diagnosing problems the system can be designed to include access points that permit the use of laptop computers.

7.3 STAFFING

Often when an ETC system is proposed, the personnel staffing the existing toll plaza functions feel some level of apprehension. It is inevitable that the employees will resist the change. Management can help employees meet the technological changes by minimizing the disruption and perceived threat, implementing training programs to optimize the use of the new technology, and restructuring position descriptions and performance evaluations to include ETC functions. Areas of employee concern include job security, safety, health, and training.

7.3.1 Job Security

Job security is a major concern of both current employees and new applicants. Usually agencies assure the toll collecting staff of assignment to new jobs dealing with operating and maintaining the ETC system. As the percentage of ETC users increases, the ETC support system will provide more accounting and audit work. There will also be a reduction in coin and cash handling, creating a shift in labor needs. Plans for this change should be shared with the entire work-force.

7.3.2 Employee Safety

Since dedicated ETC lanes can allow vehicles to travel at high speeds adjacent to attended lanes, employees are concerned about their safety. Employees need to be informed about the special safety provisions that have been included. Provisions include providing access to toll booths, using special lane separating delineators or barriers to channel and reduce the speed of oncoming traffic, using variable message signs to indicate designated ETC lanes, placing additional signs to minimize last minute lane changes as vehicles approach the toll plazas, and making employees more visible by having them wear traffic vests.

7.3.3 Employee Health

There have been worker health concerns about the possible effects of this new technology. The concerns presently center around exposure to low levels of magnetic fields used by antennas and readers. Recent reports on the effects of worker exposure to electric radiation (the carcinogenicity of which has been much debated) have prompted some authorities to specify in-ground transmitting antenna locations (Ref 9). Current research on the possible health risks associated with automatic vehicle identification (AVI) technologies has been inconclusive.

7.3.4 Employee Training

Employee training in ETC functioning is important for job performance and morale. Much of an ETC system deals with computers. An integrated toll collection system can eliminate most paperwork, perform automatic audits, and provide key indicators for evaluating employees. Employees worry the new system will require them to take on additional or different work that requires the use of computers. If they have very little experience with computers they may feel intimidated. These employees will need extensive training before they are comfortable with the new system.

7.4 SECURITY OF MONEY

As the use of ETC increases, there will be a decrease in coin and cash handling at toll plazas. And with the decrease in cash handling comes an increase in toll plaza security. Some of these coins and cash were historically lost in the collecting, handling, and transferring. This loss can be attributed to many factors, mainly: (1) toll payment evasion by drivers; (2) incorrect toll amount exchange, whether intentionally or not; (3) change lost in or around the toll booth area; (4) unethical toll collector behavior; (5) handling during the process of transferring the cash from the toll plaza to the bank; (6) inaccurate counting; and (7) robbery. The ETC system should reduce the percentage of lost revenues by eliminating or decreasing many of the contributing factors (Ref 10).

7.5 TRAFFIC OPERATION SAFETY

Authorities need to carefully evaluate the ETC system impact on traffic safety. ETC systems can be retrofitted into toll facilities or designed into new facilities.

Customer understanding of the system is a major traffic safety concern. Motorists who do not understand how to use the system put both themselves and the toll staff in danger. This knowledge and expectation of the toll plaza layout and operation emphasizes the importance of a coordinated regional system. Tollroads should use uniform standards and approved operational methods.

There have been accidents at toll plazas that have resulted in driver and agency employee injuries and fatalities (Ref 10). Toll plaza areas require vehicles to maneuver between lanes both before and after the plaza. Separate ETC lanes improve safety by allowing the removal of booths and barriers.

To provide safe passage through the toll plaza, variable message signs indicating status are used over each lane. Additional operational measures include the use of pavement markings, signing, speed limits, and channelization.

7.6 VEHICLE CLASSIFICATION

Vehicle classification, a relevant issue for any toll facility, varies tolls by vehicle type and/or number of axles within a vehicle type. This means that each vehicle that uses the facility must be checked or verified for vehicle classification. The inaccuracy of some vehicle classifiers results in substantial errors. Looking for and resolving violation questions caused by these discrepancies require the reviewing of video tapes or other enforcement material. The verification of errors requires significant staff time.

There are two common fixed toll methods utilized by ETC systems: single class use (such as passenger cars or commercial truck) or single vehicle use (the tag is associated with one vehicle only). Another method has the driver assign tags for use on any vehicle type. For this method, the tag floats between the vehicles the driver uses. For example, he/she drives a passenger car to work, changes vehicles to a commercial van and uses the same tag to pay the toll. This means the system must classify every vehicle in the system. This method is most likely to generate errors that lead to incorrect customer billing.

With the single class use of tags, a family can change the tag between their passenger vehicles instead of obtaining a tag for each vehicle. This system results in improved reliability of billing and violation detection over the assigned driver tag method, which allows the tag to float between vehicle types. The tag can be programmed with numeric characters to denote class and can be restricted to one vehicle class use. It also allows the vehicle classifier operation to be effectively monitored.

A problem with the single-class tag system is that switching tags from one vehicle to another can result in missed (non-read) tags. This occurs because equipment is moved out of position, misplaced, or lost. With low-speed ETC systems that give feedback (red or green light) after tag reading, there is time to present or reposition the equipment to obtain an acceptable reading. This second chance is possible by the longer reading periods available. In a high-speed ETC system, there is no such chance to readjust the tag, resulting in lost revenue and customers receiving enforcement notification.

With the single-vehicle use of tags, the tag is usually physically attached to each vehicle. This limiting of tag use may improve the system's reliability. With one-vehicle use (known vehicle and license number), violators can be identified as having an inoperative tag versus not having a tag; in addition, tag operation is more predictable (Ref 36).

7.7 SUMMARY

This chapter discussed toll station operations, including enforcement, maintenance, staffing, security of money, traffic operation safety, and vehicle classification. Enforcement is broken down into sections on stop and non-stop lanes, types of non-payment, video enforcement legislation, and toll evasion violation enforcement systems. The staffing section discussed job security, employee safety, employee health, and employee training. The next chapter will discuss the costs associated with ETC systems.

CHAPTER 8. COSTS

When designing a toll collection system, cost-effectiveness is a major consideration. There are many toll agencies seriously considering implementing new technology in an attempt to relieve toll plaza congestion and meet future traffic demands. Equipping, operating, and maintaining an electronic toll collection (ETC) lane is considered to be the most cost effective method if ETC utilization is high. An ETC system will reduce the number of toll booth attendants and will eliminate the ticketing associated with a closed toll system; however, the savings will be partially offset by new operating costs, including customer account handling costs, tag selling, and additional maintenance costs (Ref 10).

8.1 COST OF IMPLEMENTING AN ETC LANE

The use of ETC lanes has the potential to reduce future toll plaza expansion or reconstruction. Use of ETC lanes may reduce the number of toll lanes required. This is considered to be an important factor in the cost-effectiveness analysis. Using the traditional methods of toll collecting (manual, automatic coin machine, coupons, passes, etc.), one expressway lane must expand to three approach lanes, which expand to six tollbooths. This is to ensure the capacity of the road itself is not constricted by the capacity of the tollbooths (Ref 19).

Besides plaza construction or reconstruction cost savings, the equipment cost per lane for ETC lanes also results in cost savings. Table 8.1 shows the per lane cost of equipment for each lane type.

The manual lane includes a lane controller, a manual toll terminal, a receipt printer, a slot reader, a patron fare display, a loop detector, an automatic vehicle classifier, a canopy signal light, a toll booth, and two contact treadles. The automatic coin machine lane includes an automatic coin machine, two loop detectors, an exit gate, an island traffic signal, a canopy signal light, and two contact treadles. The dedicated ETC lane includes an ETC reader (canopy mounted), an ETC reader/controller, a CCTV violation camera, two loop detectors, an island traffic signal, and a canopy signal light.

Table 8.1. Lane Type versus Lane Equipment (Ref 55)

Lane Type	**Lane Equipment (Cost per Lane)**
Manual	$58,500
Automatic	$58,000
Manual / Automatic	$107,500
Manual / ETC	$72,700
Automatic / ETC	$69,500
Manual / Automatic / ETC	$121,300
ETC Dedicated	$15,400
Express ETC	$15,400

Note: These numbers do not include plaza or host computer equipment.

As noted in the table, the plaza and host computers are not included in the cost per lane. The cost for the plaza computer is estimated at $124,400, while the host computer totaled $296,800 (Ref 55). These costs are not included, since they are considered a general cost for toll operations. Cost for computer software is also not included because software costs vary and the total software cost will be divided by the number of ETC lanes placed.

When discussing system costs, the costs per lane start with generic numbers to provide a broad measure of costs. It is important to remember that, as the number of lanes increases, the cost per lane decreases, since system development, software, and central system costs will be spread over a larger number of lanes. For example, a small single-plaza system of ten toll lanes can have an equivalent cost per lane of about $50,000 per lane, while the larger system of 100 lanes can have a cost between $20,000 to $25,000 per lane (Ref 42). Thus, an ETC system becomes increasingly cost effective as the number of ETC lanes increases.

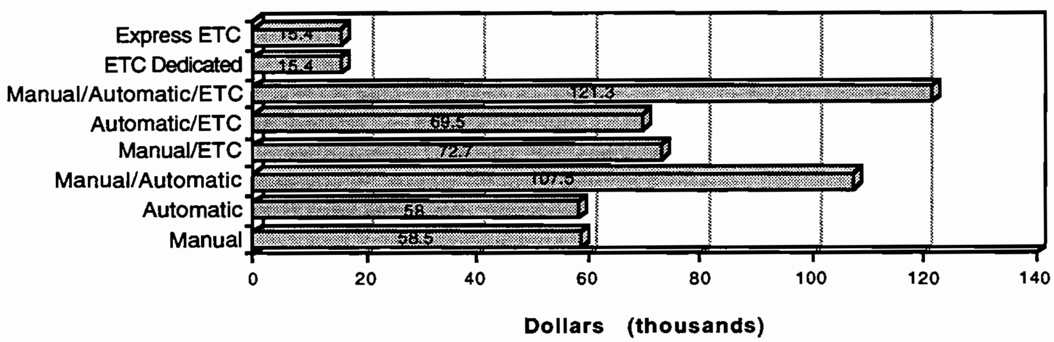

Figure 8.1. Lane Types versus Lane Equipment (Ref 55)

8.2 COST OF COLLECTING TOLLS

Operating costs, user costs, and environmental costs must be identified when examining the costs of tollway collection systems. Operator salaries, facility operation and maintenance, and revenue processing fees are the major operating cost items. The operating cost of toll facilities is highly variable depending on the number of employees, the location, number of booths, and the collection mechanism. The user cost sources include fuel and oil consumption, tire wear, vehicle maintenance and repair, rear-end accidents, and delay, all owing to the stopping maneuver required at toll booths. Around 85 percent of the user cost represents the time lost by drivers while waiting to pay (Ref 56). The environmental costs are associated with excessive emissions and noise pollution generated at toll facilities. These costs are difficult to assess and can only be reported as amounts of various pollutants generated.

8.2.1 Cost Per Transaction

In this cost-effectiveness analysis, system costs are perhaps better viewed on a per-transaction basis. As with other items, the cost per use for an ETC system decreases as the utilization increases. Costs per transaction may range from about $0.05 to $0.10, depending on system size and use. Manual toll collection costs run to about $0.086 per transaction, an estimate that includes equipment, maintenance, and auditing costs. If half the toll transactions are processed in automatic (coin and ETC) lanes, the overall average cost per transaction is reduced to about $0.056 (Ref 42).

8.2.2 Transponders

Another important cost factor is the on-board vehicle devices (transponders and/or on-board units) that will uniquely identify ETC patrons. Cost estimates range widely by vendor and desired options. However, transponders generally cost from $15 to $50 each, depending on type and number purchased. Costs for transponders run from $0.01 to $0.03 per transaction (Ref 42), depending on utilization rate per month and product life.

In distributing transponders to patrons, a toll agency may require an up-front deposit for the transponder, give the transponder to the patron (and charge a monthly service fee), have the patron purchase it outright, or have the patron pay for part of the transponder cost initially or with a monthly service fee. The method chosen will probably effect the level of ETC program participation.

8.2.3 Operating and Maintenance

Another potential area of cost savings for toll agencies will be ETC equipment operations and maintenance. The following table shows the cost per lane type for operating and maintaining toll lane types. In looking at Table 8.2, which compares lane type versus operating and maintenance costs, it is interesting to note that Triborough Bridge and Tunnel Authority (TBTA) reported that a single lane on a toll facility in New York City has a fully loaded direct labor cost of $318,000, and that maintenance of an ETC installation would be $10,000 per lane per year (Ref 41).

Table 8.2. Lane Type versus Operating and Maintenance Costs (Ref 55)

Lane Type	**Operating & Maintenance (Cost per Lane)**
Manual	$141,900
Automatic	$43,300
Manual / Automatic*	$111,000
Manual / ETC	$146,100
Automatic / ETC	$47,500
Manual / Automatic / ETC*	$115,200
ETC Dedicated	$4,200
Express ETC	$4,200

* Based on operation of 16 hours manual and 8 hours automatic coin machine

Note: These numbers do not include plaza or host computer equipment.

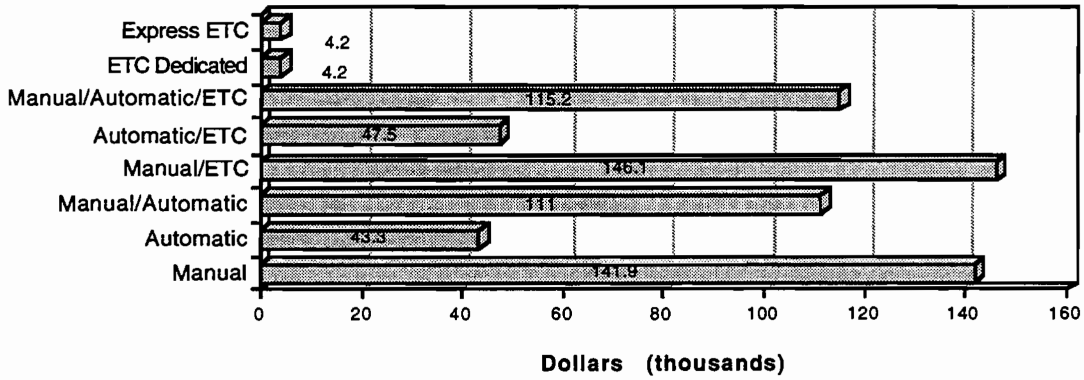

Figure 8.2. Lane Type versus Operating and Maintenance (Cost per Lane) (Ref 55)

The majority of the operating costs associated with ETC systems deal with account handling and maintenance. Payments will have to be credited, invoices prepared and mailed, and postage costs covered. The pre- versus post-payment method will influence ETC appeal. The possibility of linking ETC accounts directly to credit cards can reduce operating costs. It should be noted that the processing cost per transaction will vary widely depending on the number of transactions per month or billing cycle (Ref 42).

CHAPTER 9. SYSTEM APPLICATIONS

This chapter reviews ETC system applications within and outside the U.S. States that have installed ETC systems include California, Colorado, Georgia, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Oklahoma, Texas, and Virginia. The countries reviewed include China, England, France, Japan, Malaysia, Mexico, Norway, Portugal, Singapore, South Africa, Spain, and Sweden.

