TASK 3.1
I-15 MANAGED LANE ELECTRONIC TOLL COLLECTION SYSTEM (ETCS) CONCEPT OF OPERATIONS

SANDAG
San Diego's Regional Planning Agency

I-15 MANAGED LANES

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SANDAG
San Diego's Regional Planning Agency

I-15 Managed Lane

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HNTB I-15 ML Project Management

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1.0 INTRODUCTION

The purpose of this ***ETCS Concept of Operations (ConOps)*** is to update the February 2002 Concept Plan developed by Wilbur Smith Associates (WSA) by incorporating the latest plans and system concepts for use in the I-15 Managed Lanes (ML) Electronic Toll Collection (ETC) / Violation Enforcement System (VES). It also documents the toll collection system as required in the construction plans developed and being implemented by Caltrans.

The I-15 ML project will expand an existing two-lane reversible express lanes facility, with single entry and exit points at each end of an eight mile segment, to four bi-directional lanes over 20 miles in length and containing multiple intermediate access locations.

As with the current I-15 reversible lanes, the expanded managed lanes facility will employ a fully-automated, fully-electronic system of toll collection. From the outset, dynamic variable pricing will be used on the I-15 ML. Toll collection equipment will be installed at various locations throughout the ML and at specific access points to interrogate transponders mounted on vehicles. Toll transaction data is then forwarded to the toll collection system central computer for processing; however, the extension of the ML to 20 miles and four lanes, the move to 24/7 operations in a concurrent flow environment, and the incorporation of intermediate access points will substantially increase the complexity of the toll collection system and HOV violation enforcement.

In order to improve effectiveness in enforcing the HOV and toll evasion codes on the I-15 ML, HOV users will be required to mount a transponder in order to identify them as HOV when passing through the tolling locations. There will be 36 tolling locations on the I-15ML and in the general purpose lanes that will read and report transponder equipped vehicles for a total of 78 "toll lanes". Additionally, violation enforcement cameras will be installed at specific locations throughout the I-15 ML to provide the ability to automate the citation process of vehicles not found to be in compliance with the I-15 ML policies. In total 10 tolling locations will be equipped with violation enforcement cameras to capture and process images of vehicles deemed to violate the SANDAG requirements for lane usage.

This document describes the final toll collection system and operations concept for the I-15 ML Project. This document is not intended to be a detailed design document; rather it provides an overall design concept for the toll collection system and a concept of operations.

The remainder of this report is divided into eight sections that describe the various aspects of the system and concept of operations as follows:

Section 2.0: System Parameters
This section describes the baseline parameters that the system concept and design are built upon. It details the given conditions of operations that define the I-15 ML Toll Collection and Enforcement System.

Section 3.0: ML Access Arrangements
This section details the various access types and access location into the I-15 ML.

Section 4.0: Variable Toll Rate Structure

This section describes the toll rate structure that will be utilized to ensure SANDAG's compliance with the legislative requirements to maintain a minimum Level of Service (LOS) "C" on the I-15 ML.

Section 5.0: Overall Proposed Toll Collection System Concept
This section gives an overview of the Toll Collection System and describes the basic concept of operations.

Section 6.0: Toll Collection Subsystem
This section describes the sub components of the toll collection and enforcement system.

Section 7.0: Toll Collection System Design
This section describes the high level requirements for the toll ETC/VES system's integration and its overall design.

Section 8.0: Motorist View
This section gives a perspective of the system from the user's end.

Section 9.0: Staged System Implementation
This section provides and overview of the staged project implementation.

2.0 SYSTEM PARAMETERS

There are several parameters that have a strong influence over the final design and operation of the I-15 ML operational concept and ETC/VES toll collection system implementation. These parameters are:

2.1 AVI Technology

In 1990 the California State Legislature directed the California Department of Transportation (Caltrans) to develop specifications and standards for an Automatic Vehicle Identification (AVI) system such that a vehicle owner would not have to install more than one device to use toll facilities statewide. Caltrans developed open compatibility specifications for a two way communications protocol for AVI including an initial set of Transaction Record Type codes mandated for statewide electronic toll collection use. This standard was chaptered into the California Code of Regulations in 1992 as Title 21, Chapter 16, Articles 1 through 4, and is commonly referred to as "Title 21".

While Title 21 standards defined the interoperability specifications for the field level AVI components (namely the transponder and reader), the California Toll Operators Committee (CTOC), an organization of all toll operators in California, established cooperative user fee processing agreements and defined the interoperability specifications for the back-office file transfers in what is referred to as the Technical Specifications for Interagency Electronic Data Exchange. This file transfer protocol allows any FasTrak toll agency in California to be paid for toll charges incurred by a customer with an account at any other interoperable California toll agency.

The I-15 ML system is required to be compliant with the Title 21 specifications and should support the latest CTOC Technical Specifications for Interagency Electronic Data Exchange. The current implemented version is Revision G.4 dated April 26, 2004, and Revision G.5 is under review. The existing I-15 reversible lanes toll collection system supports the above requirements and the proposed ML system must also meet these requirements. This is discussed further below in Section 3.1, "Toll Equipment-Title 21".

2.1.1 Toll Equipment – Title 21

Dedicated short range communications (DSRC) equipment, meaning the Title 21 FasTrak transponders and readers that are standard by law in the state of California, will be used to collect tolls electronically on the I-15 ML facility.

There is no legal requirement that SANDAG must determine the toll charged to a customer in real time and as such calculation of the toll based on entry and exit can be performed at the back-office. Additionally, enforcement of transponder abuse, whereby a customer deliberately prevents the transponder from being read can be moved to the back-office. In the proposed system it is not necessary for the transponder to have "write" functionality since the functionality to support the requirements of the tolling and enforcement system can be provided through the back-office.

At the back-office where transponder inventory and customer maintenance is performed, it is required that some mechanism be provided to read the transponder. The only requirement for this transponder reader is that it be able to read T21 transponders and HOV transponders. Such a unit will help in investigating transponder issues and ensure that only operational transponders are issued to customers. A smaller device to read transponder data can also be used in the field for enforcement purposes.

2.2 HOV Usage and SOV Restrictions

Currently an "HOV" on the I-15 reversible lanes is defined as passenger vehicle (including cars, light trucks, and SUVs) with two or more occupants. Motorcycles, qualified low-emission passenger vehicles with required DMV-issued "Clean Air Vehicle" decal), buses and vanpools also qualify for an exemption from the FasTrak toll for use of the reversible lanes. HOVs and the specially-designated vehicles (for purposes of this report this group will be included as HOV) are currently entitled to use the Express Lanes at all times, for no charge, when they are open to traffic. It is a violation of the California Vehicle Code (CVC) to use the I-15 reversible lanes without two or more occupants in a vehicle or without a valid FasTrak™ transponder that is properly affixed to the front windshield and secured by a valid FasTrak customer account with sufficient funds balance. Carpool violations carry a minimum fine of $341 for the first offense.

Toll evasion penalties are limited to one hundred dollars ($100) for the first violation, two hundred fifty dollars ($250) for a second violation within one year, and five hundred dollars ($500) for each additional violation within one year. FasTrak customers who are traveling alone and have their transponder in an RF static shielding bag are also violators and are subject to citation by the CHP.

2.3 HOV Registration

Currently HOV users who travel on the I-15 reversible lanes are not required to obtain and mount a transponder, and FasTrak account holders are advised to shield their transponders in specially provided bags whenever they travel as an HOV. However, with the expansion of the ML to 20 miles and with intermediate entry and exit points, it is recommended that HOV users also be required to equip their vehicles with an approved transponder. This change in policy has the potential to ease, and partially automate the violation enforcement process. The I-15 ML system will be specified to support transponder equipped SOV and HOV customers and to provide a means of distinguishing SOV and HOV users.

2.4 Rate Announcement

SOV FasTrak customers traveling the I-15 general purpose lanes adjacent to the I-15 ML must make a determination whether to use the ML or remain on the general purpose lanes. The toll rate charged per mile and also the estimated travel time to one or more upstream locations using the ML will be displayed to the user on variable toll message signs (VTMS) to help with this determination. Implementation of dynamic pricing to maintain "free flow" conditions as defined by a minimum Level of Service (LOS) grade "C" or better will result in the need to broadcast the toll rate varying in response to traffic demand. Under all conditions the system must ensure that the rate a motorist sees on the VTMS prior to entering the ML will be the rate charged for the entire trip in the ML. It is very possible that the toll rate per mile may change many times after the SOV customer has entered the ML; however, the toll rate charged for the trip must be what was displayed to the SOV customer at the time of entry. If the toll rate decreases after the SOV customer has entered the ML, the customer is still charged the rate displayed at entry.

To ensure that the toll rate displayed is correctly associated with the recorded transaction for a customer, an AVI reader will read transponders just as the vehicle enters the ML. To that end readers will be placed over the left most general purpose lane, and at each of the direct access ramp (DAR) entry points that abut Bus Rapid Transit Centers (BRTCs). This reader will be installed as close as possible to the entry location to avoid the possibility of missing a read at the sign located at the point of entry.

The reading of the transponders at the point of entry will permit the system to make a record of the sign location (and thus the entry location), the transponder ID, and the toll rate in effect at the time the transponder passed under the sign. The entry location, transponder data, the current toll rate and other relevant information (transaction data) will be transmitted to the central processing system so that this record can be utilized when the toll is computed for the trip. If the transponder is an HOV transponder, then the transaction data is transmitted to the central processing system; however, under current I-15 FasTrak business rules, the toll charged would be zero dollars ($0.00).

2.5 Dynamic Value Based Pricing/Demand Management

The preferred pricing strategy that was approved by the SANDAG Board of Directors for the I-15 ML is a skewed, per-mile toll that would be dynamically calculated and adjusted as often as necessary (e.g., every 3 minutes) to efficiently manage demand for the I-15 ML. Other pricing

strategies were considered but were not selected. These include:

- Standard flat rate: The same standard rate would be displayed at all entry points and charged regardless of location of entry and regardless of trip length
- Flat rate with maximum length trip feature: A flat toll rate based on the maximum possible length of trip in the ML from each entry point
- Standard per-mile rates without minimum toll: Standard per-mile rates at any given time regardless of the specific point of entry
- Standard per-mile rates with minimum and maximum toll
- Standard rate segment tolls: The motorist would pay based on the number of segments traversed regardless of point of entry

The current pricing approach on the I-15 reversible lanes ensures LOS "C" by measuring actual volume and comparing volume to the facility's design capacity. A similar approach is planned for the I-15 ML since current legislative requirements mandate that SANDAG maintain LOS "C" or better; however, for the I-15 ML, there are two additional considerations that will be factored into the toll rate calculation: First, the number of managed lanes in either direction will shift over time depending upon the location of the center moveable barrier. A per-lane capacity is therefore necessary which can be multiplied by the number of lanes at a given time for a given direction to compare against measured volume.

Second, SANDAG plans to use the value of travel time savings (VOTT), i.e., the difference in travel time from the ML to the adjacent general purpose lanes, to one or more destinations such as the end of the ML in that direction, as an additional criteria for setting the price. This latter consideration will actually operate as the base calculation and would be filtered by an additional layer that measures the basic volume-to-capacity calculation to ensure compliance with SANDAG's legislative LOS requirements for the I-15 ML. Traffic parameters such as vehicle counts, speed, and occupancy will be measured at various points in the ML and the adjacent general purpose lane and used as key inputs into the algorithm computations. The algorithm is anticipated to operate as often as every three or six minutes, and could be more or less frequent based on a user-specified interval. All of the algorithm's parameters will be flexible, user definable, and table driven. Regardless, the approved pricing strategy must ensure that all users of the ML are provided a minimum LOS "C" or better for their trip on the ML that will occur by way of override by the LOS calculation whenever necessary.

2.6 Trip Cost

In 2002, SANDAG Board of Directors adopted a skewed per-mile rate to assess a per-trip toll to be paid by SOV customers for each use of the ML. Since this pricing strategy places the highest requirements on the system, the system must by default be structured in a way that provides maximum flexibility to make adjustments to the algorithm's parameters, and will compute the SOV toll charge. In order to provide the flexibility for future rate changes all parameters will be table driven.

All the data necessary for the computation of any potentially foreseeable charging scheme

beyond the basic skewed, per-mile LOS-derived toll strategy is included in this Final Concept of Operations for the I-15 ML toll collection system software development. The toll collection system shall record the following data for each vehicle:

1. Toll Transaction Data
   a. the time of entry
   b. the toll rate in effect at entry
   c. the place of entry into the ML
   d. every tolling location that is passed through by the vehicle, and the time of passage at each location
   e. the location and time the vehicle passes through the final tolling point for that trip

Using the data above the central processing system will be able to determine the length of the trip and the rate that was in effect at the time the vehicle passed under the entry tolling location. Using the length of the trip and the rate per mile the toll charged for the trip can then be calculated.

2. Traffic / LOS Data
   a. Travel time on the ML and general purpose lane
   b. Traffic speed
   c. Traffic volume on each managed lane

Furthermore, the entry points and tolling locations selected permit the capture of all significant vehicle movements. The ML toll collection system should also have the capability to assess a default toll rate at all or selected toll locations and at all or selected entry/exit points. The default rate would be utilized whenever there are system interruptions to the dynamic congestion pricing function (e.g., the zone controller does not have the skewed per-mile rate at the instance the transponder was read at entry).

