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Authors

Chan, Ching-Yao
Bu, Fanping
Singa, Krute
et al.

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INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

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Ching-Yao Chan, Fanping Bu, Krute Singa, Huili Wang

California PATH
University of California at Berkeley

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The contents of this paper reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California.

ABSTRACT

Vehicle occupancy verification is a principal impediment to more efficient HOV/HOT lane enforcement. However, no automated solution has yet been developed for permanent field implementation. Given widespread plans for development of HOV and HOT lanes in a number of metropolitan areas, improved vehicle occupancy verification techniques urgently need to be explored as well as the legal and institutional barriers to their implementation.

A research project to evaluate the technologies for vehicle occupancy verification was conducted by California PATH of University of California at Berkeley. The main role of the research team, under the sponsorship of Caltrans, was to act as independent evaluators in the process of identifying, selecting and testing concepts and methods for automated vehicle occupancy verification (AVOV) that can be adopted for future field implementation. Two subject areas are covered within this report: one on the evaluation of automated enforcement via the use of roadside infrared camera and the other on surveys of self-declaration systems and implementations.

- Automated Vehicle Occupancy Verification

  Chapter 2 first gives an overview of the technology selection process and the specific features of the selected equipment, **dtect** system. Chapter 3 is dedicated to the description of test results, which is then followed Chapter 4 with a summary of observations and conclusions.

- Self-Declaration Systems and Implementation

  Chapter 5 first provides descriptions of several types of transponders and then discusses the enforcement, regulations and privacy factors in utilizing transponder technology. Chapter 6 describes the violation and enforcement technologies used in HOT lane projects planned or in operation in the United States, which is followed by Chapter 7 with a summary of relevant factors and policy considerations.

Key Words: High-Occupancy Vehicle (HOV) Lanes, High-Occupancy Toll (HOT) Lanes, Managed Lanes, Express Lanes, Vehicle Occupancy Detection, Enhanced Vehicle Occupancy Verification (EVOV), Automated Enforcement, Infrared Camera, Self-Declaration System, Transponder, Electronic Toll Collection.

EXECUTIVE SUMMARY

Efficiently operated High Occupancy Vehicle (HOV) or High Occupancy Toll (HOT) lanes increase travel speed, reliability, and the vehicle and person-carrying capacity of roadways in urban areas. The success of these HOV/HOT facilities as a viable transportation strategy is dependent upon the enforcement of occupancy regulations. For HOV/HOT and managed lanes with road pricing that varies with vehicle occupancy, persistent violation problems can result in a significant amount of lost revenues. On-site monitoring and enforcement of these regulations is difficult, expensive, and potentially hazardous for enforcement officers. As more managed lanes emerge that employ a widening array of users and an increasing mix of managed lane strategies in combination with HOV/HOT, enforcement has become more complicated in identifying high occupancy vehicles that receive special access or pricing for travel within a varied traffic stream.

Vehicle occupancy verification is a principal impediment to more efficient HOV/HOT lane enforcement. Several partially- and fully-automated techniques for determining the number of persons in a moving vehicle have undergone limited field testing, including operator-monitored video cameras and infrared composite imaging. However, no automated solution has yet been developed for permanent field implementation, and no system has been proven to satisfy traffic courts in upholding citations issued. As a result, HOV/HOT facility operators have traditionally relied on field enforcement by police officers to manage occupancy violations. Given widespread plans for development of HOV and HOT lanes in a number of metropolitan areas, improved vehicle occupancy verification techniques urgently need to be explored as well as the legal and institutional barriers to their implementation.

A research project to evaluate the technologies for vehicle occupancy verification was sponsored by Caltrans and was undertaken as a collaborative effort between California PATH of the University of California at Berkeley and SANDAG. The larger-scope SANDAG-VPP (Value Pricing Pilot) project involves additional partners, including California Highway Patrol (CHP) and California Department of Transportation (Caltrans) and contractors for SANDAG. The main role of the research team, PATH under the sponsorship of Caltrans, is to act as independent evaluators in the process of identifying, selecting and testing concepts and methods for automated vehicle occupancy verification (AVOV) that can be adopted for future field implementation. This report covers the work that was carried out by the research team within the Caltrans-sponsored efforts, but does not offer descriptions of project activities performed by other participating organizations under the full SANDAG-VPP project.

Two subject areas are covered within this report: one on the evaluation of automated enforcement via the use of roadside infrared camera and the other on surveys of self-declaration systems and implementations.

- Automated Vehicle Occupancy Verification (Chapters 2-4)

  For this part of the project, the research team was engaged actively in the technology assessment process and the selection of vendors to participate in the field experiments.

Subsequently, the research team also assisted in the developments of experimental design and testing procedures. Finally, the research team participated in the actual field tests and performed analysis of tests results.

Chapter 2 first gives an overview of the technology selection process and the specific features of the selected equipment, dtect system. Chapter 3 is dedicated to the description of test results, which is then followed Chapter 4 with a summary of observations and conclusions. The primary findings for this part of the study can be summarized as follows:

- The overall testing results showed very low accuracy or pass rates of the tested system, and illustrated that the tested system was not ready for deployment.
- The test results do indicate that the methodologies of occupancy detection were not fully explored and field implementation issues were not understood and handled by the provider prior to the actual testing.
- Occlusion continues to be an issue for any type of image processing approach, and a better approach of camera positioning for a complete system should be investigated.

Looking ahead for prospects of automated enforcement in the future, certain observations can be made:

- It is technologically feasible to achieve better image quality and image processing output, on the basis of other comparable studies carried as well as on the advances in state-of-the-art vision and camera technologies.
- Image processing technology has progressed significantly in recent years. Techniques are now available to overcome windshield glares and provide excellent illumination to capture clear images to allow identification of subjects inside vehicles. Another area of development is in the recognition of objects and human faces by computer vision techniques. While these technologies are intended for other types of applications, they can be adopted and integrated for HOV/HOT operations.
- Technology for in-vehicle detection and recognition of human subjects also exists. For example, driver and passenger monitoring systems are existent that can be deployed for advanced safety functions. Weight sensors, infrared, ultrasound and image sensors are also applicable for identifying occupants for advanced airbag systems.
- There is a significant global trend now in pushing for connected vehicles, meaning the use of wireless communication to enable exchange of information between vehicles or with roadside or with cloud networks. For example, the USDOT Connected Vehicles Research Program[1] is exploring the use of wireless communication for safety and mobility applications. The number of occupants can easily be captured and transmitted to the infrastructure, thus fairly accurately reporting the occupancy, to enable the enforcement functions. The primary concern lies in the privacy issue, which in a way is similarly present for self-declaration systems where the information is offered by vehicle owners or users. For this type of operation to be feasible, it will need to wait until the provision of communication devices on vehicles is mandated or widely populated.

- Self-Declaration Systems and Implementation (Chapters 5-7)

[1] http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm

A survey was performed to investigate the status of partially-automated or self-declaration systems which include electronic toll payment and enforcement through transponders, radio frequency identification (RFID) and automated license plate recognition (ALPR) technologies. Advances in self-declaration technology respond to agency demands for violation detection and support ridesharing policies and incentives.

Chapter 5 first provides descriptions of several types of transponders and then discusses the enforcement, regulations and privacy factors in utilizing transponder technology. Chapter 6 describes the violation and enforcement technologies used in HOT lane projects planned or in operation in the United States, which is followed by Chapter 7 with a summary of relevant factors and policy considerations.

Several factors have defined current violation enforcement practices in HOT lanes facilities around the United States. The following list presents a synthesis of the factors in the decision-making process.

- *Legislation.* Interoperability requirements have guided the selection of electronic payment systems in all the HOT lanes facilities studied. Additionally, state laws can define which technologies can be deployed for enforcement and tolling purposes. Utah and Minnesota state laws have prohibited the use of cameras for vehicle violation enforcement process, thus requiring the state DOTs to rely entirely on manual enforcement. In the case of Salt Lake City's I-15 Express Lanes, long term enforcement plans have explicitly considered rapid conversion to camera enforcement system in the event that a change in state laws occurs.

