PB98-159247

MAY - 8 1998

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Prepared for

Associação Brasileira de Concessionárias de Rodovias

Associação Brasileira de Concessionárias de Rodovias ABCR

Prepared by

Parsons Brinckerhoff International

SET
Consultoria Ltda.

PB 100 YEARS

This report was funded by the U.S. Trade and Development Agency (TDA), an export promotion agency of the U.S. Government. The opinions, findings, conclusions or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position of TDA.

REPRODUCED BY: NTIS
U.S. Department of Commerce
National Technical Information Service
Springfield, Virginia 22161

The U.S. Trade and Development Agency

The U.S. Trade and Development Agency assists in the creation of jobs for Americans by helping U.S. companies pursue overseas business opportunities. Through the funding of feasibility studies, orientation visits, training grants, conferences, and various forms of technical assistance, TDA enables American businesses to become involved in the planning stages of infrastructure and industrial projects in middle-income and developing countries. By doing this, the agency provides American firms with market entry, exposure, and information, helping them establish a position in markets that are otherwise difficult to penetrate.

PROTECTED UNDER INTERNATIONAL COPYRIGHT
ALL RIGHTS RESERVED.
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE

Reproduced from
best available copy.

Mailing and Delivery Address: 1621 North Kent Street, Suite 300, Arlington, VA 22209-2131
Phone: 703-875-4357 • Fax: 703-875-4009 • Web site: www.tda.gov • email: info@tda.gov

U.S. Trade and Development Agency
FM / CMP / DCB
Room 700, SA-02
515 22nd Street, N.W.
Washington, D.C. 20522-0209

Electronic Toll Collection Interoperability Study in Brazil

Table of Contents

SUBTASK 4.1. ISSUE RECOMMENDED INSTALLATION STANDARDS 2
4.1.1 Assumptions 2
4.1.2. Compatibility Specifications 4
General 4
Definitions for Data Codes 4
4.1.3. Reader 5
Reader Antenna Specifications 6
Reader Communications Protocol 6
Reader Field Strength For Modulated Backscattering 8
4.1.4. Transponder (Tag) 8
Transponder Transmit and Receive Antennas 9
Transponder Activation 9
Transponder Communications Protocol 9
4.1.5. The Future 10
SUBTASK 4.2. PREPARE FUNCTIONAL SPECIFICATIONS 13
SUBTASK 4.3. COMPUTE SYSTEMS PERFORMANCE PARAMETERS 13
4.2.1. Introduction 13
4.2.2. Lane Equipment 14
Lane Controller 14
Lane Controller Software 15
Toll Terminals 16
General Specifications 16
Enclosure 17
Mounting 18
Interface Cabling 18
ETC Tags/Transponders 18
ETC Readers 20
Field Strength: 21
Automated Vehicle Classification System 21
Lane Video Enforcement System 22
ETC Signing 24
Miscellaneous 25
4.2.3. Plaza Computer Equipment 25
Processor 25
Disk Drives 26
System Video Display Terminal 26
Miscellaneous 26
Communications Ports 27
Lane Network 27
Plaza/Host Network 27
Transportable Media 27
Uninterruptible Power Supply Interface 27
Printer 27
Cables and Connectors 27
Toll Supervisor VDT 28
Toll Supervisor Printer 28
Superintendent VDT 28
Superintendent Printer 28
Plaza Computer Subsystem Power Requirements 28
Plaza Computer Software 28
4.2.4. HOST COMPUTER SUBSYSTEM 32
Host Computer Hardware 32

Host Computer Software 35
SUBTASK 4.4. DEFINE STAFF REQUIREMENTS 42
4.4.1. Methodology 42
4.4.2. The Current Environment in Account Processing and Maintenance 42
4.4.3. Moving Toward Interoperability 43
4.4.4. Staffing for the ABCR and Financial Institutions: New Roles and Responsibilities for Clearinghouse Operations Activities 44
4.4.5. An Opportunity for Standardized Maintenance Operations 49
4.4.6. Toll Concessionaire Staffing Requirements 50
SUBTASK 4.5. PREPARE MIGRATION STRATEGY 53
4.5.1. Introduction 53
4.5.2. Review of Installed Base 54
4.5.3. Planned Systems In Brazil 55
4.5.4. Existing Electronic Toll Collection Systems in the Region 57
4.5.5. Brazil's Interoperability Needs 58
4.5.6. Efforts Toward Interoperability 59
4.5.7. Technology Issues 59
Tag System Selection 59
Key Tag System Information Functions And Locate Them On The Tag Or In The Roadside System 60
Choice Of Tag System Operating Frequency 60
4.5.8. Standards Development And Testing 63
Status Report (As Of 1 February 1998) 63
Spectrum Issues 64
International DSRC Coordination 64
Standards Testing 64
4.5.9. Title 21 65
4.5.10. Brazil's migration Path 66
Active And Backscatter Tag Systems: 66
The ETC System Migration Path: Phase One 67
The ETC System Migration Path: Phase Two 68
The ETC System Migration Plan: Phase Three 69
4.5.11. Smart Cards 69
State-of-Practice 69
Smart Cards in U.S. Transportation 70
Obstacles to Implementation 71
Potential ABCR Roles 72
4.5.12. Business Issues in ETC Standardization 73
Sunk Investments 73
Sole Source Providers 73
SUBTASK 4.6 PREPARE FINAL REPORT 76
4.6.1. Summary of Other Tasks 76
Subtask 4.1 Issue Recommended Installation Standards 76
Subtask 4.2 and 4.3 Prepare Functional Specifications and Compute System Performance Parameters 76
Subtask 4.4 Define Staff Requirements 76
Subtask 4.5 Prepare Migration Strategy 76
Subtask 4.7 Identify Vendors 77
Subtask 4.8 Define Clearinghouse Functions 77
4.6.2. Additional Considerations and Issues to be Addressed by Concessionaires 77
Business Arrangements and Options 78
Clearinghouse Issues 78
Marketing Issues 79
Legal and Institutional Issues 80
Internal Policy Elements 83
Procurement 85
Litigation/Protests 90
Enforcement 90
Privacy and Liability Issues 91

Intellectual Property Rights 92
4.6.3. Recommendations *93*
SUBTASK 4.7. IDENTIFY VENDORS 96
4.7.1. Introduction *96*
4.7.2. Selecting a Vendor *96*
4.7.3. Vendors With Title 21-Compliant Equipment *96*
Amtech 97
Denso 97
MFS Network Technologies 97
Sirit 97
Tadiran 97
Texas Instruments 98
SUBTASK 4.8 DEFINE CLEARINGHOUSE FUNCTIONS 101
4.8.1 Introduction *101*
4.8.2 Benefits of the Clearinghouse *101*
4.8.3. Clearinghouse Concept of Operations *102*
4.8.4. Administration and Management *103*
Customer Accounts Administration 103
Customer Account Establishment 103
Customer Account Maintenance 103
Customer Inquiries, Complaints and Discrepancies 103
Customer Account Billing and Invoicing 104
Customer Account Audit and Reconciliation 104
Reporting Services 104
Non-Consortium Customer Account Maintenance 104
4.8.5. Banking and Other Financial Institutions Interfaces *105*
Investment of Funds 105
4.8.6. Marketing *105*
4.8.7. Violation Enforcement *105*
4.8.8. Tag Control *105*

List of Tables

Table 4.1.1. Reader Specifications *5*
Table 4.1.2. Transponder Specifications *8*
Table 4.1.3. Definition of Technical Terms *11*
Table 4.4.1. Clearinghouse Staffing Matrix *44*
Table 4.5.1. Installed Base *54*
Table 4.5.2 Brazil Road Concession Program Selected Roadways *55*
Table 4.5.3 Existing Electronic Toll Collection Systems in Argentina *58*
Table 4.7.1. Vendors and Products Matrix *98*

List of Figures

Figure 4.2.1. Generic Three-Tiered ETC System Architecture *14*
Figure 4.4.1 ABCR/Financial Institution Clearinghouse Operations Organizational Chart *48*
Figure 4.5.1. Interoperable Tag System Migration Path *66*
Figure 4.8.1 Clearinghouse Operations Chart *102*

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.1. - Issue Recommended Installation Standards

SUBTASK 4.1. ISSUE RECOMMENDED INSTALLATION STANDARDS

Given the short-term interoperability needs of toll concessionaires in Brazil and the long-term vision for integrated DSRC applications, we have prepared recommended installation standards for standardized DSRC equipment and related peripherals, specifically tags and readers. Consistent with the migration plan (fully detailed in Task 4.5), these installation standards are designed to establish interoperability using known and reliable equipment, integrating legacy systems, protecting concessionaire investments, and providing a foundation for graceful migration to a standard at the 915 MHz frequency.

Rooted in these recommendations are some assumptions about the direction of international standards, future market activities by ETC equipment and software vendors, and, most importantly, the needs and concerns of the concessionaires regarding interoperability and additional functionality.

4.1.1 Assumptions

The installation standards are based on the following assumptions:

- The primary motives for developing a national functional standard are to achieve interoperability and to enhance the functionality of DSRC systems for users and concessionaires. The objective is to pave the way for an expanded ETC market through regional interoperability.
- Concessionaires are not expected to discard existing equipment unless there is significant additional functionality provided through the new standardized technology.
- Concessionaires must make decisions in the very near future, in some cases immediately, regarding ETC technology.
- ABCR and its members do not want to create a new standard, but would rather make use of proven, existing, open standards.
- ABCR wants to create an open, multi-source, competitive market for ETC.
- The ASTM 7 standard will enable interoperability between both active and backscatter technologies in the 902 - 928 MHz range. ASTM 7-compliant products are not likely to be widely available for purchase for the next two to five years.
- To provide interoperability with systems operating at other frequencies, concessionaires will have to use additional readers (at either 2.45 GHz or 5.8 GHz) and make processing system modifications.

- International standards development is currently going in different regional directions, but in several areas, consensus is building.

- It is anticipated that over the next few years there will be a conversion of these divergent international standards at the data exchange level (Layer 7). This is the layer at which vendors will develop software for additional applications.

- With a conversion at Layer 7, third party providers will develop products and new applications will be written based on DSRC technology, providing additional functionality.

In 1992, California passed Title 21, a mandate to regulate electronic toll collection equipment used in that state. The state adopted radio frequency backscatter as the technology of choice in ETC systems for California. As a result, all toll facilities and several other applications (parking facilities, etc.) are using interoperable technology, allowing users the benefit of needing only one tag for a variety of toll and other transportation uses.

California chose backscatter technology for a variety of reasons – both practical and technological. Among backscatter's technological advantages are:

- Less power consumption, so battery life is relatively longer

- More precise read zone because of the physics of the reflection process. The system more accurately discriminates valid users from violators and it provides accurate readings despite close adjacent lanes.

- Accurate communication with vehicles maintaining high speed on a limited access open highway

- More capably reads multiple tags in the interrogation field

- Effective in environments with excessive dirt, dust, moisture, and poor visibility

- Less expensive electronics

- Smallest possible bandwidth yielding the highest robustness against surrounding RF noise

In addition to these technological considerations, Caltrans also considered practical issues as well. Title 21 was based on some early experimental systems developed at the Lawrence Livermore Laboratories in the late 1980s. These systems seemed to provide a strong foundation for the specifications that would become Title 21. Like Brazil today, California, in the late 1980s and early 1990s, experienced significant traffic growth and looked to electronic toll collection as a means of easing congestion and expanding the state's transportation funding sources. As more and more toll roads were planned, it became apparent that achieving some consistency among the roads was both necessary and desirable. In order to achieve interoperability, the state used the early Lawrence Livermore experiments to develop Title 21 specifications.

The specifications in this report are based on Title 21 as well. Most operational ETC systems in Brazil use backscatter technology developed by Amtech, a company that manufactures Title 21-compliant equipment. Backscatter technology has proven effective for Brazil's existing ETC needs, and has demonstrated its effectiveness in supporting expanded transportation and transportation-related applications (as witnessed in California and Texas). Other equipment suppliers (as identified in Task 4.7) are available to provide equipment and support. Title 21 specifications allow for backwards and forwards compatibility, provide economies of scale with reagard to equipment (as manufacturers are already producing Title 21 products in mass quantities); provide a foundation for competition; and have demonstrated strong robustness.

It is for these reasons that we recommend the adoption of Title 21 backscatter, read/write technology operating in the 915 Mhz frequency band as the functional installation standard for Brazil in the short term. As discussed in the Migration Plan, ASTM 7 should be adopted through a graceful migration as ASTM 7-compliant equipment becomes widely available. These installation standards are intended for use by concessionaires that must upgrade existing systems or install new ETC systems in the near term (within 18 to 24 months).

4.1.2. Compatibility Specifications

General

These specifications, based on the California statewide automatic vehicle identification standard (commonly referred to as "Title 21"), deal specifically with automatic vehicle identification (AVI) equipment. Individual toll concessionaires will detail the specifications for technical, environmental, and operational specifics for each site implementation. Tasks 4.2 and 4.3 provide some guidance in this area. AVI consists of two functional elements: transponders and readers. This report is intended to define a standard communications protocol and to further define an initial set of data records.

It is envisioned that more complex data records will be developed to handle anonymous transactions, secure funds transfers, information transfers, and other transactions between the reader and the transponder that will be defined as needed. ABCR, for example, could function as the authority to authorize the use of new record types and to assign record type numbers to newly authorized records.

Definitions for Data Codes

Agency Code: This 16-bit code identifies the agency that has authority to conduct the transaction.

Byte Order: Numeric fields must be transmitted most significant bit first. If a numeric field is represented as multiple bytes, the most significant bit of the most significant byte is transmitted first.

Error Detection Code: The error detection code utilized in the defined records is the CRC-16, with a generator polynomial of $X^{16} + X^{12} + X^{5} + 1$. This results in a 16-bit BCC transmitted with

each data message. The data field protected by CRC excludes any preceding header in every case.

Filler Bits: Filler bits are used to adjust the data message length to a desired length and must be set to zero.

Header Code: The header is the first field in each data message for either reader or transponder transmissions and consists of an 8-bit and a 4-bit word for a total of 12 bits. The header provides a signal that may be used by a receiver to self-synchronize (Selsyn) with the data being transmitted. The Selsyn signal has binary and hexadecimal values: 10101010 and AA, respectively.

The header code also provides for a unique, 4-bit flag that is recognized by a receiver decoder as the end of the Header with the data message to follow. The flag signal has binary and hexidecimal values: 1100 and C respectively.

Reader ID Number: This 32-bit field is used to uniquely identify the reader conducting the transaction.

Transaction Record Type Code: This 16-bit code uniquely identifies a specific type of valid transaction between a reader and a transponder. This code unique defines the transponder message fields and functions permissible with the transaction type specified by the polling message as described in Section 1704.5(e)(1). Hexadecimal numbers 1 through 7FFF are set aside for transponder message structures and 8000 through FFFF are dedicated for reader-to-transponder message structures.

Transaction ID Number: This 32-bit code uniquely identifies which transponder is responding to a polling request or is being acknowledged.

4.1.3. Reader

The minimum role of the reader is to a) trigger or activate a transponder; b) poll the transponder for specific information; and c) provide an acknowledgment to the transponder after a valid response to the polling message has been received. Table 4.1.1 shows reader specifications.

Table 4.1.1. Reader Specifications

Reader Trigger Signal	33 microseconds of modulated RF
Reader Send Mode	Downlink
Carrier Frequency	915 ± 13 MHz
Carrier Modulation	Unipolar ASK (Manchester encoded)

Data Bit Rate	300 kbps
Number of Data Bits	Application Specific
Field Strength at Transponder Antenna	500 mV/m (minimum)

RF Carrier Frequency: The RF carrier frequency must be taken from the 915 MHz +13 MHz range. Specific frequency and bandwith depend upon pending FCC assignment.

Reader Antenna Specifications

Reader Antenna Polarizations: The reader transmit and receive antennas must have predominant EM field components that are co-polarized to the horizontal polarization specified for the transponder transmit and receive antennas. Horizontal linear, circular or elliptical polarizations are allowed.

Reader Antenna Location: The reader antenna location is site specific.

Reader-To-Transponder Trigger Pulse

Trigger Pulse Definition: The reader must provide a wakeup trigger for the transponder. The trigger must consist of a 33-microsecond, RF pulse at the assigned carrier frequency that is modulated with a continuous string of ones. The trigger pulse must be followed immediately by a delay (i.e., no RF transmission) of 100 microseconds. The wakeup pulse is intended to signal a dormant transponder to fully activate itself.

Trigger Pulse Field Strength: The required horizontal component of field strength produced by the trigger pulse at the maximum downlink range (site dependent of the reader) must be greater than 500 mV/m.

Reader Communications Protocol

AM Modulation Scheme: The downlink (reader-to-transponder) modulation scheme must be unipolar ASK of the RF carrier using Manchester encoding. A data bit '1' is transmitted by sending an RF pulse during the first half of the bit period and no signal during the second half, while for a '0' data bit the reverse order is used; i.e., no signal during the first half of the bit period and an RF pulse transmission during the second half.

Data Bit Rates: The data bit rate for reader-to-transponder message must be 300 kbps.

Field Strength: The field strength of a reader data message at the transponder must be greater than 500 mV/m.

Standard Reader Data Message Format: The standard portion of a reader data message must consist of a header and transaction record type code. The subsequent length, data content, and error detection scheme must then be established by the definition for that transaction record type.

Reader Data Message Formats For AVI: There may be several reader-to-transponder data message formats. The format is determined by the transaction record type code sent by the reader. The following definitions supply the reader-to-transponder message format presently specified for AVI electronic toll collection applications.

Reader Transaction Record Type 1 (Polling Message): The polling message (which follows the 100 microsecond delay after the trigger signal) tells the transponder the type of transaction the reader wishes to conduct. For AVI electronic toll collection applications, Reader Transaction Record Type 1 Polling message also would identify the agency or toll authority. For AVI applications, the reader-to-transponder Type 1 Polling Message must be structured using the following ordered data bit fields:

Field Definition	No. Bits	Hexadecimal Value
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	8000
Agency Code	16	
Error Detection Code	16	
Total:	60	

Reader Transaction Record Type 2 (Acknowledge Message): A reader-to-transponder acknowledge data message must be provided to inform specific transponders that they have been successfully processed and to stop responding to further identical reader polling requests. The acknowledge message is used to terminate the transaction and is only sent if the transaction is successfully completed. Reader Transaction Record Type 2 (Acknowledge Message) must consist of the following ordered data bit fields:

Field Definition	No. Bits	Hexadecimal Value
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	C000
Transponder ID Number	32	
Reader ID Number	32	
Transaction Status Code	16	
Error Detection Code	16	
Total:	124	

Reader End-of-Message Frame: The end-of-message signal for reader-to-transponder data messages must consist of a minimum of 10 microseconds of no RF carrier signal. Transponder decoders must have the ability to detect this condition as an invalid Manchester code.

Reader Field Strength For Modulated Backscattering

The electric field strength produced by a reader is a function of the EIRP. The EIRP required to detect a modulated backscattered RF signal from a transponder with reasonably high

signal-to-noise ratio is determined by the maximum range to the transponder and the detection sensitivity of the reader receiver plus any gain margin. If the overall gain characteristics of the transponder were held constant, the required EIRP then becomes site dependent.

The electric field strength to accomplish modulated backscattering is expected to be lower than that required for triggering a transponder or for sending a reader data message. Sensitive reader receivers likely will be necessary, however, such as those obtained with homodyne or heterodyne technology.

4.1.4. Transponder (Tag)

A half-duplex communications system is envisioned where the transponder takes its cues from the reader. Table 4.1.2 outlines transponder specifications.

Table 4.1.2. Transponder Specifications

Technology Type	Modulated Backscatter
Transponder Send Mode	Uplink
Carrier Frequency	Same as Reader Send Mode
Carrier Modulation	Subcarrier AM
Subcarrier Modulation	FSK
Subcarrier Frequencies	600 Khz ± 10 percent and 1200 KHz ± 10 percent
Data Bit Rate	300 kbps
Number of Data Bits	Application Specific
Receiver Field Strength Threshold	500 mV/m ± 50 mV/m (minimum)
Transponder Antenna	
Polarization	Horizontal
Field of View	Operation within 90 degree conical angle
Location	Front of Vehicle (windshield)

The transponder RF carrier frequency in a backscatter system is identical to that used by the reader; the frequency will be in the range of 915 MHz + 13 MHz. The transponder must be capable of operating over the full +13 MHz band to allow site flexibility in reader implementation.

Transponder Transmit and Receive Antennas

Antenna Polarizations: The transponder transmit and receive antennas must have EM field components that are predominantly horizontally polarized transverse to normal traffic flow. Horizontal linear, circular or elliptical polarizations are allowed.

Antenna Field of Views: The transponder transmit and receive antennas must have a field of view which is a 90 cone in front of the vehicle. The projection of the horizontal component of the cone's axis must be parallel to the lane and the vertical component of the cone's axis must be 35 above horizontal.

Transponder Activation

A transponder must be fully activated and ready to decode the polling message from the reader within 100 microseconds of receipt and detection of a 33-microsecond modulated RF trigger pulse from the reader. The transponder receiver must be capable of recognizing and acting on a trigger signal and polling message when the free-space field strength at the transponder location exceeds 550 mV/m and will not respond to field strengths below 450 mV/m. (Electric field strengths are to be measured in free-space and in the absence of any vehicles.) After completion of the polling message, the transponder must begin modulating and backscattering RF with continuous zero bits. One hundred microseconds after completion of the polling message, the transponder must begin transmitting its message.

Transponder Communications Protocol

Subcarrier Modulation Scheme: The transponder-to-reader (uplink) modulation scheme must be amplitude modulation of an RF carrier backscatter created by varying the reflecting crosssection of the antenna as seen by the incident carrier signal. The antenna crossection must be varied between upper and lower limits with a 50 percent duty cycle and rise and fall times of less than 75 nanoseconds. The transponder baseband message signal must modulate the subcarrier using FSK modulation with a center frequency of 9000 kHz and frequency deviation of + 300 kHz. The lower and upper subcarrier frequencies correspond to data bits '0' and '1' respectively. The message information is conveyed by the subcarrier modulation frequencies of the transponder backscattered signal and not by amplitude or phase.

Data Bit Rates: The data bit rate for transponder-to-reader data messages must be 300 kbps.

Field Strength: The field strength at which a transponder data message is transmitted using backscatter technology is dependent upon the incident field strength from the reader, the transponder receive and transmit antenna gains, and any RF gain internal to the transponder. The transponder and antenna gain taken together must effect a change in the backscattering cross section of between 45 and 100 square centimeters.

Standard Transponder Data Message Format: The standard portion of a transponder data message must consist of a header and transaction record type code. The subsequent length, data content, and error detection scheme must then be established by the definition for that transaction record type.