9.1 SYSTEM LOCATIONS WITHIN THE U.S.

This section summarizes ETC development by agencies within the U.S. The sections are subdivided by states, with New York, New Jersey, and Pennsylvania discussed under the Tri-State Area.

9.1.1 California

California experiences are broken into five sections in approximate chronological order. The sections are Caltrans, Transportation Corridor Agencies (TCA), California Automatic Vehicle Identification (AVI) Standard for electronic toll collection (ETC), and California Private Transportation Corporation (CPTC).

9.1.1.2. Caltrans: In October 1988, the California Department of Transportation (Caltrans) initiated a test of AVI on the San Diego-Coronado Bridge. Although discontinued in 1990, the test represented the first California ETC application. The project tags used the acoustical wave technology developed by X-CYTE Corporation. These tags were each assigned an unique number that identified the vehicle and could be remotely read by radio frequency (RF) readers. The electronic tag, about the size of a credit card, was attached to the vehicle windshield (Ref 38).

As of June 1991, Caltrans was considering ETC systems for the following nine state-owned and -operated toll bridges: San Francisco-Oakland Bay, Antioch, Benicia-Martinez, Carquinez, Dunbarton, San Mateo-Hayward, Richmond-San Rafael, Vincent Thomas, and the San Diego-Coronado Bridge. The Golden Gate Bridge is operated and maintained by the Golden Gate Bridge Highway and Transportation District; there is also a small toll bridge in the City of Oceanside serving Camp Pendleton (Ref 57).

9.1.1.2. Transportation Corridor Agencies (TCA): Around 1990, the California legislature created a $2.1 billion toll project in Orange County, California, one that would use the "latest state-of-the-art electronic toll collection systems" to decrease congestion at the toll plazas. The Transportation Corridor Agencies (TCA) are incorporating automatic toll collection into the design of three new toll roads: San Joaquin Transportation Corridor, Eastern Transportation Corridor, and Foothill Transportation Corridor (Ref 58).

Owing to the substantial traffic demands on the Orange County Toll Road project corridors, planners estimate that the ETC system will have a 60 percent participation rate. The system will also have a complicated traffic management system (TMS) to assist the authority in managing the toll roads. The TMS will have an operations center, advisory radio, variable message signs, ramp meters, closed circuit TV, and loop detectors (Ref 59).

9.1.1.3. California AVI Standard for ETC: In the Summer of 1992, the California legislature established an AVI non-stop tolling standard. By October, a group of local toll authorities and vendors were trying to obtain an exemption so they could use AVI equipment not meeting the state standard.

In November 1992, there were seven toll road projects underway (three public and four private) that planned to use ETTM technology. If exemptions are granted, then California's bridges and planned toll roads would be equipped with incompatible ETTM systems. Permission to use an interim system would require conversion to state standards within 5 years after any portion of the toll road opened to revenue traffic.

The problem with the state specifications was that, in October 1992, the "standard" equipment had not yet been manufactured. Transportation Corridor Agencies (TCA) and California Private Transportation Corporation (CPTC) (one of four private firms awarded franchises by the state in September 1990) needed a proven off-the-shelf system technology.

Caltrans expected to issue a request for proposal (RFP) for an AVI-based toll system in late 1992. They hope to install state-specified systems on eight toll bridges within a few years.

The California AVI specification requires a two-way communications link based on backscatter technology operating in the 902-928 MHz band. Hughes Aircraft in Fullerton, California, opposes the state AVI standard because they do not use backscatter technology. The California standard is similar to IntelliTag2 by Amtech, which has read/write capabilities (Ref 60).

9.1.1.4. Transportation Corridor Agencies (TCA): On January 14, 1993, Lockheed Information Management Systems (IMS) in Teaneck, New Jersey, was awarded a systems integrator contract by Transportation Corridor Agencies (TCA). The contract includes designing and installing ETC equipment, providing staff, and maintaining facilities for up to 20 years on three new, publicly-owned Orange County toll roads.

The 20-year, $600 million, contract will include AVI equipment from Mark IV Industries' ITS Division and smart cards from AT&T. Lockheed will have to update the ETC component within 5 years to bring it into compliance with the California AVI standard, which is not compatible with the Mark IV/AT&T system (Ref 61).

An interesting point to TCA's vendor selection process is that they did not perform on-site AVI equipment testing, as had been the case with other ETC projects. Instead, TCA used tight requirements covering equipment response time and accuracy. The contract requires the vendor to pay for all vehicles utilizing the toll system, whether the vendor collects a toll or not. Thus, the responsibility that the ETC equipment functions properly lies squarely with the vendor (Ref 62).

The three Orange County roads receiving the new toll collection system are the San Joaquin Transportation Corridor, being constructed by the San Joaquin Hills Transportation Agency, and the Foothills and Eastern Transportation Corridors, being constructed by the Foothills/Eastern Transportation Corridor Agency (Ref 62).

9.1.1.5. California Private Transportation Corporation (CPTC): California Private Transportation Corporation (CPTC) awarded a contract to MFS Network Technologies (formerly known as Kiewit Network Technologies) located in Omaha, Nebraska. The $9 million contract, announced in January 1993, is to engineer, furnish, install, and maintain an ETC for a private toll road being built in southern California. MFS will have Texas Instruments (TI) supply AVI technology as part of an exclusive co-development agreement.

Having obtained a 35-year franchise from Caltrans, CPTC is building a 22.53 km (14 miles) toll road in the median of State Route-91, which links Orange and Riverside Counties. This toll road is to relieve congestion of SR-91 through voluntary congestion pricing. Drivers who have AVI transponders and who want to avoid the current congestion levels of SR-91 can enter the toll road. To inform drivers of congestion conditions, there will be changeable message signs 8.85 km (5.5 miles) before the tollway entrance.

Fees will be collected midway along the toll road as vehicles pass at highway speeds under readers located on an overhead gantry. A video enforcement system will record license plates of passing vehicles not having valid transponders. CPTC plans to grant special status to high occupancy vehicles (HOVs) transporting three or more people. They will be able to use the toll road without charge or at a discounted rate. At the toll collection point, there will be a third lane in the road reserved for HOVs. Video equipment will survey vehicles as they pass (to verify that they contain at least three people). If the vehicle is not eligible to use the lane, the system may charge the full price or the driver may be pulled over by the California Highway Patrol (CHP). CPTC is contracting with CHP to provide services on the toll road. A mobile radio system will provide voice communications among CPTC, CHP, and Caltrans staff.

TI and MFS are still developing the system equipment, which should conform to the California AVI non-stop tolling standards. If the toll road opens by the end of 1995 (as CPTC plans), the facility will be the first toll collection facility to accept payment exclusively in electronic form (Ref 63).

9.1.2 Colorado

A new Denver-area toll road, E-470, partially opened in June 1991. There are 14 toll lanes equipped with ETC reader systems using surface acoustic wave technology from X-Cyte, Inc., in San Jose, California. For the $4 million E-470 project, X-Cyte was a subcontractor to PRC, Inc., a McLean, Virginia, based system integrator. X-Cyte supplied AVI readers and transponders, while PRC designed the communications links, coin machines, and host computer.

. E-470 is a public highway authority consisting of the local governments of four cities and three counties in the Denver area. Although the first segment of the toll road is already open, E-470 will not start collecting tolls until mid-July 1993. It was estimated that about 6,000 vehicles will be equipped with ETC transponders. ETC users will be asked to pay a $20 deposit for the transponder, which costs the toll authority $28. The X-Cyte vehicle tags use signal encryption to prevent counterfeiting; the tags do not have batteries.

In addition to the ETC equipment, E-470 was installing 14 cameras on the new roadway for toll enforcement and inductive loops for gauging traffic flow. The ETC readers will be connected to host computers by fiber optic cables. Software for the computers was developed by PRC. While the automated toll system was fully installed in June 1991, system designers continued to readjust camera positions and to work out minor software bugs.

The automated toll collection system uses centralized accounting but not an automatic debiting feature. ETC users are billed for their toll transactions at the end of each month. Users will be asked for a credit card number from which toll transactions will be deducted monthly. Patrons requesting an itemized bill from the toll authority will be charged an additional $2 per month (Ref 64).

The Boise, Idaho, firm of Morrison-Knudsen, which has the design-build contract for the remaining 69.19 km (43 miles) of E-470, issued a RFP for a turnkey toll system. The submission deadline was June 17, 1993. The RFP called for the design, integration, and installation of an ETC system in addition to retrofitting the existing system, if necessary. The 80.45 km (50 mile) toll road is scheduled to be completed by January 1997, at which time E-470 should have about 100 toll lanes (Ref 65).

9.1.3 Florida

The state of Florida section is broken into six chronologically ordered sections. The sections include Bay Harbor Islands, Orlando, two sections on Florida Department of Transportation (FDOT), Orlando-Orange County Expressway Authority, and Metro Dade County Florida Department of Public Works.

9.1.3.1. Bay Harbor Islands, Florida: In 1990, the local government of Bay Harbor Islands, Florida, began efforts to improve its toll collection operating efficiency by installing six LazerData's laser bar code scanners on the six-lane, bidirectional causeway; Cubic Toll Systems implemented a revamped toll booth management system on the causeway that carries 20,000 vehicles daily.

The motivation for the toll collection system upgrade was to improve system efficiency by reducing the labor costs involved with issuing, collecting, re-rolling, and re-issuing tokens. The bar code scanner-based system had three key features the causeway operators liked: (1) the scanner's ability to read a bar code in any weather; (2) the units' ability to distinguish between different decal types; and (3) the scanner's ability to read four different bar codes, identifying commuter, annual, limited non-revenue and non-revenue unlimited passes. Also, the new system includes a management system to give unusual occurrence, maintenance, communication failure, and system usage reports.

The laser bar code system saves 5 to 5.5 seconds per transaction over money or token operations. Before, it took approximately 8 seconds for a person to drive up to the toll booth, roll the window down, throw the money or token in the tray, have the machine count it, and receive the green light to proceed. The laser bar code system reduced the time to 2.5 to 3 seconds per transaction.

Also, since the installation of the Cubic toll system, Bay Harbor Islands has experienced an 8 to 9 percent increase in collected revenue, which is to be used for causeway operations. While the number of vehicles using the roadway has remained constant, the system has increased the number of paying vehicles; the system had a 10 percent non-pay rate prior to installation (Ref 8).

9.1.3.2. Orlando, Florida: Orlando-Orange County Expressway Authority (OOCEA) in October 1991 awarded SAIC a $15.4 million systems integration contract that included a choice of AVI systems, Amtech or Vapor Canada (Mark IV company). Officials picked Vapor, making OOCEA Vapor's first ETC application. There was also a maintenance contract awarded to SAIC worth an estimated $4 million over 5 years (Ref 66).

OOCEA plans to equip 95 toll lanes with a Vapor in-pavement reader system, and about 50,000 vehicles with Vapor's read/write bumper-mounted toll transponders. The system was scheduled to open by August 1992.

There are several reasons why agency officials chose bumper-mounted toll transponders over the Amtech windshield mounted transponders. First, metalized windshields had been reported to interfere with windshield transponders. Second were concerns of cross-talk or cross-lane readings (where AVI readers register passage of vehicles in adjoining lanes). This problem is generally associated with roadside readers versus in-pavement or overhead reader systems. Third, in closed circuit camera enforcement, the back of the vehicle and license plate are recorded, and the system can determine if the vehicle has a transponder, if the transponder is malfunctioning, or if the vehicle's user has any toll credit. Fourth, transportation officials felt more comfortable with the bumper-mounted transponders, which are considered non-removable. Fifth, officials believed read-only tags are easier to counterfeit than read-write (Ref 67).

The contract between OOCEA and SAIC was put on hold in November of 1991, when the Florida Department of Transportation (FDOT) began efforts to establish a statewide ETC system standard (Ref 66).

9.1.3.3. Florida Department of Transportation (FDOT): FDOT is suspending ETC plans until the state issues its ETC system standard specifications. FDOT will choose an AVI vendor after drafting system specifications and issuing an RFP. The process was expected to take at least six months; the state specifications will most likely differ from those developed in Orlando. Once a vendor is selected, Orlando will receive the first installation (Ref 68).

In early spring of 1992, OOCEA withdrew from the joint ETC procurement and FDOT delayed issuance of a RFP for an ETC-based toll system. OOCEA told state officials that pulling the ETC component out of the system design and adding another one later would cost the local agency $1 million in additional design work, construction, and delays (Ref 68).

After OOCEA's withdrawal from joint procurement, state officials decided to conduct their own three-month field test of available and recently developed ETC systems. The evaluation process will delay the RFP for the state-specified ETC system until 1993 (Ref 69).

The evaluations will take place at the Sunrise Mainline Plaza on the Sawgrass Expressway, west of Fort Lauderdale, in November 1992. FDOT wants only read/write ETC technology, not read-only capabilities. Three days were allotted per vendor for equipment evaluation. The 195 tests included reading different types of vehicles and windshields during both day and night.

Testing was necessary because available performance information has been primarily vendor generated. Data from other agencies performing similar tests were limited because results are often kept confidential. FDOT had CUTR (Center for Urban Transportation Research) oversaw the tests. The eight participating vendors included Amtech, Applied Computer Science, AT/Comm, AT&T, Hughes Aircraft, Kiewit Network Technologies, TDC Electronics, and Vapor Canada.

Besides performance and reliability verification, FDOT hoped to learn how to link the ETC system to the $43 million conventional toll system the department is currently implementing. It wants to take advantage of the many opportunities for integrating ETC functions into the conventional system.

Another factor that delayed the RFP release was the desire to include image-based enforcement in the ETC system. Florida law at that time contained no provision granting a toll authority the right to use visual images to detect violations and issue fines through the mail. Current law stated merely that a uniformed officer must issue a citation in person. A state amendment allowing the use of visual images and mailed fines has been before the Florida legislature twice (Ref 70).

While FDOT claims it does not seek to establish a statewide AVI standard, it is trying to choose a system for the toll facilities it operates. FDOT hopes to begin implementation of an ETC system on Florida's turnpike in the third or fourth quarter of 1994. Installation on the more than 579.6 km (360 miles) of the turnpike system is expected to continue through the end of 1995 (Ref 70).

9.1.3.4. Orlando-Orange County Expressway Authority: Since OOCEA's toll roads tie directly into Florida's turnpike, OOCEA will have to make them compatible with FDOT's ETC system procurement. It has been estimated that ETC systems pay for themselves in 2 to 3 years. Considering that the back-office infrastructure remains the same for any ETC system, switching to another ETC would not be that expensive. Of course, it would be ideal if competing systems could "talk to each other." OOCEA expects to have its own ETC system installed, tested, and accepted by July 1993. Science Applications International Corp. (SAIC) in San Diego is the systems integrator (Ref 70).

In December of 1992, OOCEA considered taking back $8.8 million from SAIC because of software development delays and in-lane vehicle detection problems. SAIC postponed that decision by presenting a new schedule and making firm guarantees. SAIC promised that by January 29, 1993, it would demonstrate an intermediate version of its integrated toll collection system in Orlando, including the debugged version of the software. If the software was not debugged and ready to install by January, SAIC promised to return the OOCEA's $8.8 million plus another $3 million worth of toll collection hardware stored in a warehouse in Orlando.