- *Cost and schedule constraints.* Several project managers expressed that their agencies had considered technologies such as automated violation enforcement or 5.9 GHz technologies. However, these technologies were considered immature or too expensive to be implemented in a large scale project. Instead, the second-best solution given budget and project schedules were chosen in lieu of the more advance options. The case of the Capitol Beltway Express Lanes in Virginia provides an example. Given the projects schedule and budget, the lanes are planned to begin operation with manual HOT lane enforcement strategies while the long term plan is to transition to an automated enforcement system interoperable with 5.9 GHz technologies.

- *Automation of toll violation enforcement.* Although fully automated vehicle occupancy enforcement systems have not been implemented in any HOT lane facility, several project managers interviewed expressed interest in them as an ideal method for enforcement. However, the interviewees considered the technology not currently viable. Only Virginia's I-495 HOT lanes project have required the private partner to implement an automated enforcement system before the end of a ten year period. In place of the fully automated vehicle occupancy enforcement, three of the cases studied use ALPR systems to partially automate the enforcement of toll violations, namely Miami's I-95 Express Lanes, Denver's I-25 HOV Express Lanes and Houston's METRO HOT lanes. These facilities require HOV users to declare their status by either selecting the HOV lane in a self-declaration lane arrangement (Denver and Houston) or by pre-registering as a HOV (Miami).

- *HOT lane facility layout.* Multiple entry and exit points in long corridors represent a challenge to enforcement efforts. The I-394 MnPASS Express Lanes is an example of how an agency has addressed this enforcement challenge by selecting appropriate technologies. Officials selected a transponder with read/write capabilities and officers were provided with monitoring technology imbedded in handheld devices to query the transaction history of the transponder throughout the corridor. This arrangement allows officers to determine if a user has deactivated his or her device at tolling points upstream of the enforcement location.

- *Spatial and climate constraints.* Narrow corridors limit the number of enforcement spots available for highway patrol and make self-declaration lanes infeasible. This was the situation faced by officials of Minnesota's I-394 MnPASS Express Lanes project. Additional site-specific constrains include the weather, which could influence the type of barriers used to separate the HOT lanes from general purpose lanes.

- *Transponder options and the user*. The idea of providing the user with transponder choices when using the HOT lane facility was mentioned in the interviews. For example, officials of Miami's I-95 Express Lanes allowed customers to continue using their traditional hard case transponders even though the FDOT had introduced a new sticker tag. This decision provided a sense of continuity and options to the customers. Denver's I-25 HOV Express Lanes allows users the choice between of affixing a transponder or relying on video tolling.

Lessons learned from the literature review and case studies show that partially-automated systems may not capture all violations but they have proven to be the most reliable for the level of technology that is currently available. Several options for technologies and physical design of the facility are available and can be selected according to the I-15 Managed Lanes specifications and customer preference.

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1. INTRODUCTION

1.1 Background

Efficiently operated High Occupancy Vehicle (HOV) or High Occupancy Toll (HOT) lanes increase travel speed, reliability, and the vehicle and person-carrying capacity of roadways in urban areas. The success of these HOV/HOT facilities as a viable transportation strategy is dependent upon the enforcement of occupancy regulations. For HOV/HOT and managed lanes with road pricing that varies with vehicle occupancy, persistent violation problems can result in a significant amount of lost revenues. On-site monitoring and enforcement of these regulations is difficult, expensive, and potentially hazardous for enforcement officers. As more managed lanes emerge that employ a widening array of users and an increasing mix of managed lane strategies in combination with HOV/HOT, enforcement has become more complicated in identifying high occupancy vehicles that receive special access or pricing for travel within a varied traffic stream.

Vehicle occupancy verification is a principal impediment to more efficient HOV/HOT lane enforcement. Electronic toll collection, license plate recognition and a myriad of other technologies have been developed and refined in recent decades to improve the integrity of enhanced transportation systems. However, the target of many of these technologies has usually been the vehicle, and not the occupants. Several partially- and fully-automated techniques for determining the number of persons in a moving vehicle have undergone limited field testing, including operator-monitored video cameras and infrared composite imaging. However, no automated solution has yet been developed for permanent field implementation, and no system has been proven to satisfy traffic courts in upholding citations issued. As a result, HOV/HOT facility operators have traditionally relied on field enforcement by police officers to manage occupancy violations. Given widespread plans for development of HOV and HOT lanes in a number of metropolitan areas, improved vehicle occupancy verification techniques urgently need to be explored as well as the legal and institutional barriers to their implementation.

Without a robust and reliable enforcement strategy, the difficulty of monitoring and enforcing HOV/HOT occupancy regulations is becoming so onerous to some agencies that they are considering doing away with existing rideshare incentives. By identifying cost-effective systems to automatically verify vehicle occupancy, HOV/HOT strategies can be promoted and enforced, encouraging a reduction in the number of vehicles on metropolitan area freeways while increasing person throughput. The technologies that allow the implementation of automated enforcement can also ensure easy coordination of HOV/HOT strategies with other transportation strategies such as congestion pricing.

1.2 SANDAG I-15 Managed Lanes Facility and Vehicle Occupancy Studies

San Diego Association of Governments (SANDAG) embarked on a multiple-year expansion of the I-15 Express Lanes Facility. [1-2] Funded in part by the *TransNet* half-cent sales tax, the more than $1 billion project is designed to maximize capacity and relieve congestion. Scheduled for completion in 2011, the I-15 Express Lanes will feature four lanes with a moveable barrier for maximum flexibility; multiple access points to the general purpose highway lanes; and direct access ramps for high-frequency Bus Rapid Transit (BRT) service.

The San Diego Association of Governments (SANDAG) was awarded a grant in Federal Value Pricing Pilot (VPP) program grants to study the feasibility of applying state-of-the-art violation enforcement systems (VES) to improve accuracy in verifying the number of vehicle occupants and enforcing high occupancy vehicle (HOV) and toll violation provisions on the Interstate 15 Managed Lanes (ML) in San Diego, California.

The technology evaluation conducted and described in this report is one component of a multiyear violation enforcement study that is expected to result in the selection of advanced vehicle occupancy enforcement technology for deployment on the I-15 ML. The SANDAG Federal Highway Administration (FHWA)-funded study began in 2005, and thus far, has resulted in the completion of technology trade studies, the development of a suite of enforcement strategies for the I-15 ML, and an extensive public outreach process that was designed to assess public opinion and support for the technologies and strategies that were developed during the earlier phases of the project. [3]

Three operational scenarios were developed for the I-15 ML to investigate various combinations of enforcement technologies and concepts that may be suitable for field deployment in a proof-of-concept evaluation and ultimately implementation. [4] These scenarios provide a basic framework from which to combine various elements of technology, policy and operating procedures to determine an effective and acceptable occupancy and violation enforcement configuration for permanent implementation on the I-15 ML facility:

- Scenario 1: Manual Enforcement with Technology Assistance - Primary use of routine enforcement by CHP with the use of available technology to assist in vehicle occupancy determination.
- Scenario 2: Partially-Automated Technology Enforcement with Manual Enforcement Assistance - Enforcement based on the use of technology with some reliance on routine enforcement by CHP.
- Scenario 3: Fully-Automated Vehicle Occupancy Detection with Validation - Automated HOV violation enforcement with little or no manual enforcement required.