Transponder Data Message Formats For AVI Toll Collection: There may be numerous transponder-to-reader data message formats. The format is determined by the Transaction Record Type code sent by the transponder. The following definitions provide the transponder-to-reader message format presently specified for AVI electronic toll collection applications:

Transponder Transaction Type 1 Data Message: Transponder Transaction Type 1 Data Message allows for unencrypted transponder ID numbers to be transmitted. Type 1 data messages must be structured using the following ordered data bit fields:

Field Definition	No. Bits	Hexadecimal Value
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	1
Transponder ID Number	32	
Error Detection Code	16	
Total:	76	

Transponder End-of-Message Frame: The End-of-Message signal for transponder data message must consist of a minimum of 10 microseconds of no modulation.

Transponder Response to Reader Acknowledge Message: The transponder must discontinue responding to identical reader polling requests for a period of 10 seconds once a valid reader acknowledgment message has been received. The transponder must, however, respond to polling messages that are not identical to the polling message that lead to the valid acknowledgment.

Multiple Transponder Responses to a Reader Polling Message: Each transponder data message transmittal must be in response to a reader polling message.

Transponder Positioning: Transponders must be positioned at the front of the vehicle with a clear line of sight to the reader antenna without degrading the performance of the reader-transponder system below minimum specified standards. As a minimum, transponders must operate up to a maximum of 76cm (30") offset from the longitudinal centerline of the vehicle.

The front of the vehicle must be defined as that portion of the vehicle from the driver's eyes forward.

The table below defines technical terms used in this report.

Table 4.1.3. Definition of Technical Terms

AM	Amplitude Modulation
ASK	Amplitude shift keying
BCC	Block check character
CRC	Cyclic Redundancy Check
CW	Continuous wave
EIRP	effective isotropically radiated power = gain x net power
EM	Electromagnetic
FSK	Frequency-shift keying
ID	Device identificatbn
Kbps	kilobits per second
KHz	kilohertz (103 hertz)
Kph	kilometer per hour
MHz	megahertz
Reader	A fixed position reader, associated transmit and receive (TxlRx) antenna(s), and modulation and demodulation hardware and software

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

SUBTASK 4.2. Prepare Functional Specifications

SUBTASK 4.3. Compute System Performance Parameters

SUBTASK 4.2. PREPARE FUNCTIONAL SPECIFICATIONS

SUBTASK 4.3. COMPUTE SYSTEMS PERFORMANCE PARAMETERS[1]

4.2.1. Introduction

This report provides basic functional specifications for the equipment and software to be furnished, tested, and integrated into the operations of various concessions in Brazil. In addition, this subtask report includes systems performance parameters for the functions defined. The two tasks were combined in order to provide clarity to the reader and offer concessionaires a reference document for use in developing requests for proposals for ETC equipment. It is recommended that these specifications serve as the "minimum" for efficient ETC operations. However, concessionaires may choose the relax the environmental requirements (temperature, for example) and accuracy rates, if desired. This chapter is organized according to the three-tiered system architecture depicted in Figure 4.2.1. A three tiered system architecture, which consists of plaza, lane, and host subsystems, is recommended because it provides the most redundancy and reliability. If an architecture other than a three-tiered system is used, then adequate features that provide fault prevention and redundancy support should be included.

Section 4.2.2 Lane Equipment: This section specifies the in-lane equipment including lane controllers, collector toll terminals, ETC readers and antennae, ETC tags/transponders, Automated Vehicle Classification system (AVC), Video Enforcement System (VES), patron toll displays, lane use signal lights, Automatic Coin Machines (ACM), charge card readers, receipt printers, lane barrier control systems, communications systems and all software.

Although only selected lanes at each plaza may be equipped with ETC features, it may be desirable for all lanes to be "ETC-ready." This means that all lane controllers must have the hardware and software capability to be converted to operate in a dedicated ETC or mixed mode without any modifications except for adding ETC components.

Section 4.2.3 Plaza Equipment: This section specifies plaza equipment including plaza computers, various peripherals to support toll collection supervision at major interchanges, violation data processing, and communications to the host computer system. This section also provides examples of software functional specifications as well as a possible list of reports to be generated. Each set of plaza equipment will be powered by an uninterruptable power supply.

[1] For simplicity, the numbering convention used throughout this document will be "4.2.x", although both subtasks 4.2 and 4.3 have been combined in this section of the report.

Section 4.2.4 Host Computer Equipment: This section specifies the host computer and peripherals to control and coordinate plaza computers, interface with the concession accounting and audit computer, manage databases, and exchange financial data with the banks. Software functional specifications and reports are also specified. The host computer System should be powered by an uninterruptable power supply.

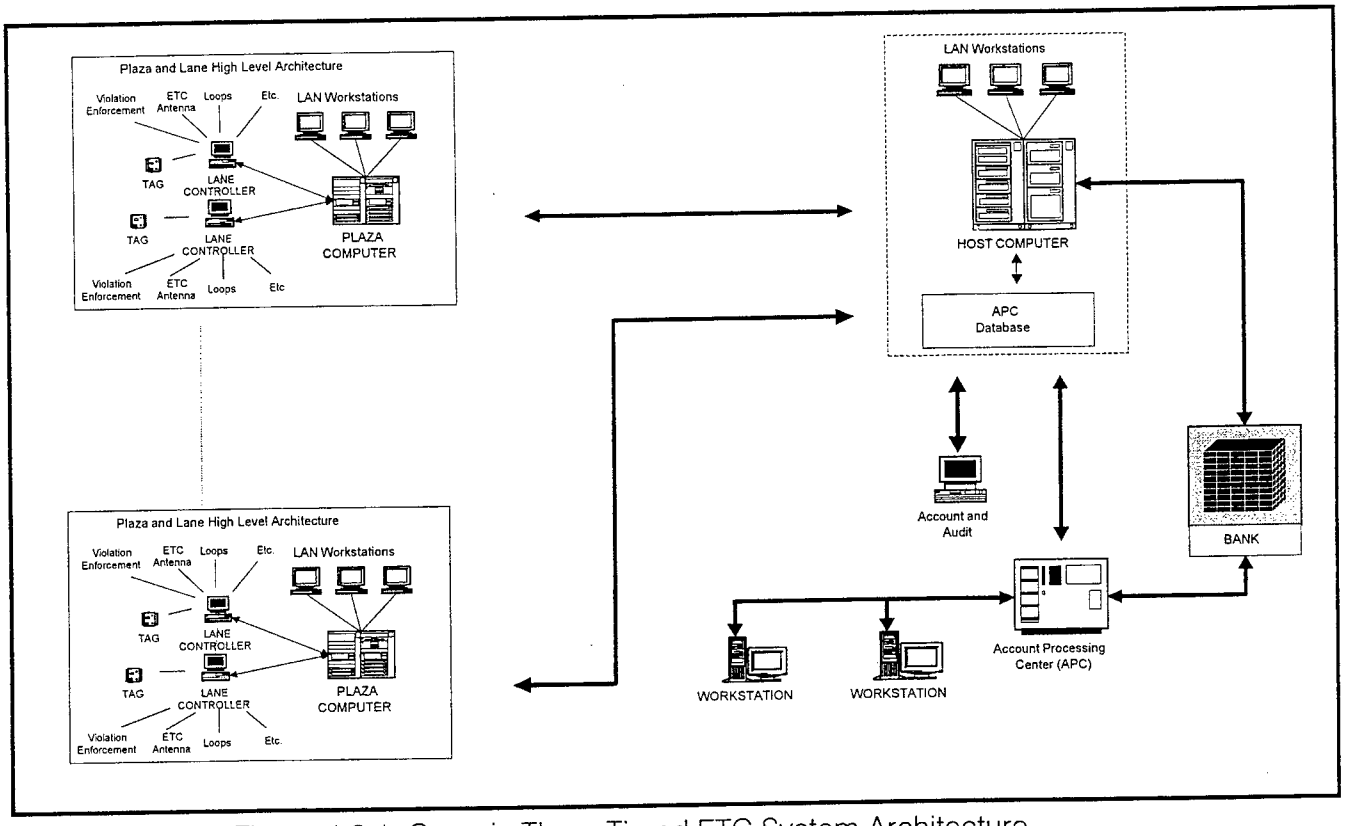

Figure 4.2.1. Generic Three-Tiered ETC System Architecture

All ETC components furnished under this functional description must be of recent manufacture, of current production, and new. Untried or prototype units should not be considered for acceptance.

4.2.2. Lane Equipment

This section specifies lane equipment pertaining to all modes of operation. Note that the lane controller, although it may be housed in the plaza, is considered a part of the lane equipment and therefore, is included in this section.

Lane Controller

The work under this section must include all labor, materials and support services to complete the design, fabrication, testing, integration and acceptance of the Lane Controller in accordance with the requirements of these specifications. The new lane controller must perform all the functions related to Electronic Toll Collection (ETC), Vehicle Enforcement System (VES), Automatic Vehicle Classification (AVC) and HOST computer/server communications.

Design Requirements: The lane controller must be designed, fabricated and laboratory tested to ensure that the lane controller will operate satisfactorily without material degradation for ten years.

Hardware Requirements: The lane controller must consist of a processor board with RAM memory, solid state disk board, input/output communications board, and electronic boards required to interface with the lane equipment and plaza computer.

Processor: The contractor must provide the processing platform and memory deemed necessary to meet performance specifications. The lane controller must support all lane operation functions.

Ethernet Communications: The lane controller must be interfaced to the plaza computer via an Ethernet interface. The contractor must indicate whether the Ethernet capability is provided through an interface card with software residing in the lane controller's main memory or unique processor card with Ethernet software residing on the card.

Delivery: The lane controller hardware must be packaged, shipped, delivered and installed at each plaza location provided under this specification. The quantities to be delivered must be in accordance with the specified quantity requirements.

Lane Controller Software

The contractor must furnish and install the lane controller software, which consists of a real time operating system, device drivers, toll collection, and concessionaire application software.

The contractor must provide the toll collection application software, and must integrate the concessionaire application software, if any, and test the software using a real time operating system (RTOS).

The concessionaire must maintain all property rights to the application software source code.

Operating System and Compiler Software: The lane controller software must be designed using a standard, commercially available multi-tasking, interrupt-driven, real-time operating system. The operating system must support 32-bit and 64-bit processor chip architecture. The application software must be implemented in the protected mode of operation with the ability to address a minimum of 32 MB of RAM memory. The most current version the selected operating system must be required.

The language for the application software should be the latest version of C or C++ from the Borland Corporation or an approved equal. The contractor must supply to the concessionaire the compiler and all utilities used to develop and program the lane controller application software. The contractor must use programming techniques and languages required to meet the performance criteria of these specifications.

The functions of the new lane controller must include but are not limited to:

- Provide all current functions, replaced in kind as required, including cash, ticket charge, mag-stripe card transactions and concessionaire exceptions
- Control the ETC subsystem, including storage and updates of the transponder database, communication with fee reader and control of the lane signal and booth indicator
- Control the VES subsystem, including notification that a violation is taking place (Separate control for the VES subsystem may be proposed.)
- Receive and analyze inputs from the AVC equipment
- Control and receive inputs from existing lane equipment
- Store transaction records and messages in the event communications with the plaza computer are lost
- Control a Variable Message Sign and/or other traffic management equipment
- Store up to 10 time-dependent or program-specific toll schedules
- Receive updates from the plaza computer
- Maintain an internal clock in synch with the System HOST clock
- Monitor all lane equipment, including itself, for performance, error messages, and failures, and communicate these messages to the HOST

Toll Terminals

The toll terminal must be a self contained flat panel, touch screen terminal that must not exceed 30 pounds in weight including any mounting bracket assembly. The touch technology must be infrared. The touch screen terminal must use electroluminescent technology for the display. The terminal must be designed to operate when direct sunlight is present and must function equally well in all ambient light conditions. The touch modes must be capable of at least 120 Button sets and have at least 120 Buttons per set. The Button response must be stored in a minimum of 8K Random Access Memory (RAM). There must be multiple Button-menu pages and the ability to overlay graphics onto any given Button-menus. The toll terminal must contain non-volatile memory for terminal configuration and storage of the various display screens. The display screen storage must be a minimum of 64KB of memory and must be capable of accepting a download from the lane controller. The graphics must consist of appropriate displays to represent classifications, toll rates, unusual occurrences, exceptions, menus, receipt key, time, date, Collectors ID number and other indicators, windows, icons or symbols required for the toll collection operation.

General Specifications

- Minimum Viewing and Touch Area: 120mm high x 195mm wide
- Display Technology: Active or Passive Backlit Matrix Color LCD
- Minimum Pixel Matrix: 640 x 480
- Pixel Aspect Ratio: 1x1
- Minimum Touch Resolution: 80 x 59
- Emulation Modes: Prosper Defined
- Operating Temperature: 0 to 40 degrees C
- Storage Temperature: -40 to 85 degrees C
- Humidity: 0 to 100 percent
- Interfaces: RS232, Opto-isolated RS422 and RS485, auxiliary serial port for future auxiliary terminal input device
- Minimum Touch Screen Features:
  - Touch sensitivity upon every entry, exit, or tracking
  - Pop-up menus
  - Variable touch zones, colors, and highlights
  - On screen keyboard
  - 128k touch zone memory
  - 16 different colors available per screen
  - Screen Saver during no activity
- External controls for screen contrast and backlight intensity
- Display both text and graphics

The toll terminal must be equipped with an audible alarm that can be energized for various events, irregular transactions or to call the toll collector's attention to special information on the screen.

The toll terminal must be designed to have a Mean Time Between Failures (MTBF) of at least 5,000 hours.

All toll terminals provided must be identical and interchangeable among all lane locations. PROM changes must not be required to operate the toll terminal in a different lane type.

Enclosure

The toll terminal must be rated NEMA 4, FCC Class A rating and must be UL approved. The terminal must have an environmental control system that must ensure that the optimal temperature is maintained and that positive pressure is applied at all times within the terminal.

The toll terminal, as a complete assembly, must meet the requirement of the NEMA Standard ICS 6-110.12 for Type 3 Dust-tight, Rain-tight industrial control enclosures. The Rain Test must be performed in accordance with NEMA Standard ICS 6-110-53 Rain Test (Rainproof and

Rain-tight). The terminal must be completely sealed to ensure that water, dust or other contaminants do not enter the assembly. Any louvers that are required must be screened and filtered to prevent entry of foreign materials.

Mounting

The Contractor must provide optional methods of mounting the toll terminal. Mounting arm assemblies must be designed to ensure ease of operation by toll collection personnel. Arm assemblies must provide for vertical, horizontal and tilting of the touch screen terminal. There must be appropriate means provided to lock the terminal in place after it has been moved.

Methods of toll terminal mounting must meet the operational needs of the concessionaire, or be modified or redesigned. In the event that the size, shape or configuration of the toll booths at the various plazas are so different as to prevent a standard toll terminal installation, the mounting arm assembly may be modified with the approval of the concessionaire.

Interface Cabling

All power and data cables connecting the touch screen terminal to the lane controller or power supply must be run through the mounting arm assembly. Cables should not be exposed. All mounting hardware used for the entire assembly must be security tight devices that limit or restrict the disassembly of the unit to authorized personnel.

All cabling from the back of the toll terminal to the lane controller, including that through the mounting arm assembly, must be installed in a flexible conduit to ensure the integrity of the cables and to prevent abrasion and wear. All data and power connectors must be terminated in a conduit or cable cover kit that must provide NEMA 4 sealing integrity to the connectors. Operational personnel must not have any access to any data or power cables at any point in the interface between the toll terminal and the lane controller. Connections must be provided for each field cable with the disconnection points outside of the toll terminal. It must be possible to connect or disconnect a toll terminal cable without moving any equipment, wiring or having access to the electronic equipment.

All wiring must be color or ribbon cable. Color coding must be selected for like control lines, common signals, voltages, system ground points and similar circuit functions. All color-coded cabling and wiring must be identified in the proper cabling diagrams.

Printed circuit boards, plug-in modules and similar devices must have locking connectors or attachments to ensure that these boards, modules or devices will not become disconnected because of vibration or other forces within the toll terminals.

ETC Tags/Transponders

Design Requirements: The vehicle tag must be designed for mounting on the interior or exterior of vehicles including motorcycles, if required. The devices must not interfere with the driver's vision or ability to properly control the vehicle. The tags must indicate the identity of the vehicle to the system. The following design requirements must be met:

- The tag must be of a non-repairable, maintenance-free design.

- The design life of the tag must be 10 years based on 50 complete daily operating cycles with equal percentages of high and low data bit voltage levels.
- Concessionaire customers must be capable of attaching or mounting the devices on their vehicles.
- The system's radio frequency must not interfere with nor be subject to interference from other radio frequency (RF) users.
- The system's equipment must not generate radiation levels greater than current applicable standards.
- The system must prevent cross lane readings and reading collision of multiple tags in a vehicle or multiple vehicles in the same lane.
- Tags issued by other agencies must be read and recorded (if possible) as non-ETC vehicles and the system must take no action. A daily record of such occurrences must be generated.
- The tags must be secure against counterfeiting or other fraudulent alterations.

Enclosure: The transponder must be enclosed in a hardened, sealed, weatherproof, shockproof enclosure to withstand the shock and vibration resulting from its installation and operation in a heavy vehicle or automobile over its design life. It must be of simple, sturdy construction and not be affected by dropping or other typical forms of accidental abuse. The read/write operation must not be affected by the presence of dirt, grime, salt, rain, snow or ice on the vehicle or on the transponder itself.

It must be designed with two types of housing, one for vehicle interior mounting and another for vehicle exterior mounting. Both housings must be of a design that will withstand direct exposure to sunlight throughout its design life. Exterior mounted tags must be designed to withstand physical impact of up to 5 g's without any operational failures.

Environmental Specifications

Interior Mounted Tag: The tag, including mount, must meet all operational specifications over the following environmental conditions, in any combination:

Ambient Temperature	-10 to +70 degrees C
Relative Humidity (non-condensing)	10 percent to 95 percent
Temperature rate of change	20 degrees C per minute

In addition, windshield mounted tags must withstand temperature differentials of up to 20 degrees C.

Exterior Mounted Tag: The tag, including mount, must meet all operational specifications over the following environmental conditions, in any combination:

Ambient Temperature	-10 to +70 degrees C
Relative Humidity (condensing)	0 percent to 100 percent
Temperature rate of change	20 degrees C per minute

Mounting

Interior Mounted Tag: The tag must be designed for mounting inside the vehicle by the user. The tag must not obstruct the driver's field of vision. The electronics portion of the tag must not be permanently affixed to the vehicle, allowing the tag to be readily moved between vehicles. Any interior mounting must be designed to prevent the tag from becoming a projectile in the event of an accident.

Exterior Mounted Tag: Exterior mounted tags must be designed for installation by the end user outside the vehicle. The tag must be designed for mounting on the grill or bumper, but must not obstruct the view of the plate. It must be mounted by means of a permanent adhesion that, once allowed to set, must cause the tag to be destroyed upon removal.

Labeling: The tag must be in a specified color and must be supplied with a permanent identification sticker. The sticker must not fade or peel during hot or humid conditions. The text on the sticker must be in Portuguese and must include the identification number and rturn address (as defined below), as a minimum.

Identification Number: A serial number must be printed on each sticker that can be correiated to its transponder ID code. The transponder code must not be printed on the sticker.

Return Address: The sticker must be labeled with a return address, to be provided by the concessionaire, so that a lost tag can be returned if found. The sticker must also indicate that postage is guaranteed.

Tag Memory: The information to be stored in the tag memory must include data for toll collection and error diagnostics with provisions for traffic and other unassigned data for future traffic management applications. The data must be partitioned into specific pages or compartments for ease of identification and memory utilization. The memory assignments in the tag memory must be as follows:

- The read-only memory must contain the tag identification data and must be only factory or agency programmable.
- The read/write transactions must require a minimum of 64 bytes RAM with partitioning capability.

Reliability: Tags must be designed for a 10-year operating life without material degregation.

ETC Readers

One ETC reader must be provided for each ETC lane (Note: May be multiple lanes if redundantly designed). The ETC reader must:

- Be designed as a module in the Lane Controller
- Contain an RF module located with the reader
- Ensure that the write transaction is conducted with the intended transponder only
- Have an operating range of 4 to 40 feet at speeds from 0 to 100 mph
- Operate within a temperature range of -10 to +70 degrees C

Detection Zone: The detection zone of each reader must be small enough to uniquely identify each vehicle. In no case must the detection zone exceed 10 feet in lateral and longitudinal planes within a lane. Minimum and maximum tag heights are left to the contractor to define, as long as each tag operates successfully in the detection zone when properly mounted on all vehicles.

Field Strength:

- The field strength of the reader inside its associated lane must be a minimum of 500 mV/m.
- The field strength outside the readers associated lane must not cause reader crosstalk in associated lanes. Cross lane reads must not exceed 1 in 100,000.

RF Specifications: An antenna must be installed overhead in each toll lane for transmitting and receiving RF signals to and from the vehicle transponders in the toll lane. The antenna performance must not be affected by minor ice buildup, wind or vibrations caused by passing vehicles. The antenna must be positioned and aligned to prevent vehicle shadowing. The RF range requirements for the antenna are as follows:

- RF emissions in compliance with all applicable regulations
- Compliance with all applicable standards

Reliability: The readers must have:

- A design life of at least 10 years
- An MTBF of 20,000 hours minimum
- Not more than 1 missed read per 100,000 vehicles at 100 mph
- Not more than 1 improper read per 10 million transactions

Communications: The contractor must provide details on the proposed configuration and communications interface. The communications lines between the lane controller and each reader must be supervised, i.e., the system must sense when communications have been lost between the lane controller and the reader. Standard interfaces must be used wherever possible.

Automated Vehicle Classification System

An Automatic Vehicle Classification (AVC) system must be designed and installed in all ETC equipped lanes, to automatically detect the presence of and classify all vehicles including motorcycles in accordance with Brazil's vehicle classifications. Any combination of sensors may be used to achieve accurate and reliable vehicle classification. The sensors must in no way affect the vehicle operator or toll collection operations in staffed toll collection stations. AVC equipment, in conjunction with lane controller logic, must detect and separate each vehicle in the lane.

Design Requirements: The AVC system must:

- Determine the number of axles within the vehicle profile and accurately track the vehicle through the designated lane
- Automatically set the toll associated with the vehicle's classification as payment for that particular vehicle

- Supersede the default vehicle class on the transponder when the toll amount is determined for an ETC transaction
- Retain an image of the vehicle's license plate on the video enforcement system if the classes differ and provide a daily report
- Correctly classify 99 percent of all vehicles according to Brazilian classifications
- Have the flexibility to be upgraded to accommodate future revisions to vehicle classifications
- Prevent errors in the case of unpaid tolls, vehicles stopping before clearing the lane, very closely following vehicles, etc.
- Not cause violations to be indicated when none has occurred or indicate a violation for the incorrect vehicle
- Be reliable and designed for the harsh environment of the toll lane
- Have a MTBF in excess of one year

Lane Vehicle Separator: Vehicle separator devices, to accurately detect and separate each vehicle in the lane, may be used in conjunction with treadles to measure the number of axles for each vehicle.