The intermediate version (called Build II by SAIC) was crucial to OOCEA because it would enable revenue collection on the new Green Way Southern Connector when it opened July 1. The "Build III" version of the software, the final, would provide an accurate audit trail for every toll transaction, an ability that was not available on any U. S. toll system. To provide a complete audit trail, SAIC had to not only complete the software, but also had to include an accurate vehicle separation method. This was required to establish how many vehicles and of what type were passing through the plaza. The system uses an in-pavement inductive loop to determine when a vehicle is in the toll pavement area but if two vehicles were very close together they became one four axle vehicle. Therefore, if both vehicles were equipped with ETC tags, the ETC system would collect tolls for two two-axle vehicles but would not raise the gate arm because it was expecting a toll at the four-axle rate.

A single ultrasonic device SAIC installed in each lane to detect the space between vehicles worked only for minimum separations of 0.608 to 0.912 m (2 to 3 feet). It did not meet OOCEA's specifications of 0.456 m (1.5 feet). Another choice was the use of a "light curtain," a vertically stacked line of lights that would shoot beams across the toll lanes. If all the beams remained unbroken, it would indicate nothing was in the lane, not even the tongue connecting a car to a small trailer. At a cost of $3,000 per lane, it was considered an expensive alternative. The third choice was an array of ultrasonic devices instead of a single ultrasonic device.

The original contract called for SAIC to have the system operating on all lanes by July 31, 1993. Under the new schedule, the implementation would be finished by the end of September 1993 (Ref 71).

SAIC did not meet their January 29 deadline because of further delays in developing software for the integrated toll collection system. SAIC agreed to return a letter of credit worth $8.8 million to OOCEA and, as stated under the supplemental contract, SAIC gave OOCEA $605,000 in interest and the title to some $3 million worth of toll collection equipment warehoused in Orlando. OOCEA will pay for the equipment, along with the rest of the system, after all elements are installed and accepted.

Under the new schedule, the Green Way Southern Connector opened with software-in-progress that SAIC created as a deliverable system. It was installed on the new road in May for the July 1 opening. SAIC's plan was to complete the system (designing and testing a version that meets specifications) in the summer and run it through extensive tests. Then, in November, SAIC would install it on one lane in Orlando and OOCEA would start collecting revenues from a small number of vehicles in a two-month test.

The OOCEA and SAIC were also working out additional features the authority wanted added to the software. SAIC expected to complete the entire project, with the enhanced software installed on all lanes, by late 1994 (Ref 72).

9.1.3.5. Florida Department of Transportation (FDOT): By April 1993, the ETC system test results were in. An executive summary of the tests was distributed by CUTR (a vendor-specific report was confidential). The tests showed that most of the systems did not live up to the vendor claims. Initially, the overall performance success rates ranged from 70 percent to 90 percent. When adjustments were made to remove errors caused by conditions that vendors were able to fix (bad transponders, loose antenna wires) the success rate grew to 89 percent to 98 percent. A final tally made without the enforcement system failures showed success rates of 90 to 100 percent.

The five teams that participated in the testing were AT&T Smart Cards Systems and Solutions and Mark IV's ITS Division; Mark IV's ITS Division alone (Vapor); Amtech Systems Corp.; Applied Computer Science and Saab-Scania Combitech Traffic Systems; and MFS Network Technologies, Texas Instruments, and Saab-Scania Combitech Traffic Systems. All the systems tested used read/write AVI equipment.

After more than a year's delay, FDOT expected to issue an August 1993 ETC system RFP. FDOT originally planned to seek bids on the system in April 1992. Also, the Florida Legislature finally passed a law shortly before Easter 1993 allowing a toll authority to issue toll violation fines through the mail, using visual image evidence (Ref 73).

9.1.3.6. Metro Dade County, Florida Department of Public Works: In June of 1992, the Department of Public Works announced plans to award a contract worth an estimated $2.5 million to SAIC, the lowest bidder of six. The contract was for an ETC system on 14 lanes of the Venetian Causeway (which connects Miami Beach and Miami) and the Rickenbacker Causeway (which links Key Biscayne and Virginia Key with the mainland).

SAIC had proposed using a read-only AVI system from either Amtech or Mark IV. The department chose Amtech equipment because of the lower price. After the Department made its announcement, two of the losing bidders (Lockheed Information Management Systems in Teaneck, New Jersey, and Cubic Toll Systems in Hauppauge, New York) filed protests with Dade County. The county rejected the protests during the summer of 1992. Then Lockheed filed suit against both the county and SAIC, questioning the procurement procedure and sought an injunction against the contract award. Lockheed was the second lowest bidder. The court ruled against Lockheed in December of 1992.

With the court case completed, the contract was presented to the lowest bidder, SAIC. SAIC decided against committing to the 210-day deadline contract; and because the Department of Public Works did not want to extend the project schedule, they re-issued the RFP in March 1993 (Ref 48).

The second procurement drew bids from Amtech and Revenue Markets, Inc. (TRMI), located in Accord, New York. The committee selected Revenue Markets' proposal in June 1993 (Ref 74). No coordination efforts had been made to ensure compatibility between Metro Dade County's system and FDOT's, whose RFP on ETC systems for the Florida Turnpike would be released before the work begins on the causeways (Ref 43).

9.1.4 Georgia

Around October 1991, the Georgia Department of Transportation awarded a $5 million contract to Lockheed Information Management Services to design, develop, and maintain an advanced automated toll collection system for the Georgia 400 Extension, a limited-access highway in Atlanta. The Georgia 400 Extension provides a direct 10.46-km (6.5-mile) connection between Interstate 285 and I-85 in Atlanta, a route that should be heavily used during the 1996 Summer Olympics. The Route 400 stretch included a single-barrier plaza midway between the two interstates.

Lockheed IMS selected Amtech to be the AVI supplier because of its cost, performance record, and because it met the client's specifications. Amtech's radio frequency tags could be mounted either on the bumper or near the license plate (the contract required exterior mounted transponders). There was an initial order of 25,000 tags for the projected 60,000 vehicles per day. All 18 toll lanes were to be equipped with Amtech roadside reader systems. Four lanes (two in each direction) would be for ETC vehicles; 8 lanes would be attended manual-automatic lanes with ETC; and 6 lanes would be equipped with automatic coin machines with ETC.

Lockheed is the project's systems integrator. It is responsible for software design and development and for integrating mechanical, electrical, and electronic components into the toll collection system; it must also provide an interface connection to a secondary computer system operated by the state DOT. Lockheed is to provide a closed circuit television (CCTV) system to monitor plaza operations. The CCTV system serves as a major component in the video enforcement system for toll violations. The toll plaza was scheduled for completion by July 1993 (Refs 75 and 76).

9.1.5 Illinois

In 1988, the Illinois State Toll Highway Authority (ISTHA) tested various types of ETC hardware at a small toll plaza near Aurora, Illinois. SAIC installed Amtech hardware in a manual lane and in an automatic lane eastbound in October 1988. Automatic Toll Systems, Inc., the agency's provider of leased toll equipment, installed Eureka hardware in a manual lane and in an automatic westbound lane.

There were about 60 transponders for each system issued to agency personnel who regularly go through the Aurora Plaza. SAIC's Amtech equipment was installed after successful testing. ISTHA continued testing the Eureka equipment after antenna location and field strength modifications.

During this testing, ISTHA addressed questions concerning the method of payment and billing, transponder distribution and point-of-sale, ETC lane configuration, need for dedicated lanes, safety implications, and requirements for lights and signage. It performed an evaluation of current plaza approach geometry to facilitate ETC lane access (Ref 77).

In November 1991, Illinois officials rejected both proposals because they were too expensive. The proposal was to equip a 27.4-km (17-mile) stretch of the North-South Tollway in metropolitan Chicago with an ETC toll system (Ref 78).

On June 10, 1992, state transportation officials issued a second RFP for a read/write system for the North-South Tollway, due July 16. In the first proposal, Illinois toll officials considered read-only AVI technology. The North-South Tollway would have 20 lanes equipped with ETC reader systems and about 20,000 toll transponders initially. Illinois officials planned to select an ETC vendor in August, with the system operational by December 1992.

The North-South Tollway installation was set up to serve as a pilot test of electronic toll technology for the authority's entire tollway network, which includes 447.5 toll road km (278 toll road miles). For the pilot test, the ETC readers would be installed on mixed traffic lanes and, therefore, would not provide non-stop payment.

The agency had specified a programmable read-write system capable of storing account balance information and the history of the last 50 transactions. Additionally, the system would include video enforcement equipment and be able to notify motorists by audio or visual signals if their account had a sufficient balance for the upcoming toll. ISTHA wanted to decentralize the accounting process and put the ability of maintaining accounts in consumer hands (Ref 79).

In late September 1992, ISTHA, through a $3.4 million contract, named SAIC its systems integrator of an ETC system, with maintenance responsibilities for all the ramps and plazas on the North-South Tollway. This 64.36-km (40-mile) toll facility processes in excess of 60 million vehicles annually and is 64.36 km (40 miles) long. ISTHA is calling their product "I-Pass." SAIC proposed to use AT/Comm's read/write technology of "smart transponders." The transponders, which include LCD displays and audio alarms, maintain prepaid account balances that are debited each time an automobile passes through an electronic toll lane (Refs 80 and 81).

ISTHA planned to install ETC equipment in 28 lanes on two toll roads in the Chicago area: 22 lanes on the North-South Tollway and six on the Tri-state Tollway. The lanes, while not dedicated to ETC use, would increase toll plaza throughput by cashless toll collection. Illinois officials planned to issue 2,500 transponders, with 500 going to commercial vehicles.

In addition to the ETC subsystem, the Illinois contract called for a video enforcement system, which SAIC is configuring. The plan called for installing two cameras in each ETC-equipped lane (Ref 82). In the spring of 1993, SAIC was to install pilot ETC and video surveillance systems on the I-355 Tollway at the Maple Avenue southbound exit (Ref 83).

9.1.6 Kansas

In early 1992, an IBM-configured automated toll system was operating on the Kansas Turnpike. IBM integrated its computer hardware and software with Amtech's RF AVI system at two toll plazas in a Wichita area pilot project. Four Amtech reader systems were installed, one in each direction at two toll booths for 100 vehicles equipped with Amtech transponders. This was one of IBM's first forays into the electronic toll market (Ref 78).

Around June 1993, the Kansas Turnpike Authority (KTA) started the design process for new ETC equipment on the Kansas Turnpike, called K-Tag. This system is scheduled to be installed and operational by mid-1994.

KTA would like to reach an agreement with the Oklahoma Turnpike Authority for compatibility between their systems, because they already have PikePass tags traveling the Kansas Turnpike. Although KTA has not made any official commitment to Amtech, no other company manufactures an ETC system compatible with Amtech's. This compatibility situation could create a de facto standard for the Kansas, Oklahoma, Texas, and Louisiana area, since all are using Amtech technology.

KTA estimates that it will cost about $4 million to implement the K-Tag system. The KTA should have 236 miles (379.72 km)of turnpike with 20 toll plazas by 1994. The agency expects to equip 64 of its 81 toll lanes with Amtech's read/write IntelliTag. Plazas that are subject to especially heavy traffic will have exclusive K-Tag lanes. At other locations, K-Tag users and other toll patrons will share lanes. The KTA plans an initial order of 50,000 ETC transponders (Ref 84).

9.1.7 Louisiana

In October 1991, the Crescent City Connection, a 12-lane toll bridge in New Orleans, had 20,000 ETC subscribers. The Louisiana Department of Transportation bridge operates on Amtech's TollTag system. TollTags, or the transponders, are credit-card size portable units displayed on the user vehicle windshields. The readers are placed on overhead gantries, allowing subscribers to pass through non-stop. It is a prepaid system, with the agency earning a modest interest income. ETC patrons receive a 30 percent discount off the regular toll rate and better toll plaza service.

Through implementing an ETC system, the Louisiana DOT's cash handling costs were lowered, reconciliation was made easier, errors and theft by employees were decreased, and commuter ticket costs (printing, inventory, and control) were eliminated. The Louisiana DOT ETC system has been linked with the Lake Pontchartrain Causeway system (Refs 77, 85, and 86).

9.1.8 Maine

The Maine Turnpike Authority hired a consultant in October 1992 to perform a feasibility analysis of potential ETC applications. Findings are not yet available (Ref 87).

9.1.9 Maryland

Maryland Transportation Authority (MTA) tested an ETC system at the Baltimore Harbor Tunnel (I-895). The demonstration program began in mid-November 1992 and continued through early 1993. One toll lane in each direction at the Harbor Tunnel toll plaza was equipped for the demonstration. The tested equipment was provided by Amtech using TollTag (windshield mounted) devices. The successful results of this test would represent an important step for MTA customer service efforts. MTA recruited 250 volunteers to participate in the test that should provide sufficient data to measure toll recording accuracy. MTA operates seven toll facilities, including the Baltimore Harbor Tunnel. The Authority serves more than 100 million motorists annually (Ref 88).

9.1.10 Massachusetts

In July 1992, the Massachusetts Turnpike Authority (Mass Pike) issued a RFP due August 17 for ETC consulting services. The consultant was to provide details of the capabilities of currently available electronic toll systems, and determine what motorist acceptance of the ETC technology might be. Once the consultanting service completed the market studies and other technical analyses, it would help draft system specifications and associated RFPs. The consultant would also oversee field tests of available ETC systems.

Mass Pike considered equipping all toll facilities on the turnpike, which extends 217.22 km (135 miles) from Boston to West Stockbridge, with read/write ETC equipment. There was controversy over the newly issued bonds for Mass Pike and repeated calls to privatize the roadway (Ref 89).

Around October 1992, Mass Pike awarded a contract to Wilbur Smith Associates (WSA) to provide technical AVI/ETTM consulting services for the Massachusetts Turnpike and the Sumner and Callahan Tunnels. Valued at nearly $500,000, the project was part of Mass Pike's comprehensive Traffic Management program (Ref 90).

In January 1993, the Massachusetts Port Authority (Mass Port) began a 90-day test of Amtech's IntelliTag on two lanes of Boston's Tobin Memorial Bridge (Ref 91). Around August 1993, Mass Port determined that a read-only system met their needs and specified it in a 1991 contract. This contract with SAIC had an option to install an ETC system on the Tobin Memorial Bridge. The option will cost about $500,000 for an Amtech read-only system on all seven bridge toll lanes. It also removed any concern the agency might have felt over the patent infringement suit filed by AT/Comm (Ref 92) when the Tobin Bridge test was announced February 2, 1993, by Mass Port (Ref 91). As noted previously, the suit claimed Amtech's IntelliTag violates AT/Comm's patent rights (Ref 92).

Initially, none of the lanes will be dedicated to ETC; however, this may change as patron usage increases. About 20 percent of the bridge patrons currently use commuter stickers that will eventually convert to ETC transponders. There are between 33,000 and 34,000 vehicles passing through the toll plaza daily. There were 44,000 vehicles per day before construction began on the roadway beyond the bridge four years ago (Ref 92).

Mass Pike is the lead agency for the New England ETTM group. It plans to release an RFP by the end of 1993 for a system to cover the Massachusetts Turnpike (Ref 92) and Boston's Sumner and Callahan Tunnels (Ref 91).