1.3 Project Scope and Report Contents

This report provides a summary of the work conducted under a research project that has been undertaken as a collaborative effort between California PATH of the University of California at Berkeley and SANDAG. The larger-scope SANDAG-VPP project involves additional partners, including California Highway Patrol (CHP) and California Department of Transportation (Caltrans) and contractors for SANDAG. SANDAG, with the assistance of participating partners, is leading the execution of the overall work plan. The main role of the research team, PATH under the sponsorship of Caltrans, is to act as independent evaluators in the process of identifying, selecting and testing concepts and methods for automated vehicle occupancy verification (AVOV) that can be adopted for future field implementation. This report covers the work that was carried out by the research team within the Caltrans-sponsored efforts, but does not offer descriptions of project activities performed by other participating organizations under the full SANDAG-VPP project.

While it is desirable to evaluate all possible technology solutions in the aforementioned three categories of scenarios identified in the SANDAG report [4], from technology-assisted manual enforcement to full automated enforcement, this research project was performed under the constraints of limited resources. Furthermore, the project was executed with a schedule that conforms to the larger-scope SANDAG project. Therefore, the paces and tasks within the project were adjusted and revised during the course of the project.

The remaining part of this report covers two subject areas: Chapters 2 to 4 on the evaluation of automated enforcement via the use of roadside infrared camera and Chapters 5 to 7 on surveys of self-declaration systems and implementations.

- Automated Vehicle Occupancy Verification

  For this part of the project, the research team was engaged actively in the technology assessment process and the selection of vendors to participate in the field experiments. Subsequently, the research team also assisted in the developments of experimental design and testing procedures. Finally, the research team participated in the actual field tests and performed analysis of tests results, which led to the presentation of materials in this report.

  The vehicle occupancy detection system used in this study, **dtect** system, is still in the prototype development stage. No mass-produced or widely tested experience is available other than the tests that have been conducted by the developer/producer of the system. Therefore, the objectives of the tests are:
  - To evaluate the field performance, specifically the capability to determine the occupant numbers inside a vehicle, of this system under various operating conditions
  - To assess the feasibility of integrating such occupancy detection functions into an automatic HOV enforcement systems that can be reliably used in Managed Lanes Operations.

  Chapter 2 first gives an overview of the technology selection process and the specific features of the selected equipment, **dtect** system. Chapter 3 is dedicated to the description of test results, which is then followed by Chapter 4 with a summary of observations and conclusions.

- Self-Declaration Systems and Implementation

  A survey was performed to focus on partially-automated or self-declaration systems which include electronic toll payment and enforcement through transponders, radio frequency identification (RFID) and automated license plate recognition (ALPR) technologies. Advances in self-declaration technology respond to agency demands for violation detection and support ridesharing policies and incentives.

  Chapter 5 first provides descriptions of several types of transponders and then discusses the enforcement, regulations and privacy factors in utilizing transponder technology. Chapter 6 describes the violation and enforcement technologies used in HOT lane projects planned or in operation in the United States, which is followed by Chapter 7 with a summary of relevant factors and policy considerations.

1.4 Review of Vehicle Occupancy Detection and Enforcement Studies

In the early stage of the project, a literature survey was conducted to provide an update on the status of current technologies for automated enforcement and vehicle occupancy detection. A limited number of studies and research projects have been conducted to date on the possibility of the AVOV strategy. These studies agree that no AVOV system has been developed so far for permanent field implementation, though there are several promising technologies that may potentially be used for this application.

Georgia DOT conducted a research test between 1995 and 1998 on the use of near-infrared imaging to determine occupancy [6]. The test on selected vehicles showed a 93% accuracy rate and researchers concluded the system had the capacity to accurately determine vehicle occupancy. Georgia Tech Research Institute recently proposed research expanding on the initial tests to modify prototype system to use a different near-infrared wavelength to effectively count occupants with changes in the tint of glass used in cars and determine whether the system can be integrated into HOV enforcement systems to help officers identify probable offenders [6].

University of Minnesota and Honeywell Corporation [7] carried out a research project to apply wave band and computer vision methods to automatically count vehicle occupants in the High Occupancy Vehicle (HOV) lane at a high level of accuracy. It was shown that use of near-infrared bandwidth offers potential as a method for developing an automatic vehicle occupant counting system. Near-infrared only can produce images when looking through glass, but not metal or heavy clothes, which limits its accuracy in counting children or occupants resting in vehicles. The mid-infrared camera did not produce clear images at highway speeds.

The 2004 Enterprise Ontario Study [8] conducted by McCormick Rankin Corporation found that research up to 2004 had not developed an AVOV System that was reliable or accurate enough for field implementation. The study reviewed available technology relating to monitoring and enforcement, including both in-vehicle and roadside equipment, in addition to Telematics for HOV monitoring. It recommended basing any AVOV system on adapting existing in-vehicle sensors currently being built into cars because of cabin penetration and data accuracy and reliability issues from roadside sensors. Use of in-vehicle sensors would require a communications link between the vehicle and roadside infrastructure. The study also developed a draft set of functional requirements for an AVOV system and identified several areas of urban transportation where AVOV systems could add value.

A more recent study conducted by TTI for the HOV Pooled Fund Study [9] reviewed the state of the art in roadside and in-vehicle technologies. Roadside detection technologies examined in this study included video, microwave, ultra-wideband radar, single-band infrared, and multi-band infrared. Several in-vehicle detection technologies were also investigated, including weight sensors, electrical field sensors, monocular imaging, and 3D-Time-of-Flight imaging. The study found that:

a) Roadside technology is the most feasible near-term solution, as Vehicle-Infrastructure Integration (later called IntellIDrive^{SM} and now branded as Connected Vehicles Concept) has not been sufficiently developed to support transmission of in-vehicle detection. Additionally, in-vehicle detectors used for occupancy verification will not be universal in the vehicle fleet on the road for the next 10-15 years because they have only recently been made standard in new vehicles and transmission of data from vehicles might trigger social concerns about privacy.
b) Most roadside detection technologies, with the exception of near-infrared, have issues with penetrating vehicle glass and resolving details from the vehicle cabin.
c) Multi-band near-infrared technology is the most promising roadside detection technology, with the ability to address the challenges of cabin penetration, environmental conditions, good imaging resolution, and fast image acquisition. This study also noted the near-infrared system being tested in the United Kingdoms.
d) Roadside detection systems are expensive, but the cost can be offset by the savings in reduced HOV/HOT violations.
e) In-vehicle detection is dependent on the sensors that vehicle manufacturers place in cars. The most likely sensors that can be leveraged for occupancy verification would be those used with advanced airbag systems, which are mandated to be standard in new cars beginning in 2009. Weight sensors are most likely to be used in the front seat and electrical field or near-infrared sensors in the rear seat. Weight sensors are widely used with air bag systems. Electrical field sensors are currently deployed in some vehicles in coordination with rear seat advanced airbag systems.
f) Rear occupant detection is an issue for both roadside detection and in-vehicle detection. Roadside sensors have issues detecting backseat occupants and rear seat advanced airbag systems are not mandated and it is not clear how commonplace they will be in the future.

An AVOV Concept of Operations was developed as a supplement to the white paper [10]. This paper defines the critical needs of HOV/HOT facility operators and describes how the AVOV system can be implemented within the ITS infrastructure. It is technology-independent and provides architectural and functional requirements for a generic AVOV system.

A recent study was conducted in Virginia by Smith et al. [11], to examine the occupancy enforcement on HOV and HOT facilities. This examination focused on three areas: assessing the impact of existing manual violation enforcement techniques on HOV violation rates; exploring the feasibility of using new technologies/techniques to improve the effectiveness of violation enforcement; and assessing the impact of violation enforcement techniques on the operations of HOV/HOT lanes. The results of the research indicate that current saturation enforcement techniques are not effective in reducing violation rates. However, no proven technologies are currently available that offer the potential to automate enforcement of occupancy restrictions. Finally, a simulation methodology was developed that may be used to estimate the operations' impacts on current and future enforcement techniques and technologies.