The details of the pricing algorithm will be addressed in a separate document.

2.7 Discount Programs

The I-15 ML System will have the capability to apply discounts and provide incentives to SOV customers who are identified as having exited the ML to use the transit services. As part of future enhancements to the SANDAG operations, the system will support the linking of ML trips to transit trips and apply various incentives programs approved by SANDAG.

2.8 Vehicle Classification

All transponder equipped SOVs are charged the same toll; i.e., the tolls charged will not be based on vehicle type. As such, there is no requirement for the system to determine the vehicle type. The vehicle detection system installed at tolling locations with VES will only detect and track the vehicle and trigger the VES camera as required. Classification of a vehicle based on

occupancy (SOV, HOV or transit bus) will be done through the use of specific transponders. It is not cost effective to pursue the enforcement of vehicles prohibited on the ML electronically. Such enforcement is better suited for manual methods.

2.9 Traffic Management

In order to effectively monitor and control traffic on the planned I-15 ML, Caltrans District 11 Transportation Management Center (TMC) Operators must have the ability to view "real time" congestion data for all lanes and segments of the facility. To collect congestion data, vehicle detectors are being installed by Caltrans at strategic locations along the ML and adjacent general purpose lanes. Inductive loop detectors on the ML will collect and report vehicle location, speed, and volume to the TMC for all lanes and segments in both directions. By comparing congestion data from general purpose lanes with the data for the ML, Caltrans TMC operators can observe the performance of the I-15 corridor freeway system and make effective traffic management decisions. Such systems will be furnished and maintained by Caltrans and the I-15 ML system will use this data for its dynamic pricing algorithm.

SANDAG and Caltrans will coordinate the appropriate response to any traffic incident in the I-15 corridor that will affect I-15 ML operations. As appropriate, authority will be delegated and the capability to override the messages displayed on the ML toll signs will be provided to Caltrans, in order to reflect the message displayed (per the policies approved by SANDAG).

2.10 Violation Enforcement System

By requiring HOV users to obtain and mount transponders on their vehicles, the opportunity to enforce HOV violations (vehicles without a transponder) automatically is now introduced. To support the automated citation process, image capture, image processing, and optical character recognition (OCR) systems are required. This violation enforcement system (VES), also called the "base VES" requires the installation of cameras and lights at specific toll locations in the ML.

As a vehicle travels through the tolling locations equipped with VES, the zone controller will verify if the vehicle is equipped with a valid transponder (HOV or SOV), and determine the vehicle's transaction status. If the vehicle is deemed to be a violator, the zone controllers will request the VES to save the image of the vehicle. The vehicle image is then processed through OCR software and the license plate number is automatically extracted. Images that were not successfully extracted are reviewed manually, and the license number and state is obtained. The license plate data can also be used to determine a trip if the transponder data is not available. If the license plate data does not belong to a FasTrak or HOV customer, it is processed as a violation.

3.0 ML ACCESS ARRANGEMENTS

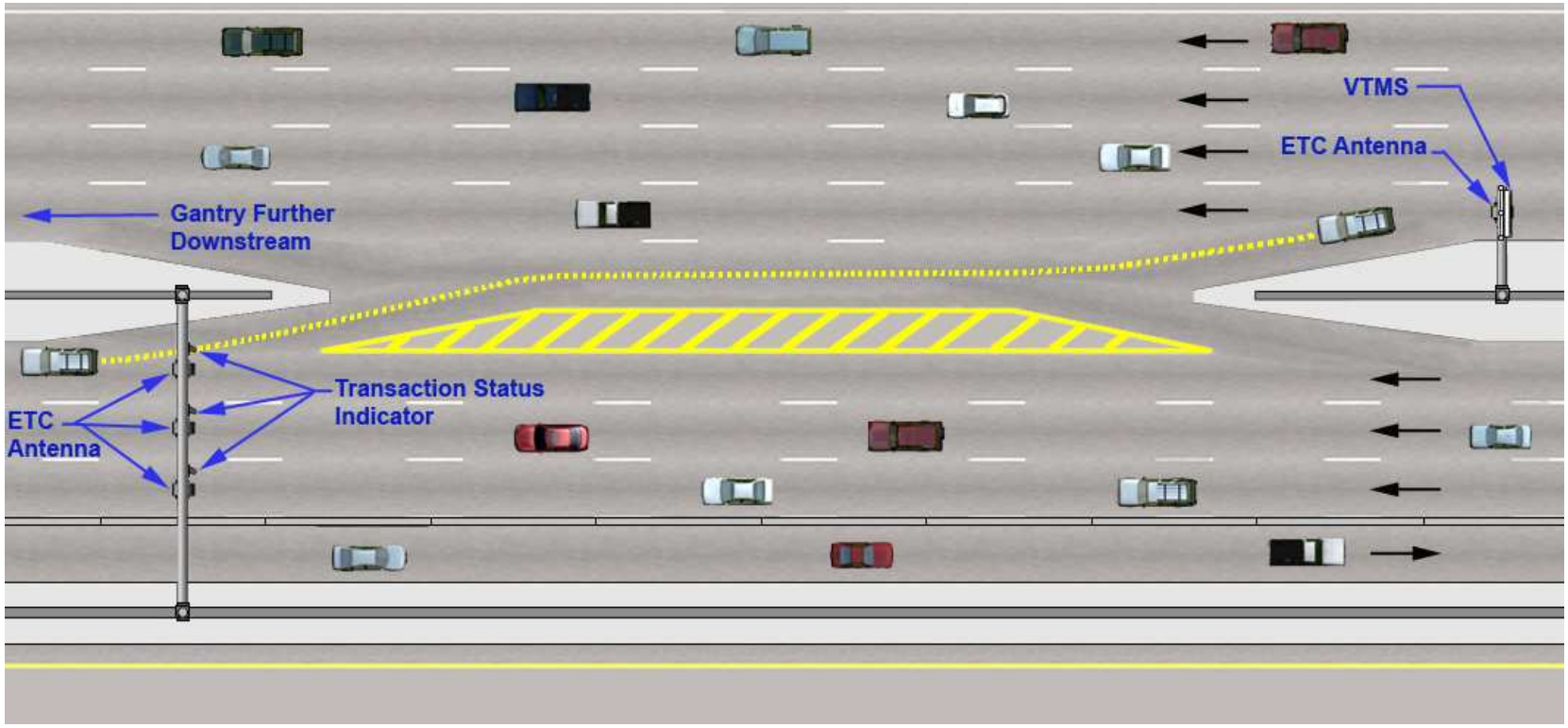
An important factor that will present a challenge in the I-15 ML toll collection system is the proposed access arrangement between the general purpose lanes and the ML. In a limited number of cases there will be DARs from local roads and the BRTCs. However, the majority of access will be by means of transition areas, as shown in Figure 3.1. A barrier wall will

separate the general purpose lanes from the ML for a majority of the ML facility. At the transition areas, there will be an opening in the barrier wall of a about one thousand five hundred (1,500) feet. It is understood that an auxiliary weaving lane will be added adjacent to the main lane in the transition area. The physical separation between the ML and the weaving lanes will be by means of paint striping only.

As shown in Figure 3.1, there will not be physically separated entry and exit lanes in each of the transition areas. Rather, the transition areas will be an opening in the barrier with striping used to delineate traffic. The location of the general purpose tolling location should be such that it gives the SOV user sufficient time to enter the ML after seeing the rate per mile displayed on the VTMS. Using the tolling location where the transponder or license plate was read the entry and exit location on the physical system can be inferred. This will allow the system to determine the trip length and calculate the toll to be charged for the user's trip.

However, given the current physical plans for the transition areas, it would not be possible to positively identify and distinguish vehicles entering and exiting, without putting some type of physical separation along either the weaving lane or in the slip ramps to and from the ML. Such information is inferred from the transponder and license plate data received from the tolling locations.

Figure 3.1 Typical Transition Area Access Arrangement



4.0 VARIABLE TOLL RATE STRUCTURE

Under any of the pricing options discussed above, a common element would be the assumed use of some type of variable pricing, adjusted dynamically based on continually measured traffic flow rates, as with the existing system. While approved plans call for measurement of I-15 ML flow as the sole determinant of price, the new pricing algorithm takes into consideration the traffic conditions in both the ML and the general purpose lanes while dynamically adjusting the per mile toll on the ML. For this reason, scaleable design is a requirement in this Final Concept of Operations to permit maximum flexibility for future changes to the variable toll rate structure.

The use of variable tolls will require the placement of VTMS located immediately prior to each of the entrance points to the ML. The VTMSs are necessary, to advise motorists of the current toll rates in effect at any given time. As noted above, it will also be critical to design into the I-15 ML toll collection system integrity that the toll rate displayed at the time a vehicle passes the entry VTMS will be the same rate that is charged for that vehicle's entire trip on the ML, even if the nominal toll rate should change while the vehicle's ML trip is in progress. In the event the system is unable to determine the exact time of entry and thus the toll rate to be charged, the lowest rate that was applicable within a reasonable period of time should be charged. This might occur, for example, in cases where the transponder did not read at entry but the system obtained subsequent transponder reads in the ML. The business rules described in this Final Concept of Operations and reviewed/updated during the system design must be considered carefully by the system in order to accurately assign the toll when ideal conditions are not met. These business rules must ensure with close to 100 percent certainty that customers are not overcharged due to system problems while also assuring that the potential for customer abuse is limited.

5.0 OVERALL PROPOSED TOLL COLLECTION SYSTEM CONCEPT

The various criteria and issues discussed above present a considerable electronic toll collection system design challenge. The 2002 WSA Concept Plan had developed a preliminary system concept which is usable with virtually any of the alternative pricing strategies under consideration. In addition, it would be designed to work with the currently planned transition from general purpose lanes to ML arrangement (i.e., without physically separate slip ramps). This section is an update of the WSA initial concept plan to include the current information available and changes in SANDAG's planned enforcement strategy. The final system involves implementation of AVI readers on both the ML and the left most general purpose lane, although only vehicles actually entering the ML would be charged a toll. With the inclusion of the base VES, some form of vehicle detection, separation, tracking and triggering system is also needed.

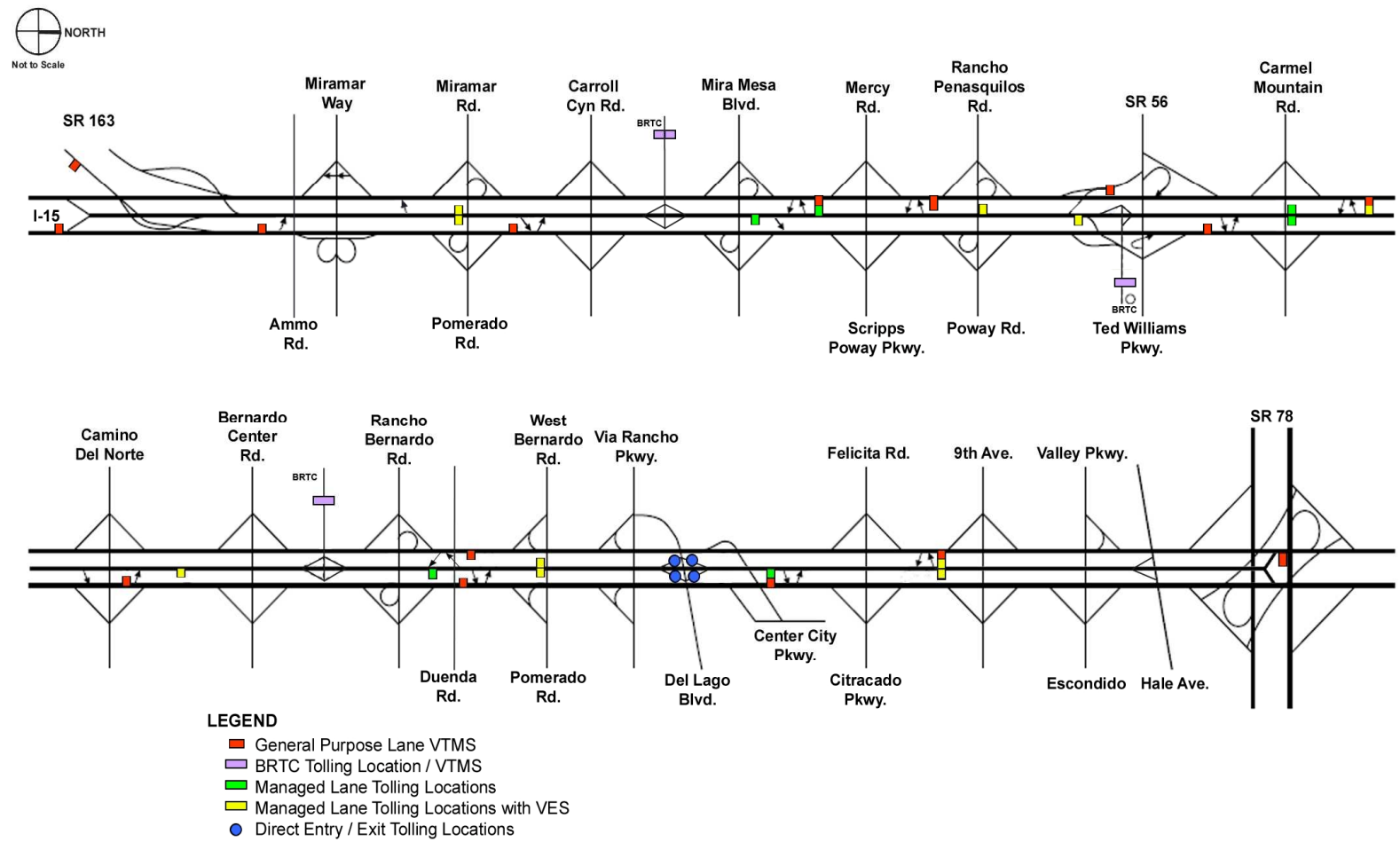
5.1 System Overview

An overview of the proposed toll collection system lane configuration and positioning, for the full build condition, is shown in Figure 5-1. Entry tolling locations will not be equipped with VES and vehicle detection system. Select tolling locations on the ML will be equipped with the base