Treadles: Treadles should be located at the exit point (or the entry point of lanes operated in reverse mode) of the toll lanes. Tests must be performed to verify that each treadle in each toll lane is accurate to 1 to 5000 axles for the specified operating speed.

Lane Video Enforcement System

The VES must be installed in all ETC lanes, except ticket-entry lanes, and must have cameras to automatically capture the rear license plate image of every vehicle that fails to pay the appropriate toll. The functions of the VES are as follows:

- Capture, store and transfer a digital image of a license plate of a violating vehicle and associated data
- Process the image and data and issue appropriate violation

The overall system must be designed to recognize a violating vehicle in time for the VES to react and capture an image. The subsystem must capture an image of every plate, record the image if a violation is subsequently indicated, or discard the image if not. The VES must always be active and prepared to capture images and must be designed and installed so as to minimize vandalism.

The VES must record (on a separate track) with the picture a time/date stamp, lane number, and plaza or ramp number at the time the picture is taken. The recorder must be a microprocessor controlled device that is capable of recording video images on a compact disk and maintaining storage on a removable data disk. The stored picture archive must be listed in a sequential time/date scheme that will permit the user to observe the recorded pictures on the video display prior to printing selections.

VES Controller: The Video Enforcement System Controller must:

- Be capable of remote and individual selection of cameras
- Remotely control the camera's power on and off, and all other functions associated with camera control

Camera Requirements: The camera equipment must:

- Include all equipment necessary to ensure that the violation images meet the quality and physical requirements during all operating conditions and environments outlined here by the concessionaire.
- Be mounted and positioned in a location that will provide the optimum view of the toll lane
- Be located in an area that is secure from all vehicles and personnel
- Be housed in an environmentally sealed enclosure with directional locking mechanisms
- Include quick mount and release devices to allow for portability, quick installation and replacement
- Automatically control the camera's zoom lens, speed, and all other necessary camera setup conditions, to provide optimum pictures of the vehicle and vehicle rear license plate
- Have a reaction time from trigger to image capture no greater than five milliseconds
- Utilize a minimum shutter speed that will ensure that sharp images free of blur are captured regardless of the camera's mounting position or vehicle position within the field of view
- Provide clear and legible image frames of the vehicle license plate at speeds from 0 to 160 kmph
- Obtain readable/identifiable license plates under all environmental conditions on a minimum of 99 percent of violating vehicles

Environmental Requirements: The VES equipment must:

- Operate in the temperature range of -10 to +70 degrees C
- Operate in an outdoor environment with a relative humidity of 5- to 95-percent non-condensing
- Not be damaged nor can operational performance be degraded after subjection to 5 g's for 10 ± 1 millisecond in each of the three mutually perpendicular planes
- Not be damaged nor can operational performance be degraded after subjection to vibration of 1 g at 15 Hz to 500 Hz

VES Illumination System: The VES illumination subsystem must:

- Not adversely impact the driving safety conditions in the lane, adjacent lanes and surrounding environment
- Use visible light strobe if the system is capable of identifying the violators and activating the image acquisition system prior to time when the rear of the violating vehicle leaves the VES focal plane

- Use constant lighting or an invisible light strobe (infrared) if the VES design captures and stores the image of every vehicle in a temporary buffer until the violation status is determined

System Operation: VES images must be stored in the database on the plaza computer system before being transferred to the host computer. VES software, using Optical Character Recognition (OCR), must perform preliminary processing of images. Automatic checks must be made and reports issued for repeat violators.

The VES must have a central workstation or stations located at the Account Processing Center (APC) for examining the data and issuing violation notices. Images and data must be accessed by this workstation via a communications network. This workstation(s) must have access to all data recorded and the facilities and tools needed for examination of images, issuance of notices, audit and administration of the payment of tolls and fees.

Once all requested information has been processed and stored, the system must, when requested, generate a custom, user-defined, mailable violation notice. The custom notice must include, but not be limited to:

- A clear picture complete with superimposed data
- Name and address of the person the vehicle is registered to (if registered with toll concessionaire)
- The message text area describing the nature of the violation
- Time/date stamp
- Lane number
- Plaza name

Speed Enforcement: The Contractor must provide a means for enforcing a speed restriction through ETC equipped lanes. A speed limit of ____ mph must be posted for ETC equipped lanes. A speed detection/enforcement subsystem linked to the violation enforcement subsystem (VES) must be installed. Speed enforcement must be linked to the "ETC System" Agreement terms and conditions. A photo must be taken of the violating vehicle's license plate, and a warning automatically issued upon the first violation of a valid program participant. Non-participants who violate the speed restrictions must be treated as toll evaders and issued a summons for speeding. Program privileges must be revoked after the third consecutive violation within a period of one month. A threshold speed must be established by the concessionaire, which must cause the VES to capture an image. The threshold speed must be capable of speed limit variation programming.

ETC Signing

The contractor must prepare a signing plan to clearly identify in which lane(s) ETC is available at each plaza in either mixed-mode or dedicated lanes. The signing must incorporate the concessionaire's selected ETC logo for easy recognition on advance signs (those installed along the approaches to a plaza) and on canopy-mounted signs. The signing program must also advise motorists of speed restrictions to be imposed by the concessionaire through dedicated and/or mixed-mode lanes.

Signs along the approach roadway must be visible by the motorist for a distance of 750 feet and must supplement existing toll plaza signing. The location of the ETC sign panel(s) must not obstruct motorist visibility to other signs and must be spaced with respect to other traffic signing to allow adequate time for the motorist to perceive and read each panel. When mounted on the canopy, ETC signing must not obstruct lane signals and must have a minimum vertical clearance above the toll lane pavement of 14 feet 6 inches or must be hung no lower than the bottom of the existing canopy structure whichever is the least.

Canopy-mounted signing must have a minimum letter height of 12 inches. All ETC canopy-mounted signs must be illuminated for improved visibility and be capable of being obscured if ETC is not available. Advance ETC and speed restriction sign(s) must be placed at least 1/2 mile in advance of a mainline barrier with a second sign(s) at approximately 1/4 mile. For ramp plazas, signs must be placed in conjunction with existing advance exit panels along the mainline and on the entry/exit ramp prior to the plaza roadway transition.

Signing plans must be submitted for approval to the concessionaire for each plaza as part of the contract documents. It must include sign location/layout, mounting supports and foundations (where required), and sign legend including colors, letter size, spacing and material. All signs must be designed in accordance with specifications.

Miscellaneous

The contractor must provide approved charge card readers, receipt printers, and the approved barrier control system.

4.2.3. Plaza Computer Equipment

This section specifies plaza equipment to be provided by the contractor. Each plaza must be equipped with all the components specified herein.

Processor

The plaza computer must be, at a minimum, a Pentium Pro Server or successor product. The processor; as a minimum requirement, must have a 32-bit architecture. Its features must include, but not be limited to:

- 266 MHz processor
- Configurable with 2 CPUs
- Dual disk drives
- Minimum memory of 128 MB
- Minimum storage of 4 GB
- I/O slots, ISA, PCI
- Minimum 8 GB SCSI DAT drive
- 12X internal CD-ROM
- Internal 10/100 MB network interface card

No more than 60 percent of the processor's physical memory must be used when all of the operating system, utilities and communications software including the networking software are loaded, typical application programs are running for toll collection at 20 lanes; and the synchronous communications line is in use at expected loads.

No more than 50 percent of the processor's operating cycles must be used (i.e., at least 50 percent idle time) when all of the operating system utilities and communications software including the networking software are operating.

Disk Drives

Each plaza computer must be furnished with at least two 2 GB Fast SCSI-2, 9ms (or faster), internal hard drives. The SCSI controller must be a 32-bit, PCI Fast SCSI-2 controller adapter or latest available. One of the disk drives must be for on-line data storage while another drive must be for synchronized shadow data storage.

Data reliability must be enhanced by an error detecting code. Modular design must be used for ease of maintenance.

Total disk space available on the system must be such that the following conditions are met or exceeded:

- Disk size must take into account the operating system software, executable copies of the applications software, data files and reports.
- At time of acceptance of the system, there must be at least 60 percent free disk space on each disk media. The contractor must substantiate this by showing calculations.

System Video Display Terminal

Video display terminals must be provided with each system to act as the system console. The VDT must be used for periodic maintenance functions required of any large computer system.

Each video display terminal must have:

- A color video monitor
- A composite video output for auxiliary monitors
- A height pedestal base that provides tilt-and-swivel capabilities

Miscellaneous

Each plaza computer must also be provided with the following accessories:

- An alphanumeric keyboard with 101 key emulation and status indications for key lock functions
- A mouse that is compatible with other hardware and software specified
- A battery backed up real-time clock/calendar

Communications Ports

The plaza computer must be equipped with two communications ports for communications with the host computer. It must be fully supported by the proposed networking communications software.

Lane Network

The contractor must furnish and install a local area network for communication between the plaza computer and the lane controllers.

Plaza/Host Network

The network medium must be the concessionaire communications system. The network must provide plaza computer communications ability to the host computer via dedicated communications through the concessionaires communications system.

Transportable Media

The transportable media will be used for transporting data between the host computer and the plaza computer when communications are not available. The media must be, at a minimum, 20-GB tape cartridge. The plaza computer must be equipped with a tape drive fully compatible with the host computer subsystem.

Uninterruptible Power Supply Interface

The contractor must furnish and install an RS-232 interface between the dedicated electronic toll collection uninterruptible power supply and the plaza computer to monitor and control all UPS input/output system parameters.

Printer

The system printer must be a high-speed laser printer meeting, at a minimum, the following specifications:

- Print Speed: 24 pages per minute
- Text and Graphics: 300 dpi, duplex printing capability
- Memory: 9 MB installed, expandable to 17 MB
- Paper Capacity: 1,000 sheets

Cables and Connectors

All cables and connectors required to integrate the plaza computer hardware must be provided by the contractor. Connectors must be keyed to prevent incorrect insertion.

Plaza Computer Subsystem Power Requirements

All electrical/electronic equipment installed at each plaza site must be safeguarded by a dedicated uninterruptible power supply (UPS).

Plaza Computer Software

The work under this section must include all labor, materials, and support services to complete the design, development, programming, unit-testing, integration, debugging delivery, system testing and acceptance of the plaza computer software in accordance with the requirements of these specifications.

The contractor must develop all files, screens, reports, interfaces and all else necessary for the development of the toll operations scheduling and reporting system. The contractor must be advised that the concessionaire-owned toll plaza system varies in size from large to small plazas resulting in various requirements for each site although the intent is to standardize all reports and files throughout the system where possible. If proprietary software is used, a perpetual license for proprietary software must be provided for use by the concessionaire.

A graphical user interface with mouse capabilities must be provided to facilitate VDT use during all facets of operations.

Operating System Software: The operating system must utilize the most recent version of the selected software platform as its operating environment and most recent database software. This must include the operating system, utilities, programming languages, communications software and any software provided by the contractor for inclusion into the plaza computer. The operating system must support both real-time and batch processes. The operating system must have a command language that permits files of such commands to be executed in either batch or on-line mode.

The operating system must support a file management system that supports sequential, relative and multiple-key index disk files. The system must allow record locking for shared environments. The operating system must support processes with assignable priorities and must provide a memory management capability. It must support security by user ID and password log-on and access control lists to restrict access to files and devices. It must support a common run-time procedure library for all languages used by the contractor in development. The operating system must include software utilities. The utilities must, at a minimum, include an on-line help facility, a text processor, a file difference utility, error logging, resource monitoring, and a patch utility.

Error and system log files must be maintained for the plaza computer. The error and system logging utilities supplied by the manufacturer must be installed and continuously operational. The error log must record all hardware and system errors. The system log must record all messages directed to the system VDT.

Languages: The plaza computer must support software development using C and C++. It must fully support the operating system's main file management system. It must include the C compiler, runtime and all utilities supplied by the manufacturer. It must also conform to the ANSI draft standard for the C or C++ language.

If the applications software is developed in a language other than those listed above, all software required to compile, execute, and debug that language must also be included.

Relational Database Management System: A relational database management system (RDBMS) must be used to design the application software. The RDBMS must be a general purpose, multi-user, centralized database and support distributed processing. It must contain supporting utilities, precompilers, back-up and recovery facilities. The RDBMS must allow the user to maintain and manipulate the database. The contractor must propose the RDBMS industry standard.

A Structured Query Language (SQL) must be provided that meets the ANSI standard for the interface to relational databases. It must be a high-level language used for both interactive database displays and software development for reporting from the database, and must contain an ad hoc function to perform queries and database administrative functions.

A data dictionary must be provided that allows for the definition and model of the software data elements and manages the application development. It must be the single logical repository for data definitions and descriptions.

The RDBMS must allow the use of routines or programs to be written in C or C++.

Networking Software: The networking software must, at a minimum, include task-to-task communications, file management, down line system and task loading, network command terminals and network resource sharing capabilities. The networking software must utilize approved network protocols.

Application Software: The application software must be of a fully integrated design. It must be menu driven and contain on-line help facilities for all functions.

The application software must be developed by the contractor to perform the following:

- Implementing and maintaining a database management system
- Collecting and storing toll transaction data
- Providing toll supervisors' lane activity monitoring system
- Transmitting ETC transaction data to host computer
- Transmitting ETC violation data to host computer
- Creating audit files and transmitting to host computer
- Storing traffic data from toll lanes and transmitting to host computer
- Receiving and processing update data from host computer
- Monitoring and reporting system status and MOMS
- Producing toll operations reports, logs and schedules and generating the output on any of the system printers and plotters

Implementing and Maintaining a Database Management System: The plaza computer must implement and maintain the following databases:

- Toll transaction data by lane, including:
  - Cash transactions
  - Charge transactions
  - ETC transactions
  - Non-revenue transactions
- Lane open and lane closed status

- Lane operational messages
- Traffic survey data, including:
  - Number of vehicles
  - Types of vehicles
  - Peak traffic counts
  - Non-peak traffic trend
- Collector cash counts
- Collector cash deposit

Collecting and Storing Toll Transaction Data: The contractor must develop software to collect all real-time transactions entered from the toll lanes and store them in appropriate databases. These transactions include:

- Cash transactions
- Charge transactions
- ETC transactions
- ETC violations
- Ticket transactions

These records must be capable of being stored in the databases for seven days and then purged.

Transmit ETC Transaction Data to Host Computer: The contractor must develop software to transmit ETC transaction data received from the lanes to the host computer. The data may be received from manual or dedicated lanes. The ETC transaction data must be stored in the plaza computer until the host computer requests it. This data transmission must occur every hour.

Transmitting Violation Data to Host Computer: The contractor must develop software to transmit violation data from the plaza computer to the host computer on request. The violation data must be received from the Video Enforcement System. The violation data must be stored in permanent storage and must be retrieved for transmitting to the host computer on request. The data must be stored in chronological order with appropriate time and date stamp.

Equipment Inventory: The contractor must develop software that maintains an inventory of plaza equipment. This inventory list must be modifiable only from the Superintendent's VDT, and can be accessed from the host computer. It must include information on the location, operability and other data for all equipment in the plaza computer and in-lane subsystems. Additional hardware requirements, and software features must be proposed by the contractor.

An inventory of equipment must be initially entered and maintained during the warranty period by the contractor on the plaza computer.

Maintenance On-Line Management System - MOMS: The Maintenance On-Line Management System must be a maintenance monitoring and reporting system consisting of software to be furnished and installed under this contract. The contractor must develop and submit with the proposal recommended MOMS programs.

Typical functions of the MOMS system to be supported or performed by the plaza computer are the accumulation of maintenance information, equipment status and fault reports, repair parts inventory, status and ordering, parts delivery, technician location and activity, unfilled repair parts orders, and other functions as required by the concessionaire. The contractor's maintenance activity during warranty period must be included. The MOMS system must be provided with a paging feature that will page technical personnel automatically upon detection of a Priority-1 message.

Equipment reports consisting of the generation of fault messages by the toll and other equipment or from diagnostic testing must be classified into three specific categories as follows:

- Priority-1 messages must include a toll lane in an inoperative state or the loss of a single or primary source of toll audit data. A typical example may be the failure of a Toll Terminal which will require immediate response.
- Priority-2 message must include a subsystem or component that is failing or has failed completely but that does not affect the operation of the lane. A typical example may be the loss of one treadle strip contact. Corrective action will not be required until the next working day.
- Priority-3 message must include a subsystem or component that is beginning to fail resulting in a lane equipment degradation but with no loss of toll audit data. A typical example may be errors in communications that are correctable by software but that indicate that corrective action should be taken sometime in the future.

The plaza computer must respond immediately to real-time communications of Priority-1 equipment messages. The plaza computer must immediately route the messages to the maintenance VDT and printer. An audible alarm must be set off for each Priority-1 message until reset by the maintenance personnel. If the Priority-1 error is not corrected by the next business day, MOMS will reissue the resettable audible alarm and will continue doing this daily until error correction. Priority-2 and Priority-3 messages must be routed to the maintenance VDT and printer.

The contractor must develop a recommended priority for each equipment status (fault) message. The software programs must be designed to allow the concessionaire to make changes to the priority levels as desired.

4.2.4. HOST COMPUTER SUBSYSTEM

The proposed system design must be able to accommodate an additional 30 percent of the plaza computer's subsystem in terms of software and hardware capabilities. The intention is to anticipate future needs such as parking facilities.

Host Computer Hardware

Processor: The host computer must be an approved server product. Its features must include, but not be limited to:

- Configurable with dual processors

- Fully redundant RAID hot swappable disk drive array
- Minimum 256 MB memory
- 512 MB and 2 GB expansion options
- 4.3 GB fast/wide SCSI-2 disk array
- Fully redundant power and cooling standard

No more than 75 percent of the processor's physical memory must be used when all of the operating system, utilities, and communications software, including the networking software package, are loaded.

On average, no more than the "Test Under Design Load" conditions of the processor's operating cycles must be used (i.e., at least 50 percent idle time) when all of the operating system, utilities, and communications software are running for host computer operations.

Processor Connection Device: The system must have a processor connection device to connect future additional processors. Installation of additional processors at a future date must be made without affecting the operation of the original processor.

Disk Drives: The host computer must be equipped with a minimum RAID level 5 or equivalent disk configuration. All disk volumes must be shadowed across the server for recovering from disk failure. The configuration must provide mirroring of these two disk arrays.

The servers must have array controller technology. The system must support on-line capacity expansion and hot-pluggable hard drives providing configuration and maintenance without disruption of server operation. The system must be configured in a RAID Level 5 Array configuration for parity protected, fault-tolerant operations.

Servers must be supplied with external storage bays with fault-tolerant capability and expandability. This storage system must include hot-pluggable drives and a RAID Array Controller for various levels of fault tolerance with a minimum capacity of 30 GB per unit (utilizing 4.3-GB drives). The system must be provided with enough storage to support the system requirements with 100 percent expansion capability.

Data reliability must be enhanced by an error detecting code. Modular design must be used for ease of maintenance.

The disk size must take into account the operating system software, executable copies of the applications software, data files and reports.

At time of acceptance of the system, there must be at least 60 percent free disk space on each disk media. The contractor must substantiate this by showing calculations.

Disaster Recovery: The system must provide a disaster recovery model to support the restoration of a server that has failed while the back-up machine is operating. The contractor must provide a tool that restores a complete image of the machine's hard drive including configuration, operating software, hard drive partitions, hidden files, and executables. The image must be stored on a CD-ROM. A boot disk must be provided to allow the image to be installed onto a failed machine. The image must restore the machine to its appropriate

configuration in a matter of minutes. This will allow any machine to be restored if the hard drive is reformatted. The contractor may propose an alternative solution for the disaster recovery process for consideration by the concessionaire, if so desired.

Rapid Recovery: The server hardware must have rapid recovery features. If an error occurs in one of the subsystems, the management software must log the error in the server logs, attempt to restart the system, and take other necessary action such as de-allocating bad memory to avoid subsequent faults.

Line Printer: The system must have a line printer, which must have two modes of operation. The first must be data processing mode. At the minimum, this mode must have an uppercase character set and print a minimum of 2000 LPM. The second mode must be a word processing mode. This mode must have upper- and lowercase character sets and print a minimum of 1500 LPM.

Laser Printer: The host computer system must have a laser printer rated at 60,000 pages per month. Additionally, it must meet the minimum specifications listed below:

- Print Speed: up to 24 pages per minute
- Text and Graphics: 300 dpi resolution, duplex printing capability
- Memory: 9 MB installed, expandable to 17 MB
- Input Trays: 2
- Paper Capacity: 1000 sheets (500 per tray)

Video Display Terminals: Video display terminals must be provided with each system to act as the system console. The VDT must be used for periodic maintenance functions required of any large computer system.

Each video display terminal must have:

- A color video monitor
- A composite video output for auxiliary monitors
- A height pedestal base that provides tilt-and-swivel capabilities

Miscellaneous: The host computer subsystem must also be provided with the following accessories:

- An alphanumeric keyboard with 101 key emulation and status indications for key lock functions
- A mouse that is compatible with other hardware and software specified
- A battery backed-up real-time clock/calendar

Character Prints: The character printer must be a desktop laser unit capable of printing on stationary or fanfold paper.

Additionally, it must meet the minimum specifications listed below:

- Print Speed: up to 17 pages per minute
- Text and Graphics: 300 dpi resolution, duplex printing capability
- Memory: 9 MB installed, expandable to 17 MB
- Paper Capacity: 1000 sheets (500 per tray)

Communications Cabinet: The system must have a communications cabinet with equipment racks. The cabinet must have a full-length transparent front door to allow visual access to devices mounted in the cabinet. The front door must be magnetically latched. The bottom of the rear door must have at least 48 square inches of cable entry space. It must have adequate cable management brackets to secure all cables in a fully loaded configuration.

Uninterruptible Power Supply Interface: The host computer subsystem must be interfaced to a smart uninterruptible power supply (UPS). The UPS must be capable of keeping the computer and all connected devices operational (at least half load) during power failures lasting in duration of up to 30 minutes, then begin its graceful shutdown period. The UPS must provide complete isolation from the normal power grid and have a pure sine wave output. The UPS must also provide surge protection to all connected equipment, as well as filter out radio frequency and electromagnetic interference. The UPS must also have a communications link to the computer that enables it to interact intelligently. The UPS must be compatible with chosen monitoring software.

Cables and Connectors: Cables and connectors required to integrate the host computer hardware must be installed and provided by the Contractor. Connectors must be keyed to prevent incorrect insertion.

Host Computer Software

The host computer software must enable the host computer to perform all of the functions required to support the concessionaire's toll collection and related operations. These functions include network operations, data collection, toll audit, traffic and statistical report generation, maintenance tracking, charge account and ETC account billing, ETC Gray List, and ETC Violator File. The contractor may propose other functions.

If proprietary software is used, a perpetual license for proprietary software must be provided for use by the concessionaire.