2. TECHNOLOGY SELECTION AND TEST DESIGN

2.1 Selection of Technology for Automated Vehicle Occupancy Detection

In the early stage of the SANDAG-VPP project, concepts of operations for vehicle occupancy enforcement were developed and outreach tasks were performed to solicit feedback from stakeholders to identify the issues and to explore the advantages and disadvantages of various strategies. [3-4] California Department of Transportation in 2008 sponsored this current project, which is separate from the SANDAG-VPP project, to engage a research team formed by California PATH of UC Berkeley to engage in the exploration and evaluation of appropriate technology for vehicle occupancy verification. Subsequently, the research team participated in the definitions and reviews of system requirements and the criteria of selecting potential vendors.

2.1.1 SANDAG RFP

In February 2009, a Request-for-Proposal was issued by SANDAG with the following key language:

- *This request for proposal (RFP) is one component of a multiyear violation enforcement study that is expected to result in the selection of advanced vehicle occupancy enforcement technology for deployment on the I-15 ML. The SANDAG Federal Highway Administration (FHWA)-funded study began in 2006, and thus far, has resulted in the completion of technology trade studies, the development of a suite of enforcement strategies for the I-15 ML, and an extensive public outreach process that was designed to assess public opinion and support for the technologies and strategies that were developed during the earlier phases of the project. More information is available at www.sandag.org.*

- *This RFP is to solicit proposals, select and award a contract(s) to a vendor or vendors (also referred to below as "consultant") to participate in a Technology Assessment and test of advanced vehicle occupancy enforcement tools and technology for the I-15 ML. Based on the responses to this RFP, it is intent of SANDAG intent to move forward in 2009 with the Technology Assessment and test of advanced vehicle occupancy enforcement technologies/applications for up to three test cases, described in more detail below in Section B. (**Note: The three test cases were same as the three categories of scenarios described in Chapter 1.**)*

- *As a part of the Technology Assessment, SANDAG intends to provide a stipend payment to the vendors who are selected to participate in the test to cover the vendors' costs up to a specified dollar amount. For those interested vendors who cannot participate in a live test of products and services on the I-15 due to constraints such as the cost of insurance, the cost or requirements of lane closures, and/or the required drawing submission and permitting process, SANDAG may consider alternative proposals to the live testing; however, the main project goal of SANDAG is to test and evaluate the equipment in a live traffic environment on the I-15 and is therefore, under no obligation to evaluate such alternative proposals.*

2.1.2 Evaluation Criteria

- *Proposers will be evaluated on the criteria as per attached Consultant Short List Evaluation Form – RFP Attachment 7. If an interview is utilized, proposers will be evaluated per the criteria as defined in attached Consultant Interview Evaluation Form – RFP Attachment 8. SANDAG reserves the right to independently score the Short List Evaluation and the Interview Evaluation or combine the scores. The criteria in the Short List Evaluation worksheet is the basis for the initial evaluation, scoring and ranking of consultant's proposals to establish a short-list of firms to be interviewed. Each panel member will convert the weighted scores to rank with the highest weighted score. The highest will be ranked one, the next highest score will be ranked two, and so on. All panel members' ranks will be combined and the lowest combined rank score will be the top-ranked firm for the short list and interview evaluations.*

The evaluation criteria for the initial screening of suitable providers and contractors were based on a set of tabulated criteria and scores. The forms used by the committee are attached in Appendix I for reference.

2.1.3 Down-Selection of Candidate Vendors

A committee was formed by recruiting representatives from collaborative partners in the SANDAG project. The research team members, PATH and CCIT, were invited to participate in the committee meetings but were not included in the voting committee when the interviews of vendors were conducted. After the issuance of RFP by SANDAG, four separate vendors submitted proposals and three companies were selected for interviews. One vendor proposed the use of an infrared camera on the roadside for the counting of occupants inside a vehicle. The second vendor proposed the use of biometric devices to record identities of occupants and to report the recorded number of occupants by transponders. The third vendor proposed to use a proprietary face detection algorithm on vehicle image captured by a combination of visible and shortwave infrared camera. The interview process ended with the selection of only one team, consisting of Delcan and VOL (Vehicle Occupancy Limited). Delcan was the main contractor responsible for managing the contract, integrating and field testing the proposed system while VOL was the technology provider with the offering of an infrared camera.

2.2 Description of the dtect System

Figure 1 shows the ***dtect*** camera system used for this project which is designed and manufactured by Vehicle Occupancy Ltd. (VOL) of England [12]. It should be noted that the design and performance specifications given in this section is provided by the vendor but not necessarily tested or proven during the evaluation process.

Figure 1 *dtect* Camera Installed at I-15

The ***dtect*** system is an infra-red camera and image processing unit designed to determine how many occupants inside a vehicle instantly. The device has a range of up to 50 meters, and is claimed to be effective on cars traveling at up to 80 miles per hour, eliminating the need for them to stop or even slow down. The ***dtect*** system operates by projecting two wavelengths of low intensity infrared light at the oncoming vehicle. As the beams are fired, each of two digital cameras, specifically coordinated to capture the infrared wavelengths, takes a photo. The accompanying software combines the two images and eliminates non-facial aspects of the photo before logging the picture with a printed timestamp, location and occupancy count. An instant after the process begins and the beams are fired, the final picture will be saved to the system's internal hard drive – with the faces masked with green blob to prevent an invasion of privacy. When the ***dtect*** system is correctly set up, and has an unhindered line of access to the windshields of oncoming automobiles, VOL claims that the accuracy rate of occupancy count is *90%*. And in the ten percent of cases when it is mistaken, and challenged, the image in question can easily be examined by a human eye.

The complete ***dtect*** system is packaged with a single weather and vandal proof housing. the ***dtect*** system can be installed either roadside on a pole or suspended over the road on a gantry. Infra-red photo images and detected occupancy text logs are stored in an internal hard disk. Ethernet connection to the ***dtect*** system is provided to facilitate remote parameter tuning and data downloading. Once installed and configured, the ***dtect*** system can be controlled remotely via an encrypted internet link.

Figure 2 shows a ***dtect*** image sample. The number of occupant detected in the vehicle is shown on the upper left corner. Date/time stamp when the image is captured is printed on the upper right corner. Each facial feature detected in the vehicle is covered by a green blob generated by the ***dtect*** system to protect passenger's privacy. A text log is also generated with image filename, occupancy results and date/time stamp.

Figure 2 *dtect* Image Sample

2.3 Test Site and Equipment Installation

2.3.1 Test Site

Figure 3 Test Site Vicinity Map

Figure 4 Miramar Test Location

Miramar Way of the Interstate I-15 is chosen as the testing site. See Figures 3 and 4. The I-15 Managed Lanes (ML) in San Diego, California is an expansion of existing high-occupancy toll (HOT) lanes known as the Express Lanes. The existing two-lane reversible Express Lanes facility had single entry and exit points at each end of an eight mile segment with a toll zone at the southern end. The new Managed Lanes will have four bi-directional lanes extending twenty miles in length and containing multiple intermediate access locations. The Miramar test location is at the southern side of the I-15 Managed Lane facility. This particular location has a two lane configuration that alternates directional flow based on a morning/afternoon schedule. The lanes are configured southbound during the morning peak and northbound during afternoon peak.