VES and vehicle detection system. There will be five overall "tolling configurations" used in the toll collection system as listed below:

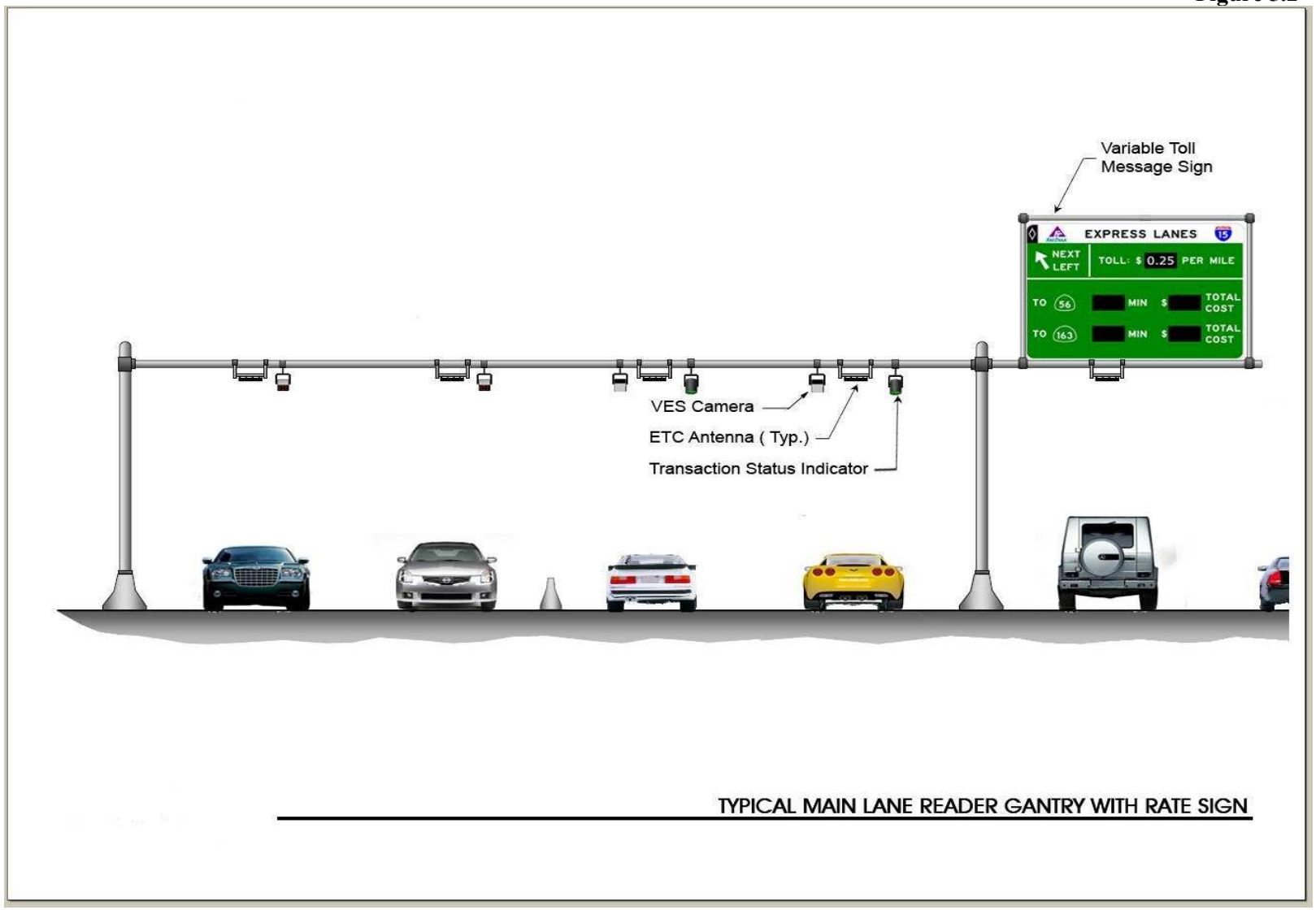
- General purpose lane entry read zones, with VTMS
- ML tolling locations with base VES
- ML tolling locations without base VES
- Direct entry/exit ramp tolling zones
- BRTC entry/exit tolling locations with VTMS

Figure 5.1 Toll Collection System Lane Configurations



The general purpose lane read zones, with VTMS, would typically be located on a gantry mounted across the left most lane immediately prior to each possible point of entry to the ML. As shown in Figure 3.1, an AVI antenna would be installed over the left most general purpose lane. A VTMS showing the current toll rate in effect, and the estimated travel time and total cost to select downstream destinations would also be mounted at this location (See Figure 5.2). Figure 5.2 represents a configuration where the ML tolling location is combined with the general purpose entry tolling location.

Figure 5.2


Variable Toll
Message Sign
EXPRESS LANES
NEXT
LEFT
TOLL: $ 0.25 PER MILE
TO 56
MIN
$
TOTAL
COST
TO 163
MIN
$
TOTAL
COST
VES Camera
ETC Antenna (Typ.)
Transaction Status Indicator
TYPICAL MAIN LANE READER GANTRY WITH RATE SIGN

The purpose of the read zones on the general purpose lanes would be two-fold:

- To advise a motorist of the current toll rate in effect immediately prior to each point of entry
- To open what might be called a "transaction envelope" for that particular transponder in the electronic toll system

The first such read for an account is considered an entry read and all other subsequent reads or license plate data for that trip is associated with this record. When the transponder is identified to have exited the ML, the system uses the data associated with entry read to create an entry/exit pair and calculates the toll to be charged for the trip based on the trip length and the rate in affect at the time the vehicle passed under an entry tolling location. In addition to the transponder number, time, date and read zone location, this "transaction envelope" would also contain the toll rate that was displayed at the time the vehicle passed under the general purpose lane gantry. This would ensure the toll rate displayed to the motorist is the same toll rate that will be applied to calculate the total cost of the trip.

A potential transaction "envelope" would be opened for all FasTrak transponder reads obtained from the AVI system installed on the left most general purpose lane, whether or not the vehicle entered the ML. Since the AVI system is installed only on the left most general purpose lane most vehicles equipped with transponders in that lane would probably enter the ML.

If the vehicle continues to proceed in the general purpose lanes without entering the ML, its transponder is read and transmitted upon passage through the next downstream general purpose read point. When the central processing system receives the second entry transaction data for this transponder it can be inferred that the vehicle did not enter the ML at a prior entry location. At this time a new "transaction envelope" is opened with the current toll rate in affect at that location and the first entry read is disregarded. If no other reads or license plate data are obtained for that transponder in the ML, and a configurable amount of time has lapsed, the transponder record is retired as 'not having entered the ML'. No toll transaction would be generated since the vehicle did not enter the ML; the entire process would be completely transparent to the motorists.

If the central processing system obtains multiple entry transactions for a transponder and it also has ML transaction data (either a transponder read or license plate) then it is presumed that the customer is weaving in and out of the ML and the tolls will be charged per entry-exit combination. This would include charging of the minimum toll per trip or per-mile, whichever is in effect, for each entry-exit pair recorded.

Given the inherent reflective nature of an RF read zone, it is possible that a vehicle with a transponder traveling the ML could be read at the adjacent general purpose entry lane. Such extraneous reads will be flagged when the central processing system performs the entry/exit matching and such reads will not be used.

It is also possible that vehicles with transponders traveling in the general purpose lanes could be read by the ML tolling locations. However, the ML tolling location and the general purpose tolling location can be co-located to minimize the possibility of this occurring. Additionally, the

RF read zones at the ML tolling locations can be optimized such that transponder reads from vehicles traveling in the general purpose lane are reduced.

If desired, the reading of a transponder at consecutive general purpose lane read zones could be used as probes to compute traffic speeds and travel times in the general purpose lanes for traffic management purposes and, if a sufficient sample size exists, to calculate the value of travel time savings between the general purpose lanes and ML. However, this would be totally transparent to the user and would in no way result in a toll charge, nor would any information about the identity of the user be retained.

If, on the other hand, the vehicle passes a general purpose read zone, and a "transaction envelope" is opened, and then the vehicle enters the ML, it would pass beneath a series of ML tolling locations, generally one tolling location per segment of the ML. A tolling location passage "event" would be electronically identified either through the reading of a transponder or through the capture of a license plate, and assigned to the appropriate "transaction envelope" in the system. The transaction envelope would contain the last toll rate in effect when the vehicle entered the ML. Once the vehicle is identified to have exited the ML, the entry/exit point is determined, and the toll is calculated for the trip length using the toll rate that was in effect upon entry, regardless of how many times the toll rate may have changed while the vehicle was in the lane.

Since the tolling location at which the vehicle exited the ML is critical to determining the trip length, the confirmation that the vehicle left the ML needs to be performed accurately. Data obtained from the base VES will be used to substitute for missed transponder reads to accurately determine the entry and exit locations. If a vehicle exits the ML before the last exit, then optical character recognition (OCR) or manual license plate review needs to be completed to confirm that a transponder read was not missed at the last tolling location. If a transponder read was missed and the system did not wait for the completion of the license plate review, then the entry transponder read will be matched with the previous transponder read and the trip length will be inaccurately calculated.

If the system only obtained transponder reads or license plate data from the ML tolling locations, but no transponder read on the general-purpose, then the system will have to estimate the possible entry location and time of entry using the transponder read or license plate data obtained from the first ML tolling location. Table 5.1 lists some of the possible entry exit combinations and the Business Rules that have to be applied while calculating the toll charged for the trip.

5.2 Business Rules for Calculation of Toll

During the design of the ML toll collection system, business rules will be established to ensure that all scenarios of vehicle entry/exit can be handled by the system. Depending on the scenarios created when the SOV customer travels through the left most lane of the general purpose lanes at the entry locations and the ML, various rules needs to be applied to ensure that the customer is given a fair assessment and that the customer does not abuse the system. Since the toll collection equipment could be upstream or downstream of the actual exit, the actual exit of the vehicle is inferred from the transponder/license plate data obtained from the tolling locations.

Table 5.1 identifies some of the common scenarios we can expect to see on the ML System, and

the handling of these scenarios is described below. During the system design these scenarios will be further explored and documented.

1. Scenario 1: The entry location (Entry 1) obtained from the transponder read is matched to the exit location (Entry 1/TLn) upon receipt of the transponder read from the last tolling location on the ML (MLTn).
2. Scenario 2: The entry location (Entry 1) obtained from the transponder read is matched to an exit location (Entry 1/TL3) using the tolling location TL3 transponder read after it is confirmed that there is no transponder read or license plate data from the last tolling location.
3. Scenario 3: The entry location (Entry 1) obtained from the transponder read is matched to the last exit location (Entry 1/TLn) using the license plate data from the last tolling location (MLTn).
4. Scenario 4: The entry read (Entry 1) is flagged as "not having entered the ML" after it is confirmed that there are no ML reads or license plate data for that transponder and the transponder read is discarded.
5. Scenario 5: From the transponder read at a ML tolling location MTL1, the vehicle entry (Entry 1) is inferred and matched to the exit location (Entry 1/TLn) upon receipt of the transponder read from the last tolling location on the ML (MTLn).
6. Scenario 6: From the license plate data obtained from the ML tolling location MTL2, the vehicle entry (Entry 2) is inferred and matched to the exit location (Entry 2/TLn) upon receipt of the transponder read from the last tolling location on the ML (MLTn).
7. Scenario 7: From the transponder read at a ML tolling location MTL1, the vehicle entry (Entry 1) is inferred and matched to the an exit location (Entry 1/TL3) using the tolling location MTL3 transponder read after it is confirmed that there is no transponder read or license plate data from the last tolling location.
8. Scenario 8: From the transponder read at a ML tolling location MTL1, the vehicle entry (Entry 1) is inferred and matched to an exit location Entry 1/TL2) using the license plate data from tolling location MTL2 after it is confirmed that there is no transponder read or license plate data from the other tolling locations.
9. Scenario 9: From the license plate data obtained from a ML tolling location MLT2, the vehicle entry (Entry 2) is inferred and matched to the last exit location (Entry 2/TLn) using the license plate data from the last tolling location on the ML (MLTn).
10. Scenario 10: If only the transponder read from the last tolling location (MLTn) on the ML is obtained, then the entry is inferred (Entry n-1) and matched to the last exit location (Entry n-1/MLTn) after it is confirmed that there is no other read or license plate data.
11. Scenario 11: If only the license plate data from the last tolling location on the ML is obtained, then the entry is inferred (Entry n-1) and matched to the last exit location (Entry n-1/MLTn) after it is confirmed that there is no other read or license plate data.