9.1.11 Michigan

By July 1991, the Grosse Ile Bridge in southwest Detroit was using a surface acoustical wave (SAW) technology by X-Cyte Inc. By using an ETC system, the Grosse Ile Bridge Company decreased the number of toll attendant transactions. Before ETC, the toll system used visual passes and tokens. This system had a problem with theft of visual passes.

With the ETC tag system, the stolen tag could be invalidated and detected instantly. Another plus for the system is that it gives the agency the ability to electronically audit each transaction by attendant and lane. The systems operates approximately 3,900 ETC transactions per day, or 65 percent of the 6,000 daily transactions (Refs 77 and 38).

9.1.12 New England ETTM Group

June 1990 marked the first meeting of officials from the New England Toll Agencies and Logan International Airport. The purpose of the meeting was to establish a cooperative effort to obtain a systematic, scientific method for testing and evaluating available technologies (Ref 11).

On October 28, 1991, an Interagency Agreement was signed establishing the New England ETTM Group, a multi-agency and a multi-state group. There were seven New England toll and transportation agencies plus the Massachusetts Institute of Technology (MIT) that signed.

The goal of the Interagency Agreement was to establish a process for exchange of ETTM information and experiences, provide a forum for ETTM discussion, create technical interfaces needed for new methods, and discuss opportunities for interagency cooperation. The technical topics included in the Interagency Agreement were to define compatibility of ETTM technologies; create standards for non-interfering systems; review standards for existing testing efforts; determine performance specifications; define legal issues; coordinate marketing research activities; and invent operational coordination.

The New England ETTM Group allows all agencies to share knowledge and experiences in advancing and accelerating preliminary plans. The agencies are working together to develop compatible ETTM systems. The Group's formation has contributed significantly to individual agency actions and joint collaborative efforts. By regular interaction between agencies, the group benefits from the synergistic effects of the cooperative environment. Also, the New England ETTM Group has established a formal liaison with the E-ZPass Interagency Group (the ETC consortium in New York, New Jersey, and Pennsylvania).

Almost two years after the first informal meeting, the Group decided to take official action and elected MIT the chair on June 4, 1992 (Ref 87). However, when the university started seeking more financial compensation for its contribution to the efforts than the agencies were willing to pay, the project participants opted to lead the initiative themselves. The New England ETTM Group was formally reorganized and had their first meeting in July 1992. Mass Pike was made chair.

The New England ETTM Group will be meeting regularly. They have also begun drafting ETTM equipment specifications. The underlying objective of the group is to establish a regional standard (Ref 89). The New England ETTM Group has not made a commitment to joint or standard procurement (Ref 92).

9.1.13 New Hampshire

In 1991, the New Hampshire Department of Transportation evaluated automated toll systems, including bar code and radio-frequency-based AVI equipment. They hoped to issue an RFP in spring 1992 (Ref 93). Later, New Hampshire DOT decided to evaluate ETC systems from additional vendors, thus postponing the RFP. New Hampshire had already evaluated systems from Amtech, LazerData Corporation, and AT/Comm and were in discussions about testing with Lockheed/AT&T and Saab (markets the PREMID system). Testing was scheduled to continue well into 1993. The DOT may even re-test some systems, further postponing New Hampshire's procurement plans. The reason New Hampshire performed these evaluations was to substantiate or dispel ETC vendor claims (Ref 89).

9.1.14 Oklahoma

From January 1991 to March 1992, an ETC system by Amtech, called PikePass, was installed on all turnpikes run by the Oklahoma Turnpike Authority (OTA). This system allows pass holders to continue at highway speeds while an overhead tag reader automatically records their passage and bills their account. Non-PikePass users are required to exit to complete a cash toll payment.

The toll tag is a transponder placed in the windshield or on the license plate. Antennas are placed under bridges overpassing the highway or on gantrys and in the pavement; however, antennas in the pavement tend to be damaged by adverse weather conditions. Enforcement of the PikePass is accomplished through video cameras and police surveillance. Enforcement has not been a problem because the fines are severe ($87) and citations can be mailed to an identified offender's home. Privacy has not been an issue because billing can be accomplished through direct computer transmission to trucking company offices.

In the first year of operation, more than 100,000 PikePasses were issued to more than 50,000 patrons. The PikePass program registers more than 32,000 transactions daily (Ref 94). The fact that cash toll prices have increased 30 percent has contributed to PikePass's popularity (Ref 75).

OTA has a unique design for its mainline barrier toll collection plazas placed on the four newest turnpikes. They also converted two of the oldest plazas to the new toll collection plazas in early 1992. New toll plazas are located around the midpoint of each turnpike and include many safety features including windows along two sides of each office structure, housing offices for toll supervisors and Oklahoma Highway Patrol, a complete view of oncoming traffic from both directions, suspending a canopy from an overhead sign truss, and placing concrete barriers to protect toll booths. There were also additional concrete barriers in place to separate toll booths from non-stop highway speed PikePass lanes.

OTA designed the new toll booth for maximum efficiency and protection of toll attendants. Many of these toll booths are mobile and can be moved as traffic patterns dictate, for example, the new design can accommodate seasonal high traffic more easily. Toll plazas can be expanded at minimal expense and in less time than traditional structures and they include restroom facilities for attendants at side gates and remote locations.

For security and enforcement purposes, the authority installed cameras to survey cash and PikePass lanes. The plaza's security cameras increase the safety of toll attendants and provide a useful auditing tool.

The reasons for locating a single toll plaza at the midpoint of a turnpike were many. First, elimination of traditional end line toll plazas reduces the number of supervisory personnel required. The volume of traffic through the toll plaza was decreased because not all traffic passes through the midpoint. Traffic congestion at the ends of the turnpike was also greatly reduced, providing easier access to connecting roadways. Finally, construction of a single toll plaza was cheaper than building two (one at each end of the tollway) (Ref 95).

9.1.15 Texas

Texas is divided into two sections that deal primarily with the cities of Dallas and Houston.

9.1.15.1 City of Dallas: The 22.53 km (14-mile) Dallas North Tollway, operated by the Texas Turnpike Authority (TTA), extends north from the Dallas Central Business District basically along an old railroad right-of-way. This facility represents the first successful AVI project on a toll road in the U.S.

By early 1987, the TTA was experiencing increased congestion at the toll plazas as a result of insufficient capacity. Noting that there was little room for expansion, Amtech Corporation contacted the TTA about the possibility of placing an ETC system on the Dallas North Tollway. In December 1987, there was an "Agreement for Demonstration Project" signed by TTA and Amtech Corporation. The agreement included the development of "basic performance standards," which both parties agreed to, a six-month controlled test on seven manned toll lanes with user logs to verify computer data, and a full system demonstration on all toll lanes. Amtech would provide ETC system equipment at their expense and TTA would provide electricity, computer housing space, and supervise installations. TollTag Store(s) would be established by Amtech to distribute tags to the public. ETC system users would pay a 5-cent surcharge on top of the toll each time they used the tag, and a $2.00 per month service charge would also be assessed. TTA would receive an electronic bank transfer of tolls collected each business day. The surcharge and service charges would be retained by Amtech as amortization of its development cost of the system.

In April 1988, the basic performance standards were agreed upon. By July 1988, testing began, with over 30,000 tags read and verified by log in six months. The accuracy was determined to be greater than 99.98 percent and met all standards for accuracy and service time. Also, during the test time many operational and technical difficulties were encountered and overcome. In July 1989, full-scale implementation began and public acceptance in Dallas has grown steadily. The full-scale system met all requirements. By August 1989, there were over 26,000 tags in use and over 35,000 ETC transactions were being handled every day (Ref 96).

The TollTag is credit-card sized and placed inside the windshield with an unique identification code. The user establishes a prepaid account and when the identification code is read by an electronic reader at the toll booth a signal "Valid Tag" and green light is shown. The toll plus five-cent surcharge is automatically deducted from the account. If the account falls below $10, a "Call Tag Office" signal appears with the Valid Tag signal. Drivers can have the toll renewal amount charged to their credit cards automatically (Ref 77).

As the ETC traffic increased, the TTA decided it needed a more efficient way of processing these vehicles. The Authority's traffic and revenue engineer, Wilbur Smith Associates, was hired to analyze the impact and practicality of implementing a dedicated ETC toll lane at each of the two mainlane barrier toll plazas.

Wilbur Smith Associates studied the optimum location, the potential safety hazards, and estimated impacts on net revenue (required by the Trust Indenture). The study found that dedicated ETC lanes were feasible, would act to increase net revenue, could create operating cost and toll equipment lease savings, and could eliminate the need to expand the toll plaza in the future. The analysis concluded that a single dedicated ETC lane should be provided in each travel direction at each plaza. These lanes were implemented in late 1990. There were no increases in violations through the dedicated lanes and net revenue increased on the Tollway because of growth in program participation and the operating cost savings.

At the end of 1991, there were over 45,000 tags being used, with more than 50,000 ETC transactions processed daily. This represents over one-third of the total daily Tollway vehicle transactions processed (Ref 97).

In June 1995, the Dallas North Tollway averaged 210,000 toll transactions per day, of which approximately 108,000 were TollTag transactions. About 30 percent of the Tollway's patrons use TollTags. There are 54 toll lanes on the North Tollway that are equipped with Amtech ETC reader systems. The coin machine system is supplied by Cubic Toll Systems. Through June 1995, approximately 97,100 toll tags have been issued by the TTA.

TTA officials would like to integrate the coin machines with the ETC system. They also want to install a video enforcement system to catch toll evaders (since the toll lanes were not equipped with toll gates). About 1 percent of the users evade toll collection.

In May 1992, TTA officials authorized Gulf Engineering consultants of Baton Rouge, Louisiana, to develop specifications for the new toll system through an $800,000 contract. The specifications are scheduled to be completed by January 1993.

The integrated electronic toll system would cover the existing toll lanes and would also be installed on 28 new toll lanes under construction, for a total of 81 toll lanes. The 9.65-km (6-mile) extension of the 24.14-km (15-mile) toll road was completed in September 1994. The current system on the North Tollway was originally owned by Amtech. TTA purchased the system from Amtech in June 1994 (Ref 98).

The month before the RFP release, the TTA board of directors voted to extend Amtech's contract to manage and operate its TollTag system through June 30, 1994. The contract was due to expire on June 30, 1993. When the extended agreement expired, the TTA purchased the read-only system for about $1.7 million. This means that the vendor chosen to supply the integrated system must incorporate Amtech's equipment into its overall design. The Authority will also pay Amtech $150 per lane per month ($13,650 per month for the total 81 lanes) to maintain the system after the buyout. On January 1, 1995, TTA dropped the 5-cent per trip surcharge patrons paid Amtech. Under the current system, credit card customers do not purchase or pay an ETC transponder security deposit.

On the 28 new lanes, Amtech will install the most recent version of its ETC reader, a modular product that offers more flexibility than the old model; Amtech will retrofit the 54 operating lanes on the older segments of the tollway (Ref 99).

9.1.15.2 City of Houston: Around June 1992, the Harris County Toll Road Authority (HCTRA), which operates the two Houston toll roads, decided to exercise an option in its contract with Cubic to install an ETC-based toll collection system. Toll officials established criteria for the ETC system and Cubic evaluated Amtech, Vapor, and X-Cyte. Amtech's read-only system was installed on the 69 toll lanes in the fall of 1992.

Video enforcement equipment was not placed with the ETC toll gear, since most of the toll lanes were equipped with gates. These gates require ETC-fitted vehicles to come to at least a rolling-stop. There would be a handful of ETC-only lanes without gates; those lanes could eventually be equipped with a video enforcement system.

It was estimated that $70,000 in tolls would be lost annually by toll evading motorists driving through the ETC-only lanes. Therefore, Harris County officials evaluated whether it was cost effective to install a video enforcement system with currently available technology. An effective video enforcement system would cost Houston toll officials from $700,000 to $1.5 million (Ref 98).

On October 23, 1992, the new ETC system, called "EZ Tag," began operating on the Sam Houston and Hardy Toll Roads. The tag adheres to a patron's windshield and communicates with readers installed in the lanes. As a vehicle approaches an EZ Tag lane, the system will automatically verify the account, deduct the appropriate toll from a prepaid deposit and flash a green "go" signal, all in about one-tenth of a second.

A total of 69 lanes, including ramp locations, will be equipped to handle EZ transactions. Directional signs stating "Left Lane EZ Tag" have been installed approximately one mile from the plazas to allow EZ Tag patrons enough time to safely position themselves in the appropriate lane. The far left inside lane was identified as the most logical and efficient for dedicated EZ Tag Only purposes, since motorists already associate the left lane with faster moving traffic. As participation in the program increases, the inside lanes also offer greater flexibility for the future conversion of additional mixed-use lanes to dedicated EZ Tag Only lanes (Ref 100).

Around August 1993, the HCTRA started adding EZ Tag equipment to the automatic lanes at six ramp locations on the Sam Houston and Hardy Toll Roads. The original objective in installing EZ Tag readers only in the attended lanes at the ramp locations was to handle not only passenger cars, but also multi-axle EZ Tag transactions. As the EZ Tag program and traffic volume was increasing and patrons were requesting additional EZ Tag lanes at specific locations, officials decided to install readers in both attended and unattended lanes on heavily traveled ramps.

The Authority monitors traffic volume and EZ Tag usage on a daily basis. Its goal was to have 70 percent of the traffic using the EZ Tag system within 3 years. To maintain the convenience and efficiency of the EZ Tag program, more equipment will be added to ramp locations and additional dedicated lanes will be created at the plazas as enrollment increases (Ref 101).

9.1.16 Tri-State Area: New York, New Jersey, and Pennsylvania

The Tri-State Area, which covers the states of New York, New Jersey, and Pennsylvania, has been very active in ETC system installation. To discuss the developments in these states, this section is broken down into fifteen parts. These parts are presented in chronological order, with some topics discussed more than once if a major development occurred. Parts include the Delaware River Port Authority, Port Authority of New York and New Jersey, Regional ETC Standards, TRANSCOM, Interagency ETTM Group, New Jersey Department of Transportation, New York State Thruway Authority, New Jersey Highway Authority, and the E-ZPass Interagency Group.

9.1.16.1. Delaware River Port Authority: Major bridges between Philadelphia and New Jersey are operated by the Delaware River Port Authority (DRPA). Each of the agency's four major toll bridges utilized remote optical laser scanning equipment by LazerData Corporation.

Commuters were issued special bar-coded stickers that attached to an automobile side window. On entry into any lane, a remote scanner reads the data contained within the bar-code and determines its validity. If valid, a reduced toll is automatically recorded. If the sticker is not valid, the "go" light would not come on and the barrier would not open unless the standard toll rate was deposited. This was not a non-stop toll collection system, since motorists were required to stop and pay the reduced fare. ETC patronage on these four bridges during April 1990 accounted for approximately 30 percent of the total traffic (Refs 77 and 38).

9.1.16.2. Port Authority of New York and New Jersey: In 1987, the Port Authority of New York and New Jersey was looking for a way to improve commuter bus operations at the Lincoln Tunnel, which connects Weehawken, New Jersey with midtown Manhattan, New York City. The existing system had an Exclusive Bus Lane (XBL) operating between 5:30 a.m. and 10:30 a.m. each weekday. The system had a counterflow lane established for 4.02 km (2.5 miles) before the toll plaza for Class 8 (two axles) and 9 (three axles) buses; if they participated in the toll payment honor system, these vehicles had a sticker and could travel non-stop at 35-40 mph. Each bus operator was expected to estimate their tunnel traffic and send monthly payments to the Port Authority. This system had problems with auditing and enforcement. It allowed bus operators to avoid paying tolls and the Port Authority could not check accounts.