A graphical user interface with mouse capabilities must be provided to facilitate VDT use during all facets of operations.

Software Submittal: All host computer software must be provided on the same transportable media as specified herein. Once the software is properly loaded in the host computer, the transportable media with the software must be kept by the concessionaire as a backup.

Operating System: The operating system must utilize the most recent version of the approved software as its operating environment, and the most recent version of the chosen database software as its database.

The operating system must include all software utilities necessary to support the proposed operation. These utilities, at a minimum, must include but not be limited to:

- On-line help facility
- Text editor
- Network mail facility
- File comparison utility

- Disk compression utility
- Report generator
- Linker
- Code management utility (librarian)
- Symbolic debugger
- Patch utility

Languages: The host computer must be able to support software development using C and C++. It must fully support the operating system's main file management system. It must include compiler, runtime, and all utilities supplied by the manufacturer. If the applications software is developed in a language other than those listed above, all software required to compile, execute, and debug that language must also be included.

Form Management System: The forms management system must be integrated with the host computer operating software and provide a forms processing capacity in a transaction environment.

Relational Database Management Systems: A relational database management system (RDBMS) must be used to design the application software. It must be the most recent version of Oracle (version 7.1 or later). The RDBMS must allow the user to maintain and manipulate the database while maintaining referential integrity.

A data dictionary must be provided that allows for the definition and model of the software data elements and manages the application development. It must be the single, logical repository for data definitions and descriptions. The data dictionary must perform consistency and quality checks during the analysis and design stages while documenting each component. Subsequent to the application design, the data dictionary will assist the users in the analysis of database design changes.

A facility must be provided for forms-based transaction processing with a minimum of programming activity. The facility must allow for the specification of the user transaction needs and must interface with the data dictionary to generate the transaction screen. With this non-procedural facility, the user may prototype the application and refine the transaction screen as desired.

Networking Software: The networking software must, at a minimum, include task-to-task communications, file management, down-line system and task loading, network command terminals and network resource sharing capabilities. Any modifications of the functions or the use of other communications functions outsiae the networking software will not be permitted. The networking software as a minimum must support all chosen network protocols as detailed below.

Performance and Coverage Analyzer: This software must be used to analyze the execution behavior of the application programs. This software must monitor execution bottlenecks and provide test coverage analysis by measuring which parts of the user programs are executed or not executed. It must be an aid in tuning the performance and testing of application programs.

Network Router/Server Software: The router/server software must be a dedicated routing system that supports both inter-area routing for local nodes connected to the network and for remote nodes. The software must be capable of expansion of an additional 30 percent of local and remote nodes.

Host Computer's Distributed Services: The host computer's distributed services must be provided to allow for the extension of the standard queuing system, enabling users to print jobs on any printer connected to the system.

The host's distributed file service must allow users to use proposed remote disks or printers as if they were directly connected to the local system.

Configuration Control System: This software system must be installed to maintain the software and hardware configuration management. The software must be menu driven and provide modifiable management of the individual parts of hardware or software product. The system must offer fully automated change and configuration control.

Application Software: The host computer application software must be a complete, fully integrated design. It must be menu-driven and contain on-line help facilities for all functions. The minimum requirement of the host computer application software must be to provide the following capabilities:

- Toll Audit System
- Credit Management System
- Traffic Analysis System

The Contractor must provide software to poll daily, at a user specified time, the plaza computers for the uploading of previous day(s) transactions. These transactions will include but are not limited to the following:

- Collectors transaction summary files
- Collectors charge files
- ETC violator information file
- 24 hour traffic counts, with hourly breakdowns for each plaza

Upon successfully uploading the transactions the system must automatically add to or update the appropriate databases and notify the user by issuing a broadcast message giving the database effected, the name and number of elements updated or added.

Security System: Security for the host computer system must be developed by the contractor and must use the security functions of the operating system. The security system must have a complete audit trail that contains at a minimum, data on user access, failed log-on, files accessed by user, and times of use.

All users of the host computer system will be assigned a user ID. Each user ID must be assigned a security class. Each security class must be assigned a list of programs and functions to which that security class has access.

Application software programs must only be accessed by menu. Each application software program must be assigned a security class. When a menu is displayed, the user must see only

those menu entries that the user has permission to access. The program that manages security files is protected by the same system.

The contractor must provide an overview of the security system with the proposal. The actual design of the security system must be submitted by the contractor at the SPDR.

The contractor must provide display screen facsimiles. All screens must be accessible from any terminal connected to the host computer with proper ID. As with all programs, standard security access protection must be provided for all display screens.

Toll Audit System: The transaction input must be provided by the plaza computers. Upon successful transmission of the shift data the host computer must automatically update the Monthly Shift database.

The contractor must develop software to allow for the input of currency counts generated by the Toll Cash Room. The inputs will be made on-line via the user's terminal. The minimum inputs must be:

- Plaza number
- Business day
- Collector ID
- Total coin count for the collector
- Total currency count for the collector

These inputs must be appended to a Monthly Cash file developed by the contractor.

The contractor must develop a "Tickler" file (table) containing the following:

- Plaza Number
- Date (days 1 through 31)
- Transaction elements, defined as:
  - Shift - representing shift transactions
  - Charge - representing charge transactions
  - Currency - representing cash counts

Ts a minimum the Collector Toll Audit function must produce selected reports. The users must be able to review the reports on their terminals. They must have an additional flexibility of having the reports printed on their local printer or the system printer. Once the reports have been reviewed and all adjustments have been made, the users must have the capability of transmitting the reports to the printers located at the remote plaza sites.

Charge Card Management System: The charge card management system must have the capability to create new accounts, update or delete existing accounts, compare receivables to surety-cash bonds, and produce monthly detailed statements of transactions by account. Examples of information maintained by the credit management system are as follows:

- Valid accounts
- Suspended accounts
- Customer invoicing
- Billing register

- Aged accounts receivable
- Bond analysis

The transaction input must be generated by the plaza computers. Upon successful transmission of the charges from the plazas the host system must automatically update the monthly charge file.

The system must automatically produce monthly billings for all active charge account customers. It must be capable of processing payments and handling customer service for charge account customers.

The contractor must develop an ETC account file consisting of, at a minimum, the following data elements:

- Account number
- Name and address of account holder
- Date amount prepaid and deposited
- Method of payment (check, cash, credit card)
- Current balance
- Daily account activity by plaza, date, time and classification

The ETC Account File must be capable of receiving inputs from three sources.

- Direct inputs from the users' on-line terminals. These inputs must include:
  - Updates to existing accounts
  - Addition of new accounts
  - Deletion of existing accounts
  - Ad-hoc queries as to the status of an existing account
- Daily transactions received from the plaza computers must include:
  - Every hour the host computer must poll the plaza computers for the latest ETC transactions.
  - The host computer stores the transactions in the ETC Transaction database.
  - The host computer updates the ETC account master file by decrementing or incrementing the account balance by the amount(s) for the given class.
  - If the balance equals zero or the balance falls below some pre-defined threshold, the account must be flagged.
  - All flagged accounts must be written to an updated transaction file (users list) for transmittal to the plaza computers.
  - The updated transaction file must be transmitted to the plaza computers
- Daily transactions received from the ETC Service Vendor

The Contractor must develop an ETC account file.

The contractor must develop a violator information file containing violator data received from the plaza computer. This file must maintain up to 200,000 records of violations containing the violator's license plate number, the site, date and time stamp, and a status tag, which can be set when enforcement steps have been taken.

Bank Deposit System: The contractor must develop the bank deposit subsystem to allow toll collection and ETC deposit data to be input from the following sources:

- The Toll Cash Room
- The ETC Service Vendor

The subsystem must produce, at a minimum, the following reports:

- Reconciliation report
- Bank test report
- Monthly deposit recap report

Equipment Inventory Database: The contractor must develop a modifiable equipment inventory system. There must be separate database files for each plaza site, and the database must include information on the location, operability, and other data for all equipment in the plaza computer and in-lane subsystems. A master database of all plaza sites equipment inventory information must be established and maintained on the host computer.

Host Computer Restart: In the event of a restart, the host computer must independently load all required software and initialize/restore all associated hardware so that network communications among the plaza computers can be reestablished. The lane controller, plaza and host computer databases must be updated to reflect system information that was unavailable during the absence of network communication.

Vault Deposit Report Database: The host computer must receive the information entered from the plazas' vault deposit report screens and store the information in a database.

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.4. - Define Staff Requirements

SUBTASK 4.4 DEFINE STAFF REQUIREMENTS

The move toward interoperability and standardization will require changes and additions to existing staff at the ABCR, toll concessionaires, and financial institutions involved in electronic toll collection. This report outlines the staffing requirements needed for providing interoperable toll operations throughout Brazil.

The Migration Plan (Task 4.5) and the Final Report (4.6) recommend a number of institutional changes that will require adjustments to the staffs of the ABCR and toll concessionaires. Most significantly, the suggestion that the ABCR (in partnership with one or more financial institutions) assume responsibility for clearinghouse and maintenance activities would require staffing increases and new organizational arrangements. Toll concessionaires may also need to add some staff to accommodate new responsibilities associated with electronic toll collection. These staffing changes, however, should be relatively minor.

4.4.1. Methodology

The recommendations contained in this report are based on the following:

- General staffing arrangements of toll concessionaires
- Existing ABCR staffing
- Staffing arrangements of U.S. toll agencies with toll systems interoperable with other systems (for example, Interagency Group members, California toll authorities)
- Functions to be performed by a national clearinghouse
- Maintenance operations functions
- New functions for toll concessionaires as a result of clearinghouse, maintenance, and other ETC-related activities.

4.4.2. The Current Environment in Account Processing and Maintenance

Currently, Onda Livre is providing account processing services for the Niteroi Bridge facility and the Via Lagos facility. Thus, customers from the Niteroi system may use their tags on the Via Lagos system and vice versa. The company also is in negotiations to provide account services (primarily invoicing) to the concessions in Parana, although it is unclear whether the tags used on the Niteroi and Via Lagos system will be interoperable with the Parana system.

All other concessionaires handle their own account processing, and their systems are not interoperable. Thus, in order for customers to use a particular toll system, they must have established separate accounts with each concessionaire. Otherwise, their tags will not be recognized by the system and will be counted as violations. This places a great burden on the

customer who must establish separate accounts with each system and, in some cases, leave deposits to establish each account.

Each concessionaire has its own maintenace staff and also relies on maintenance support services from its ETC equipment vendor. The proprietary nature of the equipment forces concessionaire maintenance staffs to learn vendor-specific maintenance skills and creates a strong dependence on the equipment vendor to support high-end maintenace needs.

4.4.3. Moving Toward Interoperability

An interim solution to make cross-facility use easier would be to streamline the enrollment process. Toll concessionaires should allow a customer to obtain a tag at whatever service center is most convenient, yet use the tag at any other participating agency's toll facilities. To begin this process, the customer would contact the "home" agency service center—the agency where the customer obtains the tag—to open an account and obtain the tag. The customer would be given an application to complete and would return it to the "home" agency for entry into the accounting processing system. This application will include boxes for the customer to check indicating which toll facilities he or she wishes to use. By signing the form, the customer agrees that the account and payment information on the application can be sent to these "away" agencies in order for them to establish companion accounts. Once these accounts are established, the customer may use all of the facilities for which an account using a single tag has been established.

But what happens when a customer does not register with an "away" agency? With interoperability, many toll customers may assume that their tag may be used on any system. An interoperable toll system must address the issue of "casual use." A casual user is a single toll facility account holder who uses his or her tag on another facility. Toll concessionaires should agree to allow such casual users a 10-day grace period during which the casual user would be allowed to use the "away" facility prior to establishing a companion account with that facility. The plaza computer would register the tag number (including the home agency's code) and, according to a pre-established schedule, transmit the toll transaction to the account maintenance system.

Whenever an interfacility tag is read in a lane and the plaza computer does not recognize the tag number, a casual use customer toll transaction record is created by the plaza/lane system. The customer is allowed passage but the service center is notified. When the casual user transaction is received by the toll agency account maintenance system, it will send a payment request transaction to the home agency and create a casual user record in its database. After 10 days, the record will activate the violation camera or disable the gate as this tag is no longer considered a casual user. The customer is then submitted to the agency's violation processing procedures. Once a companion account is established, the casual user record will be removed from the database.

4.4.4. Staffing: New Roles and Responsibilities for Clearinghouse Operations Activities

Truly seamless toll operations will require a major coordination effort on the part of toll concessionaires, financial institutions and the ABCR. Perhaps the most significant and labor intensive element of this coordination is the creation and operation of a regional clearinghouse for electronic toll collection and other DSRC applications. The ABCR, in partnership with one or more financial institutions, is well suited to coordinate and manage clearinghouse operations. The institution was created to facilitate the coordination and consensus building necessary to achieve interoperability and standardization. This facilitator role makes it an ideal candidate to bring those functions to the day-to-day operations of a clearinghouse. In addition, the ABCR's intimate understanding of toll collection and the needs of toll concessionaires is a critical complement to the financial industry's expertise in money handling and smart cards.

Thus, a partnership between the ABCR and a financial institution (or institutions) should be created. The staffing requirements would include a permanent, dedicated clearinghouse staff with expertise in money collection and account management, as well as staffing to support the unique needs of electronic toll collection. A suggested ABCR/Financial Institution Clearinghouse staffing matrix is presented in Table 4.4.1.

Table 4.4.1 - Clearinghouse Staffing Matrix

TITLE	PREREQUISITES	RESPONSIBILITIES
Clearinghouse Director	• Business degree. • 10 years management experience	• Manage all clearinghouse operations
Operations Manager	• Business Degree • 8 years management experience	• Directly supervise Customer Service Manager, Processing Manager, and Accounting Manager
Customer Service Manager	• Business degree and related management experience	• Implement the instructions and plans of the operations manager • Manage the operations of the customer service and walk-in facilities • Ensure employees are receiving proper training • Coordinate and supervise special marketing initiatives

Title	Prerequisites	Responsibilities
Customer Service Manager (continued)		• Handle personnel issues • Prepare status reports • Account for cash box reconciliation's and transponder security • Supervise the daily system uploads and downloads • Handle high-level customer complaints and inquiries
Customer Service Representatives	• High school diploma • Customer service experience	• Maintain professional appearance • Maintain professional and courteous conduct • Process applications • Qualify, approve, activate, and distribute tag kits • Handle customer inquiries • Process tag payments • Balance cash box
Customer Service Technicians	• High school diploma • Customer service experience	• Maintain professional and courteous conduct • Process applications • Qualify, approve, activate and package tag kits for distribution • Handle customer service research and inquiries • Process tags payments received via mail
Processing Manager	• Business degree • Related management experience	• Implement the instructions and plans of the operations manager on a daily basis • Manage the violation, inventory, and mail operations • Ensure employees are receiving proper training • Handle personnel issues • Prepare status reports

Title	Prerequisites	Responsibilities
Violations Supervisor	• High school diploma • Two years of supervisory experience	• Implement the instructions and plans of the operations manager on a daily basis • Account for receipt of violation and image transactions • Review data entry • Authorize adjustment of tolls or fees billed • Maintain indexing and archive of images
Violations Technician	• High school diploma • Data entry experience	• Review violations images • Enter license plate number, make, model, and vehicle classification of violators vehicle • Conduct un-reviewable images • Initiate violation notice process
Mail Processor	• High school diploma • Mail room experience	• Process incoming mail by date stamping, sorting and distributing to proper departments • Process outgoing mail for tag kits, customer correspondence, violation noticing and special mailings
Inventory Technician	• High school diploma • Inventory experience	• Receive test tags • Maintain inventory system • Prepare tag kits • Maintain tag security • Coordinate shipment of tags to walk-in facilities
Accounting Manager	• Accounting degree • Prior management experience	• Manage the accounting functions of the operations center • Report productivity status to operations manager • Contact point for credit card services • Coordinate lock-box operations with local banks • Ensure employees are receiving proper training • Handle personnel issues • Prepare status reports

Title	Prerequisites	Responsibilities
Accounting Supervisor	• High school diploma • Two years accounting and supervisory experience	• Implement the instructions and plans of the accounting manager on a daily basis • Supervise check and clearing process • Supervise the bank reconciliations, transfers, credit card and merchant bank remittance, electronic fund transfers • Prepare periodic status reports
Accounting Technician	• Accounting/finance degree • Accounting/bookkeeping experience	• Conduct bank reconciliations • Account for MTA, credit card and merchant remittances • Record electronic fund transfers
Commercial Vehicle Operations Coordinator	• High school diploma • Experience with Commercial vehicle operations	• Provide communication and act as a liaison with commercial vehicle operators • Work with Marketing Coordinator to establish commercial vehicle accounts
Public Relations Coordinator	• Degree in public relations or marketing • Experience in public relations	• Ensure timely and accurate dissemination of information related to ETC to the public • Track and maintain information about the ETC • Act as a spokesperson for the concessionaire
Marketing Coordinator	• Marketing degree • Experience in marketing transportation services	• Work with Public Relations Coordinator to establish foundation to promote ETC
Facilities Supervisor	• Degree in management • Experience in facility management	• Oversee facilities management such as payment of rent, leasing of space, purchase of equipment and supplies.
Project Engineer	• Degree in systems engineering • 10 years experience in the development of toll systems	• Oversee the implementation of the customer service center

The organization chart below suggests how the clearinghouse might function.

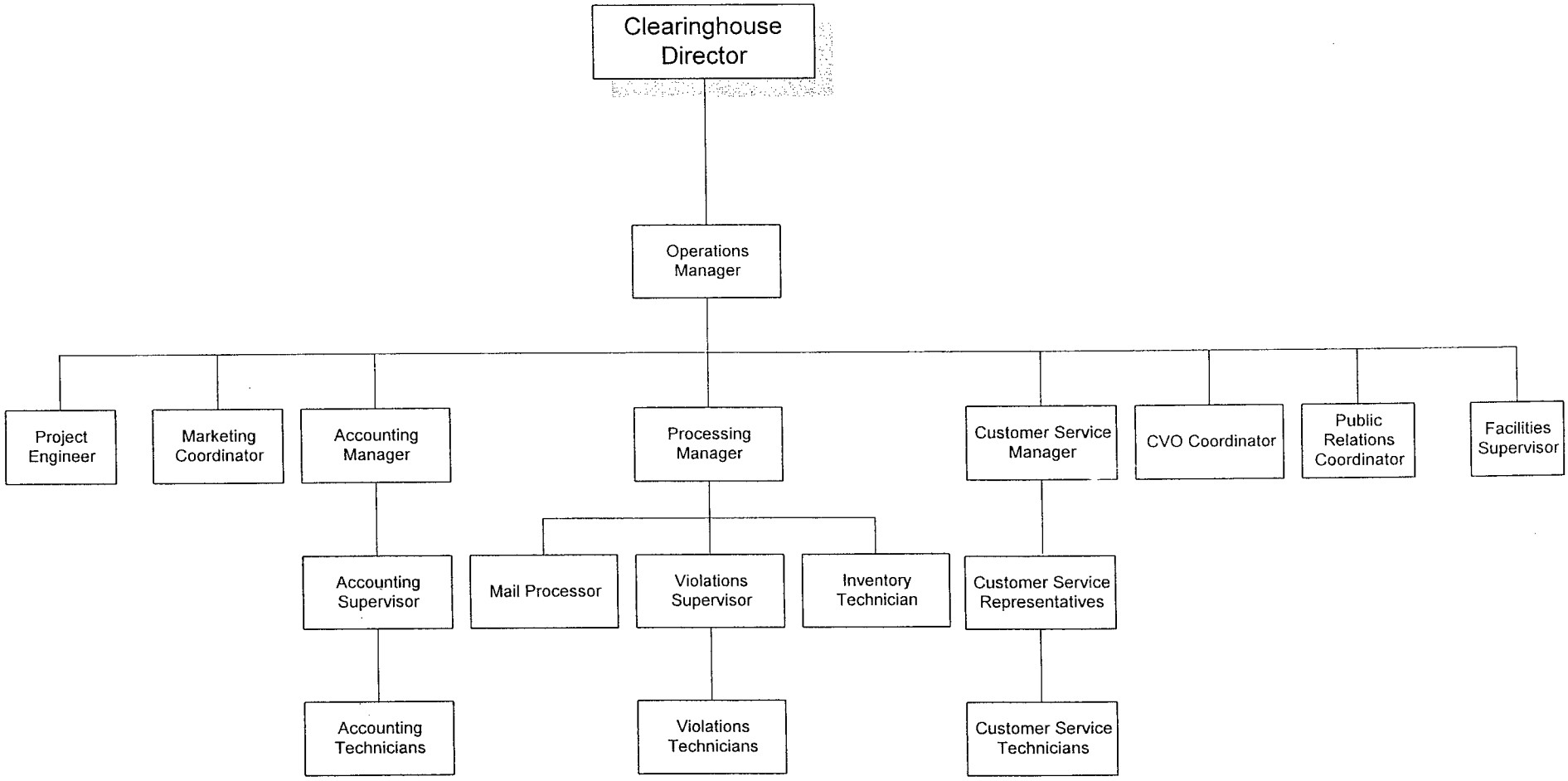

Figure 4.4.1 - ABCR/ Financial Institution Clearinghouse Operations Organizational Chart

4.4.5. An Opportunity for Standardized Maintenance Operations

With technology standardization comes efficiencies in maintenance costs. Standardized equipment will eliminate the need for vendor-based equipment repair and maintenance. Here is another potential service the ABCR could provide its members—a centralized maintenance and repair staff that would eliminate the need for concessionaires to maintain a significant on-site maintenance and repair staff. While some emergency maintenance and repair staff would still be required, the bulk of the repair work could be managed through the ABCR.

For example, a director of field operations (housed in the ABCR) would be responsible for providing corporate resources to staff the field organizations for all the ETC installations. The director would be responsible for providing experienced maintenance and support personnel, tools, equipment, and other resources as required to provide prompt support to the toll concessionaires. This would include dealing with and obtaining the services of third party manufacturers, suppliers, etc. In addition, a software maintenance system response center would operate from the ABCR headquarters, to provide software support services to field operators on 24-hour basis. Additional ABCR personnel might also include: a field services manager, a bench repair technician, a field operations administrator (for office and logistics support), and a response center field dispatcher to coordinate incoming calls and respond to field needs.

As mentioned above, on-site maintenance and repair would also be required. Field service technicians, providing 24-hour support to the toll concessionaires, would be allocated to each toll facility to provide such support. The on-site staff will provide ETC system maintenance including preventive care inspections and preventive, corrective, and emergency maintenance on system equipment with a special emphasis on in-lane components. The on-site personnel will provide the liaison to the toll concessionaires, the ABCR central maintenance operations, and third party providers. All required training could be conducted through the ABCR for efficiency and consistency.

The chart below lists some potential ABCR staff positions that would be required to support such activities.