Table 5.1: Entry/Exit Scenarios

Item #	Entry 1	ML Inter. TL 1	ML Inter. TL 2	ML Inter. TL 3	Last ML TL n	Action	Result
1.	Transponder Read	Transponder Read	Transponder Read	Transponder Read	Transponder Read	Scenario 1	Entry1/TL n
2.	Transponder Read		Transponder Read		Transponder Read	Scenario 1	Entry1/TL n
3.	Transponder Read		License Plate		Transponder Read	Scenario 1	Entry1/TL n
4.	Transponder Read	Transponder Read	Transponder Read	Transponder Read		Scenario 2	Entry1/TL 3
5.	Transponder Read		License Plate	Transponder Read		Scenario 2	Entry1/TL 3
6.	Transponder Read	Transponder Read	Transponder Read		License Plate	Scenario 3	Entry1/TL n
7.	Transponder Read				License Plate	Scenario 3	Entry1/TL n
8.	Transponder Read					Scenario 4	Vehicle Did Not Enter ML
9.		Transponder Read	Transponder Read	Transponder Read	Transponder Read	Scenario 5	Entry1/TL n
10.			License Plate		Transponder Read	Scenario 6	Entry 2/TL n
11.		Transponder Read	Transponder Read	Transponder Read		Scenario 7	Entry 1/TL 3
12.		Transponder Read	License Plate			Scenario 8	Entry 1/TL 2
13.			License Plate		License Plate	Scenario 9	Entry 2/ TL n
14.					Transponder Read	Scenario 10	Entry n-1/TL n
15.					License Plate	Scenario 11	Entry n-1/TL n

Inter.	Intermediate
TL	Tolling Location
	Tolling Location with VES
	Entry/Exit Match
	Entry/Exit Match

5.3 BRTC Toll Collection Signage

Special tolling zones with rate signs would be provided at direct access points to and from BRTCs. This would be intended to at least permit the possibility of some type of joint pricing strategy. For example, SANDAG policy might permit discounts or other incentive programs for usage of the ML for vehicles which then proceed directly into BRTCs, as an incentive for modal transfer or carpooling. By having separate tolling zones on these direct access roadways, it would be possible to identify vehicles entering or leaving the BRTCs, which could entitle the customer to a reduced rate for ML travel.

5.4 Communications Network

The entire system will be connected by a fiber optic backbone along the full-length of the ML Project. There will be three major hubs, one at University Avenue, one at Saber Springs, and one at Escondido. In addition, six minor hubs are planned; one each at El Cajon Blvd., Mission San Diego, Balboa Ave., Mira Mesa, Rancho Bernado, and Del Lago. Each minor hub will have a primary and secondary connection to a major hub. Each of the tolling locations will have a primary and secondary connection to a minor hub. The fiber network is shown in Figure 5.3a

At the south end, the fiber will terminate at the SANDAG Imperial Avenue Division (IAD), and at the north end it would terminate at Hale Avenue/Sprinter. Depending on the location of the Customer Service Center (CSC), and the ML back-office location (or redundant site), a fiber connection to the network may be possible from these locations. If not, there would be a dedicated leased line from the SANDAG IAD to the CSC location and the ML back-office location (or redundant site). The SANDAG Headquarters at 401 B Street will have a connection to this network.

The ML toll collection communications network would integrate all zone controllers and its sub-systems (the AVI System, the AVDS, the VES and the VTMS) on a real-time basis, with the central processing system. The ML toll collection system network architecture is shown in Figure 5.3b

Figure 5.3a: Bus Rapid Transit (BRT) Network Architecture

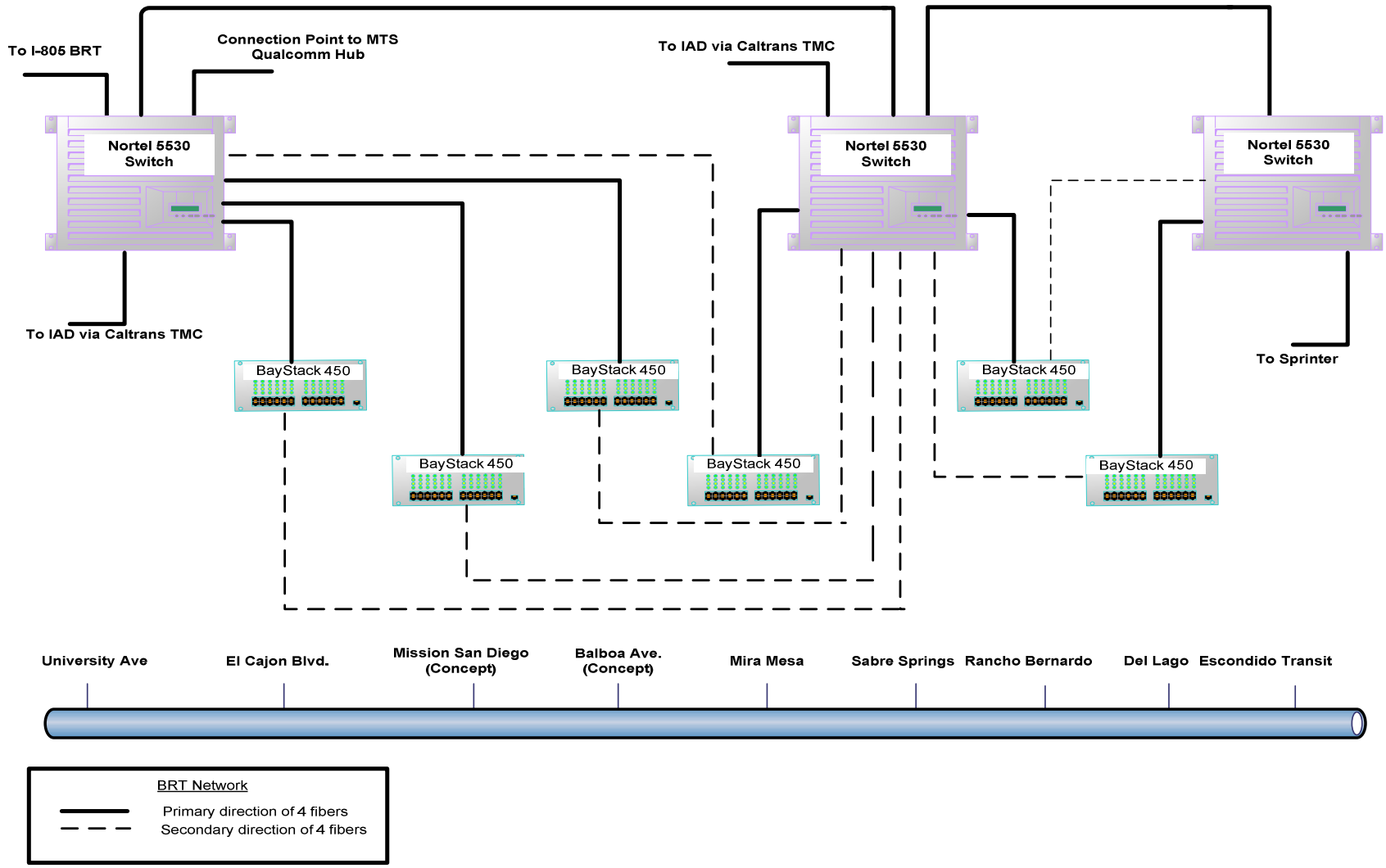
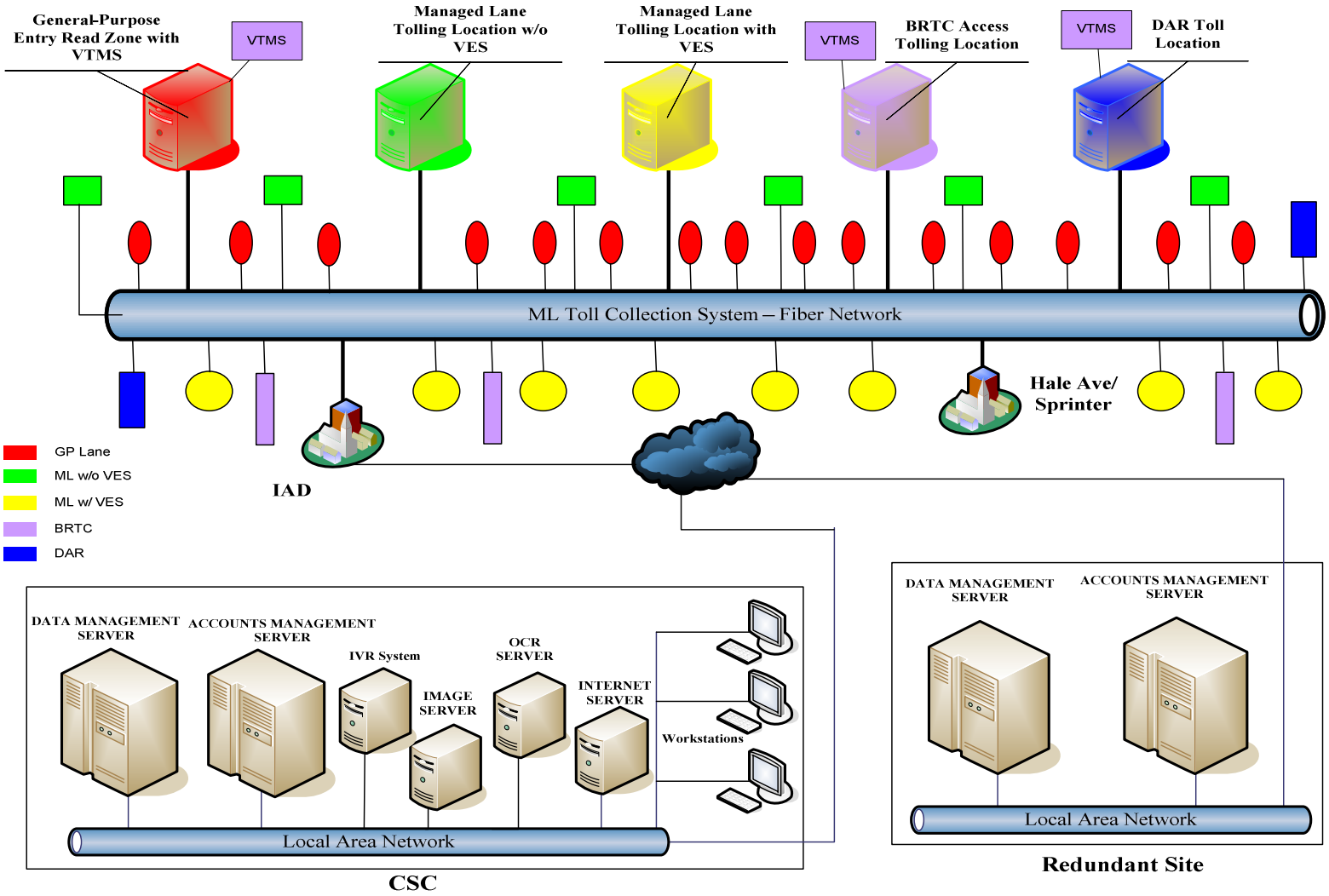


Figure 5.3b: ML Toll Collection System Network Architecture



5.5 Toll Collection System Configurations

As noted previously, there are five tolling configurations for the I-15 ML. Table 5.2 shows all the tolling locations, the type of gantry structure needed to support the toll collection system at that location and the phasing of these tolling locations.