Accordingly, in 1987, the Port Authority awarded a contract to SAIC to design and install a functional, revenue-collecting ETC system in the non-stop toll lane at the Lincoln Tunnel. This ETC system became fully operational during the summer of 1988, with revenue collection starting after extensive testing and further enhancements, including a video enforcement system. In 1990, there were 35 bus companies participating in the ETC project with just under 3,000 tagged vehicles. Tags were mounted atop the commuter buses. There were over 500,000 transactions logged by the system and approximately $1 million in revenue collected (Ref 102). Audits in 1992 indicated accuracy rates of 99.95 percent or greater were attained (Ref 103).

9.1.16.3. Regional ETC Standard: Drafting technical specifications for a regional ETC standard was started in January 1991 by a consortium of transportation agencies from New York, New Jersey, and Pennsylvania. Their intent was to establish a regional toll collection standard that would permit drivers to pay tolls electronically throughout the tri-state area with a single ETC transponder. Officials were not going to pick equipment from a single vendor in order to promote competition (Ref 104).

By October 1991, the Tri-State Electronic Toll Group decided it wanted a third party to operate as a back-office service provider. (Toll agencies want to be insulated from patrons and escape from the clearinghouse complexity.) The back-office service provider would be responsible for acting as the guarantor of toll payments to the agencies (area tolls for a year top $1 billion), transferring appropriate funds to the separate toll agencies, providing audit data of the transactions, updating patron accounts (including processing delinquent accounts), processing applications, distributing tags, and marketing the system.

The toll agencies' goal in establishing a back-office service provider was to reduce costs, reduce duplicity of efforts, provide a single point of contract for the patron, and reduce potential conflicts in ETTM efforts between agencies (Ref 104).

9.1.16.4. Delaware River Port Authority: The Delaware River Port Authority had agreed around November 1991 to a six-month test of Texas Instrument's (TI) Autotoll on the Walt Whitman Bridge. This was a newly developed system. Autotoll was not to be placed in an active toll lane but on an access lane designated for use by authorized vehicles only. Delinquent motorists were using this lane to evade bridge tolls and the toll authority was installing an access gate and TI's Autotoll system.

The prime contractor for the project was Kiewit Network Technologies, which configured the gate control system with TI's ETC technology. If the test performs well, Delaware River Port Authority will consider equipping its toll lanes with an automated collection system (Ref 106).

9.1.16.5. TRANSCOM: By January 1992, an institutional unity group was formed for the New York metropolitan region for implementing and administering ITS technology. The group was called TRANSCOM (the Transportation Operations Coordinating Committee) and was based in Jersey City, New Jersey. TRANSCOM was funded and staffed by 14 major highway, transit and public safety agencies in New York and New Jersey. These TRANSCOM member agencies included:

- New York Thruway Authority
- Metropolitan Transportation Authority
- New Jersey Department of Transportation
- New Jersey Highway Authority
- New Jersey State Police
- New Jersey Transit Corporation
- New Jersey Turnpike Authority
- New York City Department of Transportation
- New York State Department of Transportation
- New York State Police
- Palisades Interstate Park Commission
- Port Authority of New York and New Jersey
- Port Authority Trans-Hudson Corporation (PATH)
- Triborough Bridge and Tunnel Authority

The Staten Island-New Jersey corridor became the focus of TRANSCOM's ITS efforts because of demonstrations of ETTM being undertaken by the Triborough Bridge and Tunnel Authority at the Verrazano Bridge (Brooklyn to Staten Island) and by the Port Authority of New York and New Jersey at the Goethals Bridge (New Jersey to Staten Island).

In the fall of 1991, the agencies involved in the operation of this corridor (NJDOT, NJ Highway Authority, NJ Turnpike Authority, NYCDOT, NYSDOT, Port Authority of NY/NJ, Triborough Bridge and Tunnel Authority), along with TRANSCOM staff and the Federal Highway Administration, selected a team led by Farradyne Systems, Inc., to perform the feasibility and design work for determining ETC incident detection capabilities (Ref 107).

9.1.16.6. Interagency ETTM Group: In January 1992, the tri-agency interagency ETTM group issued an RFP for a standardized automated toll collection system. The ETTM group established functional specifications and vendors were to configure a system to meet operational speed and accuracy requirements.

The 150-plus-page RFP recommended toll transponders with read/write capability, but did not require them. Read/write capabilities are needed on closed toll systems. Other key requirements in the RFP included an error rate maximum of 1 in 10 million at speeds of 0–64 kilometers per hour (0–40 mph). The main reasons for all the technical specifications was to establish a standardized AVI-based ETC system. A radio frequency transponder issued by one agency is to be compatible with those issued by another. Motorists could use one transponder for all toll transactions. Also, during January 1992 the toll group released RFI (Requests for Information) for a regional toll clearinghouse (Ref 108).

9.1.16.7. New Jersey Department of Transportation: During the annual budget process in Washington, D.C., in 1991, Senator Lautenberg, Chairperson of the Senate Appropriations Transportation Subcommittee, managed to appropriate a total of about $64 million for ITS-related projects in the New Jersey metro area for the 1992 fiscal year. Of that amount, $25 million was allocated to implement ETTM projects. In order to receive the $25 million, the state toll roads (New Jersey Turnpike, Garden State Parkway and Atlanta City Expressway) would have to match the federal funds with $6.25 million. The funding would be used to implement compatible AVI-based toll collection equipment that the tri-state interagency group had specified (Ref 109).

9.1.16.8. Interagency ETTM Group: The interagency ETTM group had recently developed an RFP for a standardized ETC system, but out of the 15 agencies involved only 5 issued the RFP. The five agencies included the Port Authority of New York and New Jersey, the New York State Thruway Authority, the Triborough Bridge and Tunnel Authority, the New Jersey Turnpike Authority, and the New Jersey Highway Authority.

For some of the non-participating agencies, funding issues could have served as an obstacle to early implementation of electronic toll technology. Another problem could be reaching a consensus on system specifications for a compatible system (Ref 109).

9.1.16.9, New York State Thruway Authority: In early May 1992, the New York State Thruway Authority issued an RFP for the implementation of its ETC system. The RFP called for an account management and customer service system. The proposals were due June 18. The authority was planning to use the ETC technology selected by the ETTM group. The system which would be used throughout the tri-state area was E-ZPass.

There were questions from ETC vendors as to whether they could properly respond to the RFP without knowing what type of ETC tag would be used. Still there were several systems integrators who planned to submit proposals.

The RFP stated that the account management system must interface with the Authority's existing plaza computers, lane controllers, and selected ETC equipment as well as with a video enforcement and driver feedback system. It was the Thruway Authority's intent to install a driver feedback system that would provide three signals to customers, indicating that the transaction was valid, invalid, or that the account funding needed to be replenished.

The enforcement system would digitize images of violator's license plates. That information would be used by the back office service provider to process the violation, ultimately procuring payment for tolls and applicable fees. While the Thruway Authority had committed to the common tag and reader system design, it remained questionable as to whether the agency would participate in the regional toll clearinghouse planned by the ETTM group.

The Tappan Zee Bridge in New York City and the two Grand Island Bridges just north of Buffalo would be the first facilities fitted with the new ETC equipment. The agency was planning to issue between 20,000 to 50,000 toll transponders as part of the initial installation. Following the bridge installations, the Authority planned to equip the remaining six fixed barrier locations on the Thruway with the E-ZPass system. An estimated 10,000 to 50,000 more E-ZPass tags would be issued to area motorists. Implementation at the barrier sites was scheduled to begin January 1993, with service commencing in March. Also, the closed-toll portion of the Thruway, which uses a ticket system, would be fitted with the E-ZPass equipment between 1994-1996 (Ref 110).

In 1990, the Authority hired Vollmer Associates, with SAIC serving as subcontractor, to conduct an ETTM study program in a three-stage process. Stage I, a needs analysis, was completed in April 1991. Stage II involved a technical survey of ETTM technologies and evaluation of their potential Thruway system use. More than 50 vendors were surveyed, several of which were selected for testing; only three systems were able to provide the Authority with equipment for testing. One system was read-only and the other two were read/write systems.

Stage III, the testing of the selected systems, would be conducted in three phases designed by SAIC. The phases were: static testing in a laboratory environment, controlled testing using dedicated test vehicles, and long-term automatic data collection with trips as part of the normal daily commute for a period of 6 weeks.

Phase I, the static testing, was performed at an Authority laboratory. These tests were technical demonstrations and situational tests, including: (1) slow vehicle roll-through, (2) close/far lane position, (3) vehicle backup, (4) adjacent lane reading, (5) clutter reading, (6) hand-held driver reading, (7) rain and salt spray buildup, (8) ice buildup, (9) caked/wet dirt reading, and (10) hot/cold transponders.

Phase II testing was performed at the Spring Valley barrier in the New York Division. Two adjacent lanes were equipped with devices in a manner consistent with possible future implementation. Included in the test parameters were the following: (1) speed testing, (2) RF/optical interference testing, (3) adjacent lane tests, (4) position of vehicle in lane, (5) vehicle separation, (6) multiple tags, (7) windshield tests (resistive, reflective and photo gray), (8) transponder positioning, and (9) environmental testing (variations of the static test).

Phase III testing involved long-term testing conducted at two New York Division sites: Spring Valley and the Tappan Zee Bridge. These tests were designed to demonstrate operational reliability by simulating the use of ETTM technology in an actual toll collection setting and included vehicles driven by Authority employees. Additional testing was performed after Phase III for three months (with the approval of one of the vendors) to gauge customer expectations and reaction to ETC equipment and to test equipment under uncontrolled harsh weather conditions. The test was administered by Authority personnel and involved 200 Grand Island resident commuters. There was also a post-test survey (given June 1992) designed to gauge reaction to the equipment and to possible pricing results. The preliminary reports indicated positive test results. There was also positive response to the Grand Island Bridges test (Ref 111).

9.1.16.10. New Jersey Department of Transportation: By June 1992, the New Jersey Legislature considered placing a six-month moratorium on toll agency construction projects, a move that delayed ETTM plans that started with proposals to refinance the toll agencies' debt. This ignited a controversy fueled by a local radio station that spearheaded the initiative to remove tolls. There were more than 20 bills concerning tolls introduced in the state legislature; almost half of them would impose some restrictions on the state's toll authorities. Some even called for abolishing the toll authorities and removing the tolls. There would, of course, be little need for ETTM systems if tolls were removed. Also, New Jersey could lose $25 million in federal funding allocated for electronic toll systems on the state's three toll roads.

It was considered highly unlikely that New Jersey's tolls and toll agencies would be abolished because the state would be taking on almost $4 billion in debt. The Turnpike Authority had $2.8 billion in outstanding debt, the Highway Authority $629 million and the Atlanta City Expressway Authority $40 million (Ref 112).

9.1.16.11. Interagency ETTM Group: The toll authority officials in New York, New Jersey, and Pennsylvania area decided to further evaluate two of the proposed read/write ETTM systems around July 1992. The systems were Amtech with IntelliTag and a joint venture of AT&T/Vapor with a smart card-based system. They were to provide transponders and readers for testing at two toll plazas. Before the additional evaluations, the interagency group had planned to pick an ETC system vendor in July 1992. They were still planning to begin implementing the E-ZPass system in early 1993.

E-ZPass officials plan to test the two systems at the Hillsdale toll plaza on the Garden State Parkway and the Spring Valley toll plaza on the New York State Thruway. It appears that one of the two systems will ultimately be selected for use by all the participating agencies (Ref 113).

As of October 1992, the Port Authority of New York and New Jersey and TBTA had tested ETC systems on Staten Island at the Goethals Bridge and Verrazano Narrows Bridge. The service E-ZPass is expected to be operational at some toll plazas as early as 1993, with a region-wide network targeted for 1995.

9.1.16.12. New York State Thruway Authority: By November 1992, the New York State Thruway Authority chose Lockheed Corporation to provide an account management and customer service system for its automated toll collection. The Authority has made some decisions about how to market E-ZPass; motorists will pay a $10 refundable deposit for the AVI tag and a $1 per month service charge. The low up-front cost, combined with a small, ongoing charge, will help the agency get good market penetration while still recovering some capital costs (Ref 114).

9.1.16.13. New Jersey Highway Authority: In January 1993, the New Jersey Highway Authority was considering proposals from companies interested in developing, installing, operating and maintaining a fiber optic communications network for use in ETTM and other ITS systems on the Garden State Parkway. The solicitation period closed January 8, 1993. According to the RFP, the Authority expected to share the cost of the communications system with the successful proposer, which would be allowed to use up to three empty conduits for its own purposes (Ref 115).

9.1.16.14. E-ZPass Interagency Group: On March 31, 1993, the E-ZPass Interagency Group (IAG) announced it would conduct another round of tests on two AVI systems that had been under consideration since the summer of 1992. The group extended testing based on the results of the last round and asked the two vendors to make some system modifications. The tests were scheduled to begin in mid-July and last three months, with IAG expecting to choose a vendor by the end of 1993.

The contest between Amtech and AT&T/Vapor is crucial. The winning vendor would be able to sell hundreds of reader systems and thousands of transponders in the tri-state area. Another important point would be that the technology chosen for common use throughout the densely-populated New York and Philadelphia regions could become the de facto ETTM standard (Ref 116).

9.1.16.15. New York State Thruway Authority: Two days after the IAG announcement of continued testing, the New York State Thruway Authority (NYSTA) announced it wanted to honor their commitment of providing ETC in 1993. It installed an interim system at selected toll plazas during the summer. The Thruway used read-only ETC equipment from Amtech on bridges and barrier-only plazas. Most of the 1,032-km (641-mile) Thruway is a closed ticket system that requires a read-write system (Ref 116).

ETC began on August 2, 1993, on the NYSTA as scheduled at the Spring Valley plaza near New York City. They had planned to operate two mixed-mode lanes and one dedicated ETC lane in each direction; however, a suit filed by Teamsters Local 72, representing NYSTA's toll collectors, delayed implementation. The Teamsters claimed that the dedicated ETC lanes would pose a danger to toll collectors who needed to cross the lanes to reach other areas of the plaza. NYSTA planned to post an 8 kilometers per hour (5 mph) speed limit at the dedicated lanes, although it is commonly acknowledged that most drivers exceed posted limits.

The New York State Supreme Court ruled that NYSTA could operate only mixed-mode and cash-only lanes until the grievance was resolved. Arbitration was scheduled to begin on

August 17, 1992. As a result of the injunction, the plaza operated two mixed-mode lanes and one cash-only lane in each direction.

NYSTA did not expect the union's safety concerns to affect the E-ZPass operation since the problem came up at the last minute. A committee that included NYSTA officials and toll collectors had been working with the union addressing the safety issues of crossing the non-stop lanes. NYSTA purchased new safety vests, brighter and more reflective than the old ones, to make the toll collectors more visible to motorists. It also adjusted break schedules so collectors would not have to cross the dedicated lanes during the hours of heaviest traffic. Other possible solutions, such as a system that would allow a toll collector to push a button to temporarily "turn off" the ETC lane before crossing it, could not be implemented in time for the debut of E-ZPass.