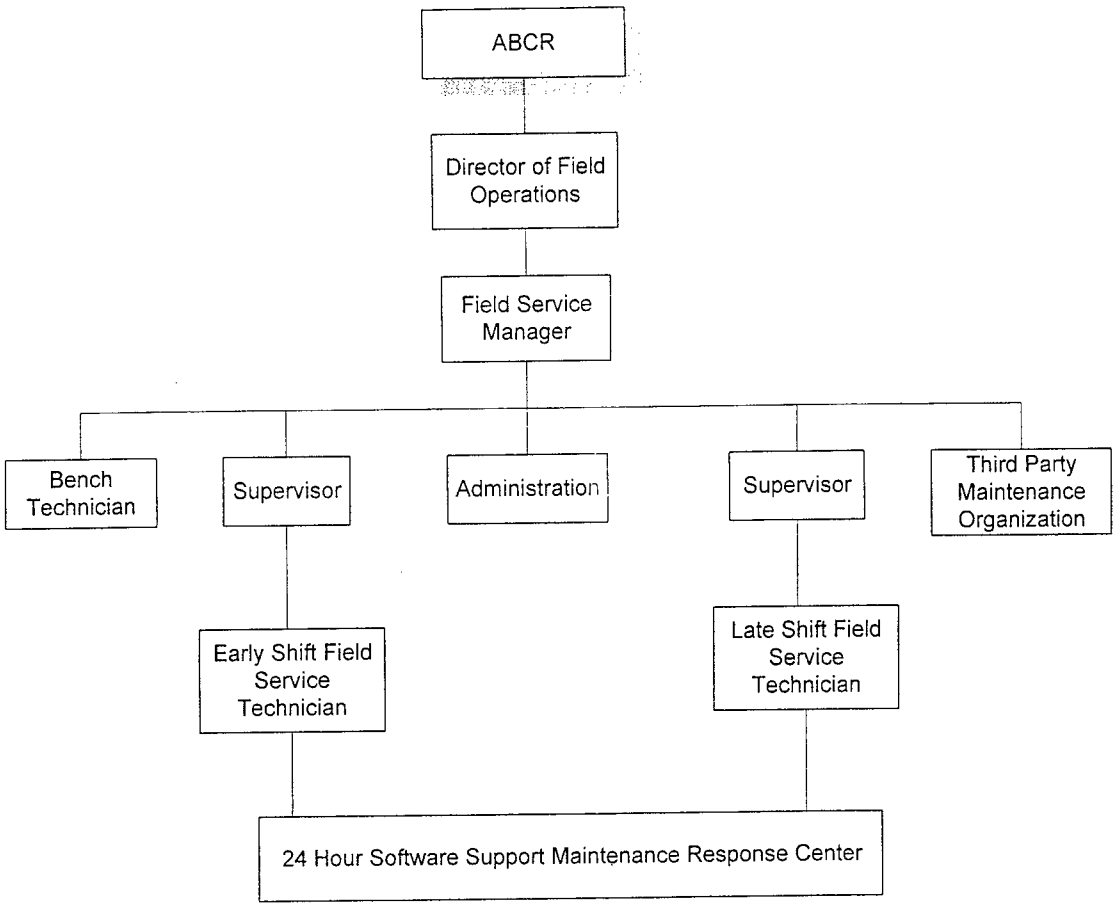

Figure 4.4.2 - Maintenance and Repair Organizational Chart

4.4.6. Toll Concessionaire Staffing Requirements

New staffing requirements for toll concessionaires will be minimal. Only a few new, full-time positions will be required. Toll concessionaires will need at least one ETC coordinator to provide liaison between the toll concessionaires and the ABCR. (Note: Some concessionaires already have such a position, in which case his or her responsibilities would be expanded to provide the ABCR/concessionaire liaison functions.) This position will ensure that the toll authority's needs and concerns regarding ETC are properly met and coordinated seamlessly with existing operations. Particularly during the transition phases (from no ETC to ETC and from current ETC to interoperable ETC), a working group, task force, or committee should be created to coordinate and integrate the activities necessary to provide a smooth transition to the new system. The group should be comprised of the general manager of the toll concession, the ETC coordinator, the concessionaire's chief engineer, its safety manager, its quality assurance manager, its engineering manager, its traffic operations engineer, and its toll operations engineer.

While not every concessionaire may have these specific positions, it is likely that these functions are being performed, in one combination or another, by existing concession staff. In addition, concessionaires may consider hiring an integration/installation manager, whose responsibilities would be to oversee and coordinate system upgrades and migrations to newer, more advanced technology.

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.5. - Prepare Migration Strategy

SUBTASK 4.5. PREPARE MIGRATION STRATEGY

4.5.1. Introduction

To support deployment of nationally, and perhaps internationally, compatible Intelligent Transportation Systems (ITS) using Dedicated Short Range Communications (DSRC), the ABCR and its members have commissioned PBI to develop a migration plan to adopt and implement a DSRC standard for ITS applications both for the near and long terms. The objective of this effort is to ensure that existing and planned DSRC installations (most notably electronic toll collection systems) can work together to provide seamless travel throughout Brazil and lay a strong foundation for the deployment of additional interoperable ITS and other travel-related applications in the future.

Also known as vehicle-roadside communications (VRC), DSRC consists of short-range communications devices that are capable of transferring data at high rates over an air interface between mobile or stationary vehicles and normally stationary devices that are mounted to structures along the roadway or are hand-held. One way of accomplishing this communication is through use of radio frequency (RF) beacons. RF beacon technology generally consists of a transponder (tag), transceiver (reader) and transceiver antenna (beacon).

This Task Report is a Migration Plan. It serves as a vehicle for migrating from the current state of practice to a national standard in the 915 MHz frequency. It describes near-term actions to be taken to achieve DSRC compatibility and a national standard.

The ABCR and its road concessionaire members, federal and state road agencies, financial interests and the DSRC vendor community are the primary audiences for this plan. Cooperation and "buy-in" from these groups are essential for successful migration, and we have attempted to reflect the needs and concerns of these groups in our migration approach.

The material is organized as follows:

- Review of Installed Base: This section reviews the current installed ETC in Brazil.
- Planned Systems in Brazil: This section reviews state and federal plans for additional road concessions in Brazil.
- Existing Toll Collection Systems in the Region: This section reviews other ETC systems in neighboring countries and the technology choices these regions have made.
- Brazil's Interoperability Needs: This section discusses Brazil's interoperability needs—both within the country and with other regions.
- Efforts Toward Interoperability: This section discusses vendor-based efforts to develop interoperability among current proprietary installations.

- Technology Issues: This section examines technology choices available in ETC systems, evaluates relative strengths and weaknesses.
- Standards Development and Testing: This section provides an update on the current status of standards development activities in North America, Europe and Japan.
- Title 21: This section summarizes the technical parameters of California's Title 21 standard and the rationale behind its development.
- Brazil's Migration Path: This section outlines a two-phase strategy for Brazil's migration for the current state to full standardization at 915 MHz.
- Smart Cards: This section discusses the full range of issues relating to smart cards and makes recommendations on how ABCR can assist in developing smart cards for Brazil.
- Business Issues in ETC Standardization: The section briefly discusses practical business considerations related to the movement towa d standardized ETC equipment.

4.5.2. Review of Installed Base

Seventy-nine thousand of the electronic toll collection tags currently in circulation in Brazil are manufactured by Amtech and operate in the 915 MHz frequency, or approximately 81 percent of the ETC market in use. The Nova Dutra facility has purchased ETC tags from Amtech that operate in the 915 MHz frequency, but the facility has not yet begun electronic toll collection. The only other vendor with tags in circulation in Brazil is Combitech, with 1000 read/write tags, which are planned to begin operating in March 1998, at the 2.45 GHz frequency (representing 1 percent of the existing market). Both Schlumberger and Philips supply smart cards in Brazil, constituting about 18 percent of the total ETC market (or 18,000 cards).

Table 4.5.1 provides a detailed listing of the installed base.

Table 4.5.1. - Installed Base

Type	Location	Km	Name	Vehicles per Day	Lanes		Vendor	Freq.	Tags
					C.E.P.	Total			
State Bridge	Espirito Santo	3.3	3ª Ponte de Vitoria	41,000	---	14			
State Road	Santa Catarina	35.3	Linha Azul	17,000	2+2	12	Combitech	2.45GHz	1,000
Federal Bridge	Rio de Janeiro	13.3	Ponte Rio - Niteroi	110,000	2+2	14	Amtech	915MHz	44,000
Municipal Road	Rio de Janeiro	15.0	Linha Amarela	50,000	2+2	20	Amtech	915MHz	10,000
Federal Road	Rio - Sao Paulo	402.4	Nova Dutra	22,500	8	48	Amtech	915MHz	
Federal Road	Rio - Minas Gerais	179.7	CONCER	40,000	2	22	Schlum-berger	Smart card	10,000
Federal Road	Rio de Janeiro	142.4	CRT	19,000	4	16	Amtech	915MHz	1,000
Federal Road	Rio Grande do Sul	112.3	Free Way	15,000	8	56	Philips	Smart card	10,000
State Road	Rio de Janeiro	60.0	Via Lagos	11,000	2	11	Amtech	915MHz	20,000
		963.7		325,500					

Source: ABCR

4.5.3. Planned Systems In Brazil

DSRC utilization can be expected to expand in three ways: new agencies installing systems, current agencies selling more tags, and current agencies expanding the services offered.

Additional road concessionaires will be installing ETC systems over the next few years. It is reasonable to expect that many of the concessionaires, as they install ETC, will consider their neighboring systems' hardware selection so that they can install compatible systems. Tables 4.5.2 through 4.5.7 list planned road concessions in Brazil, many of which are likely to adopt ETC.

Table 4.5.2. Brazil Road Concession Program on Selected Roadways

	Already Concessioned			Programmed for Concession		
	Federal	State	Municipal	Federal	State	Total
DNER	856			8,177		9,033
Sao Paulo		846			4,309	5,155
Rio Grande do Sul	1,967	850				2,817
Santa Catarina		35		537	593	1,145
Parana	1,763	571				2,344
Rio de Janeiro		60	15			75
Espirito Santo		3			65	68
Minas Gerais				1,843	438	2,281
Norte/Centro Oeste				219		219
Nordeste				114	243	357
	4,586	2,375	15	10,890	5,628	23,494

Source: ABCR

Table 4.5.3. Existing Electronic Toll Collection Systems in Argentina

LOT #	Length (KM)			Status of Concession Process
	Federal	State	Total	
1		76	76	Commercial bids/offers: May 1998 Contract to be signed: July 1998
2	23	362	385	Commercial bids/offers: May 1998 Contract to be signed: July 1998
3	445		445	Commercial bids/offers: May 1998 Contract to be signed: July 1998
4	238		238	Commercial bids/offers: June 1998 Contract to be signed: Sept. 1998
5				Bidding will be made by DNER
6				Bidding will be made by DNER
7	415		415	Commercial bids/offers: June 1998 Contract to be signed: Sept. 1998
8	308		308	Commercial bids/offers: June 1998 Contract to be signed: Sept. 1998
9	414		414	Commercial bids/offers: June 1998 Contract to be signed: Sept. 1998
	1,843	438	2,281	

Source: ABCR

Table 4.5.4. Santa Catarina Road Concession Program

System	Length (KM)			Status of Contracts
	Federal	State	Total	
Brusque		126	126	Bids submitted: 30 March 98; Contract signing: 31 August 1998
Norte	178	172	350	Bids submitted: 4 August 98; Contract signing: 7 January 1998
BR/470	359	122	481	Bids submitted: 24 June 98; Contract signing: 23 November 1998
Criciuma		153	153	Bids submitted: 11 August 98; Contract signing: 18 January 1998
	537	573	1,110	

Source: ABCR

Table 4.5.5. Sao Paulo Road Concession Program

Lot #	Name of System and General Area Covered	Length (KM)	Status of Contracting Process
1L	Sistema Anhanguera - Bandeirantes (DERSA)	312	Contract signing: April 1998
2L	Nova Odessa, Piracicaba, Rio Claro	71	Internal analysis
3L	Catanduva, Bebedouro, Barretos, Taquaritinga, Pirang	156	Contract signing: March 1998
4L	Catanduva, Jales, Sta. Fe do Sul, S.J. do Rio Preto, Danta Albertinai	280	Internal analysis
5L	Riberao Preto, Igarapava, Setaozinho, Bebedouro, divisa MG	237	Contract signing: March 1998
6L	Mogi Mirim, Limeira, Porto Fereira, Sao Carlos, Casa Branca, Divisa MG	340	Contract signing: May 1998
7L	Jacarei, Campinas, Atibaia, Anel de Campinas (parte)	158	Internal analysis
8L	Limeira, Rio Claro, Sao Carlos Brotas, Jau, Bauru, Itirapina	218	Contract signing: March 1998
9L	Sao Carols, Borborema, Sertaozinho, Bebedouro, Jabiticabal	442	Contract signing: April 1998
0L	Santa Rita do Passa Quatro, Ribeirao Preto, Batatais	308	Contract signing: March 1998
1	Campinas, Mogi Buacu, Mococa, Sao Jose do Rio Pardo S.J.B. Vista	291	Contract signing: March 1998
2	Sistema Castello Branco - Raposo Tavares	162	Contract signing: March 1998
3	Campinas, Itu, Sorocaba, Tatui, Tiete Piracicaba, Itapetininga/	275	Contract signing: May 1998
4	Avare, Espirito Santo do Turvo, Ourinhs, Assis	353	Internal analysis
5	Espirito Santo do Turvo, Lencois Paulista, Bauru, Pirajui, Lins	172	Internal analysis
6	Tupa, Marilla, Assis, Taruma, dirceu, Divisa PR	170	Internal analysis
7	Martinopolis, Pirapozinho, Regente Feijo, Assis, Divisa PR	244	Internal analysis
8	Reg. Fiejo, Pres. Bernardes, Tupa, Parapua, Oswaldo Cruz, Martinopolis	89	Internal analysis
9	Parapua, Adamantina, tupi Paulista	216	Internal analysis
0	Itapetininga, Capao Bionito, Itapeva	351	Contract signing: May 1998
1	Campinas, Tiete, Capivari, Piracicaba, Sao Pedro	134	Internal analysis
2	Sistema Anchieta - Imigrantes (DERSA)	176	Contract signing: June 1998
	TOTAL	5,155	

Of the 22 lots, it was expected in December 1997 that by the first quarter of 1998, 12 lots would have conceded for a total of 3,268 Km.

Source: ABCR

Table 4.5.6. Parana Road Concession Program*

Lot No.	Consor-tium Company	Shareholders	Name of Section	Length (Km)				Offering				Grand Total
				Ref.	Fed.	State	Total	Section	Ref.	Km	Total	
01	Ival/ Triunfo	Construtora Triunfo Ival Engenharia	Porto Charles Nauffal - Cambe Cambe - Porto Melo Peixoto	PR-322 PR-445 BR-369	 169.20	62.00 13.90 	 245.10	Entr. BR0-369 (Ibipora) - Entr. PR-323 (Sertanopoli	PR-090	29.77	29.77	274.87
02	Parana/ Maringa	Carioca - C. Nielsen Queiroz Galvai OAS EIT - Emp. Indust, Tec.	Camba - Apucarana - Maringa - Paranavai Maringa - Cascavel	BR-158 BR-369 PR-444 BR-376 PR-317 BR-369	15.90 61.00 114.60 171.60	 39.10 71.90 	 474.10	Entroncamento PR-182(A) - PR-569 (Nova Londrina-Paranaval)	BR-376	70.90	70.90	545.00
03	Parana - Integracao	Banco Bandeirantes Civilia Engenharia DM - Constructora Memento Engenharia	Fox do Iguacu - Cascavel - Guarapuava	BR-277	387.10		387.10	Cascavel - Juniopolis Sta. Terezinha Itaipu - Term. Turistico Entr. BR-277 - Campo Branco Entr. BR277 - Ramilandia	PR-180 PR-874 PR-474 PR-590	37.03 13.59 7.4 13.58	71.84	458.94
04	Caminhos do Parana	Redram/Gaba & Cis. Goetze Lobato Tucumann/Guaianazes JB Barros/Cartellone Codi/Welbers Insus	Guarapuava - Relogio - Sao Luiz do Puruna Relogio - Caetano (Ponta Grossa)	BR-277 BR-373	203.50 101.50		 305.00	Entr. BR-277 - Teixeira Soares	PR-438	17.10	17.10	322.10
05	CBPO/ Castilho	CBPO Constructora Castiho	Curitiba - Sao Luiz do Ptuna - Ponta Grossa Ponta Grossa - Apuarana Ponta Grossa - Jaguariava	BR-376 BR-277 PR-151 BR-373	327.40 46.30 7.80	 106.00 	 487.50	Entr. PR-151(A) - Entr. PR-151(B) Entr. PR-239(A) - Entr. PR-092 Ri9o Itarare - Entr. PR-151 (Sanges) Entr. BR-376 - Fumas Ortigeira - Entr. BR-376 Entr. PR-151(A) - Entr. PR-153	PR-092 PR-151 PR-239 PR-813 PR-340 PR-090	7.20 33.12 12.29 1.360 1.37 25.00	80.28	567.78
06	PRIMAV	PRIMAV Construcoes e Comercio	Curitiba - Alexandra - Parnagua Alexandra - Matinhos	PR-407 PR-508 BR-277	 85.70	19.00 32.00 	 136.70	Entr. BR-277 - Entr. PR-408 Morretes - Entr. PR-277 Entr. PR-340 - Morretes Entr. PR-410 (S.J.P.) - Morretes	PR-804 PR-4089 PR-408 PR-411	2.60 13.20 9.60 13.00	38.40	178.10
					1,691.60	343.90	2,035.50				308.29	2,343.79

*All contracts have been signed.
Source: ABCR

Table 4.5.7. Rio Grande Do Sul Road Concession Program

Polo	Consortium	Shareholders	Theoretical Length (km)			Conceded Length (km)		
			Fed.	Est.	Total	Fed.	Est.	Total
1 Pelotas		Triunfo, Ivai SBC	539.00		539.00	551.50		511.50
2 Metro-politano	Metrovias	Sultepa	598.00	207.00	805.00	598.00	207.00	805.00
3 Caxias	Convias	Toniolo Busnelo Brasilia Guaiba	92.84	73.01	1653.85	92.84	80.91	173.75
4 Vacaria	Rodosul	Encalso, Malucelli Construtora de Obras, TV Tecnica Viaria	121.18		121.16	132.66		132.66
5 Gra-mado		Brita Portoalegrense		110.37	110.37		131.97	131.97
6 Cara-zinho	Coviplan	Bolognesi	209.38		209.38	211.38	39.02	250.40
7 Santa Maria		Via Engenharia ESUCO	194.76	54.45	249.21	201.75	54.45	256.20
8 S. Cruz do Sul		Serveng	5.33	149.17	15450	47.66	149.17	196.83
9 Lajeado	Sulvias	Toniollo Busnello Brasilia Guaiba	131.10	151.20	282.30	131.10	187.70	218.80
			1,891.57	745.20	2,636.77	1,966.89	850.22	2,817.11

Source: ABCR

Tag sales will increase as customers continue to see the benefits of participation. This growth will expand current installations and will increase the investment by the agencies and thus will add to the cost of DSRC.

Another area of growth will include the offering of new services to the users as well as expanded utility to the facility operator. This is a central concept of the need for Brazilian national standards.

There are a variety of potential applications for DSRC from traffic management, to payment systems, to in-vehicle information. The assumptions are that a national standard will be required to allow these services to be developed and offered. The corresponding question for the migration strategy is: Who benefits from those services and who pays for the migration?

As we evaluate various migration alternatives, it is important to make the connection between the cost of migration, the potential expanded services that may be offered, who benefits from these services, and who pays for these benefits. In some cases it will be the road concessionaire and public agencies that benefit. A good example is traffic management where the direct beneficiaries are the concessionaire or the state transportation authority. In

this case it may be entirely appropriate for the operating agency to pay for migration to a more useful system.

In other cases the benefits of a new system will flow to third party providers, such as payment systems and in-vehicle information. In these cases, it may be appropriate for the third party providers, and ultimately the customers, to make a financial contribution to the migration process. In other cases the beneficiaries are the end users who can access multiple toll/CVO systems, and in this case they should bear the financial burden.

This determination is not simple because the determination of who pays for the conversion in the first instance (new tags or readers or both) is not necessarily the party that pays in the long run. Costs can be passed on by the operators to their DSRC customers through service charge or toll rate increases or to all customers through toll increases or diversion of funds from other purposes. Commercial end users can pass route information costs along to their customers.

4.5.4. Existing Electronic Toll Collection Systems in the Region

In addition to interoperability among all ETC systems in Brazil, it is important to consider interoperability needs with neighboring ETC systems in other countries, to the extent that interoperability is desired for other DSRC applications. The table below lists several installations in Argentina which can be interoperable with systems in Brazil. Obviously, Amtech read-only systems in Argentina are already technologically interoperable with systems in Brazil. The technology is the same—backscatter read-only at 915 MHz. However, true interoperability will require that these systems develop some means of handling "back-office" operations (opening tag accounts, processing transactions, auditing, etc.).

A major installation in Argentina, Autopista del Sol–Ausol, uses Combitech read/write technology at 2.45 GHz on its system. It is significant to note here as it consists of 100 AVI-equipped lanes, with 125,000 tags in use. Although it is one of the few systems in the region using read/write technology, its size and proximity to the systems in Brazil may have a bearing on future ETC installations in Brazil, as well as Argentina. The Combitech system can be made interoperable with the Brazilian systems through the use of a second reader, capable of reading active read/write at 2.45 GHz. The companies have already initiated the "two-reader" approach on the Buen Ayre facility. Table 4.5.8 details the current ETC systems in Argentina.

Table 4.5.8. Existing Electronic Toll Collection Systems in Argentina

System Name	Location	ETC Lanes	Number of Tags	Vendor	Freq.	Tech.
Autopista de Sol	Buenos Aires, Argentina	100	110,000	Combitech	2.45 GHz	Read/Write
Ezeiza-Canuelas	Buenos Aires, Argentina	6	20,000	Amtech	915 MHz	Read Only
Autopista de la Plata	Buenos Aires, Argentina	8	10,000	Amtech	915 MHz	Read Only

System Name	Location	ETC Lanes	Number of Tags	Vendor	Freq.	Tech.
Autopista 25 de Mayo	Buenos Aires, Argentina	8	26,500	Amtech	915 MHz	Read Only
Del Oeste	Buenos Aires, Argentina	N/A	5000	Amtech	915 MHz	Read Only
Autopista Buen Ayre	Buenos Aires, Aregentina	22	N/A	Amtech and Combitech	915 MHz (Amtech) and 5.8 GHz (Combitech)	Read Only and Read-Write

4.5.5. Brazil's Interoperability Needs

As can be seen from tables above, Brazil clearly has a need for ETC interoperability, from a number of different perspectives.