Table 5.2: Location of the Five Tolling Configurations

I-15 MANAGED LANES ELECTRONIC TOLL COLLECTION SYSTEM (ECTS) SUBSYSTEM COMPONENTS

	Lane Type[1]	Location	Station #	No. of Lanes	Lane Controllers	AVI System	VES	VTMS	Gantry Type
Stage 3	GP	I-15 NB Before Ammo Road	206	1	1	1	0	1	SPC
	GP	Miramar Rd. NB	245	1	1	1	0	1	SPC
	BRTC	Mira Mesa BRTC	262+20	3	1	3	0	2	FSp
	ML	Mira Mesa Blvd/Mercy Rd. NB	275	3	1	3	0	0	B
	GP	Mercy Rd. SB	285+20	1	1	1	0	1	FSp/SPC - C
	ML	Mercy Rd./Mira Mesa Blvd SB	285+20	3	1	3	0	0	
	GP	Rancho PQ Rd. SB	298	1	1	1	0	1	SPC
	ML	Rancho PQ Rd SB	303	3	1	3	3 SB	0	B
STAGE 1	GP	I-15 NB entrance	185+00	1	1	1	0	1	SPC
	GP	SR-163 NB entrance	196	1	1	1	0	1	SPC
	ML	Miramar Rd.	240	6	2	6	6 NB/SB	0	B
	ML	Rancho PQ Rd./Ted William Pkwy NB	315	3	1	3	3 NB	0	FSp
	GP	SR-56 SB C-D Rd	318	1	1	1	0	1	SPC
	BRTC	Sabre Springs BRTC	322	2	1	2	0	2	FSp
	GP	SR-56/Ted Williams Pkwy NB	328+40	1	1	1	0	1	SPC
	ML	Carmel Mtn Rd	341+60	6	2	6	0	0	B
	GP	Camino del Norte SB	360	1	1	1	0	1	FSp/SPC - C
	ML	Camino del Norte SB	360	3	1	3	3 NB	0	
	GP	Camino del Norte NB	365	1	1	1	0	1	SPC
	ML	Camino del Norte/Bernardo Center Rd.	375	3	1	3	3 SB	0	FSp
	BRTC	Rancho Bernardo BRTC	384+40	4	1	4	0	2	FSp
	ML	Rancho Bernardo Rd & Duenda	397	3	1	3	0	0	FSp

I-15 MANAGED LANES ELECTRONIC TOLL COLLECTION SYSTEM (ECTS) SUBSYSTEM COMPONENTS

	Lane Type[1]	Location	Station #	No. of Lanes	Lane Controllers	AVI System	VES	VTMS	Gantry Type
		Rd NB							
	GP	West Bernardo Rd. SB	408	1	1	1	0	1	SPC
	GP	Duenda Rd NB	411	1	1	1	0	1	SPC
	ML	West Bernardo Rd.	429	6	2	6	6 NB/SB	0	B
	DAR	Del Lago South Side	446	4	1	4	0	2	FSp
	DAR	Del Lago North Side	451	4	1	4	0	2	FSp
STAGE 2	GP	Centre City Pkwy NB	472	1	1	1	0	1	SPC/SPC - C
	ML	Centre City Pkwy NB	472	3	1	3	0	0	
	GP	9th Ave.SB	494	1	1	1	0	1	SPC/SPC - C
	ML	9th Ave.	494	4	2	4	4 NB/SB	0	
	GP	SR-78 SB	520	1	1	1	0	1	SPC
	Total			78	36	78	28	25	

Table of Abbreviations

GP	Left Most General Purpose	Northbound	NB	G	Gantry	FSp	Full Span
ML	Managed Lanes	Southbound	SB	B	Bridge	SPC	Single Post Cantilevered
DAR	Direct access ramps			C	Combined	VMT	Variable Message Toll Sign
BRTC	Bus rapid transit center					ETC	Electronic Toll Collection Reader
C-D	Collector - Distributor road						

The five tolling configurations are described briefly below:

5.5.1 General purpose Entry Read Zone with VTMS

As discussed above and shown previously in Figure 5.2, the general purpose entry read zone would span the left most lane on the general purpose lanes only, just prior to each of the ML transitional access areas. There are fifteen (15) general purpose entry read zones with VTMS in total on the I-15 ML, with eight (8) general purpose entry read zones with VTMS in the northbound direction, and seven (7) general purpose entry read zones with VTMS in the southbound direction. These lane configurations will be outfitted with an AVI antenna and reader; the antenna will be affixed to the support structure that suspends from the steel gantry span overhead the inside shoulder area and the left most general purpose lane. A VTMS would also be installed in this area, mounted to the front, left side of the gantry structure. The intent is to both read transponders on vehicles driving in the left most general purpose lane, and to display the current per-mile toll rate for that location at that time, directly in advance of the entrance to the ML. Also displayed would be the estimated travel time and total cost from that point to two downstream locations as shown in Figure 5.2b.

The general purpose read zone will not have the base VES installed since not all vehicles on the left most lane will enter the ML. Additionally, once a vehicle has entered the ML the vehicle will have to pass through at least one ML tolling location prior to exiting the ML facility. If the vehicle has no transponder, then an image will be captured at that time and processed if the tolling location is equipped with VES. It is intended that most vehicles will pass at least one tolling location equipped with VES.

Vehicle transponder reads passing under a general purpose entry read zone gantry would be used only to open or close “transaction envelopes”; no actual toll transaction will be developed unless the vehicle enters the ML and passes through one of the subsequent ML tolling locations.

5.5.2 ML Tolling Locations with Base VES

With all vehicles required to have transponders, it is possible to enforce HOV violations through an automated citation process. Selected ML tolling locations will be equipped with violation enforcement cameras and automatic vehicle detection equipment, along with the AVI system. There are ten (10) ML tolling locations with VES in total on the I-15 ML, with five (5) ML tolling locations with VES in the northbound direction, and five (5) ML tolling locations with VES in the southbound direction. License plate images of vehicles will be captured on the ML for any trip without a valid transponder read, and will be transmitted to the back-office for further processing. To assist the CHP officer monitor the vehicles and pursue HOV violators, license plate images of all vehicle will be transmitted to the CHP PDA.

Figures 5.4a and 5.5a show typical ML tolling locations with base VES on gantry and bridge-mount support structures, respectively. Figure 5.4a would be a freestanding, gantry-type. The gantry would be constructed from barrier wall to barrier wall across the

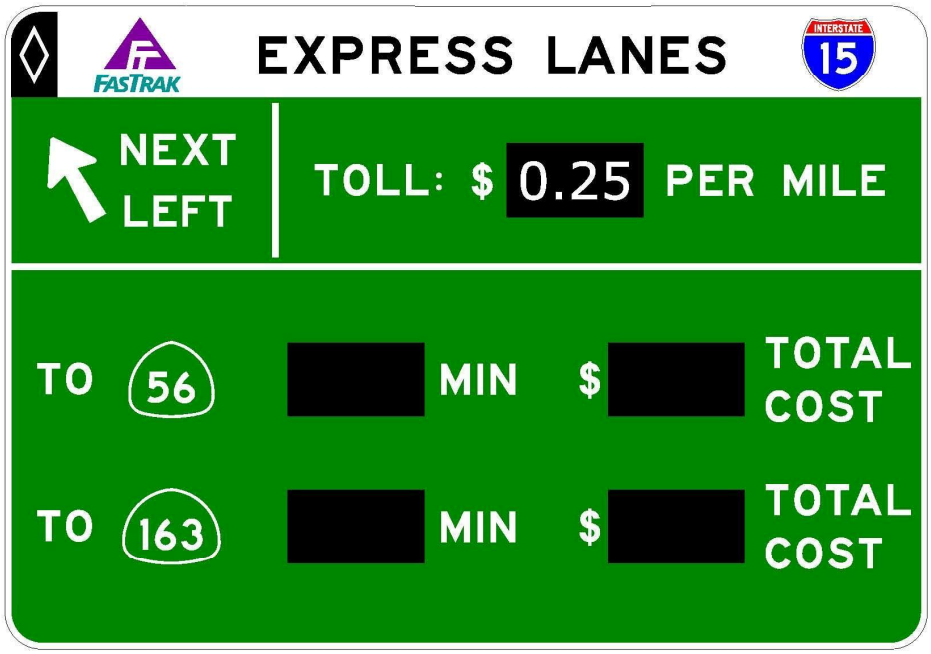
ML. If loops are used as the vehicle detection equipment, then a single gantry structure will support the system requirements. Loop installation has guidelines for the pavement surface that need to be considered in order to meet the system requirements. Additionally the loop system design needs to take into consideration the physical requirements, including loops of the moveable barrier machine. In some cases, the gantry structure would serve both travel directions, but in many cases it would serve only a single travel direction.

Sufficient antennas, automatic vehicle detectors and violation enforcement cameras will be provided to cover all four lanes. On the two lanes that can be operated as reversible lanes two sets of antennas, cameras and automatic vehicle detection equipment will be required to support the ML electronic toll collection system requirements.

Wherever possible, it may be desirable to mount the ML tolling location equipment on existing structures, such as bridge overpasses. An example of this is shown in Figure 5.5a. Several of the proposed tolling locations have been identified as capable of being "bridge mounted." It is critical that all installations meet the minimum clearing requirements for the bridges. Based on the location of these toll locations, additional lighting may be required for the VES cameras to obtain high quality images that will meet the system OCR requirements.

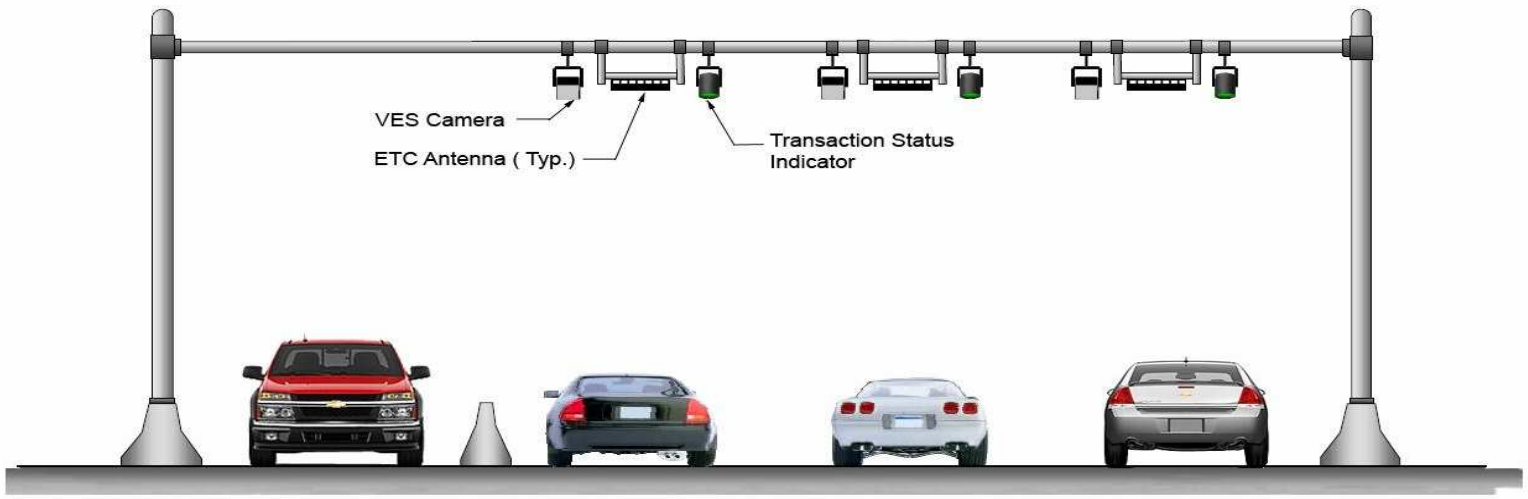
At the northern end of the ML, a vertical post with counter-balanced cantilevered horizontal arms will be used, since a fixed barrier is proposed in the center of the ML. At this location, there would be no physical barrier wall between the ML and the general purpose lanes in each travel direction. Rather, the toll collection equipment would need to be mounted in the center median barrier, as shown in Figure 5.6a.

General Purpose Entry VTMS



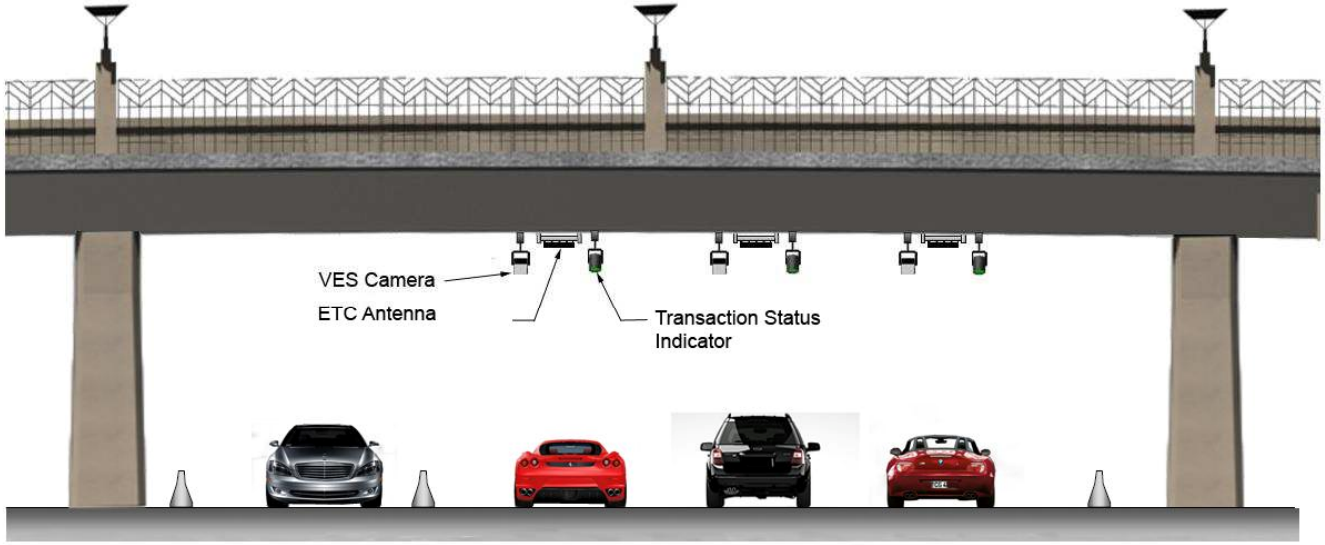
25' wide x 17'-6" tall

Figure 5.2b



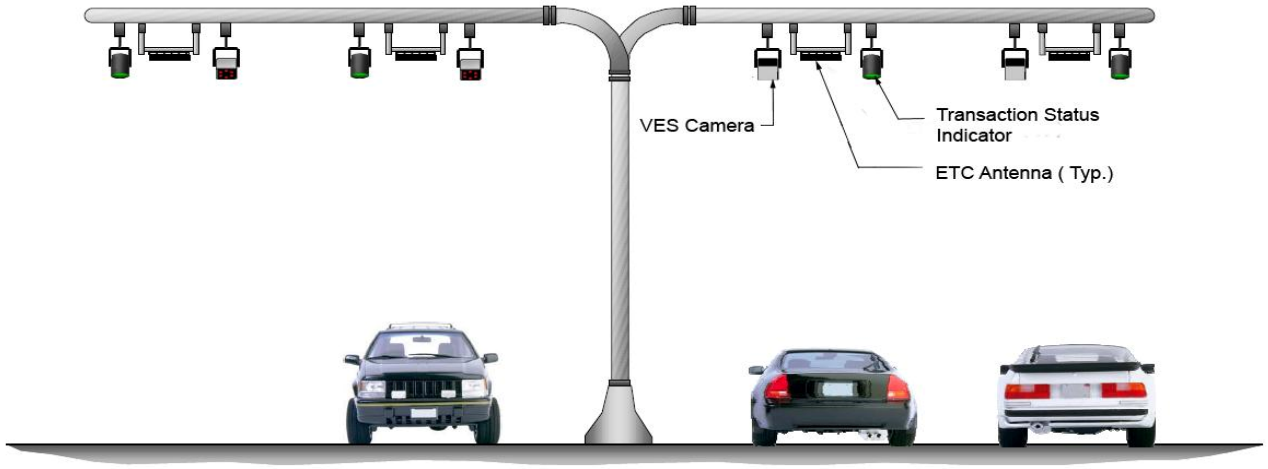
TYPICAL MANAGED LANES TOLLING ZONE (with VES) - GANTRY TYPE