An August 2 *New York Times* article alluded to the possibility that NYSTA's toll collectors were really concerned that the introduction of unattended ETC lanes threatened jobs. The article said the union had a no-layoff contract, but quotes a NYSTA official who said that if the electronic system works well, the authority might reduce the number of toll collection jobs through attrition.

NYSTA had distributed about 3,000 E-ZPass transponders by August. The next plaza slated to begin operation of the ETC system was the Tappan Zee Bridge (Ref 92).

9.1.17 Virginia

The Virginia section is divided into two parts: the Richmond Metropolitan Authority and the Dulles Toll Road.

9.1.17.1. Richmond Metropolitan Authority (RMA): Around December 1992, the Richmond Metropolitan Authority (RMA) awarded Westinghouse Electric Corporation a $4.5-million contract to design and integrate a computerized toll collection system capable of non-stop ETC. The system will be installed on the RMA's Powhite Parkway and Downtown Expressway main barrier plazas and remote ramp locations (Ref 117).

9.1.17.2. Dulles Toll Road: In February 1991, the Virginia Department of Transportation (VDOT) rejected the first bids for the Dulles Toll Road ETC system (called "Fastoll"). The bid was rejected because tests found the Amtech system proposed by Westinghouse in Baltimore did not meet all the proposal's requirements. Amtech's system is typically configured with an above-ground antenna and could not get the in-pavement antenna to work properly (Ref 118).

In September 1991, VDOT issued a revised RFP and hoped to have an AVI-based toll collection system in operation by the end of 1992. The new RFP had changed the old RFP to cut costs. The previous bids exceeded the project's $12 million budget. Changes to the RFP included an optional fiber optic communications system and two-way communications. The placement of the antenna was a problem in the first RFP. The state clarified how the in-pavement antenna would be installed. It was specified that the slots in the pavement could not be more than two inches deep or three inches wide at a minimum spacing of two feet (Ref 119).

Also in September 1991, Virginia officials were considering expanding the Fastoll system to the 22.53-km (14-mile) planned privately funded extension of the toll road to Leesburg. The existing toll road runs from Dulles Airport to Lewisville, Va. (Ref 119).

The revised RFP deadline was extended from October 31 to December 2, 1992, so the state could answer prospective bidders questions adequately. Also included in the RFP was a requirement that the prime contractor had 250 working days from the date of the contract to install the system and get it working (Ref 120).

In the bids, there were two ETC systems, TI and Vapor. These systems were tested before a contract was awarded. Testing protocols were designed in March 1992. The tests took place in an unutilized rest area at speeds of 64-80 kilometers per hour (40-50 mph).

The four firms that submitted bids in the second round were Cubic Western in San Diego, Science Applications International Corp. in San Diego, Kiewit Network Technologies in Omaha, Nebraska and Westinghouse in Baltimore. Kiewit's bid included an ETC system from Texas Instruments (TI); the other three systems integrators utilized Vapor's ETC equipment (Ref 121).

January 4, 1993, VDOT posted an intent to award the contract to MFS Network Technologies (formerly known as Kiewit Network Technologies) which bid the system with ETC technology from TI. Both Cubic Western in San Diego and SAIC in San Diego lodged protests with VDOT claiming TI's ETC did not meet VDOT's specifications. The MFS official said the system met the RFP's functional requirements but did not comply with every letter of the specifications because of specific data rates (Ref 49).

Cubic filed suit against VDOT. After several trial postponements, on June 11, 1993, VDOT notified all vendors who had submitted proposals that it was withdrawing its intent to award to MFS and that it would begin a new procurement. The intent was withdrawn because of the coin machines and not the ETC equipment. VDOT discovered that MFS had erred in the information they supplied about the coin machines.

Cubic withdrew its suit leaving Cubic, MFS, and VDOT without a ruling on the original question as to whether the TI ETC system met the specifications. (VDOT negotiated with Cubic Toll Systems first, but failed to reach an agreement, so they went to MFS Network Technologies.)

The third RFP would be a slightly modified version of the last one. The length of the evaluation period would depend on how many responses the department receives (Ref 50).

9.2 SYSTEM LOCATIONS OUTSIDE THE U.S.

This section describes ETC efforts in countries outside the U.S. These countries include China, England, France, Japan, Malaysia, Mexico, Norway, Portugal, Singapore, South Africa, Spain, and Sweden.

9.2.1 China

In January 1992, Hong Kong officials approved a plan to conduct a 30-day pilot demonstration project using AVI-based, non-stop toll collection equipment. This occurred less than a decade after deciding against a plan to operate an electronic road pricing system. This time officials intend to use AVI for a flat rate of non-stop toll collection systems versus charging a premium fare at peak travel times in the electronic road pricing system. They may eventually establish variable charges for different times of day, a variation of congestion pricing.

For the 30-day pilot test scheduled to start March 1992, radio frequency AVI equipment from Amtech would be installed on two toll lanes on the Aberdeen Tunnel. The system integrator for the project was Mitsubishi Corporation in Japan (Amtech's licensed distributor in Asia). This government-owned tunnel was operated by the Cross Harbor Tunnel Company, Ltd.

Once the pilot test was over and the system accepted, Cross Harbor Tunnel Company will place a full commercial-scale installation at the tunnel. The objective was to expand the system to other tunnels in Hong Kong under a clearinghouse concept that would use Amtech's systems, technology, and experience base.

Even though the pilot contract was for minimal money, the commercial roll-out would be a lucrative contract. Also, while the number of AVI readers would be a comparatively small amount, Hong Kong had about 300,000 registered motor vehicles in the area using the tunnel network on a regular basis. Plus, even if the system was limited to the Cross Harbor and Aberdeen Tunnels, they have 200,000 crossings daily that will require a large number of transponders.

The reason the electronic road pricing system was not installed in the late 1980s had nothing to do with technology, which field tested as feasible and reliable. It was because the Hong Kong residents were concerned about privacy issues. They mistrusted the government's promises not to use the system as a congestion-fighting scheme. It was to be a method for revenue collection.

This new system took into account the citizens' reservations and planned to offer the motorist the option of equipping their vehicle with a transponder for a flat annual fee. Payment for the transponder could be made by cash, credit cards, or by other commercial arrangements. Also, system users would be able to establish anonymous accounts (Ref 122).

9.2.2 England

These sections deal with specific locations of ETC systems in England, including the Thames River Crossing, Severn River Bridge, and Mersey River Tunnels.

9.2.2.1. Thames River Crossing: Dartford River Crossing (DRC) operates the tunnels under, and the bridge over, the Thames River at Dartford, about 25 km (15 miles) east of London. They awarded a contract valued in excess of £2 million ($3.6 million US) to CSEE (Compagnie de Signaux et d'Equipments Electroniques) of Paris in April 1991. CSEE is to supply a non-stop toll system based on the Saab (originally Philips) PREMID AVI tag. The initial target for tag use was 5,000 to 10,000 vehicles (Ref 123).

This system opened in April 1992 with the name "Dart Tag." The tag is mounted off center on the front windshield. The crossings have an average daily traffic (ADT) of 90,000 vehicles, and have a total of 24 toll lanes (18 manual, 12 automatic, 2 dedicated ETC, and 6 mixed). Enforcement includes pre-classification and blacklisting of stolen vehicles. There are account options for upfront payment, including cash, credit card, check, and bank transfer. The following minimum balance by vehicle classification was established: cars, $50; light-goods vehicles, $75; and heavy-goods vehicles, $125 (Ref 124).

9.2.2.2. Severn River Bridge: In April 1992, Severn River Crossing (SRC) obtained the toll collection concession from the British government for the existing Severn River Bridge (located on the boundary between England and Wales near the city of Bristol) and the new bridge over the Severn River (completion date 1996) for 30 years. SRC was selected by the British government to construct, operate, and maintain a new bridge over the Severn River, with tolls from the old bridge going toward the costs of the new bridge (Ref 125).

Severn River Crossing had an agreement with the French-based agency, Cofiroute (Compagnie Financiere et Industrielle des Autoroutes), for toll collection operations (design and concessions). In June 1992, Cofiroute awarded a contract to Amtech and an Amtech distributor, Elsydel S.A. The contract would equip the Severn River Bridge with ETC and video monitoring systems. The bridge averages 35,000 vehicles per day in each direction, with tolls collected in one direction only (westbound from England to Wales). The contract, worth approximately French Franc (Ffr) 2.2 million ($464,000 US), equips three lanes with a turnkey ETC hardware and software system and includes 4,000 TollTags (Ref 126).

Around July 1992, SRC began testing Amtech's radio frequency AVI system (read-only tag) on three of the eight toll lanes on the bridge. Originally, bar code technology was under consideration for this site, but was later rejected. Sources familiar with initial test results said the Amtech system had suffered from electronic interference problems. Cofiroute officials at the site denied that there had been any interference problems and are satisfied with test results to date (Ref 125).

9.2.2.3. Mersey River Tunnels: In 1990, CSEE-Peage was selected to supply Mersey Tunnels (the operator of the two Mersey River tunnels linking Liverpool with its western suburbs) with a fully integrated toll collection system for approximately £ 4.5 million ($8 million US). The contract was not put up for competitive bid, since CSEE had been selected for the overall toll system job. Detailed specifications of the AVI installation were not settled until August 1991. Installation of the new toll equipment began in February 1992; it was completed three months later, with testing starting in May 1992.

Mersey Tunnels chose to install PREMID AVI reader systems (read-only technology) along with automatic coin-operated systems and manual toll collection gear on all 38 toll lanes of the two tunnels. The in-lane antennae were mounted about 2.43 m (8 feet) above the road surface on poles. Barrier gates were used with the ETC system to alleviate the need for video enforcement equipment.

An initial quantity of 10,000 AVI tags were ordered; local toll officials expect to order another 10,000 once commercial operation of the ETC system is underway. The two Mersey Tunnels, the Kingsway and the Queenways, had a combined ADT of 80,000 vehicles in both directions. Peak volume of 4,000 vehicles per hour was reached during the morning rush.

This new ETC system replaced an aging magnetic stripe card system that had been experiencing reliability problems. Maintaining all the devices for the card system at proper calibration was difficult, and contributed to traffic delays when card holders were held up at toll gates by unreadable cards. This unreliability caused Mersey Tunnel to place backup cash and coin-operated systems in each lane for the new system.

While tunnel management wanted to open ETC-only lanes, unresolved traffic control issues made dedicated ETC lanes presently unfeasible. There was a merging traffic situation at the toll plazas and ETC-only lanes would create additional weaving. Also, ETC-only lanes posed additional safety problems with its higher operation speeds (compared with mixed-lane use).

The toll collection system was scheduled to commence operation on the 38 toll lanes in December 1992 without ETC-only lanes. Officials were confident that patrons would participate in the ETC system without ETC-only lanes because of the convenience of not handling cash and rolling down their windows in the inclement Liverpudlian weather (Ref 127).

9.2.3 France

France has an extensive tolled motorway network — 5,360 km (3,331 miles) in 1990 — offering an wide range of toll payment methods. These methods included cash, checks, bank cards, cards belonging to the motorway concessionaires, and specialist cards. As of March 1991, about 30 percent of payments were made with magnetically-encoded cards.

Automatic toll collection (télépéage) completes the range of payment systems. Several sites were already equipped, as shown in Table 9.1. These sites are used primarily in near-urban areas by regular commuter traffic and use read-only technology.

The first two-way experiment in France was run by SAPRR on the A42 near Lyon using HAMLET, a second generation microwave transceiver/smart card unit providing for storage and debiting of funds. Both of these components fit in a credit-card-sized device only 5 mm (0.20 in.) thick, developed by CGA and Gemplus, both part of the CEGELEC group (Ref 128).

At a July 1993 meeting in Paris, French toll agencies formally agreed to implement a standardized ETC system nationwide and agreed to gradually implement TIS (the procurement name, TIS, Telepéage Inter Société) over the next 5 years. Two of the eight toll authorities attending amended the agreement so that non-conforming ETC equipment could be used in urban areas (Ref 27). COFIROUTE (Compagnie Financiére et Industrielle des Autoroutes) and SAPN (Société des Autoroutes Paris-Normandie) had concerns about price and its ability to handle high traffic volumes (Ref 130).

The new ETC system uses a cashless "smart card" technology as an automatic payment system that will allow drivers to pay tolls at entry points without stopping. With this system, the driver inserts a smart card into a dashboard microwave transponder. The card will be read by remote control and debited the appropriate amount every time the vehicle is driven by a tollbooth (Ref 131).

Several incompatible ETC systems are already operating or being tested in France, including equipment from Amtech, Saab-Scania Combitech and CGA (Compagnie Générale d'Automatisme) (Ref 27). However, with the 5-year requirement for placement of TIS, there should be enough time to amortize the cost of the first-generation systems before replacing them with the new system. Likewise, there should not be a problem operating the existing systems side-by-side with the new ETC system. The systems could be placed on opposite sides of the toll plaza with no electronic interference. The real problem is guiding equipped vehicles to the appropriate lanes without incident (Ref 127).

USAP is planning to select one of two prototype systems being developed by two consortia teams as the TIS standard. Early in 1993, USAP awarded contracts worth Ffr 11 million ($1.96 million US) to the two consortia that had emerged from a field of six bidders. They are Compagnie Générale d'Automatisme (CGA) with smart card manufacturer Gem-plus Card International and Compagnie des Signaux et Equipments Electroniques (CSEE) with Saab-Scania Combitech and Compagnie Grenobloise (CGE).

Prototypes from the two consortia are expected to be completed by spring 1994, after which several months of field testing are scheduled. Only one of the two remaining teams will be awarded a contract to develop a production version of the system, which is scheduled for completion in early 1995 (Ref 27). The second contract is worth an estimated Ffr 14 million ($2.49 million US). Even more enticing would be a contract to actually supply the standardized ETC equipment to France's toll facilities. This is estimated at being worth Ffr 100 million ($17.82 million US) per year (Ref 130).

A USAP procurement committee has established the functional and technical specifications for the TIS system. USAP is calling for a read-write based radio frequency ETC system incorporating smart cards. The system would operate at 5.8 GHz.

Originally, USAP envisioned that its nationwide ETC system would be used primarily by commercial trucks (Ref 27). Some 200,000 trucks will be equipped with the RF toll transponders within 2 years of commencement of the service. Eventually, numerous passenger vehicles would also be equipped. With up to 800 toll plazas in France fitted with standardized in-lane antennas and reader systems, motorists could be allowed to pay tolls without stopping.

The new electronic toll system is intended to replace the subscription-card-based toll system for trucks now used on all French toll roads. USAP's members operate CAPLIS, a clearinghouse system that currently handles invoicing and settlement of tolls (Ref 130). There are currently no ETC systems on French highways used by commercial trucks (Ref 127).

The other six toll agencies in USAP are SARR (Société des Autoroutes Paris-Rhine-Rhöne), AREA (Autoroutes Rhöne et Alpes), ASF (Autoroutes du Sud de la France), SANEF (Société Autoroutes du Nord et l'Est de la France), ACOBA (Société Autoroute de la CÔte Basque), and ESCOTA (Société Autoroute Esterel-CÔte d'Azur).

In addition to reaching a consensus about ETC standards within its own borders, France is eyeing links with ETC networks in Italy and Spain; however, regional compatibility problems have not been resolved (Ref 27). For the writing of a RFP for TIS, ASFA (the trade association of all USAP companies) had consulted with both AISCAT (the Association of Italian Operating Companies for Toll Motorways) and ASETA (the Association of Spanish Operating Companies for Toll Motorways) on the functional and technical requirements (Ref 127).