Users: Users traveling from one toll system to another throughout Brazil (and particularly between Rio and Sao Paulo) should be able to do so using only one tag. This will result in reduced delay on all toll facilities because drivers will no longer have to stop at any toll booths. In the longer term, a single tag will enable them to make cashless transactions while on the move. Through the use of smart cards, they will be able to pay for a variety of commercial and transportation services without the need to carry cash. These services include gasoline and food purchases, as well as transportation fees and fares, such as for tolls, parking and transit use. These tags may also be used for receiving information directly into the vehicle.

Toll Concessionaires: Toll concessionaires will benefit greatly from interoperable systems. First, they will be able to procure ETC equipment with greater confidence that these systems will be compatible with others in Brazil. Second, by entering into agreements with bank/credit card companies to handle electronic payments, toll concessionaires will be able to largely withdraw from the financial processing business. They can thus become leaner operations that will be able to focus on the business of optimally managing their facilities to provide the best customer service possible and generate the greatest profits.

Federal and State Agencies: Public sector authorities need interoperability to improve commercial vehicle regulation and facilitate seamless border crossings among various Brazilian states and across national borders.

Vendors: Interoperability will encourage the development of standardized equipment and expand the number of equipment suppliers, meaning greater competition, lower prices and enhanced products.

Financial Institutions and Third Party Applications Providers: Financial institutions and third-party providers will have a larger base of customers motivated to use smart cards to pay tolls, get information, make drive-through purchases, pay for parking, and buy fuel without the nuisance of ticket lines and counting out cash. It will encourage expanded opportunities for DSRC use, increasing fees and profits for these institutions.

4.5.6. Efforts Toward Interoperability

As noted above, there are a number of different types of tags and readers currently installed in Brazil and in surrounding countries. However, a number of manufacturers are actively working to develop technology that will allow currently incompatible systems to interoperate with one another.

Amtech and Combitech have devised a "low-tech" solution to the interoperability problem in Argentina by installing two readers at plazas where customers use different systems. The Amtech reader reads the backscatter read-only tags at 915 MHz and the Combitech reader reads the active read-write tags at 2.45 GHz.

Interoperability will require that choices be made and a number of issues be addressed. These are discussed below.

4.5.7. Technology Issues

Tag System Selection

In the United States as well as other countries, the tag selection process selection is not limited to cost and technology decisions but frequently includes political, regional, legislative, and frequency issues. This section will review the factors to be considered in the selection of the tag system. This discussion assumes that a standard, interoperable tag system will be used in Brazil.

Key Tag System Information Functions and Location Issues

A fundamental factor is whether to retain the financial accounting/transaction information on the tag or in the roadside system—the plaza and agency processing system. Key factors in the decision are privacy, security, tag and roadside system cost impact.

Privacy: Especially important to commercial customers is the issue of privacy. U.S. companies have stated that they do not want to risk having their competition "download" their commercial vehicle's tag information that could reveal customer, route, times, etc. Many consider privacy to be a right and the more they find out about the information that could be stored on a tag, the more concerned they become about invasion of their privacy.

Security: While related to privacy, security is basically a concern of the toll facility operator and/or its supporting financial institution. Financial institutions are increasing the security of their media—magnetic strip cards, smart cards, automatic teller machines, etc. They are building increased security into customer accounts and transactions systems. While encryption technology is advancing, it is a constant challenge to stay ahead of the threat. Financial institutions have relevant security experience and will eventually be participants in the toll financial systems. It is recommended that they be active participants in important decisions on tag system security. Security requirements add to the tag costs, although these are usually relatively small.

Tag Cost Impact: The decision on whether to store information in the tag versus roadside system has relatively small impact on the cost of the tag. As with computers, tag memory, especially for small amounts of data, is cheap. Security and privacy will also add small contributions to tag cost. The major tag cost considerations including relevant communications challenges will be covered in a subsequent section.

System Cost Impact: Roadside system costs are impacted by a decision to store information on the tag or in the roadside system. If the information is not stored on the tag, all the financial information not only must be stored at a central agency location but also must be periodically communicated to the plazas thus increasing communications costs. Storing financial information on the tag does not alleviate the central agency from "recording" the individual transactions. When other financial information or transactions are stored on the tag, central agency costs could rise because of the need to process this additional information. When the tag is used for other purposes by the tag owner (such as commercial fleet operators using the tag for security access, maintenance data, etc.), there could be added costs because of the software additions/modifications needed for system interoperability.

4.5.8. Standards Development and Testing

The previous discussion has reviewed the complexity of the decision that toll operators face in determining their system requirements and the system decision including choice of contractors. Critical to system performance is the acceptance testing that takes place as the system is being delivered. The testing of the standards and the tags that are produced to meet the standard is critical to successful system performance. Standards themselves do not guarantee tag system performance.

The U.S. market consists of 32 toll agencies in 17 states using over 4 million tags—a major market. Commercial vehicles are using electronic clearance tags for state and international border clearance. Parking and fueling applications are emerging. Nearly all North American DSRC systems operate in the 915 MHz band. Active and backscatter technology tags are in widespread use and supplied by many vendors. Through regional cooperation, ad hoc agreements have facilitated the use of interoperable tags and common back room financial clearinghouses. The maturing markets along with a joint public-private effort to develop a National ITS Architecture have resulted in an major effort to develop a U.S. national standard for Dedicated Short Range Communications. On 16 January 1998, Canada and Mexico signed an agreement to use the this national standard for North American international border crossings.

ITS America and the U.S. Department of Transportation have formed a DSRC users group to coordinate the various user requirements. The significant advantage of this approach is that the users (toll facilities, CVO electronic clearance, and international border crossing) are determining the requirements and the tag vendors are observers. The resulting effort has drawn on DSRC activities of SAE, ASTM, and IEEE. The U.S. DOT is providing funding to these and other standards organizations (ITE, AASHTO, etc.) to expedite the development and coordination of the DSRC standards.

Status Report (as of 1 February 1998)

Using the ISO 7-layer OSI reference model, ASTM is responsible for Layer 1 (Physical layer - primarily frequency band) and Layer 2 (Data Link). ASTM is going to start the ballot process for the Layer 1 standard in February, 1998. This standard will support both active and backscatter technology. Once this process starts, this will be the provisional standard.

ASTM will initiate the ballot process for Layer 2 in the March/April 1998 time frame. While most of this standard is based on the European CEN pre-standard, there are outstanding data definition issues to be worked out. Once the balloting process begins, this will be the provisional standard. The ASTM DSRC standards documents are being referred to as ASTM Draft 7.

The IEEE Layer 7 standard is based largely on the CEN Layer 7 standard. Refinements are in process to adapt the CEN standard to meet specific (master/slave) communications needs. IEEE balloting is expected to begin in March/April 1998.

ASTM states that Draft 7, once available, will enable North American interoperability but will not enforce it. ASTM Committee Chair Lee Armstrong states: "To enforce interoperability would require that either all transponders or all receivers work on both active and backscatter technologies. You can't get the lowest possible cost if you need to guarantee interoperability —the forthcoming proposed draft standard will fully address any system that requires such interoperability."

International DSRC Coordination

The United States is an active participant (as is Canada) in the International Standards coordination process—specifically the ISO TC204 (ITS) process. Because the U.S. process described above has attempted to use the acceptable portions of the counterpart CEN DSRC standards, it is hoped that the remaining differences can be worked out. There will be active discussion (and probably debate) as efforts continue to harmonize the two standards.

Standards Testing

As stated previously, testing is a critical part of the standards development process. Standards validation is the process of verifying that the standard is a good standard—it is complete, provides all the required functionality, provides the required performance, and that the standard documents are understandable and not ambiguous.

ASTM in coordination with IEEE has proposed the establishment of a DSRC test facility to accomplish the above objectives. It is estimated that it will take 12 to 15 months to design the facility, procure test equipment, and conduct the required standards tests. It is anticipated that minor modifications to the standards documents will be required as a result of the tests.

The same facility could then be used to test vendor tag systems for compliance to the specification. Whether the facility would be used for certification of compliance is yet to be determined; tag system users will probably be a part of this decision.

4.5.9. Title 21

In 1992, California passed Title 21, a mandate to regulate electronic toll collection equipment used in that state. The state adopted radio frequency backscatter as the technology of choice in ETC systems for California. As a result, all toll facilities and several other applications (parking facilities, etc.) are using interoperable technology, allowing users the benefit of needing only one tag for a variety of toll and other transportation uses.

California chose backscatter technology for a variety of reasons, both practical and technological. Among backscatter's technological advantages are:

- Consumes less power, so battery life is longer
- Defines more precise read zone because of the physics of the reflection process (The system more accurately discriminates valid users from violators, and it provides accurate readings despite close adjacent lanes.)
- Communicates accurately with vehicles maintaining high speed on a limited access open highway
- More capably reads multiple tags in the interrogation field
- Works effectively in environments with excessive dirt, dust, moisture, and poor visibility
- Requires less expensive electronics
- Allows the smallest possible bandwidth yielding the highest robustness against surrounding RF noise

In addition to these technological considerations, Caltrans also considered practical issues as well. Title 21 was based on some early experimental systems developed at the Lawrence Livermore Laboratories in the late 1980s. These systems seemed to provide a strong foundation for the specifications that would become Title 21. Like Brazil today, California, in the late 1980s and early 1990s, experienced significant traffic growth and looked to electronic toll collection as a means of easing congestion and expanding the state's transportation funding sources. As more and more toll roads were planned, it became apparent that achieving some consistency among the roads was both necessary and desirable. In order to achieve interoperability, the state used the early Lawrence Livermore experiments to develop Title 21 specifications.

4.5.10. Brazil's Migration Path

This section will discuss the options of using backscatter or active ETC systems and make specific ETC system migration recommendations.

Active and Backscatter Tag Systems

While the ETC system components (sensor or antenna system, plaza hardware and software systems, etc.,) for each type of system are similar, a major difference is the type of Radio Frequency (RF) communications system, both in the tag and in the plaza sensor system. In a backscatter system, the sensor system transmitter sends a signal to the tag on a designated frequency. The tag, upon receipt of the signal that includes the digital codes that turns the tag on, uses the received RF energy to re-transmit on the same frequency an RF signal back to the plaza sensor system. The tag is basically re-radiating the received energy back to the plaza sensor or "scattering back" the received RF signal power. Information resident in the tag such as an identification number is added to this return RF signal. A long-life battery is used to power the tag or, in some cases, the received RF energy is used to provide power to the tag digital electronics.

The active tag system has a transmitter in the tag powered by an internal battery (larger capacity than the backscatter battery) or by the vehicle battery. Upon receipt of the signal transmitted from the plaza sensor system, the transmitter is turned on and responds by sending a new RF signal on a different frequency to the plaza sensor system with tag identification information and other programmed information.

Both types of tag systems have their technical and operational advantages. Once a company chooses the type of tag system it will manufacture, it is a costly decision to change designs; the company is locked into design and production implementation. In some cases, this emotionalism is regional—certain countries or regions get "locked in" to a decision they have made due to the cost of change. In the United States, certain states have made the decision to use backscatter and other states (or regions) have chosen active tags.

Because the backscatter tag design is simpler and uses a smaller battery, it is usually a cheaper tag to manufacturer. While active tags have a greater range, some question the need for increased range unless message sets and communications sessions are unusually long, which is a more likely case for commercial vehicle applications. Active tags require increased battery power, which usually results in a shorter (than backscatter tags) tag life.

The ETC System Migration Path: Phase One

In Phase One, which extends for the next two years, we are recommending the use of the 915 MHz backscatter ETC system. Most of the current ETC systems in the state of Rio de Janeiro use backscatter tags at 915 MHz. These tag systems have been purchased sole source from a vendor. We recommend that the California Title 21 standard be adopted for future procurements (next two to five years). There are currently several vendors that produce tags that meet this standard, and additional vendors can be anticipated to provide compliant tags. This meets a key objective of having price competition for procurements.

We need to address backward compatibility—the requirement to ensure that the 915 MHz backscatter tags currently in operational use (but not built to the Title 21 standard) are interoperable with future systems that will use Title 21 as the system standard. We have been informed that both the current Title 21 tag vendors meet this important criteria.

Amtech provides the vast majority of the tags in Rio, with most using read-only technology. As a first step, toll systems employing this technology should be able to easily upgrade their existing tags to read/write tags (which can also operate with read-only readers). The second step for these systems would be to install upgraded dual mode readers, which can process both read-write and read-only tags. Thus, concessionaires who have invested in read-only technology can be confident that there is a bridge from read-only to read-write within the 915 MHz frequency.

For tags or readers to interoperate with Amtech read only tags, they require a proprietary Amtech protocol know as ATA. If ABCR agrees to this recommended path, Amtech has agreed make this protocol available in Brazil to all tag manufacturers at no cost. In this way, Title 21 tags can be read by existing readers and existing tags can be read by Title 21 readers.

Once interoperability is achieved, and a standard is developed and adopted, movement toward installing standard-compliant equipment can begin. As systems age and require replacement, standard-compliant equipment can be installed.]

In our discussions with tag vendors, we are informed that at least one vendor is producing a Title 21 tag that offers the additional read-write capability (Title 21 requires read only performance). This feature provides growth potential should toll, CVO or international border crossing needs require read-write performance. It is recommended that ABCR coordinate concessionaires tag procurements to get the best possible competitive price.

To summarize the basis for our Phase One recommendation:

- Existing, operational ETC systems are using the Title 21 standard.
- Title 21 provides for backward compatibility with the existing backscatter tags.
- Title 21 backscatter tags are the least complex because they use cellular components, which results in a lower cost tag.
- At least two vendors produce tags that meet the Title 21 specification; competitive procurements will provide the lowest price for Brazilian procurements.
- A Title 21 test plan is being finalized that will help ensure that ETC systems will meet performance specifications.

The ETC System Migration Path: Phase Two

The United States is moving toward approval of a 900-MHz ETC system. The provisional standard ASTM Version 7 (V7) is anticipated to be approved by the end of 1998. Discussions are underway in the international standards process to harmonize ETC standards. As the above chart illustrates, ASTM V7 will have standards for both a backscatter and active RF tag system. The ISO levels 2 and 7 will be identical for both RF transmission versions. In discussions with U.S. industry representatives, we are told that both backscatter and active tags can be used with a common reader system (presuming specification of the need).

There is an active debate on whether the CVO needs can be met with a backscatter read-write tag system. The answers should be available after an ASTM and/or European test program,

when controlled tests are run at road speeds with the longer CVO message sets. If the tests show that an active tag system is needed for CVO requirements, it is anticipated that the more expensive active tag will be required to meet CVO requirements while the ETC system requirements can be met with the less expensive backscatter tag system version of ASTM V7. Standards developers indicate that ASTM V7 will allow a switch to active technology, if necessary. The survey of U.S. vendors indicates that both of the existing U.S. backscatter and active tag systems will require modifications to meet ASTM V7. Cost estimates for the new tag range from a 50 percent to 100 percent per unit in production quantities. New plaza sensors will be required for ASTM V7. These increased costs will affect the projected time frame for ASTM V7 implementation. We would estimate products will be available in three or more years (around 2001).

In summary, for the second phase, we recommend waiting for the current U.S. and international standards setting and testing processes to provide answers to important system performance questions. These answers should be available in the next two to three years (by the end of 2001). At that time, international toll activities will be evaluating the ASTM V7 test results and deciding if the advantages of the ASTM V7 tag merit the increased costs for large scale tag replacement and dual plaza sensors required for ETC lanes.

4.5.11. Smart Cards

Many toll facilities in Brazil intend to use smart cards for toll collection. A number of banks have expressed strong interest in participating in the concession program as a first step toward providing smart cards and related services to the toll concessionaires. In fact, banks in Parana are participating as shareholders in the concessions there. Several banks in the Rio area (including Bradesco) have already indicated an interest in providing smart cards within the next 5 to 10 years. Public agencies letting these concessions have expressed a similar vision of having banks take over responsibility for tag distribution, marketing, etc., particularly once smart card technology becomes available.

State of the Practice

European smart card users, led by France, have been dominating the industry both in terms of market share and expertise. Almost one out of four cards used in Europe are for mobile communication purposes. The rest is spread among banking, medical, and entertainment. There are a number of European transportation agencies using smart cards as an alternative to cash payments, but most of these are in transit applications. Only a few programs are dedicated to toll collection or include toll collection as one of many applications. The Telepeage Inter Societe and Marseilles Tunnel Prado Carenage in France, the Autostrade in Italy, and the AGE in Germany are some of the examples.

In Asia, the Japanese Ministry of Construction has made smart cards compatibility an element of the DSRC program to be implemented by the end of this century. The Singapore government has begun to test smart cards in toll collection and congestion pricing. Emerging economies in Southeast Asia are expected to follow.

In the United States, smart cards are used by government agencies mostly for security and identification purposes. States including New Jersey and Utah are experimenting with smart card driver's licenses. The federal government has recently released a major RFP soliciting suppliers of smart cards for "benefit delivery systems" such as social security payments and food stamps. Many federal agencies are using smart cards to provide identifications, security, and purchasing mechanism to employees. Over 200 smart card applications have been identified, and many more are expected in the near future.

Smart Cards in U.S. Transportation

In the transportation sector, the overwhelming majority of smart cards are used in transit operations to replace traditional ticketing systems and to expedite processing time. The experience in the last few years has been so encouraging that many transit agencies are planning major upgrades to significantly increase the use of smart cards. The San Francisco Area Metropolitan Transportation Commission (MTC) is in the process of releasing a major RFP to procure a smart card system that will be used by all transit agencies in the area. Meanwhile, the U.S. DOT is unleashing the Commercial Vehicle Information and System Network (CVISN) program aimed at fostering national interoperable commercial vehicle information exchange and border crossing clearance using DSRC technology. This program is committed to applying smart cards to provide rapid and economical means of information exchange in the future. The DOT has sponsored research into smart cards in commercial vehicle operations to help plan for the migration.

Smart cards are also used as communication devices for automated vehicle location to enhance efficiency and security.

Surprisingly, there is little, if any, effort in developing smart cards for toll operations in the United States. Although there seems to be high interest among smart cards vendors and banking institutions, there has been little productive dialogue among the stakeholders. A few years ago, the Transportation Corridor Agencies in California experimented with the early version of smart cards. That experiment provided important insight into market expectations and pertinent institution issues related to smart cards usage. Unfortunately, the experiment did not lead to implementation.

Recently, the desire to bring together key toll agencies, banking and credit card companies, and card makers has been reignited by the ITS America Electronic Payment Task Force. This task force has sponsored a series of talks among the stakeholders with the primary objective of developing smart cards for toll operations. The task force coordinates with other entities such as the American Bankers Association, the Smart Card Forum, the IBTTA, etc. The task force's objective is to identify requirements of toll operations using smart cards and to identify market, economical, and institutional barriers. This series of talks began in the summer of 1997.

Motorola recently announced that it has created a new business unit called Smartcards Systems Business to manufacture smart card products. Motorola cites figures from Dataquest that microprocessor-based smart cards accounted for only 84 million units in 1995 will increase to 1.2 billion units by the year 2000.

Obstacles to Implementation

The intense interest and expectation of toll concessionaires, public transportation agencies, and financial institutions have for smart card applications is very encouraging. But, implementing smart cards is another matter until the following barriers are addressed:

- A DSRC standard must be established to enable the development of standard smart cards.
- In toll operations, smart cards are still an unproved technology. Major efforts are needed in testing and demonstrating the reliability of smart cards to attract investments in this area. Concessionaires should, through the ABCR, build a consortium of smart card users early on to minimize risk.
- There is no DSRC transponder on the market currently capable of communicating with smart cards. Cooperation between DSRC tag vendors and their counterparts in smart card industry is needed to design and develop such tags.
- There is no adequate smart card infrastructure in place. Banking institutions will require assurance from toll agencies that a critical market mass exists to justify building a network of smart card readers and infrastructure and providing the settlement responsibilities for collection, deposit and reimbursing service providers who allow smart card use. However, the environment in Brazil suggests that there is a strong foundation on which to develop this critical mass.
- The public must buy into smart cards. This can be accomplished through an evolutionary introduction of smart cards into key business and financial uses, although experience in Brazil suggests that public acceptance will not likely be a significant barrier to implementation.

Potential ABCR Roles

The ABCR is an interested party in smart cards at two levels: First, concessionaires have service and efficiency stakes in early implementation of smart card technology; and second, there may be a revenue-generating role that the ABCR overall can play.

ABCR members will be significant beneficiaries from the increased use of electronic payments systems and the encouragement of related technology with other applications (such as AVI) both in terms of increased service and efficiency and reduced cost.

The ABCR should consider establishing a smart card user group modeled after the Interagency Group that supported the development of EZPass. Working with other national and international groups, such as the ITS America Task Force, this user group could provide the smart card industry and tag vendors with increased assurance and motivation to develop products for toll collection more rapidly.

While technical development takes time, ABCR members should consider migration strategies from Electronic Toll Collection to smart card ETC. Such a migration strategy includes:

- Allowing smart cards as payment media at attended toll booths. This step will introduce the general public to the benefits of smart cards and prepare them for the next level of migration.

- Establishing prototype and pilot smart cards as a part of the DSRC technology and standards development effort. This step will require a new generation of DSRC equipment, one that is likely to comply with the national DSRC standard and has the smart card interface capability.

- Establishing full-scale smart card system. This step will require infrastructure modifications to meet smart card requirements. Financial arrangements will be made with institutions such as banks and credit card companies for the distribution of smart cards and the revenue processing.

On a more speculative level, the ABCR may consider a role in "making a market" for smart cards on a large scale that might provide ABCR members with reduced costs or even a source of revenue. Transportation applications constitute a unique distribution channel and mode of introduction for wide-spread use since tolls, gas, transit fare and parking make up a large number of the small transactions of the type smart cards target.

A coalition representing a large number of outlets and uses for cards will have some bargaining power to negotiate attractive financial agreements with smart card providers which may include profit sharing in addition to receiving smart cards at no costs. ABCR could negotiate as a group with companies bidding for settlement responsibilities and looking for the lowest costs or more direct financial benefits to help reduce/offset the costs of continuing ABCR activities. ABCR could then develop a partnership with the financial institution and jointly operate a clearinghouse operation, creating a single organization with both the transportation and financial expertise required for efficient and effective operations.

4.5.12. Business Issues in ETC Standardization

Sunk Investments

Road concessionaires have spent considerable amounts of money on existing toll systems. While it is generally recognized that all such systems must be upgraded over the course of time, many toll concessionaires fear losing money if a standard is chosen that is not compatible with its equipment. This concern is especially acute among those users who have recently installed equipment. In addition, an environment of shifting and unstable standards will not encourage private-sector investment. If manufacturers have proprietary systems that are profitable, they may not be enthusiastic about moving to an open standard. As businesses, toll concessionaires must be assured that their investments are protected and that future investments are prudent.

Given the current installed base, toll concessionaires can protect their investments by moving toward the adoption of standardized equipment (Title 21 compliant, backscatter, read/write technology) in the 915 MHz frequency in the short term (provided that Title 21 is interoperable).