2.3.2 Installation

Figure 5 *dtect* camera position

Figure 6 *dtect* System Roadside Installation

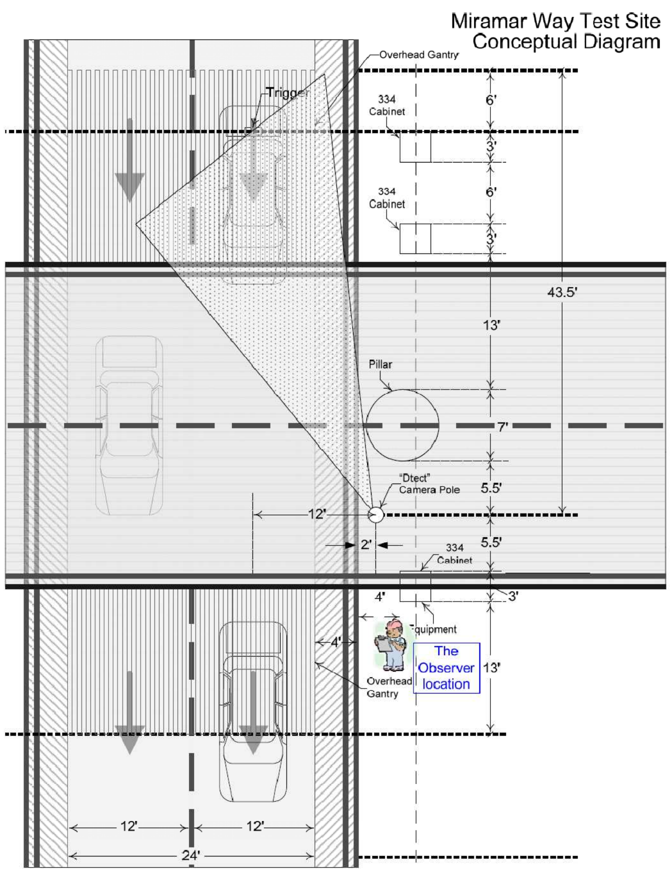

Figure 7 Test Site Conceptual Diagram

As shown in Figure 5 and Figure 6 **Error! Reference source not found.**, the ***dtect*** camera is installed on a pole by the side of HOT lane. Figure 7 shows a conceptual diagram of camera installation. The camera pole is located 43.5 feet downstream of a trigger signal from a toll tag reader system, which is enabled by a laser beam projected from an overhead gantry. When the oncoming vehicle passes the trigger location, ***dtect*** system is activated and infra-red images will be captured by ***dtect*** camera for occupancy identification. The location is chosen such that it can provide best line-of-sight between camera and coming vehicle when trigger signal is fired.

2.3.3 Integration and System Readiness Tests

Integration and system readiness tests were conducted after system installation. The primary objective of Integration Testing is to verify that various components of the ***dtect*** system interact according to their requirements or specification. The components to be tested include power, camera alignment, trigger signal processing, data processing, image verification, DVR recording, and remote operation (including data upload/download). The primary objective of the System Readiness Testing is to verify that data is being collected, stored and updated in the proper system locations. Data were collected over a continuous 48- hour period.

2.4 Experiment Design

In order to verify the capability of the tested system in the normal HOT lane operation as much as possible under the logistic constraints of this project, experimental design was carried out and test sample size was calculated to achieve statistical significant results.

Ideally, the experimental design will incorporate the potential variations of environmental (such as weather) or operational (peak and non-peak) factors so that the evaluation scope will cover a broad spectrum of operating conditions. However, in actual testing periods certain testing conditions such as weather was not fully controllable or available and as a result the experimental data would not be as diverse as preferably desired.

The ***dtect*** system is an infrared (IR) image processing system. Its accuracy could be limited by various factors during everyday operation of HOT lane. Environmental conditions such as lighting conditions, ambient temperature and weather conditions (e.g. fog, rain and snow) could have large impacts on the accuracy of an IR imaging system. Since image processing consumes some processing time, vehicle speed and traffic density could also affect system performance. Partial or complete occlusion (e.g. passengers sitting in the rear seat or 3rd row seat) will always affect the result of image processing system. Other factors such as passenger skin tone, size, vehicle type, fake dummy and a large pet could also change the result of IR imaging processing system.

2.4.1 Test Types

To fully assess the accuracy of the passenger detection and counting system under normal HOT lane operation conditions, many control variables such as different environmental conditions, vehicle types, vehicle speeds, traffic densities, passenger seating and sizes should be included in the testing scenarios. The number of exhaustive combination of all control variable values will be too large for the experimental study with limited time and resource. In order to achieve statistical significant results under time and resource constraints, three different types of tests were considered:

- Uncontrolled Testing

The first type of the experiment is uncontrolled testing, i.e. regular field testing. For the regular field testing, the ***dtect*** system will log its photos and occupancy results of all vehicles in the test lane on live traffic. The resulting occupancy counts from the **dtect** system were verified against human review of those photos. Although achieving large number of testing cases is possible through uncontrolled field testing, one of the major drawbacks of such field testing is that there is no effective method to get "ground truth" data for the verification purpose.

- Controlled Testing

With the assumption that regular field testing could encompass the majority of the factors mentioned above, small scale of controlled experiment will be conducted to test a number of tests cases where specific test parameters can be specified. During controlled experiments, different types of vehicles with different known passenger counts and seating positions were driven passing through the ***dtect*** system. The results from the ***dtect*** system were compared with known passenger count to verify its performance. Controlled field testing requires the closure of the I-15 Express Lanes, therefore the total number of controlled testing case is limited by logistics. Table 1 lists the types of control variables and their values.

Table 1 Control Variable for Controlled Tests

	Vehicle Types	Body Types	Seating Positions	Speed (mph)	Time of Day
Control Variable Types, Values, and Conditions	Sedan Truck SUV Minivan Minicar	Adult Teen Child Dummy	1st row passenger side 2nd row driver side 2nd row middle 2nd row passenger side 3rd row driver side 3rd row middle 3rd row passenger side	10 30 45 60 80	Daytime Nighttime

- Semi-controlled Testing

Semi-controlled testing is the compromise between controlled and regular field testing. It requires driver driving vehicle with known passenger occupancy through the test location in live traffic. Occupancy outputs of those vehicles from the tested system were verified against known passenger count.

2.4.2 Test Sample Size Specifications

To achieve meaningful testing results in the statistical sense under time and resource constraints, the number of testing cases was calculated carefully. Given the level of expected performance, the minimum testing sample size can be calculated in a manner that is illustrated below. The hypothesis can be verified or rejected afterwards by utilizing the experimental results for validation. The detailed descriptions of the methodologies are provided in Appendix II.

In the examples below, the sample sizes are generated for case studies with the following parameters:

- Margin of errors d = 0.05, 0.3, and 0.025
- Confidence levels 1- α, where α = 0.2, 0.1, 0.05, and 0.01 and α denotes the significance level.
- Expected performance accuracy γ = 0.90 (calculation of sample sizes numerically equivalent to γ = 0.10).

For example, the system may be expected to perform almost perfectly at 90% accuracy of detecting vehicle occupancy. The calculation of such as case provides sample sizes estimation given in Table 2.

Table 2 Case Study: γ =0.90 (90% accuracy)

sample size n / confidence level $1-\alpha$ / margin of error d	0.80	0.90	0.95	0.99
0.05	27	59	99	196
0.03	73	164	273	543
0.025	105	236	393	782

As can be seen from the estimated samples for difference case studies, for a certain accuracy level and the same margin of error, a higher confidence level will require a larger sample size and vice versa.

2.4.3 Experimental Design Summary

Three types of experiments are proposed for the performance verification of the ***dtect*** system. For the uncontrolled testing, large numbers of testing runs can be achieved within limited testing time in live HOT lane traffic. Its drawback is that the evaluation can only be done manually and it is not possible to systematically process a large set of test data comparisons against "ground truth" data for verification purposes. On the other hand, the "ground truth" data for the controlled testing is predetermined before test. However, only limited test runs can be completed within short window of Express Lanes closure. Semi-controlled testing is the compromise between controlled and regular field testing but it will also demand considerable arrangements to acquire valid data sets.

3. TEST RESULTS AND ANALYSIS

In this chapter, the procedures of carrying out actual field tests and analysis of testing results are presented.

3.1 Testing Procedures

Figure 8 Test Platoon at Starting Location

- *Controlled Test*

Controlled tests were conducted on evenings and nights of July 30, 2010 and July 31, 2010, and during daytime of July 31, 2010. For each controlled test run, control variables and their values (Table 1) such as vehicle type, speed, seating assignment and body type are predetermined and recorded. The detailed test case descriptions can be found in Appendix III.