Table 9.1. Automatic Toll Debiting Sites in France (as of Jan/Feb 1991) (Ref 128)

SITE	SUPPLIER (SINCE)	TECHNOLOGY	LANES VEH-S	LANES VEH-S**
Autoroutes du Nord et de l'Est de la France (SANEF)	NEDAP (NL) (1989)	100 KHz AVI	30-40 5-6 sites 5000	
Autoroutes de l'Esterel (ESCOTA) Antibes	AMTECH(US) +ELSYDEL(F) (1990)	2.45 GHz AVI	10 2500	62 17,000
COFIROUTE Dourdan (near Paris)	MATRA (M2S)(F) (1990)	3 MHz AVI	2 1500	
COFIROUTE Tours	AMTECH (US) (1990)	2.45 GHz AVI	2 500	12 2000
Autoroutes de Paris Normandie (SAPN)	SAAB (PREMID) (S) + CSEE (F) (1991)	2.45 GHz AVI	about 40 8 sites 5000	
Autoroutes de Paris Rhin-Rhone (SAPRR) Lyon	CGA/GEMPLUS (HAMLET)(F) (1991)	9.9 GHz / 5.8 GHz Two-Way	about 20 5 sites Test	9 2000
AREA Alpes	SAAB (PREMID) (S) + CSEE (F) (1991)	2.45 GHz AVI	5 Test	24 30,000

9.2.4 Italy

Italy's largest toll road agency is the Autostrade S.P.A., which controls 3,000 km (1,863 miles) of toll road using both stop and nonstop forms of ETC with a credit/debit method (Ref 132). An interesting legal requirement for Autostrade is that, before a toll road can start operations on a roadway, it is required to establish a radio communication link with the national police authorities. There must also be a written agreement for towing and related services with the ACI (Italy's national automobile association). All this must be done because the Italian government considers it essential to respond to incidents efficiently and with utmost concern for safety on their 5,000-plus km (3,105.5 mile) tollway system (Ref 133).

There are three ways a person can pay tolls on the Autostrade: *contante* (with cash); with a ViaCard (in use since 1982); and with a Telepass (in use since 1990). The ViaCard and Telepass are different ETC systems that collect about 35 percent of the tolls.

To use a ViaCard, motorists enter a clearly marked ViaCard toll gate and stop to insert their ViaCard (a magnetic plastic card) and toll ticket (where necessary) into the ViaCard computer. There are two pay methods for ViaCard. One is a current account (some 800,000 active), which debits tolls directly to an account arranged with the Autostrade or a bank, and the other is a deduction card (3 million sold each year).

Deduction ViaCards are bought at local tobacconist shops, restaurants and service areas along the highway and at special Autostrade offices in denominations of 50,000 to 90,000 *lire* ($40 or $75 US). Each time a deduction ViaCard is used, the computer reduces the value on the card for the toll payment.

The Telepass is a non-stop ETC system that uses a plastic AT&T smart card containing a microchip. To use Telepass, motorists insert their Telepass card into a two-way communication device (cigarette pack size) that is mounted on the top center of the windshield before entering the roughly 500-meter (1,640 feet) Telepass lane. The system reads and writes data on the card from a series of overhead radio frequency units (ranging from 5,785-5,815 GHz) as the vehicles passes at speeds of up to 30 km/hr (19 mph; this low speed is for safety purposes — it can function at 130 km/hr, or 80 mph). If there is a problem with the verification of the Telepass, possibly owing to an insufficient credit account balance, there are audio and visual signals from the communication device to the driver while he/she still has time to switch from the Telepass lane to a manual toll gate. If the motorist ignores the alarm, an image of the vehicle's license plate and the registration number is captured by video camera and placed on the Autostrade's *lista nera* (black list). Additional administrative action is taken. The user of Telepass is provided a monthly debit statement.

Telepass users are usually former or current ViaCard users. It is a small change from one to the other for non-stop tolls. Autostrade pays approximately $40 for each Telepass two-way communication device and currently provides them free-of-charge to motorists.

In 1990, the Autostrade began using Telepass along a 750-km (466-mile) corridor between Milan, Rome, and Naples. Here, Telepass toll gates are required at both entry and exit points, since toll charges depend on distance and vehicle type. There are about 30,000 Telepass users in the Milan area alone, a figure that is expected to double over the next year when Telepass service is added in the Milan-Brecia area.

Since January 1992, approximately 60 kilometers (37 miles) of roadway in the Milan-Laghi area have been outfitted for Telepass. For this facility the distance is fixed and tolls vary only by vehicle type. Vehicle type is determined through treadles that count axles and through infrared devices that measure the frontal vehicle height. A toll gate is required only at a single location. Autostrade is trying to coordinate with other transportation providers in Italy so that Telepass can be used on other toll roads. It also wants to extend the payment network so Telepass can be used on air, rail, port, and parking facilities (Ref 132).

9.2.5 Japan

The Japan Highway Public Corporation (JH) has been taking part in and conducting extensive research on ETTM technologies. At the present time, most of the Japanese toll roads are under the management of JH, which is looking for an appropriate ETTM system.

There is a magnetic card system being widely used on the toll roads. Toll rates vary road by road, with long arterial highways having incremental mileage charges and short rural roads, bridges, and tunnels having a flat rate.

JH is most interested in the ID Card System. They are planning to develop a read/write type ID card system to meet future applications of ETTM technology.

From February through April of 1992, JH conducted a field test of a read/write type ID card system. The results of the test showed no major problems when it processed only one car moving under 32 km/hr (20 mph), but when varying sized cars moved above 20 mph there were significant functional errors. In January 1993, JH decided to conduct additional studies targeted at the following critical points of improvement:

- To establish a format for data collected at an entrance ramp, main driving lane and exit ramp.
- To improve the rate of radio data transmission speed between a system antenna and an ID card.
- To locate a suitable radio beam dispatch zone for the radio data transaction.
- To investigate the flexibility of ID card installment position.
- To examine the effect of radio exposure on the human body.

There were other, broader issues of concern as well. Japanese officials felt the need to study the effect of ETTM systems on safe and smooth traffic management, the requirement of having an effective back-up system of ETTM in case of emergency, and the necessity of integrating ETTM systems into risk-management schemes (Ref 134).

9.2.6 Malaysia

Around June 1993, the PLUS (Projek Lebuhraya Utara-Selatan BHD) in Kuala Lumpur invited ETC firms to participate in a pre-qualification exercise for the design, supply, and installation of a planned non-stop electronic toll system. This effort could make Malaysia the next Pacific Rim country to implement ETC technology (Ref 135).

9.2.7 Mexico

Mexico's federal toll administration, Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE), in April 1992 contracted Amtech to provide many of the country's federally controlled toll roads and bridges with a turnkey ETC system. The system will include both Amtech's proprietary AVI hardware and revenue collection software.

Initially, the system will consist of 134 lanes at 58 locations throughout Mexico. System implementation is scheduled to begin in the second quarter of 1992, with substantial completion by year's end. Intregra Ingeriera S.A. de C.V. of Mexico City will also be actively involved in this project. The initial value of the contract is approximately $2 million, including an initial supply of 5,000 electronic TollTag identification devices (Refs 126 and 136).

9.2.8 Norway

The Norway section is divided into three different ETC systems: PREMID, KØFRI, and Q-Free system.

9.2.8.1. PREMID System: The world's first automatic tolling system was installed for commercial use at the Ålesund tunnel in Norway, October 27, 1987. The system called PREMID (Programmable REMote IDentification system), developed by Philips, was based on an intelligent tag with a small, 10-year life battery. The tag is attached inside one of the side windows of the vehicle (Ref 137). The transponder contains coded information related to the identity of the vehicle and when passing the toll site, the incident microwave signal from the roadside interrogator is reflected back from the transponder. Once the vehicle had been identified and validated, the toll charge is automatically debited from the driver's account. The toll sites around Ålesund have three lanes — one with a manned booth, one with a coins/card validating machine, and one automatic non-stop lane using PREMID. In 1989, almost 60 percent of the vehicles using the toll site were fitted with PREMID, increasing to 80 percent during rush hour (Ref 5). After some minor problems (malfunctioning or poorly mounted tags) had been resolved, the system has become very stable.

9.2.8.2. KØFRI System: In 1985, a pilot project was initiated by the Public Roads Administration, District Office of South-Trøndelag (county), to evaluate the possibility of creating a simple, reliable, and inexpensive electronic non-stop toll payment system. After a proposed solution was formulated, work began on the main project for the Public Roads Administration in South-Trøndelag for later use in a toll station on a new highway at Trondheim, which opened in 1988. This resulted in a demonstration of a prototype system in August 1987 and in a full-scale test in May and June 1988.

The Køfri ID tag, developed by Micro Design A/S, was a passive (no battery) transponder built around the surface acoustic waves (SAW) technology, which gave each tag a unique number. The Køfri registration unit was a microwave transceiver to ensure clean signals in a heavy noise environment. The Køfri signal processing unit was a computer that calculated the correct ID number from each vehicle tag passing the gate.

Along with the Køfri system, there was an accounting system running on a standard host computer. This program was especially designed to track every transaction and update each subscriber's account both in writing and by phone. This program communicated directly to each toll station and could transfer data between banks, post offices, etc. The system used video pictures of license plates for enforcement (Ref 137).

9.2.8.3. Q-Free System: An ETC system in Norway's third largest city, Trondheim, began operating in October 1991. The system, called Q-Free, was designed by Micro Design AS in Selbu, Norway. Q-Free, a SAW-based ETC system, was installed at 12 toll plazas encircling Trondheim. Toll authority officials ordered 60,000 passive SAW transponders; by October 1991, some 45,000 tags had been issued to Trondheim motorists, representing two-thirds of the registered vehicles in the area. The high issue rate was probably owing to user discounts (which average about 30 percent per transaction), good marketing, and the absence of tag fees. Users would be charged if the tags were lost. Booklets were mailed to every household and company in Trondheim (population approximately 140,000) explaining how the system worked and where to acquire tags.

Trondheim collected tolls from city-center bound motorists from 6:00 a.m. to 5:00 p.m., Monday through Friday. Outbound traffic was not charged. The Trondheim toll ring included 14 dedicated ETC lanes. Readers were placed overhead on gantries for each lane. There were physical barriers (e.g., gates). Tag-equipped vehicles were expected to pass through the toll plaza at about 56 kph (40 mph). Q-Free transponders were placed on the windshield behind the rearview mirror. A video detection system was installed to catch violators. Motorists who violated the system would be mailed notices requiring them to appear before local authorities.

Motorists had two payment options: pre-paid or post-paid by receiving invoices in the mail (which included only the number of toll transactions). System users could remain completely anonymous with a pre-paid cash account. Records of all individual toll transactions were required, by directive from the central government in Oslo, to be deleted from the system's centralized accounting system 24 hours after they occurred. Thus far, no Trondheim motorists has established an anonymous Q-Free account (Ref 138).

The ETC system in Trondheim, Norway, posted a driver-participation rate of 80 percent during its first ten months of operation ending July 1992. In that period, the Toll Road Company registered more than 8 million crossings of the toll ring. By May 1992, the number of issued tags rose to 60,000, from 45,000 in October 1991 and, by August, participation had stabilized at around that level. Participants in the Q-Free system could buy pre-paid subscriptions of 500 Norwegian krone ($90 was the most popular pay-in-advance amount), Nkr2,500 and Nkr5,000, or pay direct debit from their bank accounts (which amounts to almost 50 percent of all subscriptions to Q-Free). Subscribers with higher-value prepaid subscriptions received greater discounts from the Nkr10 paid by all manual-payment users each time they enter the ring. Retrospective debit subscribers receive the same small discount as subscribers to the prepaid Nkr500 subscription (Ref 139).

Another Q-Free installation, and the largest, started operating in October 1990 in Oslo. There were 28 dedicated ETC lanes, with 210,000 Q-Free tags delivered to Oslo toll authorities (Ref 138).

9.2.9 Portugal

In October 1991, the government-owned Portuguese toll motorway concessionaire, BRISA, installed an automatic toll collection system at two toll plazas near Lisbon, Portugal. The system, called Via Verde, used the passive SAW-based tag from Micro Design of Norway. It included 10 dedicated ETC lanes and initially issued 5,000 transponders.

As of October 1992, there were about 12,000 drivers who had tags, with approximately 10,000 tag-based transactions occurring each day. Drivers were required to pay a $35 deposit for the green (verde) tag and provided details of a debit account to which the toll charges could be transferred to using the Portuguese Multibanco funds exchange system.

The driver's account was set up so it could be used with any of four vehicle types. Toll charges were based on the observed classification at the toll motorway. In the beginning, BRISA did not have any enforcement procedures for vehicles which used the Via Verde lanes without a valid tag. Suitable legislation was passed to provide BRISA with adequate penalty powers.

BRISA sends full transaction details by electronic funds transfer to the debit account bank. The bank bills the individual toll transactions and collects payment. BRISA has been looking into using others to provide the customer billing facilities (Ref 140).

9.2.10 Singapore

On March 27, 1992, local transportation officials in the Public Works Department in Singapore issued a new call for proposals for their electronic road pricing (ERP) system. The proposals were due in three months. The problem with the first proposals, which were rejected in summer of 1991, was that the contractors did not meet system requirements and some of the proposed technologies were not fully tested.

Back in 1975 this island-state at the southern tip of the Malaysian peninsula started a supplemental licensing system. This system required morning motorists traveling into the city center to pay an entry fee. Later, fees were changed for peak travel time in the evening also. There were 27 entry points into the city center which were manned by officials responsible for checking vehicles for valid stickers issued with the supplementary licenses (Ref 141). The vehicle fee for entering the restricted city area during morning and evening rush hours ran about $2 per day or $55 per month (Ref 142).

The plan in the RFP was to equip each site with AVI reader systems and to install transponders and smart cards on most of the vehicles in Singapore, which has more than 500,000 vehicles. The system is not scheduled to be installed and operational for 3 years.

The specifications called for AVI transponders integrated with smart cards, which will function as a debiting system. The in-vehicle units would have displays indicating how much road-use credit was stored on the smart card. Other equipment includes AVI reader systems, a central computer, data transmission equipment, and a video enforcement system. While the system required a two-way communications tag, either in-pavement or above ground antennas are acceptable.

Though the government had not released budgeting figures for the project, it was estimated that the electronic road pricing contract could be worth 90 million Singapore dollars ($54.5 million US). There were 18 teams of firms seeking pre-qualification status. They included (1) United Engineers in Singapore, which is working with Vapor Canada; (2) Singapore Electronic & Electric, which is teamed with General Electric Company in the United Kingdom; (3) Philips Singapore and Saab; (4) Singapore Computer Systems, which is working with Amtech and others; (5) Thomson CSF, Transroute International and Keppel Engineering; (6) ANT from Germany, RNH from the Netherlands and Singapore's Communications & Network Systems; (7) Hughes Aircraft and EDS International; (8) Teledata in Singapore and Japan's NTT; (9) EB Communications in Singapore and Scandinavia's Micro Design; and (10) Material Handling Engineers in Singapore, which is working with Redar from Germany.