Those currently with equipment operating at a different frequency should carefully consider their short-term interoperability needs. It is likely that there will be limited needs for interoperability among systems with different frequencies, but interoperability could be achieved by installing two readers to accommodate tags at both the 915 MHz and 2.45 GHz frequencies.

Sole Source Providers

The ABCR wants to avoid creating a situation in which only one tag supplier is available to road concessionaires. Once a national standard is developed and standard compliant products are produced and sold, this concern will largely evaporate. In the meantime, road concessionaires must move forward with equipment purchases, but want to do so in a manner that maximizes their options and selection.

As discussed in greater depth in the Task 4.7 Report, "Identify Vendors," there are a few manufacturers that provide Title 21 compliant equipment. The largest of these is Amtech, which has a number of installations throughout Brazil and other parts of South America, with its heaviest concentration in Rio. Texas Instruments also supports Title 21 standards and has installed equipment throughout California. TI recently sold its Title 21 product line to Sirit, a Canadian company. Other vendors whose equipment meets Title 21 requirements are MFS, Denso and Tadiran. Denso plans to aggressively market and expand its Title 21 equipment and installations in the near future. Other established ETC vendors (such as PEEK and a number of European vendors) are also expected to develop Title 21 compliant equipment in the near future. Information on these vendors is available in the Task 4.7 Report and in the Task 1 Appendix.

ABCR should use its influence and the nation's enormous road concession program as leverage to encourage product development and market expansion. This leverage will allow ABCR members to have considerable impact on the development of international standards and provide an impetus for more choices, less expensive equipment, more reliable equipment and more enhancements and features.

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.6 - Prepare Final Report

SUBTASK 4.6 PREPARE FINAL REPORT

4.6.1. Summary of Other Tasks

Subtask 4.1 Issue Recommended Installation Standards

In the short term, Brazil should adopt California's Title 21 using backscatter read/write technology that operates in the 915 MHz frequency. Adoption of this technology will achieve national interoperability using existing and proven technology, while paving the way for a graceful migration from Title 21 to the American Standards and Testing Materials (ASTM) DSRC standard version 7. This report details the specifications for Title 21.

Subtask 4.2 and 4.3 Prepare Functional Specifications and Compute System Performance Parameters

This report outlines the functional specifications and system performance parameters for ETC systems based on a system operating with Title 21 equipment. The report serves as guidance to toll concessionaires looking to issue Requests for Proposals to implement ETC.

Subtask 4.4 Define Staff Requirements

As Brazil moves toward interoperability and standardization, new roles and functions will be required. The report describes staffing needs for the ABCR, which include additional staff to provide support for a regional or national clearinghouse and to provide standard maintenance services. The report also suggests staff positions for toll concessionaires to coordinate and guide the implementation of ETC and the migration from existing equipment to standardized equipment and operations.

Subtask 4.5 Prepare Migration Strategy

The recommended migration strategy for Brazil consists of two phases.

In Phase One, which extends for the next two years, we are recommending the use of the 915 MHz backscatter ETC system. Most of the current ETC systems in the state of Rio de Janeiro use backscatter tags at 900 MHz. These tag systems have been purchased sole source from a vendor. We recommend that the California Title 21 standard be adopted for future procurements. There are currently two vendors that produce tags that meet this standard; additional vendors can be anticipated to provide compliant tags. This meets a key objective of having price competition for procurements.

In Phase Two (migration from Title 21 to ASTM version 7 at the 915 MHz frequency), we recommend waiting for the current U.S. and international standards setting and testing processes to provide answers to important system performance questions . These answers should be available in the next two to three years (by the end of 2001). At that time,

international toll activities will be evaluating the ASTM V7 test results and deciding if the advantages of the ASTM V7 tag merit the increased costs for large scale tag replacement and dual plaza sensors required for ETC lanes.

Subtask 4.7 Identify Vendors

There are several vendors who support Title 21 equipment. Among them are Amtech, Sirit, Texas Instruments, Denso, Tadiran., and MFS Network Technologies In addition to these established firms, it is anticipated that a number of other companies (including several European manufacturers) will provide Title 21 compliant equipment.

Subtask 4.8 Define Clearinghouse Functions

For Brazilian travelers to realize the full benefits of electronic toll collection, a number of functions and operations must be coordinated. In no instance is that more important than with patron services. Toll concessionaires must find a means to provide for the transfer of cash between the patron and the toll facility, including all the paper trails for the transactions. If ETC is truly to serve travelers throughout Brazil, it will have to do so without requiring the patron to have a tag for each agency the patron uses. This will require a centralized clearinghouse to provide tag, account, and reconciliation services to toll concessionaires. Such coordination provides toll concessionaires with significant cost savings, since they now will be able to sell a single tag that can be used on all toll facilities in the country.

The clearinghouse will be responsible for all business dealings with customers. Functions of the clearinghouse include:

- Maintaining tag inventory and security
- Testing tags
- Activating and distributing tags
- Setting up and maintaining customer accounts
- Processing customer transactions
- Controlling tags
- Collecting amounts due from customers
- Resolving customer disputes

4.6.2. Additional Considerations and Issues to be Addressed by Concessionaires

In addition to the information provided in the other subtask reports, concessionaires should consider a number of other issues related to ETC as they move toward standardization. In the sections that follow, we offer some further advice and recommendations on these topics.

Business Arrangements and Options

Getting the Best Buy: Concessionaires, as ETC equipment procurers, have a number of business objectives they must achieve when negotiating an ETC procurement. These include:

- Ensuring that tags and readers are fully technically compatible

- Ensuring that the concessionaires receive the lowest possible price for the equipment, and that other concessionaires do not receive the same equipment at a lower price (the "most favored customer" objective)
- Guaranteeing that there is an available supply of the equipment in the required quantities
- Obtaining protection against supplier business interruption
- Ensuring that the equipment purchased complies with an established migration plan

To achieve these objectives, the ABCR should lead an effort to collectively procure ETC equipment for all current and future ABCR members. Vendors should be asked to submit an irrevocable offer, which could be utilized solely at the discretion of the concessionaire to provide ETC equipment. The vendor would be required to meet the business objectives stated above. The potential market size in Brazil should stimulate the market to offer very competitive prices along with the necessary guarantees.

The "Shared Resources" Opportunity: An often overlooked opportunity is the concept of "shared resources." Road concessionaires are installing fiber along the road network's right of way to provide for electronic toll collection. As the telecommunications system in Brazil is privatized, telecommunications providers will be looking for access to rights of way to deliver their services. Forward thinking toll concessionaires can increase their profit opportunities over the long term by installing (at minimal cost) additional strands of fiber along the road network, which can then be leased to telecommunications companies. The additional income can increase concessionaire's profits, as well as provide more funding for road and service improvements along the roadway.

Clearinghouse Issues

Efficient interoperable systems require effective back room operations. As described in detail in subtask 4.8, back room operations offer considerable advantages for toll concessionaires. But in order for these operations to be successful, a number of issues must be resolved regarding the current manner in which ETC accounts are handled and how the financial community might function under such an arrangement.

For example, Bradesco and other banks have expressed a strong interest in smart cards. They see a very strong market for smart cards in Brazil and are looking to ETC as an initial application to jump start smart card use. Sao Paulo is, in fact, assuming that banks will be responsible for tag (and/or smart card) distribution, account establishment and maintenance, etc. Meanwhile, in Rio de Janeiro, concessionaires have approached this issue in different ways. Some are using a post payment approach, where customers are either billed for their use of the system or can have the amount automatically debited from an account. This requires invoices to be mailed and other administrative costs that can add significant operating costs. The Onda Livre system uses a post payment approach and is responsible for invoicing customers on both the Ponte SA and Via Lagos systems. It also is in negotiations to provide similar account services to the toll concessions in Parana. Other Rio systems are using prepaid accounts which do not require invoicing, saving on administrative costs.

Toll concessionaires must find a means to provide for the transfer of cash between the customer and the toll facility, including all the paper trails for the transactions. If ETC is to truly

serve travelers throughout Brazil, it will have to do so without requiring the customer to have a tag for each agency the customer uses. The solution could be a centralized clearinghouse—developed and operated by a partnership between ABCR and a financial institution (or a consortium of financial institutions)—to provide tag, account, and reconciliation services to toll concessionaires. Such coordination will provide toll concessionaires with significant cost savings, since they will be able to sell a single tag that can be used on all toll facilities in the country.

Marketing Issues

In order to attract customers to electronic toll roads, toll agencies must apply basic marketing principles: they must know their product, know their customer, and bring them together. A number of issues must be addressed by ETC marketing efforts. The first is convenience. Electronic toll collection makes, or should make, highway travel easier. In addition to promoting the convenience and time savings gained by using ETC, authorities must also make obtaining transponders, establishing and maintaining accounts and addressing problems, easy and convenient for customers as well.

Toll authorities must recognize and address concerns among the public regarding the safety of ETC systems. There is a public perception that using the technology could lead to harmful radiation effects on motorists. Although DSRC use produces radiation levels far below that of common household items such as microwave ovens, many people still have reservations about such effects. In addition, many people have a general "phobia" about new technology, another issue that marketing efforts need to address.

Privacy concerns may also discourage wide acceptance of electronic toll collection. Systems should be employed to assure driver privacy, and this information should be communicated effectively to potential users.

In addition, estimating market penetration is extremely important in planning for ETC. Indeed, the extent to which motorists can be expected to shift from cash to electronic payment options may well affect the overall viability and justification of implementing ETC. The success of ETC projects depends on whether the public clearly recognizes the benefits of the system—and if the tag acquisition, installation and account payment methods are simple and efficient. Market research on several North America toll projects suggests that the probability of using ETC is a function of a number of factors, including: 1) the trip characteristic demand profile, 2) the program parameters of a particular ETC application, and 3) the implementation strategy used by the agency.

There is a relatively high correlation between the reasons for travel and the use of ETC. In general, commuter trips to and from work have the highest probability of ETC use, followed by trips made for company business. Other types of trips show considerably less likelihood of ETC use.

Toll collection in Brazil is a business and, as such, it requires effective marketing campaigns to ensure adequate revenue to operate the system and retain a profit. Again, each system has different approaches to marketing. We recommend that the sale and distribution of tags and

the management of toll accounts be handled through the clearinghouse operation to provide a coherent marketing strategy.

Procurement

How road concessionaires procure ETC equipment and services can have significant impacts on private sector interest and participation in ETC in Brazil. If a procurement process is unwieldy, slow, risky or costly, private involvement and interest may be suppressed. To provide a cohesive and coherent ETC system, and lay the foundation for additional DSRC transactions in the future, toll concessionaires may have to coordinate their procurements. There are some useful lessons to be learned from U.S. experience. Three case studies—the Interagency Group (in the Northeast U.S.), California (which uses Title 21 standards) and Florida (which selected Amtech equipment)—are presented below.

Interagency Group (IAG)

The Interagency Group, a coalition representing eight toll authorities in New York, New Jersey, Pennsylvania and Delaware, has selected compatible toll collection technology for the four-state region. The coalition's members account for about 40 percent of all toll transactions and approximately 67 percent of total toll revenue in the United States. As members of the 1-95 Corridor Coalition, a partnership of the major public and private transportation agencies in the Northeast Corridor, these agencies are working to unite various transportation services to provide a seamless transportation network. Part of that seamless network will allow motorists to pass through all tollways from Maine to Virginia without the need for multiple tags.

The IAG faced numerous institutional and organizational challenges during the development of the E-ZPass specification. Among those issues were separate procurement procedures and requirements of the participating agencies, the pace of technological change, and parallel standards setting activities at the national level. The IAG example is instructive for a variety of reasons. First, it is a voluntary, interagency compact and illustrates the degree of interagency cooperation necessary for interoperability. Second, it illustrates the degree of tension between the desire to use state-of-the-art technologies to improve service and operation on one hand, and on the other, the slow difficult process of coordinating across agencies. Third, it demonstrates the risk of committing a number of toll agencies to adopting technology that may, once standards are developed, become obsolete.

Several agencies in the New York region had begun testing ETC systems by the late 1980s. A number of these agencies became concerned that tag operations from one system could interfere with those from another. In addition, they were concerned that the early selection of technology by one agency could force a sole source procurement on other neighboring agencies. These concerns formed the basis for several agencies to establish a platform for communication—the IAG. Previous collaborative initiatives (TRANSCOM, relationships built through the International Bridge, Tunnel and Turnpike Association, for example), had created a level of cooperation and trust among the agencies involved in the development of the IAG. A policy committee and executive committee, both comprised of senior agency officials, were developed to secure needed resources for the IAG and to commit policymakers to making the project successful and moving progress along.

A number of issues emerged from the early IAG meetings. First, each agency had different procurement procedures, different implementation timetables and different operating requirements. The IAG's first decision was to agree to a preference for read-write technology in their solicitations for proposals from vendors, but because some agencies did not require it and were under pressure to implement ETC quickly, proposals were also accepted for read-only technology with a migration plan for read-write.

Second, the IAG had to determine which procurement award option it would follow: either one based on price only, or one based on a set of criteria reached through mutual agency agreement. It used a Request for Proposal that allowed maximum flexibility in obtaining and evaluating proposed technology and in negotiating commercial business terms. It also developed an "irrevocable offer," an agreement in which the vendor insured identical business terms were provided to each agency while allowing the agencies to act independently. In return, the agencies agreed to procure ETTM products exclusively from the selected vendor. In addition, the irrevocable offer allowed agencies to pursue legal action, collectively and individually, for any breach of the agreement; provided for the unconditional availability of the terms and pricing for a specific period of time, and afforded the flexibility of adding other agencies.

A critical issue to all of the agencies in the selection process was the accuracy of the technology. Given the large number of daily transactions handled by the IAG (approximately 4 million), a minimum allowed tag identification rate of 99.6 percent was required. This would guarantee that IAG members would not suffer financial loss. A billing error tolerance of 1 error per million percent was also required to virtually eliminate the possibility of billing errors. Field testing showed that the two final contractors had met basic requirements, but IAG members still lacked confidence in the technology's ability to consistently meet the 99.96 percent accuracy requirement and were uncomfortable with large scale procurements. More testing was conducted. At the same time, business negotiations had ensued. The IAG's business requirements included the need to require vendors to establish or license alternate manufacturing agreements so that the IAG would not be in a continued sole source situation; a requirement for multiple suppliers of proprietary parts; protection in the event of default to the extent of setting up IAG manufacturing as a worst case scenario; patent and copyright identification and perpetual, non-exclusive irrevocable software license for integral software. Technical risks were addressed by requiring warranties and on-site vendor response, providing for front-end technology modifications, financial incentives for performance, and contractor provisions for technical support and maintenance.

Another major issue the IAG faced is a regional clearinghouse for toll account payments without which the customer would have to maintain eight toll accounts in order to drive throughout the greater New York area using E-ZPass toll booths.

The IAG prepared, advertised, and sent to interested vendors an RFP for a central clearinghouse. The specifications were an order of magnitude more demanding that those for the ETC technology itself. The IAG received only one fully responsive submission and elected to shelve the idea for the moment. Two agencies, the Thruway and MTA Bridges and Tunnels, today have a fully reciprocal system. If a vehicle has an account with one system and uses ETC on both, the agencies will offer reciprocity. Currently the New York State Thruway and MTA Bridges and Tunnels are operational, the Port Authority of New York and New Jersey is

operational, and the New Jersey agencies recently awarded a contract for installation on their three roadways. The New Jersey agencies are expected establish a second clearinghouse in New Jersey, and they are expected to offer reciprocity to New York users.

California

In the late 1980s, as traffic congestion in the Orange County area grew along with "slow growth" sentiments among the public, local government officials recognized that they would have to find a new approach to transportation development. In late 1984, the California legislature authorized the county to impose development fees for highway construction. With the building industry's support, the county adopted a fee program under which new building construction would pay corridor fees as a condition of receiving building permits. Land developers in the corridor would be required to dedicate corridor right of way in return for credit against these fees. In order to ensure the financial and political feasibility of these projects, all affected communities would have to participate in their financing and approval.

As a result, in 1986, the county and several cities within the county executed two Joint Powers Agreements creating the Transportation Corridor Agencies (consisting of the Eastern, Foothill, and San Joaquin Hills Transportation Corridors) to oversee the design, finance and construction of the projects. Each city agreed to implement the fee structure within its own jurisdiction. In 1987, the state amended the law to allow the TCAs to finance corridor construction through tolls. On completion of the project, the corridors will be owned and maintained by Caltrans, but the TCAs retain the right to operate the toll system, with revenues used to pay for operations and construction financing costs.

In 1992, the California legislature passed into law Title 21, a mandate to regulate electronic toll collection equipment used in that State. In doing so, the State adopted radio frequency backscatter as the technology of choice in ETTM systems for California.

Potential investors to the TCA projects needed to be comfortable with the electronic toll collection system's ability to actually collect tolls and identify violators. A contractor was selected to provide and operate the toll system. The contracts contain several features of enhanced financeability:

- Automatic vehicle identification (AVI) system guaranteed to be at least 99.7 percent accurate
- System upgrades and updates meeting future governmental requirements and alternative technology in case of patent litigation
- Damages of several thousand dollars per lane, per day, on completion delays
- Substantial insurance, payment, and performance bond requirements
- Expedited alternative dispute resolution
- Intellectual property escrow
- Restrictions protecting the bonds' tax exemption

The contracts also address important ITS issues such as customer privacy and intellectual property in novel ways. Customer data is shielded from public disclosure by being kept out of

TCAs' possession, and Lockheed Martin is subject to strict limitations regarding its use. TCAs accepted a license and royalty for intellectual property developed under the contract instead of retaining title, since the contractor is in the best position to exploit the market value.

Florida

After four years of evaluation (and a couple of false starts), Florida DOT has finally awarded a contract to Amtech to install an ambitious, statewide SunPass electronic tolling program. The contract is worth $38.6 million, considerably less than the bids from its competitors. The Amtech system is used in several neighboring states. Amtech will supply toll equipment for 455 toll lanes, 110 of which are dedicated electronic toll lanes. The remaining lanes are mixed. The system will use Amtech's 915 MHz Intellitag product, and will be integrated into existing coin and manual collection equipment. The SunPass system will cover Florida's turnpike, run by the state DOT, the Orlando-Orange County Expressway Authority and several smaller county and city toll systems in the state. Mark IV equipment is currently used on the Orlando toll expressway and on some causeways in the Miami area. These systems will eventually have to replace their equipment to be compatible with SunPass' Amtech equipment.

Installation started in the Miami area in early 1996 and is scheduled for completion by mid 1998. The western part of the state (around Tampa) will be the next area to install the ETC equipment, and central Florida (Orlando area) will be last, with the contract expected to be completed by late 1999.

In Florida's first RFP, the state had required that the system operate at 2.45 MHz, a frequency not currently in use (nor expected to be in use) by electronic toll systems in the United States. In addition, it called for open highway tolling, 100 mph treadles, and other, in the eyes of many vendors, unrealistic and costly requirements. The DOT later scrapped that RFP and tried again. This time, DOT officials brought the vendors together for a roundtable discussion on technology, specifications, costs and other issues associated with installing ETTM and writing an RFP to get them there. The resulting RFP no longer included the 2.45 MHz requirement and was at least technically more sound than its previous attempt. However, the RFP consisted largely of the "best of everyone's" technology, despite the fact that the agency had a budget of only $39 million. Among the features the DOT wanted in the new system was smart cards. The Amtech proposal included smart cards as an option, but did not include it as part of its baseline bid, as the costs of implementing such a system is currently cost prohibitive at about $100 per transponder.

Lessons Learned

Among the lessons to be drawn from these procurement experiences are:

- Develop an IAG-like agreement on interoperability and procurement. Based on the findings of this study effort, Brazilian toll road concessionaires should develop a voluntary, interagency compact that will develop and subscribe to a single standard for ETC equipment, develop a coordinated procurement process, and ensure that parties to the agreement receive equal treatment by vendors. This activity should be conducted under the auspices of the ABCR.

- Require that vendors certify that a second source is available to supply the required technology and that the second source's equipment is interoperable with existing equipment.
- Learn what is technologically possible before drafting an RFP. Avoid issuing RFPs that "ask for the impossible" by soliciting input from vendors about their equipment, its limitations, and timetables for upgrades. Again, leverage ABCR's strength to gain reliable information and sift through vendor claims.
- Look for the best deal possible (in terms of both cost and functionality) for the long term. Include contract provisions to ensure that the system purchased can be expanded to accommodate future functionality.
- Include contract clauses to ensure that vendors will provide system upgrades as necessary.
- Clearly define intellectual property rights to protect the concessionaires interests and ensure that, in the event of default by the ETC supplier, the concessionaires will not be "held hostage" and can continue operations without interruption. This may involve putting the source code for the system in escrow, giving the concessionaire license rights, or other means to provide concessionaires with access to source code.

Litigation/Protests

The toll industry is a hotly competitive one. Without standards, the rush to capture more and more market share by competing equipment vendors is fierce. The objective is to gain a large enough portion of the market to essentially force a de facto standard or to earn oligopoly profits. In addition, ETTM technology is rapidly evolving and many agencies have, to date, not been faced with procuring communications and electronic equipment, making detailed and realistic specification writing difficult. Unfortunately, as a result of this competition and technology evolution, litigation and protests regarding ETTM procurements are common. Getting details on these matters is often difficult. Agencies are reluctant to go on record about such matters for fear of future protests.

The Florida SunPass award has received a great deal of attention for several reasons, including the fact that the winning bid was almost $30 million less than the nearest competitor. A required "protest bond" may have prevented a challenge.

Another recent controversy has surfaced in New Jersey. The state awarded a contract to MFS to install EZPass equipment on its toll system. Lockheed-Martin, competing for the contract, cried "foul." Lockheed-Martin criticized the details of the MFS deal, where the toll supplier was also providing fiber to offset costs. The $500 million deal involved equipping 700 toll lanes (making it the biggest ETC job to date). Chase Manhattan has been selected to run the customer service center, which is expected to begin soon.

Enforcement

Effective enforcement is critical to maintaining integrity and confidence in the system, as well as for ensuring profit. Video enforcement is generally required by toll concession contracts. Although cameras take pictures of toll violators, there is currently no means to enforce the

violations. A new law, which became effective in January will allow enforcement of toll violations, but concessionaires in Rio are not likely to be compensated for the violations, and fines are paid to DETRAN, not to the concessionaires. In Sao Paulo, DERSA is considering some type of partial reimbursement to concessionaires for violations. Currently, three percent of overall income from the plazas is sent to the state of Sao Paulo. This fund is then used to "reimburse" concessionaires for violations.