Table 3 Breakdown of Controlled Tests with Number of Occupants

Count of Occupants	Number of Runs	Data Missing Cases	No. of Evaluated Cases
1	60	0	60
2	210	4	206
3	151	1	150
4	131	1	130
Total	552	6	546

During controlled test, the Express Lanes were closed to public traffic. In order to complete as many runs as possible in the limit time of closure and simulate regular vehicle traffic, platoons (Figure 8) of 5-8 vehicles were formed according to the testing descriptions in Appendix III. After a vehicle platoon passed ***dtect*** camera with designed speed, it returned to the starting point. Another vehicle platoon with different control variable configurations was formed at the start point and ready for the next test run. A total of 552 controlled test cases were completed for two days' testing. Table 3 shows the breakdown of cases with known counts of occupants in controlled tests.

- *Semi-controlled Test*

Semi-controlled test were conducted by SANDAG employees from July 24, 2010 to July 30, 2010. Test participants drove their vehicles passing ***dtect*** camera in regular traffic. For each test run, vehicle type, vehicle speed, detailed occupancy and the exact time when a test vehicle passed ***dtect*** camera were logged by testing participants. Total 48 runs were completed with different combinations of vehicle types (e.g. sedan and SUV) and occupant body types (e.g. adult, toddler and child, dummy, etc.).

- *Uncontrolled Test*

From July 20, 2010 to August 4, 2010, ***dtect*** system was operated to identify occupancy of vehicles in regular traffic for 24 hours a day. Photos and final results were logged and saved in internal hard drive for further analysis.

3.2 Testing Results Analysis

The initial review of logged images reveals a notable default behavior of the ***dtect*** system as shown in Figure 9. In many cases, the ***dtect*** system could not find any human facial features in the captured images, which by design prompted the system to provide a default output of one occupant and to place a green blob at a fixed location in the middle of the right-hand side of the image even if there is no occupant detected.

Figure 9 A Default Case for the dtect Camera

This default feature to represent at least one driver in the vehicle quickly caught the attention of all evaluators involved in the review and analysis of the test results. Subsequently, a coordinated effort was made to clarify with VOL to clarify the issues that were encountered in data review. More descriptions of the responses from VOL will be provided in a later section. In the following analysis, we will treat such default system behavior as a false-positive failure to identify occupants in the vehicle.

3.2.1 Controlled Tests

First, the test results can be summarized as follows:

- Of 552 controlled test runs, photo images and occupant logs of 6 runs are missing.
- For the remaining 546 runs, the results of 311 runs can be classified into default cases after carefully reviewing logged images.
- If we treat each vehicle passing as an event, the total passing rate for controlled testing is about 4.2%.

Table 4 shows occupancy results with respect to different vehicle types. In general, the pass rate is so low that it is difficult and not meaningful to find correlations between system performance and vehicle type. Since Minivan usually carried multiple passengers seating across three rows, it has the lowest pass rate as 0. A sequence of four tests was conducted with a minicar (Mini Cooper) with one test result missing. While the pass rate is higher for these three events than the other scenarios, it is not statistically meaningful

Table 4 Vehicle type and occupancy results

Vehicle type	Total events	Pass	Fail	Passing rate (%)
Sedan	132	1	131	0.7
Minivan	132	0	132	0
Truck	145	3	142	2.0
SUV	134	18	116	13.4
Minicar	*3*	*1*	*2*	*33.3*
Total	546	23	523	4.2

Table 5 shows occupancy results with respect to vehicle speed. Again, no particular characteristics can be found due to low passing rates.

Table 5 Vehicle speed and occupancy results

Vehicle speed(mph)	Total events	Pass	Fail	Passing rate (%)
10	64	1	63	1.5
30	73	2	71	2.7
35	1	0	1	0
40	39	1	38	2.5
45	71	7	64	9.9
50	55	1	54	1.9

55	16	3	13	18.8
60	39	0	39	0
65	79	5	74	6.3
70	39	0	39	0
80	70	3	67	4.3
Total	546	23	523	4.2

To further investigate the effects of different seating positions and body types, extensive review of logged images was carried out. During photo review, each occupant including dummy is count as an event. If an occupant is detected by the ***dtect*** system with a green blob printed on his/her face in the logged image, then such an event will be counted as *pass*. Otherwise it will be noted as *failure*. For the dummy, the criterion is different. If a dummy is identified by the ***dtect*** system as a normal occupant, such an event will be noted as *failure*. Otherwise, it will be noted as *pass*. It should be noted here that by treating the dummy representation differently in this manner, the results may be misleading because the system might not have made the correct detection when the dummy was not indicated in the output. Therefore, this particular aspect of analysis only serves to provide a reference.

Total events with respect to different seating position and body types are shown in Table 6.

Table 6 Total events with respect to different seating positions and body types

Seating position	Adult	Teenager	Child	Dummy
Driver	546	N/A	N/A	N/A
1st row middle	N/A[2]	20	N/A	N/A
Passenger	317	26	3	21
2nd row driver side	78	23	107	N/A
2nd row middle	6	34	14	10
2nd row passenger side	41	31	78	25
3rd row driver side	10	N/A	N/A	N/A
3rd row middle	N/A	N/A	40	N/A
3rd row passenger side	5	N/A	26	17
Total	1003	134	268	73

If the detection of each occupant is treated as an event, the success rate is approximately 20%, excluding the event associated with the dummy occupant, as seen in Table 7. Of all the seating positions, 2nd row driver side may be the worst place for all the body types.

Table 7 Events of Occupant Detection in Controlled Tests by Seating Positions

Seating position	Total Events	Pass	Fail	Passing Rate (%)
Driver	546	180	366	32.97%
1st row middle	20	4	16	20.00%

[2] Note that the counting of teens and adults for certain seating positions may show slight discrepancies in other reports since the body sizes of teens can be visually perceived to be larger than some adults in some test cases.

Passenger	346	36	310	10.40%
2nd row driver side	208	2	206	0.96%
2nd row middle	54	21	33	38.89%
2nd row passenger side	150	20	130	13.33%
3rd row driver side	10	1	9	10.00%
3rd row middle	40	12	28	30.00%
3rd row passenger side	31	2	29	6.45%
Total	1405	278	1127	19.79%

For each body type, statistics were compiled with respect to different seating positions as shown in Table 8 to

Table **11**. All the data shows very poor performance for different body type and different seating positions. Of all the seating positions, 2nd row driver side may be the worst place for all the body types. That may be due to partial or complete occlusion by the driver seating in the front.

Table 8 Detection result for adult body type with respect to different seating positions

	Total events	Pass	Fail	Passing rate (%)
Driver	546	180	366	32.9
1st row middle	N/A	N/A	N/A	N/A
Passenger	317	33	284	10.4
2nd row driver side	78	1	77	1.3
2nd row middle	6	2	4	33.3
2nd row passenger side	41	4	37	9.7
3rd row driver side	10	1	9	10.0
3rd row middle	N/A	N/A	N/A	N/A
3rd row passenger side	5	0	5	0
Total	1003	221	782	22.0

Table 9 Detection result for teenager body type with respect to different seating positions

	Total events	Pass	Fail	Passing rate (%)
Driver	N/A	N/A	N/A	N/A
1st row middle	20	4	16	20.0
Passenger	26	0	26	0
2nd row driver side	23	0	23	0
2nd row middle	34	10	24	29.4
2nd row passenger side	31	14	17	45.1
3rd row driver side	N/A	N/A	N/A	N/A
3rd row middle	N/A	N/A	N/A	N/A
3rd row passenger side	N/A	N/A	N/A	N/A
Total	134	28	106	20.9

Table 10 Detection result for child body type with respect to different seating positions

	Total events	Pass	Fail	Passing rate (%)
Driver	N/A	N/A	N/A	N/A
1st row middle	N/A	N/A	N/A	N/A
Passenger	3	3	0	100
2nd row driver side	107	1	106	0.9
2nd row middle	14	9	5	64.2
2nd row passenger side	78	2	76	2.6
3rd row driver side	N/A	N/A	N/A	N/A
3rd row middle	40	12	28	30
3rd row passenger side	26	2	24	7.7
Total	268	29	239	10.8

Table 11 Detection results for dummy body type with respect to different seating position

	Total events	Pass	Fail	Passing rate (%)
Driver	N/A	N/A	N/A	N/A
1st row middle	N/A	N/A	N/A	N/A
Passenger	21	21	0	100
2nd row driver side	N/A	N/A	N/A	N/A
2nd row middle	10	1	9	10.0
2nd row passenger side	25	4	21	16
3rd row driver side	N/A	N/A	N/A	N/A
3rd row middle	N/A	N/A	N/A	N/A
3rd row passenger side	17	9	8	52.9
Total	73	35	38	47.9

3.2.2 Semi-Controlled Tests

For the semi-controlled test, the exact time a test vehicle passes ***dtect*** camera is used to find its images and occupancy logs. For a total of 48 runs, the images and logs of 37 runs were matched successfully. Table 12 **Vehicle type and occupancy results** shows occupancy results with respect to different vehicle types.