The contract technology transfer conditions of the proposal require all international companies bidding on the project to link with local firms. A bidder's conference was scheduled to in Singapore on April 20, 1992 (Ref 141).

From the second round of proposals, the Public Works Department (PWD) in Singapore short-listed three firms. The three bids were selected out of the five tenders received in April 1993. These short-listed firms are scheduled to carry out a 15-month demonstration project before a final decision on awarding the contract is made.

Two Japanese firms were short-listed. They were NTI International Corporation associated with Teledate, a local company, and Miyoshi Electronics Corporation working with Philips Singapore. The third bid was a joint bid by GEC Traffic Automation of Britain, Marconi Spa of Italy and Singapore Electronic and Engineering. The names of the two unsuccessful bidders were not disclosed.

This was the first phase of the ERP implementation, which would replace the present manual controlled system to restrict entry of vehicles into the city's central business district during peak hours. This first phase should be in place by 1997 at an estimated cost of $300 million US (Ref 142).

9.2.11 South Africa

In July 1991, a company representing traffic control systems in South Africa approached the Department of Transport of South Africa about the introduction of an ETC system on one of the major toll roads in South Africa. Their system was demonstrated to a toll road operator, which led to an offer being submitted to the Minister of Transport. The Minister appointed a review committee under the chairmanship of a representative of the trucking industry to further the discussion. The Jacobs Committee was formed to conduct a review of AVI and ETTM systems available in South Africa, to consider their suitability against the minimum requirements determined by the Department of Transport, and to take into account the requirements of the users. Members of the committee were representatives from the Department of Transport, the Railway Operating Authority, the Automobile Association and the Road Freight (trucking) Association plus various potential suppliers. The report, entitled "A Proposed Strategy for the Implementation of Automatic Vehicle Identification (AVI) / Electronic Toll and Traffic Management (ETTM) in South Africa and an Evaluation of AVI/ETTM Submissions to the Jacobs AVI/ETTM Review Committee," was delivered to the South African Department of Transport in October 1991.

In March 1992, an RFP was issued for the supply, installation, operation, and maintenance of ETTM systems on toll roads in South Africa. The RFP was issued by the Department of Transport on behalf of the South African Roads Board. A condition of the RFP was that the ETTM equipment be installed at all 17 toll plazas throughout the country. The extent of ETTM usage would be determined by the potential market. Any firm, organization, company, or consortia were encouraged to participate in the RFP.

To gather more information on and investigate AVI/ETTM systems an official of the Department of Transport went on an overseas study tour to the United Kingdom and United States. A report was made in April 1992 with recommendations on South Africa's proposed ETTM system. These recommendations were hoped to be incorporated into the guidelines by the Minister of Transport. Examples of recommendations included using radio frequency systems, operating on a prepayment basis, using tags capable of read/write communication, making suppliers responsible for marketing their tags, adopting one ETTM system for the entire country, and using ETTM technology that could be expanded into vehicle tracking and theft control.

When the South African Roads Board approved the recommendations in principle, it initiated negotiations between the Department of Transport and the Department of Posts and

Telecommunications (the regulating authority which controls and manages the frequency spectrum) for the allocation of a standard operating frequency for ETTM technology. In late 1992, a national seminar was held in Pretoria, South Africa, with the Department of Posts and Telecommunications. The seminar had each interested supplier addressing their requirements for an operating frequency with regard to the toll industry and to vehicle identification and tracking aspects. The seminar was successful in allocating a standard operating frequency, effective immediately, between 2.4 and 2.5 MHz, to be regulated by the Department. Also considered were the 5.8 to 5.9 GHz range (the European standard) and the 900 to 920 MHz range, though each required more time to study the consequences of allocating these frequencies.

In conclusion, the reviewers of ETTM felt South Africa was moving in the right direction. They also hoped that the first ETTM system would be operational in South Africa by early 1994 (Ref 143).

9.2.12 Spain

In the summer of 1992, Autopistas Concessionaria Espanola, S.A. (ACESA), placed an ETC system in operation. There were several other concession companies (TABASA, AUCAT, and AUTEMA) that had equipped two lanes of their motorways near Barcelona with the ETC system.

The system works with a tag (TELETAC) affixed to a vehicle's windshield, while ground equipment, composed of an antenna, a radio frequency module, and a "smart reader" registers the Teletac's coded data as the vehicle goes through the toll lane. Teletac is coded according to the ISO standards used in commercial credit cards, with the charging process employing similar techniques.

ETC lanes are situated at the end of toll plazas and are currently used only by cars. Vehicles without Teletac or with a non-working Teletac tag are guided to a normal toll lane by means of a high speed switching light signal. Lanes are 155 m (508 ft) long and are composed of different points:

- detection and information, 45 m (148 ft)
- transition 30 m (98 ft)
- exit 20 m (66 ft)
- deviation to a normal toll lane 20 m (66 ft)

The maximum speed in an ETTM toll lane is 40 km per hour (25 mph), though it is possible to drive safety at speeds around 60 km per hour (37 mph).

It is estimated that as many as 1,200 vph could use Teletac; ACESA had six ETC lanes operating as a quick teletoll system. It seems that a mixed teletoll system was more popular with ACESA, since it equipped 36 lanes this way before 1993. A mixed teletoll uses hardware similar to that used in the quick teletoll system, but was developed to be used in automatic lanes with open tolls. These mixed teletoll lanes manage three different payment methods: the teletoll system, coins, and credit cards, at the same time (Ref 144).

9.2.13 Sweden

By 1996, Stockholm and Göteborg should have in place some form of automatic tolling, most likely based on a city-center cordon system. Also, the Swedish National Road Administration (SNRA) would like to offer automatic toll debiting on other motorways and bridges.

SNRA would like to create national standards for all areas of a debiting system. This goal serves two purposes. It allows equipped drivers to use all tolled facilities equally and, with system standards, procurement could be opened to a wide range of bidders without proprietary constraints. The SNRA is the lead agency in this endeavor, with the following members: Transport Research Institute, the City of Göteborg, Saab-Scania AB (parent company to Saab Automobile in partnership with General Motors), Volvo AB and Swedish Telecom.

A test site has been established to provide a suitable environment for testing products and systems under realistic traffic context in Göteborg. The site was called "Test Site West Sweden" (TSWS). The site, is based on Greater Göteborg, includes the E6 route passing from Oslo to Denmark, and the E3 from Helsinki and Stockholm ending at the Göteborg port. As of October 1991, there were several pilots planned for TSWS emphasizing industrial development with the proviso that services eventually be paid for by road users. Pilot trials include driver information system tests based on RDS-TMC and SOCRATES, dynamic parking and park-and-ride advice, and fleet and public transport management.

TSWS will play an important part in the development and testing of automatic debiting systems based on a 25-vehicle test fleet. There are two companies involved in this process: Micro Design and Saab-Scania.

Micro Design supplied the automatic tolling systems for Oslo and Trondheim in Norway and was concerned with the central control and enforcement aspects of the Swedish system. Saab-Scania (took over Philips Kistaindustrier) had interests both in the PREMID automatic vehicle identification system and in the microwave/smart card developments carried out within the DRIVE I PAMELA project.

The system in Sweden will use an ISO-standard smart card to handle the funding transactions. The use of a card should allow for totally anonymous transactions, except where a system violation is detected, plus all transactions will be recorded on the card to allow for auditing.

The trials will review different payment methods (pre-, post-, and charging). Also, it will compare fixed payment versus payment based on actual route and time of travel. Attention is placed on the problems of funds reconciliation when the same debiting system is used by more than one toll facility operator.

The initial specification for the communication link will be from the DRIVE I PAMELA microwave work. Other system components could be tested as the pilot develops. It was considered that, with the progress made by the industrial parties in the last few years, within both DRIVE research and in delivered systems, it was likely the trials would develop a successful automatic debiting product (Ref 145).

CHAPTER 10. CONCLUSION

As shown, there are distinct advantages and disadvantages to using ETC technology. The benefits seem to exceed the drawbacks in major ways — for example, by increasing capacity of the toll plazas, decreasing environmental consequences of toll collection, and making toll roads more convenient for users.

ETC opens up the possibility of setting virtually any toll-pricing regime. If desired, the tolls can be distinguished by time of day, type of vehicle, laden weight, speed of travel, distance traveled, and traveler types entitled to a discount (Ref 146).

Implementation of an ETC system represents a major investment. With the rapid emergence of new technologies, and with the need for integration with conventional toll systems and other regional ETC systems, agencies must carefully evaluate their needs and determine optimum system configurations. Some agencies are delaying ETC implementation to take advantage of emerging technologies.

As stated, there is a problem with several competing systems on the marketplace using a range of technologies. These competing systems may offer similar functions or capabilities through alternative technical approaches. The implementation of several systems to support different applications or geographical locations could require motorists to install a number of devices on their vehicles. These additional devices would be unnecessarily expensive, aesthetically unpleasant and inconvenient, and also act as a disincentive to potential users. In addition, competing systems could potentially interfere with one another, resulting in reduced performance and loss of benefits (Ref 147).

Dual usage or secondary applications of the AVI technology is possible through equipment deployed for ETC, especially when a large base of vehicles are tagged. With additional antennas and readers installed at selected points in heavily traveled corridors, travel time can be measured and traffic incidents can be detected and cleared more quickly. AVI can be used to monitor traffic flow, grant special clearances, and regulate roadway access. Traffic advisories can be communicated to motorists by integrating the traffic monitoring information provided from electronic tags on vehicles with electronic variable message signs on highways. Electronic tags can be used to pay fees for parking lots, car washes, public transportation, and other services. The possibilities for ETC system uses are endless, requiring only good planning, funding, and demand use.

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APPENDIX A.

ETC DEFINITIONS

APPENDIX A. ETC DEFINITIONS

ALS - Area License schemes

ATT - Advanced Transport Telematics in Europe

AVI - Automatic vehicle identification (AVI) is the term used for techniques which uniquely identify vehicles as they pass specific points on the highway, without requiring any action by the driver or observer. It combines an on-board transponder with roadside receivers to automate identification of vehicles for purposes such as electronic toll collection and stolen vehicle recovery.

Cross-lane Reads - problem endemic of reflective tags whereby the tag identification is read in the wrong lane by a reader, making it difficult to determine in which lane the vehicle is traveling. This causes significant problems with enforcement and audit.

DRIVE - Dedicated in Road and In-VEhicle Safety (a project in Europe). A European Community program to find ways to alleviate road transportation problems through the application of advanced information and telecommunications technology. DRIVE has more than seventy projects, including CIDER, DACAR, IMAURO, INVAID, PAMELA, PANDORA, SIRIUS, SMART, SOCRATES, TARDIS, and VIC. The ultimate target of the DRIVE effort is to produce an integrated road transport environmental (IRTE).

EEPROM - electrically erasable, programmable and read-only memory

ENP - electronic number plate

ERP - electronic road pricing

ETC - Electronic Toll Collection refers to advanced toll collection systems using transponders and telecommunications devices such as AVI.

ETTM - Electronic Toll and Traffic Management refers to systems that incorporate both toll applications and the use of transponders to keep track of traffic and provide tools to manage traffic better. Uses AVI to electronically collect tolls, enabling vehicles to pay tolls without stopping at tollbooths.

FCC - Federal Communications Commission

HELP/Crescent - Heavy Vehicle Electronic License Plate program. CRESCENT is a demonstration project within the HELP program. It includes a multi-state, multi-national research effort to design and test an integrated, heavy vehicle monitoring system using AVI, AVC (automated vehicle classification), and WIM (weigh-in-motion) technologies. The project will take place along I-10 and I-20 form central Texas, west through New Mexico, Arizona, and California to the greater Los Angeles area, then north along I-5 through California, Oregon, and Washington to the international border, continuing into British Columbia along portions of both the trans-Canada and Alaska highways. Data will eventually be monitored at more than 30 locations.

IBTTA - International Bridge, Tunnel and Turnpike Association

IEEE - Institute of Electrical and Electronics Engineers, Inc. A professional society and standards-making body, IEEE is composed of some 30 individual societies, including the Computer Society and the Vehicular Technology Society. It has established an IVHS Standards Coordination Committee.

IVU - In Vehicle Unit

Inductive loop antenna - an antenna constructed of a wire loop embedded in the pavement that couples energy via a time varying magnetic field passing through the loop

Intelligent Vehicle-Highway Systems Act of 1991 (IVHS Act) - Included in the ISTEA, this act proposes the establishment of a national IVHS program to include evaluation and implementation of IVHS technologies; development of standards; establishment of an IVHS information clearing house; utilization of advisory committees (one of which is IVHS AMERICA); and funding of an IVHS research, development, and testing program.

IVHS: Intelligent Vehicle Highway Systems (IVHS) is the term to describe all those applications that place intelligence and a communication capability in the vehicle. This could be for electronic tolls, traffic management, fleet operations, hazardous materials management, ground transport management, route guidance systems, etc.

MAPS - Multi-modal Access and Payment System concept concentrates primarily on moving more people, rather than moving more vehicles through an existing transportation infrastructure

MOMS - Maintenance On-Line Management System

OBU - On Board Unit

OBC - On-board computers

PAMELA - Pricing And Monitoring ELectronically of Automobiles. A DRIVE project that is investigating two-way microwave communications between vehicles and roadside equipment. Its purpose is to facilitate automated toll collection that does not require vehicles to stop.

PREMID - Programmable REMote IDentification

Q-Free - An ETTM system operating in Norway, Q-Free uses a camera system for enforcement and has passive AVI tags.

Read-only - This refers to tags in or on vehicles that can be read by a roadside device such as a bar code scanner or reflective radio reader. Data can not be written onto read-only tags. Sometimes called Type I.

Read-write - This refers to vehicle-borne devices (tags or transponders) that can be read or onto which data can be written. Closed, ticket-type tollways require read-write capability, so that at a minimum, the entry point onto the road can be written and stored into the transponder memory for proper toll calculation upon exit. Sometimes called Type II.

SMART - A DRIVE project aimed at developing an intelligent information carrier (such as Smart Card) for use in various transportation applications, and to develop specifications for the most promising applications.

Smart Card - An electronic information carrier system that uses a plastic card -- about the size of a credit card -- with an imbedded integrated circuit that stores and process information.

Smart transponders - This is third generation technology sometimes known as Type III in which the transponder can be read, data written into it, and most uniquely, the accounting and validation is done by this intelligent vehicle-borne device, thus eliminating the need for the so-called "clearinghouse." Type III transponder - read/write with display of data to driver and/or inputs from driver or vehicle computer

TARDIS -Traffic And Roads - Drive Integrated Systems. A DRIVE project - includes investigating the possibility of combining communication for route guidance with that for automated toll debiting

TRANSCOM - TRANSportation operations coordinating COMmittee. TRANSCOM is a consortium of 14 transportation and public safety agencies in the New York and New Jersey area. Its goal is to improve inter-agency response to traffic accidents. In order to accomplish that goal, a cooperative ETTM effort has been initiated for managing a heavily traveled corridor between northern New Jersey and New York City. The project will equip approximately 1,000 commercial vehicles with electronic transponders. Readers will be placed at selected tollbooths to provide automated toll collection for equipped vehicles. Additional readers will allow transponder-equipped vehicles to serve as traffic probes. The test will evaluate the use of this data to determine real-time traffic information such as speed, travel time, and the occurrence of incidents.

VES - violation enforcement system