Figure 5.4a



TYPICAL MANAGED LANES TOLLING ZONE (with VES) - BRIDGE MOUNT

Figure 5.5a



TYPICAL MANAGED LANES TOLLING ZONE (with VES) - CANTILEVERED GANTRY TYPE

Figure 5.6a

5.5.3 ML Tolling Locations without Base VES

Not all of the ML tolling locations need to be equipped with the base VES. In certain locations only the AVI system is required and this can be supported by a single gantry as shown in Figures 5.4b, 5.5b, and 5.6b. There are six (6) ML tolling locations without base VES in total on the I-15 ML, with four (4) ML tolling locations without base VES in the northbound direction and two (2) ML tolling locations without base VES in the southbound direction. At these locations the system will report the transponder read information only.

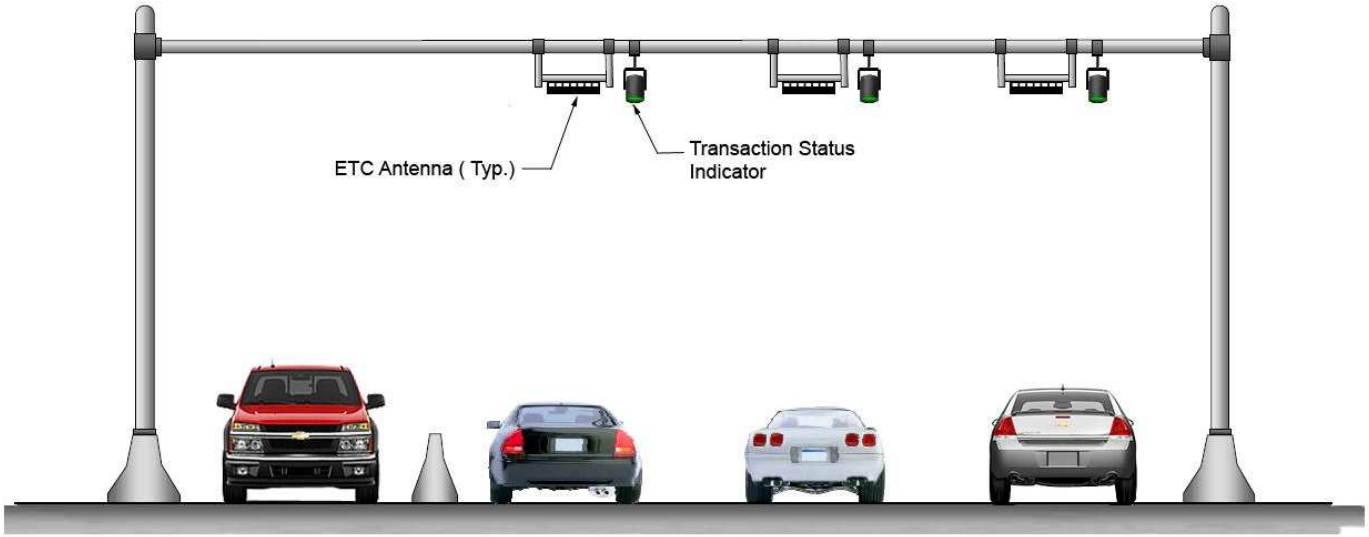
5.5.4 Direct Entry Ramp Tolling Location

At select locations in the ML, direct access ramps (DAR) will span the general purpose lanes and connect the ML with the local street network or descend directly into a bus rapid transit center (BRTC)/park-and-ride lot. There will be tolling locations on the DARs for additional entry and exit AVI reads besides those located within the ML. There are two direct entry tolling locations in total on the I-15 ML which are located on both sides of Del Lago Blvd. Each direct access tolling location reads transponders from vehicles entering and exiting the ML. A two-directional (NB/SB) entry VTMS will be installed directly on the ML entry side of the BRTC at the furthest point on the local access road before a motorist could turn around without entering the ML. The typical DAR tolling location is a relatively simple configuration as shown in Figure 5.4b. At such locations the system would only report the transponder read information. From a transaction processing perspective, the central processing system will treat this as an entry or exit transaction.

5.5.5 BRTC Access Toll Location

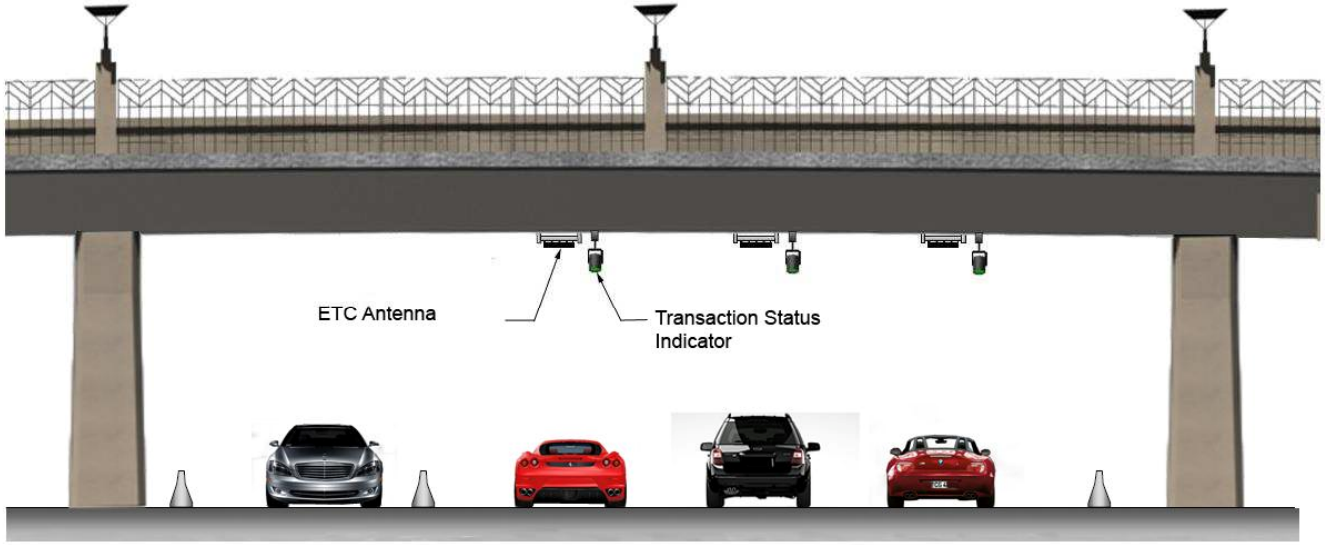
There are five proposed BRTCs in the I-15 ML corridor. At these BTRCs there will be dedicated roadway access between the ML and the BRTC station. There will be tolling locations at specified BRTCs to obtain AVI reads from vehicles entering or exiting the ML at a BRTC. A two-directional (NB/SB) entry VTMS will be installed directly on the ML entry side of the BRTC at the furthest point on the local access road before a motorist could turn around without entering the ML. Depending on the location of the tolling location, the VTMS sign would be mounted to a gantry that has AVI antennas or it could be mounted on a separate gantry. Figure 5.7 depicts a typical two-way VTMS sign that would be installed on the local access roads.

Tolling equipment would be mounted on a gantry similar to one shown in Figure 5.4b or 5.6b. At such locations the system would only report the transponder read information, including the rate that was displayed to the motorist upon entry. From a transaction processing perspective, the central processing system will treat this as an entry or exit transaction.



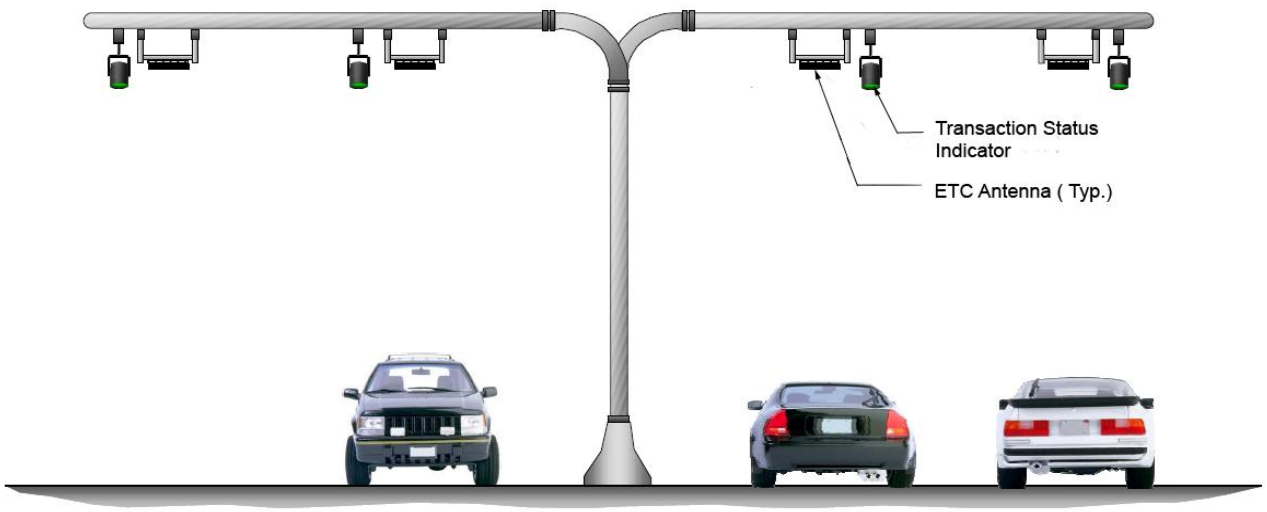
TYPICAL MANAGED LANES TOLLING ZONE - GANTRY TYPE

Figure 5.4b



TYPICAL MANAGED LANES TOLLING ZONE - BRIDGE MOUNT

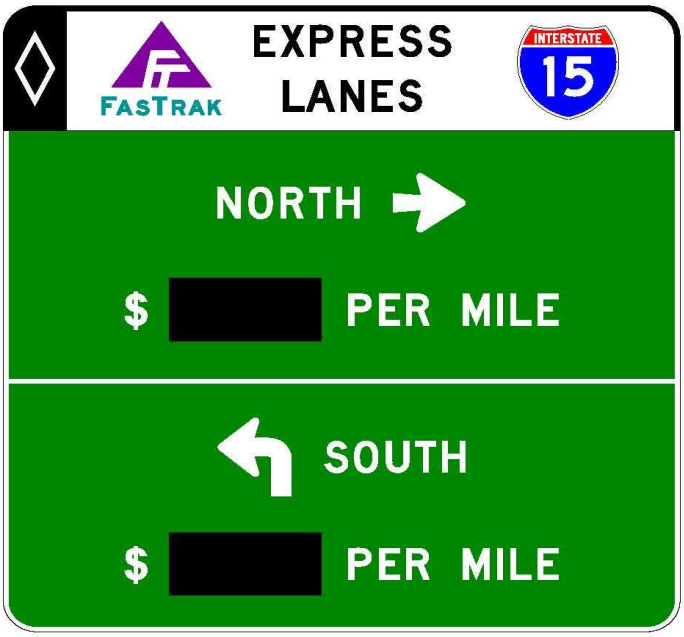
Figure 5.5b



TYPICAL MANAGED LANES TOLLING ZONE - CANTILEVERED GANTRY TYPE

Figure 5.6b

Figure 5.7



BRTC Ground Mounted Sign
Option 2
10'-0" H x 10'-0" W

6.0 TOLL COLLECTION SUBSYSTEM

The I-15 ML toll collection system is comprised of the following subsystems:

- Variable Toll Message Signs (VTMS)
- Automatic Vehicle Identification (AVI) System
- Automatic Vehicle Detection System (AVDS)
- Reversible Lane Detectors
- Transaction Status Indicator
- Violation Enforcement System (VES)
- Zone Controllers
- Central Processing System
    - Data Management Server
    - Accounts Management Server
    - Interactive Voice Response (IVR) System
    - Internet Server
- Communications Network

Workstations will be available at various locations to access the system and support customer service and system maintenance. Redundancy will be provided in the system to ensure that failure of a critical subsystem does not put the toll collection system out of service. All the field elements will be connected over a high-speed fiber optic backbone to the IAD and all local areas communications will be at 100Mbps or greater. The CSC will be connected to the IAD through a dedicated leased line if no fiber connection is available. There will also be a fiber or dedicated leased line connection to the redundant server site which could be the back-office location if it is not the same as the CSC location. The bandwidth of the leased line will take into consideration the images transferred to the back-office for processing.