Table 12 Vehicle type and occupancy results[3]

Vehicle type	Total events	Pass	Fail	Passing rate (%)
Sedan	17	0	17	0
SUV	20	2	18	10.0
Total	37	2	35	5.4

[3] Each passing vehicle is counted as an "event" in this table

3.2.3 Uncontrolled Tests

Since there are thousands of images logged by ***dtect*** system during each testing day, it is beyond the resource constraints to go through all the testing results. We chose to only review images on August 2, 2010. The "ground truth" occupancy data is determined by human review of the images. Therefore, only images with legible details were counted in final statistics. Also the occupant body types are only limited to adult and child. Of all 1308 cases counted in the final statistics, 899 runs are classified as default cases. The total successful rate is slightly higher than the controlled test, which might be due to the fact that the images we chose were at least readable from human eyes. Overall, it still shows very poor performance for different body types and seating positions.

Table 13 Vehicle type and occupancy results[4]

Vehicle type	Total events	Pass	Fail	Passing rate (%)
Sedan	652	65	587	9.9
Minivan	88	23	65	26.1
Truck	155	31	124	2.0
SUV	369	118	251	31.2
Minicar	6	1	5	16.7
Van	14	3	11	21.4
Motorcycle	24	10	14	41.7
Total	1308	251	1057	19.2

Table 14 Detection result for adult body type with respect to different seating positions[5]

	Total events	Pass	Fail	Passing rate (%)
Driver	1308	472	836	36.1
1st row middle	2	2	0	100
Passenger	509	122	387	24.0
2nd row driver side	7	1	6	14.2
2nd row middle	19	7	12	36.8
2nd row passenger side	63	12	51	19.0
3rd row driver side	N/A	N/A	N/A	N/A
3rd row middle	N/A	N/A	N/A	N/A
3rd row passenger side	1	0	1	0
Total	1909	616	1293	32.3

[4] Each passing vehicle is counted as an "event" in this table
[5] Each passenger/driver is counted as an "event in this table

Table 15 Detection result for child body type with respect to different seating positions[6]

	Total events	Pass	Fail	Passing rate (%)
Driver	N/A	N/A	N/A	N/A
1st row middle	1	0	1	0
Passenger	16	1	15	6.25
2nd row driver side	4	0	4	0
2nd row middle	20	5	15	25
2nd row passenger side	87	14	73	16.0
3rd row driver side	1	1	0	100
3rd row middle	2	0	2	0
3rd row passenger side	N/A	N/A	N/A	N/A
Total	131	21	110	16.0

If the detection of each occupant is treated as an event, the success rate is approximately 31%, excluding the event associated with the dummy occupant, as seen in Table 16.

Table 16 Events of Occupnact Detection in Uncontrolled Tests by Seating Positions

Seating position	Total Events	Pass	Fail	Passing Rate (%)
Driver	1308	472	836	36.09%
1st row middle	3	2	1	66.67%
Passenger	525	123	402	23.43%
2nd row driver side	11	1	10	9.09%
2nd row middle	39	12	27	30.77%
2nd row passenger side	150	26	124	17.33%
3rd row driver side	1	1	0	100.00%
3rd row middle	2	0	2	0.00%
3rd row passenger side	1	0	1	0.00%
Total	2040	637	1403	31.23%

3.3 Discussions of Test Results and Correspondence with Provider VOL

Given that the field test results were drastically different from the originally claimed performance when the provider was interviewed, a number of inquiries and a sequence of correspondence was made with the equipment provider. The responses and observations are summarized below.

- Technical issues regarding the test results according to VOL
  - The model that was used in testing was not suitable for high speed applications.
  - Modification to the optics to even out the characteristics across the field of view would be needed to improve visibility of occupants at the edge of the field of view.

[6] Each passenger is counted as an "event" in this table

- To avoid image blur, the camera exposure time would need to be reduced to accommodate the higher vehicle speeds.
- The speed variability caused the windshield to be placed in different locations at the trigger plane, which led to poor image processing results.
- There was a delay between the cameras and (triggering) lasers that needed to be compensated but was not properly accounted for in the setup.
- Due to the limited bandwidth of remote access, it was very difficult for VOL to optimize image recognition algorithm online.
- The variations in lateral position of vehicles compounded the captured images and caused the system to identify the non-uniformity of the beams at the edges of field of view.

- Response to inquiries about the claimed high accuracy of tests conducted in England
  - Accuracy posted on VOL's website accuracy was determined from controlled testing undertaken in the UK during product development.
  - Tests were carried out in controlled conditions at a race track on a fixed set of cars. The range of windshield heights allowed a higher illumination power density.

- Response to inquiries about factors that may affect performance of image systems.
  - The degree of occlusion will affect the ability to count the occupants.
  - Other factors affecting the occupancy count are windshield transmission, obscuration by inanimate objects (e.g. "A" pillar, headrest) and "blending" of occupant faces.

- Response to inquiries about the changes made for the specific unit tested in San Diego
  - The field of view of the cameras was changed to suit the range of vehicle windshield heights and sizes.
  - The area of illumination was increased to suit the same.
  - The exposure duration of the cameras was decreased to minimize blurring from vehicle speed. For the system tested in San Diego, the camera exposure time was reduced by a factor of 5 (from the original setting) to accommodate the higher vehicle speeds.
  - These changes affected system accuracy across the speed range.

- Response to other inquiries
  - The use of a second camera looking from sides into vehicles will not be recommended because transmission of rear passenger vehicle glass is indeterminate and unregulated. The rear side passenger would be detected by positioning a "slave" unit looking through the windshield from the near side.
  - The provider will improve the algorithms and re-process the images to see if better results can be obtained.
  - A newer version of camera will incorporate increased power of one of the lasers to improve the illumination power density in the target plane.
  - To overcome the lateral position variation of passing vehicles, the system needs to increase the field of view and area of illumination.
  - The quality of the images is affected by windshield transmission, windshield reflection, the speed of the vehicle, beam coverage and ambient light.

- Reflection off the windshields, blurred images and obscurations will affect the result. Partial illumination of occupants will affect results. Illumination of occupants at the edge of the field of view are affecting the results currently due to the light rays transmitting through the band pass filters being attenuated as a function of angle from the optical axis. This can be seen with the occupants on the right appearing darker.

3.4 Summary Remarks

The overall testing results showed very low accuracy or pass rates of the ***dtect*** system output. Nevertheless, some observations can still be made.

- Despite the loss of the confidence in the tested system, it will not be unreasonable to suggest that none of the technical issues that have been identified is a show stopper.
- It is technologically feasible to achieve better image quality and image processing output, on the basis of other comparable studies carried as well as on the advances in state-of-the-art vision and camera technologies.
- The test results do indicate that the methodologies of occupancy detection were not fully explored and field implementation issues were not understood and handled by the provider prior to the actual testing.
- Occlusion will remain an issue for any type of image processing approach, and a better approach of camera positioning for a complete system should be investigated.