Stringent enforcement of toll violations is critical to public acceptance of ETC. It is necessary to discourage attempted violations because ETC can open new avenues for toll evasion, including: passage through an ETC only lane without a tag, use of a tag with inadequate funds on deposit; use of a tag with a different vehicle classification (passenger car vs. truck), and use of a lost or stolen tag. Effective enforcement systems identify the number of good transactions and violations in high-speed open lanes by reconciling vehicle count to transaction count, then storing the details of each transaction for audit processing on a total system basis. In order to accurately identify and enforce violations, collection, validation and enforcement processes must be completed in about 500 milliseconds or the next car will be in the collection and enforcement zone before the previous transaction can be completed.

For most toll booth systems, a conventional, single frame enforcement camera is sufficient. But for open road systems, a set of high-performance digital video cameras to cover the roadway is required. In order to capture an offender's license plate, the ambient lighting and position of the vehicle is critical.

Privacy and Liability Issues

Some toll customers may have concerns about financial, personal and other data obtained as part of their participation in electronic toll collection. Such concerns can have direct impacts on the willingness of customers to embrace electronic toll collection. In addition, deployment of electronic toll collection may involve putting in place complex contractual relationships that allocate roles, responsibilities and intellectual property rights among multiple parties; more than one agreement is often required to provide full ETC functionality.

IBTTA reports concerns that motorists would feel their privacy was compromised under an ETTM system that records vehicle movements were unfounded. Toll agencies recording this information do not make it available to outside parties. In fact, existing ETTM projects reveal that a majority of motorists choose payment options, such as credit cards that do not provide anonymous transactions. Some privacy advocates do express some concern over various enforcement mechanisms used by toll collection agencies. The ability of traffic operators to catch violations through video detection has raised some concern on the part of privacy advocates. Although evidence suggests that system users have not considered this minor intrusion significant enough to outweigh the benefits and convenience of electronic toll collection.

ITS America has developed a set of ITS Fair Information and Privacy Principles, intended to educate and guide transportation professionals, policymakers, and the public as they develop their own principles for specific ITS projects. These principles are designed to ensure that driver privacy is protected to the maximum extent feasible, while still providing transportation managers with sufficient information to deliver intelligent transportation services. The

principles require that personal identification be stripped from information obtained from intelligent transportation systems, that the use of this information is made clear to drivers, that this information is kept secure, and that only those requiring access to the information should have it.

ITS America will develop adherence guidelines for various ITS applications to assist transportation officials in complying with the principles. These guidelines will tailor the principles to specific applications and provide scenarios explaining how the principles would apply in practice.

While privacy concerns are not generally considered to be significant barriers to current DSRC applications, as these applications are integrated and expanded these issues may take on greater urgency.

Two areas, in particular, could pose greater challenges in the future. First, DSRC applications at border crossings are likely to raise privacy implications. Commercial vehicle regulators are interested in obtaining information on the vehicle, such as its route, identification information, cargo. Immigration officials are seeking information on the driver, such as his or her citizenship status, name, address, and other personally identifiable information. Both kinds of information can be obtained quickly, efficiently and cost-effectively through a single DSRC tag/reader interface. However, the personal identification information must be kept separate from the vehicle identification information, in order to protect the driver's privacy.

Second, DSRC technology allows for integrated fare payment systems. Centralized payment accounting for a variety of purchases (transportation-related and otherwise) stores a significant amount of information about an individual's financial and travel activities and would likely require personal identification information for billing and account reconciliation purposes. Again, assuring the security of personal information and preventing access to it by those who do not need such access may create some concern.

Liability issues related to electronic toll collection are few. Liability concerns are generally not viewed as "show stoppers" for toll agencies considering the implementation of ETTM. Industry analysts say the only liability concern of consequence regarding ETTM (other than privacy, discussed below) relates to the safety of toll operators working on mixed lane facilities. These operators often must cross electronic toll lanes (where vehicles may be traveling at highway speeds but do not have to stop to pay the toll) and are sometimes injured by oncoming vehicles.

Intellectual Property Rights

Copyright protection is a critical aspect of international trade. As ETC systems require the use of sophisticated (and sometimes newly developed) software, intellectual property (IP) rights are often key features of ETC system contracts.

Intellectual property refers to patentable inventions, copyrights and trade secrets, as well as compilations of data derived from the operation of ITS technologies, which may or may not be subject to copyright protection. ITS applications raise challenging new questions regarding

intellectual property. The allocations of sufficient contractual IP rights to enable the private sector firms to make a profit is critical.

Institutional issues regarding IP can be an area of tension between parties. The opportunity to exclusively apply intellectual property rights over an extended period of time is the private sector's incentive to invest in research and development. The public sector, on the other hand, encourages competition and resists creating monopolies.

Allocating IP rights is critical in the context of ETC on concessioned roads, as these currently "private" roads will eventually revert back to public agencies. Will public agencies require certain rights to the technology in order to continue toll collection operations once the road returns to the public? The question of who retains IP rights in the toll collection equipment at this point must be clearly resolved to the satisfaction of all parties.

4.6.3. Recommendations

This section provides a detailed list of recommendations for the toll concessionaires, ABCR and public agencies on issues related to electronic toll collection. Among the recommendations are:

- The concessionaires should develop a common ground for baseline equipment. The Interagency Group in the New York/New Jersey/Connecticut area is an instructive model for toll agencies coming together to develop common specifications aimed at achieving interoperable toll systems. These efforts have begun, but should be expanded and encouraged.

- A national clearinghouse should be established to provide a firm foundation for smart card implementation, relieve concessionaires of the burden and expense of handling money, and improve customer convenience.

- Concessionaires should secure consulting support (from consultants without product ties) in moving toward electronic toll collection. These are relatively new, complex, and rapidly evolving technologies. The ETC business is quite competitive and an objective "eye" toward vendor products and services will assist concessionaires in making informed, sound decisions on ETC investments. As these investments can run well into the millions of dollars, careful scrutiny is critical to ensure that these decisions are supported by the press and the public.

  Among the qualities to look for in such consulting support are:

  - Length of time in the toll collection business and depth of experience
  - Resources to support such ETC evaluation services
  - Experience in dealing with backroom operations and requirements
  - Experience in smart card applications and development

- Experience in the full range of ETC and other electronic traffic management systems

- If the concessionaires choose not to secure outside, independent consulting support, they must carefully consider a number of issues when choosing a vendor, including:

  - Ensuring that the vendor provides cost-effective, reliable and maintainable lane, host, plaza, tag, video enforcement, and vehicle classification systems

  - Ensuring that the vendor's equipment meets all technical requirements of the Title 21 standard outlined in Task 4.1

  - Ensuring that the vendor has substantial experience in ETC design, installation, and maintenance

  - Ensuring that the vendor has experience in traffic management and traveler information systems so that ETC systems can be easily integrated with other transportation-related services and applications

  - Ensuring that the vendor has experience in and understands account processing systems to enable full integration and coordination with regional/national clearinghouse operations

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.7. - Identify Vendors

SUBTASK 4.7. IDENTIFY VENDORS

4.7.1. Introduction

This section identifies the vendors that offer ETC related products and services. The main products and services that may be needed for an ETC system include:

- Automatic Vehicle Identification (AVI) lane equipment
- AVI transponders
- System integration
- Back office software
- Smart cards
- Enforcement system
- Classification system

This report does not recommend vendors. Concessionaires must decide for themselves which vendors are best qualified to provide them with the specific equipment and services they desire. However, this report does provide concessionaires with some basic guidance and issues to consider when selecting a vendor, in light of other recommendations made in other subtasks of the Task 4 reports.

4.7.2. Selecting a Vendor

Among the things concessionaires must consider when selecting a vendor are:

- Ensuring that the vendor provides cost-effective, reliable and maintainable lane, host, plaza, tag, video enforcement, vehicle classification systems
- Ensuring that the vendor's equipment meets all technical requirements of the Title 21 standard outlined in Task 4.1
- Ensuring that the vendor has substantial experience in ETC design, installation and maintenance
- Ensuring that the vendor has experience in traffic management and traveler information systems so that ETC systems can be easily integrated with other transportation-related services and applications
- Ensuring that the vendor has experience in and understands account processing systems to enable full integration and coordination with regional/national clearinghouse operations

4.7.3. Vendors With Title 21-Compliant Equipment

The largest of these is Amtech, which has a number of installations throughout Brazil and other parts of South America, with its heaviest concentration in Rio. However, Sirit also supports Title 21 standards and has installed equipment throughout California. Other vendors whose

equipment meets Title 21 requirements are: Denso, MFS Network Technologies, and, perhaps, Tadiran.

Amtech

A name familiar to road concessionaires in Brazil, Amtech is a vendor of wireless data technologies. The company designs, manufactures, markets, integrates, and supports various ITS products, but particularly in the ETC field. It supports vehicle to roadside communications, classification equipment, enforcement equipment, back office systems, and systems integration. It has more than 5 million AVI tags and 7,500 readers distributed worldwide. It is based in Dallas, Texas, USA.

Denso

Denso, headquartered in Tokyo, Japan, supplies components to automotive manufacturers. The company specializes in vehicle-to-roadside communications systems and is developing, designing, and manufacturing products for ETC such as in-vehicle tags and antennaes. Denso employs 57,000 people and has 41 locations in 21 countries. Its 1-piece read/write tag conforms with Title 21 and is used in parking applications in addition to ETC. Its ETC-related equipment includes vehicle-to-roadside communications, smart cards and smart card readers, in-vehicle tags and roadside antennaes. Sources close to Denso report that it is planning a major push to increase in Title 21 installations and enhance its equipment.

MFS Network Technologies

MFS provides ETC software (for back office and accounting systems), systems integration services, hardware for lane controllers, and toll terminals. It is a major integrator of large-scale network infrastructures and specialized systems for communications, intelligent transportation systems, and security applications. It has an 80 percent share in MFS TransTech, a subsidiary specializing in software development and systems design specific to ITS. The company is headquartered in Mt. Laural, New Jersey, USA.

Sirit

Sirit is an ETC systems integration company based in Ontario, Canada, that recently acquired Texas Instrument's Title 21 product line. The company has systems with the Halifax-Dartmouth Bridge Commission and the Highway 104 of the Trans Canada Highway.

Tadiran

This Israeli-based company provides vehicle-to-roadside communications equipment. It specializes in communications, data links, digital image and military electronics equipment. It is participating in the Caltrans Title 21 R&D program. Information available about the company does not list any current ETC installations.

Other companies expected to provide Title 21 products in the near future are PEEK Traffic and a number of European ETC vendors (since CEN-compliant equipment is easily converted to Title 21 specifications).

Table 4.7.1 identifies vendors that provide each of these products and services.

Table 4.7.1. Vendors and Products Matrix

	AVI lane equip-ment	AVI trans-ponders	System integra-tion	Back office software	Smart cards	Enforce-ment system	Classifica-tion system
Mark IV	X	X					
Amtech	X	X	X	X		X	X
Alphatech						X	
Combitech	X	X	X			X	X
Marconi/ Autostrade	X	X					
AT/Comm	X	X	X	X			
Micro Design	X	X	X	X		X	
Mitsubishi Heavy Industries	X	X	X	X			
Sirit	X	X					
Nedap	X	X					
US Public Technologies						X	
Schwartz Electro Optic						X	X
Electronique Control Mesure							X
Intellitag	X	X					
Tecnotel							X
Thomson	X	X					
X-cyte	X	X					
Peek							X
Cohu						X	
Ascom/ Elsydel	X	X	X				
Computer Expertise							X
CGA	X	X	X	X			
Matra Securite	X	X					
Integrated Silicon Design		X					
MFS			X	X			
Autostrade			X	X			
Transcore			X	X		X	X
GEA			X	X			
Phillips Singapore			X	X	X		X
Lockheed			X	X		X	X
Integra Ingeniera			X				
CS Route			X	X			
Hughes			X	X		X	
SICE			X				
IBM			X				
Arce Systemas			X	X			X

	AVI lane equip-ment	AVI trans-ponders	System integra-tion	Back office software	Smart cards	Enforce-ment system	Classifica-tion system
Cubic Toll Systems			X				X
Translink Systems			X				
TST International			X	X			
Siemens			X	X			
ISKRA			X				
Compsis			X	X			
Gesig			X				
Gulf Engineering			X	X			
Tecsidel			X				
Paragon ETTM			X				
SEMA Group			X	X			
Kapsch			X				
DISEL			X				
Digital Equipment Corporation			X	X			
ACS			X				
ITMI/CIRIEL				X			
Castle Rock Consultants				X			
Gemplus					X		
Mikron					X		
Schlumberger					X		
Olivetti					X		
ORGA					X		
Motorola							

Electronic Toll Collection Interoperability Study in Brazil

Task 4 - Recommendations and Final Report

Subtask 4.8. - Define Clearinghouse Functions

SUBTASK 4.8 DEFINE CLEARINGHOUSE FUNCTIONS

4.8.1 Introduction

In order for Brazilian travelers to realize the full benefits of electronic toll collection, a number of functions and operations must be coordinated. In no instance is that more important than with patron services. Toll concessionaires must find a means to provide for the transfer of cash between the patron and the toll facility, including all the paper trails for the transactions. If ETC is to truly serve travelers throughout Brazil, it will have to do so without requiring the patron to have a tag for each agency the patron uses. This will require a centralized clearinghouse to provide tag, account, and reconciliation services to toll concessionaires. Such coordination provides toll concessionaires with significant cost savings, since they now will be able to sell a single tag that can be used on all toll facilities in the country.

4.8.2 Benefits of the Clearinghouse

The clearinghouse concept isolates the toll concessionaire from the patron and the patron from the toll concessionaire. The isolation is achieved through a "back office" third party provider. The goal of the clearinghouse concept is to reduce costs, reduce the duplication of efforts, provide a single point of contact for the patron, reduce the potential conflicts in ETC and other traffic management efforts between agencies, and to make the most efficient use of resources.

The patron's point of contact with the ETC system is through the clearinghouse. Through the clearinghouse, the toll concessionaire's concerns regarding toll collection, overhead, and patron service are met. The clearinghouse provider can do many things that a toll concessionaire doea not the the expertise and resources to do, such as technical, financial, customer service, and marketing efforts. While those currently marketing ETC are doing an exceptional job, such activities divert time, resources, and attention from allowing the concessionaires to do what they do best—operate and maintain the roadways.

The clearinghouse will act as the guarantor of toll payments to each concessionaire. Tags sales and distribution will be the responsibility of the clearinghouse. No one agency will have to worry about becoming the region's tag provider. Marketing plans for ETC will be coordinated through a single entity. Back office costs will be reduced because only one entity will be responsible for producing and mailing invoices, etc.

The patron will be authorized to travel on all of the toll facilities participating in the clearinghouse, and will be able to select from a variety of account types that best suit his or her needs. The single point of contact will improve customer service and allow the patron to avail himself of additional services from the system that might not otherwise be available.

4.8.3. Clearinghouse Concept of Operations

The diagram below illustrates how the system will operate. The clearinghouse creates a buffer between the toll concessionaire and the patron. The clearinghouse will authorize the accounts that it will guarantee and cancels the accounts that are no longer valid. This takes place through the Account Information Updates function. The toll concessionaires collect ETC data from patrons passing through its facilities and verifying them against the authorized accounts before granting passage. The data gathered is transmitted for settlement at the end of the business day to the clearinghouse. The clearinghouse processes this data and transfers the appropriate payments to the agencies' banks through electronic funds transfer within 24 hours. These functions are represented by the Settlement function. The final action is a check and balance procedure necessary to assure that the system is functioning properly. This is depicted as the Audits function. Late payment tracking is provided through the Statement Preparation and Collection function.

The clearinghouse operator will set up outlets for tag distribution through the Account Initiation and Tag Distribution and Marketing functions. Complaints and questions will be handled through the Customer Service function. A patron will receive a single itemized statement of charges for toll use through the Statement Preparation and Collections function.

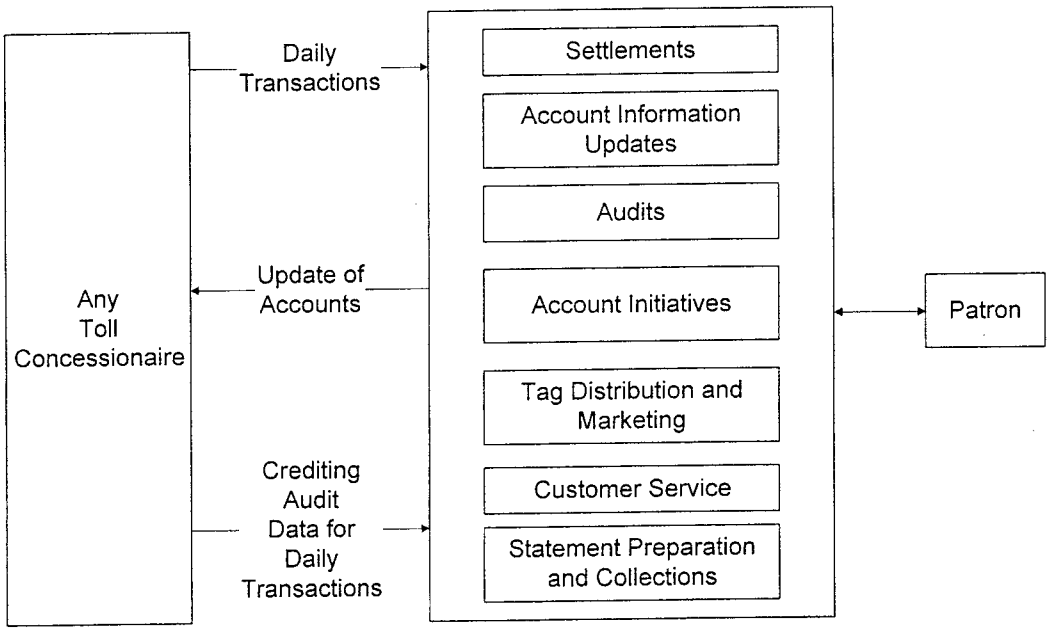

Figure 4.8.1 - Clearinghouse Operations Chart

The clearinghouse will be responsible for all business dealings with customers. Functions of the clearinghouse include:

- Maintaining tag inventory and security
- Testing tags
- Activating and distributing tags

- Setting up and maintaining customer accounts
- Processing customer transactions
- Controlling tags
- Collecting amounts due from customers
- Resolving customer disputes

A more detailed description of the clearinghouse functions is provided below.

4.8.4. Administration and Management

The clearinghouse house will be responsible for day to day operations. These operations will be defined prior to operation of the system. Procedures to be developed and implemented will include:

- Administrative procedures
- Customer and public relations
- Security
- Emergency and safety

Customer Accounts Administration

The following describe the customer account functions that the clearinghouse will be required to perform.

Customer Account Establishment

The clearinghouse will develop three types of consumer accounts: individual, commercial and non-revenue. The clearinghouse will establish customer accounts by creating account records in an account database, updating tag status databases, and processing initial payments. Applications will be received by mail and processed by the clearinghouse. The clearinghouse will provide new customers with enrolment kits by mail.

Customer Account Maintenance

The clearinghouse will implement and operate an automated customer account management system for maintaining customer account information. The clearinghouse will provide controls for account set-up, account updates, payment receipt and processing, and account closing. Accounting may require updating for any of the following reasons:

- Customer name, phone number, or mailing address has changed.
- Credit card account has been closed for an account with pre-authorized, balance renewal.
- Credit card number, or expiration data has changed.
- Additional tags have been issued to the account.
- Changes to vehicle information (make/model, license plate number, state of registration) have been made.

Customer Inquiries, Complaints and Discrepancies

The clearinghouse will provide customers with information related to account balances, account status, and other relevant information. The clearinghouse will install and operate a customer service system that is linked to the customer account information database. Policies on procedures to handle customer complaints and reconciliation of accounts will be established, implemented, and followed by the concessionaires

Customer Account Billing and Invoicing

Under normal operating procedures, the amount owed by a customer will be deducted from the customers pre-paid account balance. However, in the event that charges are incurred on an account without a sufficient pre-paid balance, the clearinghouse will:

- Operate an automated system to generate invoices
- Maintain open accounts
- Apply payments and other transactions that may be required

The clearinghouse will automatically invoice customers for items that that are not automatically deducted from the customers account. Invoices will be prepared on a daily basis.

Customer Account Audit and Reconciliation

The clearinghouse will reconcile all amounts entered with the actual monies received. The clearinghouse will reconcile funds deposited into bank accounts, either directly or through a third party such as a bank, with funds received by the bank according to the bank records. The clearinghouse will reconcile bank balances with deposit data, customer account transaction records, transfer to other concessionaires, and all other bank account transactions.

Reporting Services

The clearinghouse will generate monthly reports for review of the Project Engineer concerning the performance of the clearinghouse operations. The clearinghouse will also generate reports for use by each concessionaire upon request. At a minimum, these reports will include:

- Auditing reports
- Revenue reconciliation reports
- Bank reconciliation and fund transfer reports
- Tag inventory and distribution reports
- Clearinghouse performance reports
- Customer account, and maintenance and invoice reports
- Violation processing reports

4.8.5. Banking and Other Financial Institutions Interfaces

The clearinghouse will send and receive information to/and from banks and other financial institutions as part of normal operations. The clearinghouse will be responsible for coordinating with banks and other financial institutions to resolve any issues that may relate to:

- Timing and frequency of information exchanges
- Identification and corrections of errors in transmission
- Protocols for data transmission

Investment of Funds

The clearinghouse will be responsible for managing funds paid into customer accounts. The clearinghouse will be responsible for transferring funds to concessionaires accounts on the same day that a transaction has occurs. Funds will be transferred by the clearinghouse to accounts specified by the individual concessionaire.

4.8.6. Marketing

An ongoing task of the clearinghouse will be to conduct market research to gain an understanding of consumer's attitudes and expectations about ETC. Information derived from the market research will be used to forecast potential impact on traffic volumes. In addition, this information will be used to develop marketing strategies to promote the use of ETC.

The development of a marketing strategy will also be an ongoing function of the clearinghouse. The marketing strategies will reflect the ETC goals as identified by concessionaires. Marketing strategies may include:

- Press releases
- Advertising campaigns
- Other promotional initiatives

4.8.7. Tag Control

The clearinghouse will provide inventory controls for the distribution of tags. Each tag issued to customers will be maintained in the tag status database. Tags will be identified with a code scheme that is agreed upon by concessionaires. The clearinghouse will also maintain an adequate supply of tags at all times. Other tag control functions that the clearinghouse will provide include:

- Tag issuance – The clearinghouse will encode and issue tags to customers in enrollment kits, or as replacement tags. The clearinghouse will also be capable of verifying that tags sent by mail were received.
- Tags replacement – The clearinghouse will replace tags that have been lost, stolen, are non-functioning, or are at the end of their useful life.
- Tag returns – The clearinghouse will accept tags and provide receipts to customers for returned tags. The clearinghouse will also return the tag deposit to the tag customer if a deposit has been required.
- Tag testing – The clearinghouse will have the capability to test all tags before dispensing them to customers.
- Tag status database processing – The clearinghouse will maintain a database that identifies the current status of all tags that have been issued.