All data transmissions will employee a guaranteed message protocol wherein the receiving entity will acknowledge the receipt of a message. Each entity that is transmitting the data will retry message transmission if the receiving entity is not communicating at the time of data transmission. Checks will be instituted in the system to ensure that no data is lost and the required data reached the recipient.

Equipment enclosures for the various sub-system controllers, power, and communications systems will be located close to the tolling locations, typically along the inside shoulder of the ML and will be protected from oncoming traffic to provide easy and safe access to the equipment in the event of maintenance. At the BRTCs, all toll collection system equipment will be installed in the BTRC control room.

6.1 Variable Toll Message Sign (VTMS)

The VTMS will be installed at all locations where customers can enter the ML as described and illustrated above. The signs will be a hybrid of static sections and variable sections. The variable section will be full matrix LED with multi-line capability that will support dynamic changes to the messages. The VTMS can be connected to the network and programmed in several ways:

- Locally by infra-red wireless keyboard
- Connecting the VTMS directly to a PC via serial or USB ports

- Through the WAN/LAN from centralized location

The message displayed on the VTMS will be controlled by the zone controller for that location. When the central processing computer determines that a rate change is required or the travel time has changed, it will transmit the information to the zone controller which will then initiate a change in the VTMS. An acknowledgement of this change will confirm the correct message is displayed on the VTMS.

Loss or failure of the VTMS will be detected by the zone controller and reported to the central processing system.

6.2 Automatic Vehicle Identification (AVI) System

The AVI system will be installed at all tolling locations to read transponders mounted on vehicles potentially entering the ML, and vehicles driving through the ML. The AVI system will be Title 21 compliant and will read all FasTrak and HOV transponders. The AVI system will consist of antennas with transceivers mounted on the gantry structure, RF modules located at the road-side and AVI readers installed within the zone controller. Based on the communications requirements between the AVI reader and the antennas there may be some distance constraints in the location of the AVI reader. As the vehicle passes under the antenna (AVI read zone), it interrogates the transponder and reports the transponder data to the zone controllers.

The AVI system will synchronize its time with the local zone controller. The AVI system will be capable of performing diagnostics and reporting its health to the zone controller. Loss of communication to any element of the AVI system will be detected and reported.

6.3 Automatic Vehicle Detection System (AVDS)

At tolling locations with the base VES, an AVDS will be installed to detect, separate, and report vehicles, and trigger the violation cameras. The AVDS will have the added responsibility of ensuring that sufficient data is transmitted to the zone controllers so that transponder reads are assigned to the correct vehicle. At tolling location with base VES, the AVDS can also be used to determine the direction of travel when the moveable barriers are re-arranged to allow for a change the direction of travel.

The zone controller will take traffic measurements (traffic count and speed) using the AVDS and this data will be forwarded to the central processing system. Traffic flow in the managed lanes may be reversed so traffic measurements will be directional. The measurements and the computation of charging rate adjustments will be addressed in a separate document.

The AVDS will be capable of performing diagnostics and reporting its health to the zone controller.

6.4 Reversible Lane Detectors

At the tolling locations without base VES, standard traffic loops or alternative sensors will be installed on the two lanes that support traffic flow in both directions to determine the direction of traffic.

6.5 Transaction Status Indicator

At all tolling locations within the ML, overhead signals/feedback indicators will be installed to indicate the transponder read status to law enforcement personnel that may be patrolling the ML. An LED light array is suggested for displaying the transaction status. For example:

- GREEN light for valid SOV transponder read
- AMBER for HOV transponder read
- BLUE for invalid transponder read and no transponder read.

The transaction status indicator also serves as a deterrent to potential violators.

6.6 Violation Enforcement System (VES)

At specific tolling locations within the ML the violation enforcement system (Base VES) will be installed to capture and process license plate images of vehicles traveling through the ML without a transponder. The VES consists of the following components:

- Rear cameras and lighting components
- VES controller supporting (one of several cameras)
- Image Server/OCR Server

License plate images of vehicles identified by the zone controller to be in violation (did not obtain a transponder read) will be processed by the base VES controller and transmitted to the image processor where an OCR will be performed to obtain the license plate number. If vehicles considered in violation are to be pursued, some level of manual review will also be required to obtain the license plate number and state, and verify OCR accuracy. The license plate numbers are then processed through the account management server for possible plate posting, i.e., converting the violation to a toll transaction if the vehicle license plate is verified to belong to a customer. This data is also used by the data management server to complete trip history for a customer who entered the ML in the event the transponder failed to read or there was no transponder data.

All computers required to support the base VES functionality will synchronize its time either with the local zone controller or the central processing system as appropriate. The base VES will be capable of performing diagnostics and reporting its health to the zone controller or the central processing system. Loss of communication to any element of the base VES will be detected and reported.

6.7 Zone Controllers

The zone controllers located at each of the tolling locations process all the data obtained from the other subsystems within that zone to generate a transaction record for each vehicle passage under the tolling gantry. The zone controller:

- Maintains the transponder list used to validate the status of a transponder and based on the status trigger the appropriate customer feedback light
- Controls the toll data, travel time and message displayed on the VTMS

- Obtains the toll data, travel time and variable sign messages from the central processing system
- Uses the data obtained from the AVDS to assign the transponder read to the correct vehicle
- Notifies the VES to capture and process vehicle license plate image if no transponder read is obtained from a vehicle
- Controls the light status on the transaction status indicator based on the status of the vehicle transaction
- Transmits the transaction record with vehicle detection data, transponder data toll rate data, and all other pertinent information regarding the vehicle to the central processing system
- Transmits to the central processing system all alarm messages relating to the health of each subsystem

The zone controllers will be implemented with redundancy that will ensure that failure of one zone controller does not affect the collection of toll data at that tolling location. The zone controllers will be built with sufficient storage to buffer seven days of transaction and alarm messages in the event communication between the zone controller and the central processing system is down.

The zone controller will be capable of monitoring its health and performing diagnostics checks. All alerts and failures will be reported to the central processing system for further action including maintenance paging and resolution.

6.8 Central Processing System

The ML toll collection will be administered and controlled by a central processing system as shown in Figure 5.3b. This computer system will consist of a number of servers as described below:

- Data Management Server that will:
    - Communicate with all the zone controllers in receiving transaction and alarm messages and transmitting transponder and plate status lists
    - Communicate with the zone controllers to transmit pricing changes, travel times and message data
    - Perform the trip determination and calculate the toll charged for the trip.
    - Interface with the SANDAG Intermodal Transportation Management System (IMTMS) to obtain traffic and travel time data from the general purpose lanes and the I-15 ML
    - Compute the levels of service on the I-15 ML and compute dynamically the varying toll rate per the dynamic pricing algorithm
    - Interface with the account management server and the image server to make sure license plate data related to an account is obtained to match missing trip data (transponder read)
    - Perform maintenance management functions of the system including alarm notification and tracking, equipment inventory, maintenance history and other maintenance related functions

- Provide traffic measurement data to the IMTMS, and in a variety of ad hoc traffic toll reports
- Provide various management reports that assess the operational performance of the system
- Be responsible for synchronizing time to a reliable source and ensure other subsystems are time synchronized with the same time

This server will be a fail-safe design or will incorporate a redundant configuration to minimize downtime.

- Accounts Management Server that will:

  - Provide an interface that allows both CSC staff and customers directly manage the FasTrak™ accounts including capability to create new accounts, close accounts, replenish accounts, balance and update payment information, prepare and print account statements and reports, and other account maintenance capabilities
  - Provide the functionality required to pursue the violation citation process, including noticing and violation closure
  - Interface with the interoperable agencies for the transfer and reconciliation of interoperable toll transactions similar to the process on the I-15 Express Lanes
  - Provide various operations, management, audit and reconciliation, and financial reports as necessary to successfully operate and manage a customer service center
  - Provide the ability to electronically manage customer related correspondence
  - Interface with the internet server and the Interactive Voice Response System (IVRS) to assist customers with account maintenance and inquires

  The system design should ensure that most of the processes and notifications are automated and customers have easy access to account data

- Internet Server - This server provides a firewall-protected interface to the internet enabling motorists to fill out account applications, inquire about their account balance, trips, etc., and perform account maintenance.

The central processing system will also have a number of workstations and printers for use by the office staff.

The central processing system will be located at the main customer service center. One or more satellite customer service centers may also be established that would connect to the main customer service center.

It is recommended that a high level of redundancy be built into the system to support high availability requirements. Additionally, it is also recommended that disaster recovery requirements be addressed by having the redundant servers at different physical locations.

6.9 Communications Network

At each of the tolling locations, upon entry and on the ML, communications equipment will be provided to connect the zone controllers to the fiber network. The fiber network will terminate at the IAD at the south end and at Hale Avenue/Sprinter at the north end. Communications equipment will also be provided at the locations of the central processing system to provide wide-area-network connection and connection to the internet.

7.0 TOLL COLLECTION SYSTEM DESIGN

The central processing system's data management server will communicate with the zone controllers at the entry read zone with VTMS and the ML tolling location as described below:

7.1 Entry Read Zone with VTMS

The VTMS will be configured to display a default message when it powers up until receipt of information from the zone controller. The minimum information sent to the zone controller that controls the VTMS is shown below:

- Time synchronization
- Toll rate changes
- Estimated travel time
- Display messages

The AVI system at the entry location will interrogate vehicles equipped with transponders and report the transponder read to the zone controller. The zone controller will report the transaction to the central processing system in real time. The minimum information sent to the central processing system from the zone controller that controls the VTMS is shown below:

- Location data
- The date/time of the transponder read
- The transponder ID
- The toll rate
- Alarm data

7.2 ML Tolling Location

The minimum information sent to the zone controller at the ML tolling location is shown below:

- Time synchronization
- Transponder status list

The AVI system at the ML tolling location will interrogate vehicles equipped with transponders and report the transponder read to zone controller. At the same time at ML tolling location with VES, the AVDS will indicate the detection of a vehicle and trigger the base VES cameras to capture an image if a vehicle is determined to be a violator; no transponder read, invalid FasTrak transponder or suspended HOV transponder. The zone controller will validate the transponder status and initiate the status of the vehicle transaction on the Transaction Status Indicator for enforcement purposes. The transaction will be reported to the central processing system in real time. The minimum information sent to the central processing system from the ML zone controller is shown below:

- Transaction data
  - Location data
  - The date/time of the transponder read
  - The transponder ID
  - Vehicle data (from tolling locations equipped with AVDS)
- Alarm data

If the vehicle does not have a transponder, then the image that was captured will be saved, and the image along with transaction data is transmitted to the image processor. To assist the CHP officers, the image of every vehicle will be transmitted to the officer's PDA along with its transaction status.

The central processing system will receive transaction messages from each zone controller in real-time. All messages will be acknowledged as being received. It will also have access to the violation data that was processed by the base VES, including data obtained after the completion of the OCR routine and/or manual image review. The central processing system will, at specified times, run the toll calculation process for SOV account holders. Prior to this it will:

- Confirm that all zone controllers are communicating with it
- Confirm that all zone controllers are current with their transaction transmission
- Confirm that a vehicle has exited the ML
- Match the transponder read at entry to a transponder or license plate at exit
- Compute the trip distance
- Calculate the toll charged for the trip.
- If either the entry or exit data is missing apply the trip charge per SANDAG's business rules.
- Post the trip data and the toll charged to the customers account.

For a trip to be considered complete for a transponder read at entry, one of the listed data should be received:

- Transaction data (transponder read) is received for this vehicle from a zone controller that is last in the direction of travel; or
- License plate data is received from a tolling location with base VES that is last in the direction of travel; or
- Some configurable time has lapsed since the last transponder read was reported from the ML zone controller other than the last zone controller; or
- Some configurable time has lapsed since the receipt of the license plate data from a location other than the last tolling location.

Once the vehicle entry is matched to the vehicle exit or the system has determined the entry/exit locations per the business rules in Section 6.2, the following information regarding the trip can be computed:

- Entry into the ML and exit from the ML
- Transponder ID/License Plate Number
- Time of entry to the ML

- Time of exit from the ML
- Distance traveled in the ML
- Toll rate displayed to the customer at entry into the ML
- Toll charged for the trip
- Travel time for the trip

The correct toll posted to the customer account for the trip clearly can be computed if the central processing system receives the data from zones controllers at entry and exit. If the point of entry information, normally recorded at the zone controller at entry is missing from the trip record, the toll rate in affect at the time of entry would be unavailable and would have to be reconstructed. In the most extreme example, no entry point and only one tolling location would be recorded thus the entry location might be ambiguous. In such cases business rules approved by SANDAG that define the toll to be charged will be used.

7.3 Operational Concept

The operational characteristics of each of the operating elements in the system from the viewpoint of those elements are described below.

7.3.1 Entry Points

Every entrance to the ML will be immediately preceded by a VTMS advising all motorists that an entrance to the ML lies directly ahead. For the benefit of SOV customers, these signs will also announce the toll rate currently in effect and the travel time(s) to the next major destination(s) and/or the end of the ML or other location further downstream. AVI readers will be placed on each sign structure so as to read every transponder passing beneath in the lanes prior to every entrance.

The central processing system will periodically transmit the toll rate, the travel time and companion VTMS display text updates to the zone controller at the location of the entry signs. These revisions of the charging rate will result from the measurement of level of service (LOS) on the ML and are intended to ensure the provision of a high LOS, graded "C" or better, on those lanes; degraded LOS, defined as anything below LOS "C" would result in increased charging rates that are intended to reduce traffic in the ML and restore LOS "C" conditions or better. Received VTMS display text will be displayed on the sign immediately upon receipt. When charging rates change, care should be taken to prevent charging the motorist a different toll rate than was read on the VTMS at entry. It is possible that the toll rate per mile may change many times after the SOV customer has entered the ML, however, it is critical that the toll rate charged for the trip be exactly the same as the rate that was displayed to the SOV customer at the time of entry.

If rates are decreased the VTMS message and the new rates will be put into effect immediately. If rates are increased, however, the revised VTMS message will be displayed for a period defined by an operator-settable system parameter (nominally to be about 5 or 10 seconds) before the new rate is actually put in effect (before the higher rate is associated with the transponders). This should ensure that the SOV motorist is never

charged at a higher rate than was read on the VTMS at the time the decision to use the ML was made, though the motorist may be charged at a lower rate.

7.3.2 Tolling Locations

All zone controllers on the ML and DAR/BRTC exits record transponder passage through the tolling location. The data from these locations is used to match the entry data for a vehicle and then used to determine the toll that had to be charged the account for the trip.

8.0 MOTORIST'S VIEW

The motorist's view of the system is quite uncomplicated. While driving in the general purpose lanes of I-15, VTMS placed prior to every entrance to the ML announce the entrance is immediately ahead and display the toll per mile for use by SOVs and also the travel time to two locations downstream of the entrance to the ML. Both HOVs and SOVs must have a valid transponder mounted on the windshield when using the ML. Both HOVs and SOVs that enter and complete a trip on the ML travel under AVI readers at the tolling locations. Passage of vehicles under the toll zone gantry results in the activation of the transaction status indicator based upon the status of the transponder read and the presence of a transponder.

For a SOV, the entry transponder read is matched to the last transponder read or license plate data obtained from the ML a trip is created, the account is posted the toll fare for the trip. Transactions created for a HOV are not posted to the account. On a periodic basis (e.g., monthly, or quarterly) the SOV account holder receives a statement which reflects all trips taken and the charge for each trip based upon the charging rate that was in effect and displayed on the VTMS prior to the motorist's entry to the ML.

The following example is offered to further clarify how a typical toll transaction would occur.

8.1 SOV Customer

1. Traveling south on I-15 general purpose lanes, an SOV customer decides to enter the ML from a point just north of Rancho Bernardo Road.
2. The SOV customer, with a valid FasTrak transponder mounted on the windshield passes a sign just north of the break in the barrier wall allowing exit and entry from and to the ML (illustrated in Figure 4.1).
3. The sign will inform the customer of the toll rate per mile to be charged for the planned trip.
4. The customer will also see the time it will take to reach the end of the ML or travel time to next major destination point.
5. As the customer passes under the sign, the transponder on the vehicle is read and the transponder number, toll rate, sign location, date and time are sent to the central processing system. If the transponder supports audible tone, it can be made to

beep based on the transaction status.

6. The central processing system identifies this transaction as the entry and stores the sign location, the toll rate, date and time, and other relevant data.
7. The customer then proceeds to the entry lane and begins traveling in the ML.

8.1.1 Motorist Travels the Entire Length of the ML

1. As the customer proceeds south, the transponder will be read at the tolling location for each segment of the ML route. With each read, the transponder ID tolling location, date and time, and other transaction data will be sent to the central processing system. If the transponder supports audible tone, it can be made to beep based on the transaction status.
2. The status of the transaction is displayed on the transaction status indicator upstream of the tolling zone.
3. The central processing system will associate each transaction for this transponder with the entry data received.
4. When the vehicle reaches the last tolling location on the ML, the central processing system will recognize the end of the trip. It will match the entry location to the exit location and determine the length of the trip.
5. The central processing system will then calculate the toll to be charged for the trip using the rate recorded when the vehicle crossed under the VTMS at entry and the customer account will be posted the toll amount.

8.1.2 Motorist Exits the ML at an Intermediate Exit

1. If the vehicle exits the ML prior to the end of the ML project, the central processing system will recognize that no tolling activity has taken place for a pre-determined period of time (configurable by SANDAG).
2. The central processing system will use the last tolling location from where a transponder read was obtained to infer the exit location and match the entry, and to determine the length of the trip.
3. The central processing system will then calculate the toll to be charged for the trip using the rate recorded when the vehicle crossed under the VTMS at entry and the customer account will be posted the toll amount.

8.1.3 Motorist's Transponder Does not Read on the ML

1. If no transponder read is obtained on the ML, but a license plate image of the vehicle is obtained from the base VES system, then the license plate data is obtained either by OCR and/or manual review.
2. The license plate data obtained from the ML is matched to the entry transponder read to determine the trip length.

3. The central processing system will then calculate the toll to be charged for the trip using the rate recorded when the vehicle crossed under the VTMS at entry and the customer account will be posted the toll amount.

8.1.4 Motorist's Transponder Does not Read at Entry or on the ML

1. If no transponder read is obtained at entry or on the ML, but an image of the vehicle is obtained from the base VES system, then the license plate data is obtained either by OCR and/or manual review.
2. Based on SANDAG Business Rules a default trip length will be used to determine the toll charged.
3. The license plate is matched to the customer account and the toll is posted to the account (pay-by-plate or VTOL).
4. Thus, the permanent record for the account containing the transponder and/or license plate will have the location of the start of the trip, the date and time of the start, the toll rate, the location of the end of the trip, the date and time of the end of the trip, the intermediate tolling points and the charge for the entire trip.

8.2 HOV Customer

1. Traveling south on I-15 general purpose lanes, an HOV customer decides to enter the ML from a point just north of Rancho Bernardo Road.
2. As the customer passes under the sign, the transponder on the vehicle is read and the transponder number, toll rate, sign location, date and time are sent to the central processing system.
3. The central processing system identifies the transponder as being HOV and processes the transaction as a HOV transaction.
4. As the customer proceeds south, the transponder will be read at the tolling location for each segment of the ML route.
5. The status of the transaction is displayed on the transaction status indicator upstream of the tolling zone. With each read, the transponder ID tolling location, date and time, and other transaction data will be sent to the central processing system.
6. The central processing system identifies the transponder as being HOV and processes the transaction as an HOV transaction.

9.0 STAGED SYSTEM IMPLEMENTATION

The system will inherit the accounts and transponder base from the existing system. The middle segment of the expanded facility will be constructed initially, between the northern end of the current project at Ted Williams Parkway and Centre City Parkway, a distance of about 8 miles. This will be constructed as a four-lane facility, but will initially connect to the two-lane reversible lanes facility now in use. In subsequent phases, the northern most five-mile section will be added, and then the existing two-lane Express Lanes project will be widened to four lanes. Central processing system development will require detailed study due to the impact of this incremental road development and the staging of the ML system. When the central processing

system begins operation the new computer system will have to incorporate the two-lane reversible lanes operation currently in use to ensure that the transition to the new system and the expansion of the ML facility is seamless to the customer.

Prior to converting the account management and operations to the new central processing system, data from the current system will be migrated to the new system and reports generated to make sure both systems reconcile. Additionally, both systems may have to be run concurrently to ensure the new system is ready for live operations. A transition plan will be developed by the Systems Integrator prior to implementation. The current tolling location with new system equipment will be integrated with the new system to produce a seamless whole. The new central processing system will likely need to start operating with just the existing southern end of the roadway and be expanded as shown below as roadway sections are added:

- Initially, the new computer system will control the existing two reversible lanes with new equipment installed;
- The middle segment would then be built and the section would be added to the central processing system possibly incrementally;
- The northern section would be added to the central processing system, possibly incrementally;
- Finally the existing two reversible lanes would then be expanded to four possibly incrementally and the system would have to incorporate these changes.

The staging of the I-15 ML toll collection system implementation is shown in Figure 9.1a and 9.1b. As illustrated above, the central processing system and the dynamic pricing algorithm will need to continually adapt to the evolving configuration of the roadway and a flexible table driven system architecture will be essential.

Figure 9.1a: Stage 1Middle Segment Opening

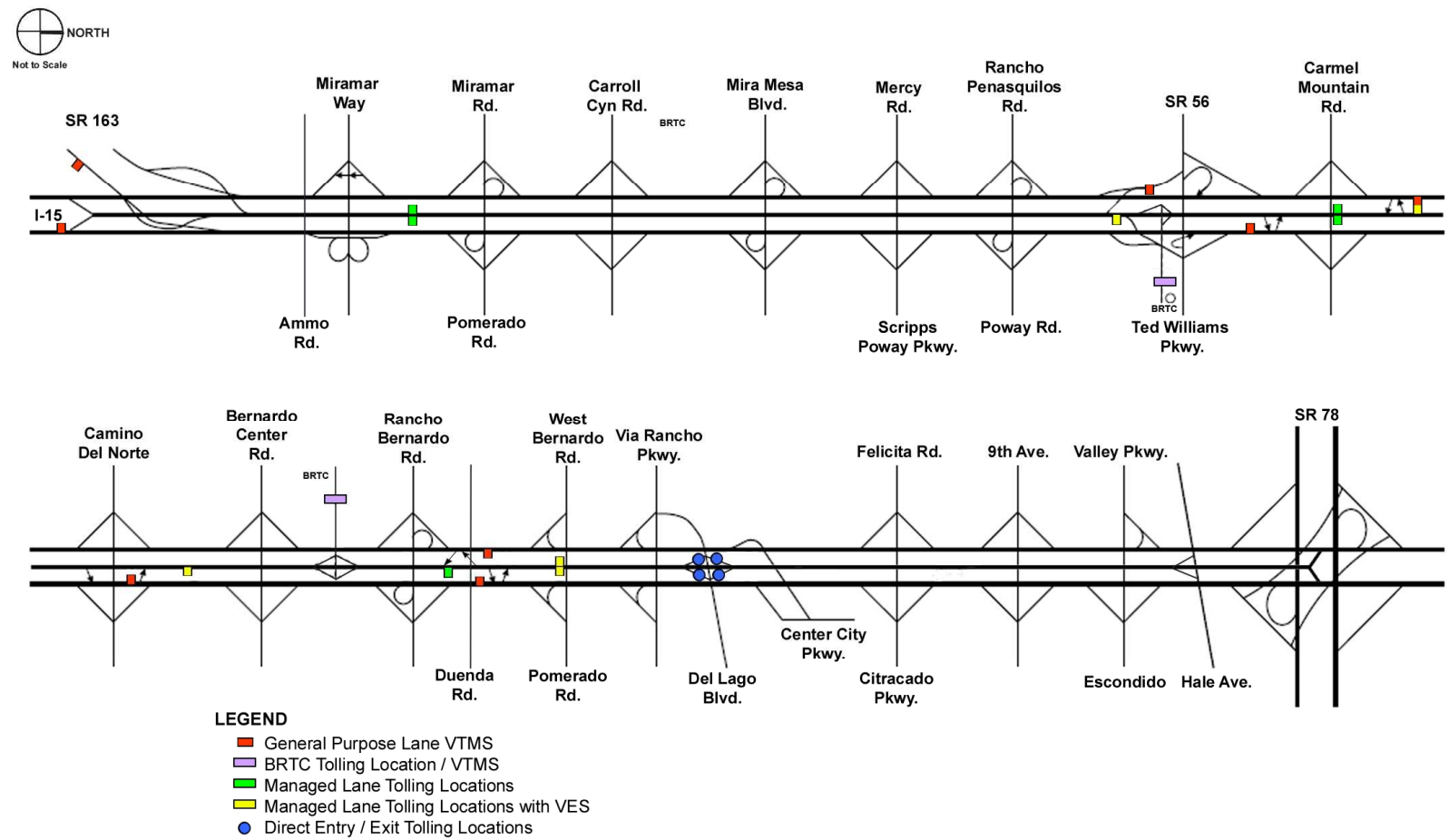


Figure 9.1b: Stage 2 North Segment Opening