4. LESSONS LEARNED FROM AUTOMATED VEHICLE OCCUPANCY VERIFICATION FIELD TESTS

4.1 Review of Processes and Practices during the Evaluation of AVOV

In this section, we wish to convey observations of several aspects of practices taken during the evaluation of the AVOV system. This summary is focused on the activities that the research team participated in. There are more broad-based considerations and in-depth issues that should be considered at a higher level within the overall SANDAG project scope.

4.1.1 Selection of Technology Provider

It is noteworthy that the RFP issued by SANDAG only attracted a small number of bidders and only three were deemed qualified to enter the interview process. The observations from the process of searching and down-selecting the providers can be summarized below:

- SANDAG and its partners were looking for products that could be deployed in the short terms (2-3 years), but no provider offered products that were close to deployment.
- Even though three vendors were interviewed, none of them demonstrated the readiness for product introduction to the market.
- The products offered by the potential vendors were still research prototypes, and still required significant research investments, regardless of the claims that might be presented by providers.
- The lack of validated products during the RFPs made it more challenging to optimize the selection of prospective providers.

4.1.2 Experimental Design and Preparation

The schedule experienced considerable delays in the whole process of carrying out the field experiments due to various reasons, including the need to coordinate the schedules on the actual construction on the test sites and to reach a consensus among all participants of the test arrangements and procedures. These factors led to significant challenges, for example:

- The provider made two separate trips from England to California for the initial installation and validation tests due to the need to relocate the installation spot at the test site.
- Several parties on the team were under different contractual and scheduling constraints, and there was pressure for many participants to expedite the work at the later stages of the contracts especially with the initial delays.

Most participants were disappointed by the surprisingly poor test outcome, especially when compared to the earlier results claimed by the provider. Several factors might have played a role in the preparation stage:

- The provider was home based in England, even though the primary contractor was from US. This unavoidably created potential logistic issues in executing the work plan and resulted in higher risks when problems occurred.
- Although a readiness test was planned before the full field trial, the provider claimed afterward that they could not fine-tune the system as much as they could due to ineffective remote access and networking issues.
- Due to the inadequacy of products and insufficient in-house testing preparation by the provider, the performance was much worse than what was previously claimed and anticipated.

Some of the technical issues were hindered and constrained by the availability of resources and time. The provider was also not very forthcoming in recognizing the problems that they could have foreseen and observed in the early stage of their own testing, but did not provide advanced alerts. The technical issues with the tested system that were disclosed later in their response were generally the types of problems that could have been identified and tested in their local environment, without having to be postponed and exposed till the on-site testing.

4.1.3 Field Test Execution

This is one area that the team has executed diligently and fully, where advanced planning and onsite coordination helped to achieve an almost flawless progression of actual on-site tests.

4.2 Assessment of Technology for Automated Enforcement and Future Prospects

Even though the **dtect** system has failed in this field of technology evaluation, there are promising prospects that continue to move forward and will enable the implementation of automated operation of enforcement in the future.

- Image processing technology has progressed significantly in recent years. Techniques are now available to overcome windshield glares and provide excellent illumination to capture clear images to allow identification of subjects inside vehicles. Another area of development is in the recognition of objects and human faces by computer vision techniques. While these technologies are intended for other types of applications, they can be potentially adopted and integrated for HOV/HOT operations.
- Technology for in-vehicle detection and recognition of human subjects also exists. For example, driver and passenger monitoring systems are existent that can be deployed for advanced safety functions. Weight sensors, infrared, ultrasound and image sensors are also applicable for identifying occupants for advanced airbag systems.
- There is a significant global trend now in pushing for connected vehicles, meaning the use of wireless communication to enable exchange of information between vehicles or with roadside or with cloud networks. For example, the USDOT Connected Vehicles Research program [13] is conducting research of such systems for safety and mobility applications. With the consensus of owners or users, the number of occupants can easily be captured and transmitted to the infrastructure, thus fairly accurately reporting the occupancy, to enable the enforcement functions. The primary concern lies in the privacy issue, which in a way is similarly present for self-declaration systems where the information is offered by vehicle owners or users. For this type of operation to be

feasible, it will still need to wait until the provision of communication devices on vehicles is mandated or widely populated.

4.3 Summary

Despite the failure to confirm a deployable technology solution that can be readily deployed for occupancy verification, the work that was carried out in the project still offered valuable lessons. The following points will be noted:

- The conceptual framework of categorizing enforcement functions in three levels of scenarios – from manual to full automation – is still valid.
- Technology for full automated operation of enforcement functions is still not available for deployment, at least in the latest survey. Considerable challenges still remain in the implementation of automated enforcement systems. [14]
- Technology for semi-automated or assisted enforcement is already existent, such as the use of self-declaration transponders. The following chapters will address this subject area.

5. OVERVIEW OF SELF-DECLARATION SYSTEMS AND IMPLEMENTATIONS

This chapter provides an overview of partially-automated or self-declaration systems, which include electronic toll payment and enforcement through transponders, radio frequency identification (RFID) and automated license plate recognition (ALPR) technologies. Advances in self-declaration technology respond to agency demands for violation detection and support ridesharing policies and incentives. The survey is part of a collaborative effort with the San Diego Association of Governments (SANDAG) to identify and evaluate promising concepts and methods for vehicle occupancy verification technologies that can be adopted for permanent field implementation the Interstate 15 Managed Lanes Facility in San Diego. First, several types of transponders are described then the enforcement, regulations and privacy factors in utilizing transponder technology are discussed.

5.1 Approach

Though the collaborative project is mainly focused on automated vehicle occupancy verification technologies, a review of self-declaration technologies and interviews with HOT facility project managers around the United States assists in understanding other available technologies and practices in enforcement. The findings of these interviews and a literature review informed the development of this report.

To survey the self-declaration systems available, a literature review was conducted on current practice in vehicle occupancy enforcement of HOT lanes projects. Several projects in planning, construction or operation stages were identified and a questionnaire was developed to help guide the telephone interviews with managers of the identified projects (provided in Appendix IV). The questionnaire explored three main topics 1) HOT lane operations, 2) infrastructure and electronic payment systems planned or operational, and 3) HOT lane violation and enforcement technologies and strategies. Interviews were conducted with representatives of the following organizations:

- Bay Area Toll Authority
- Metropolitan Transportation Commission (MTC)
- Florida Department of Transportation
- Los Angeles County Metropolitan Transportation Authority
- Metropolitan Transit Authority of Harris County, Texas
- Minnesota Department of Transportation
- Texas Department of Transportation
- Utah Department of Transportation
- Virginia Department of Transportation
- Washington Department of Transportation

All the HOT facilities surveyed used self-declaration systems and partnered with law enforcement agencies to enforce occupancy requirements. An interview was conducted with a representative of the California Highway Patrol to recognize possible enforcement concerns of new self-declaration systems and configurations.

5.2 Available Self-Declaration Systems and Enabling Technologies

This section presents a review of self-declaration systems and configurations, with a discussion of the merits and constraints of each option.

5.2.1 Option 1: Transponders for SOVs Only

Some toll facilities require single occupancy vehicles (SOVs) to declare their status by presenting a transponder while high occupancy vehicles (HOVs) with two or more passengers (depending on the number of passengers required by the facility) can use the facility without a transponder. Users without a transponder and the required number of passengers are in violation. Occupancy violations are enforced manually through visual inspection by the highway patrol and the use of electronic devices such as transaction status indicators (TSI), mobile enforcement transponders (MET) or automatic license plate recognition systems (ALPR). The SR-167 HOT lanes facility in Seattle, Washington employs this type of enforcement configuration (detailed in Section 6.1).

Figure 10 A Standard FasTrak Transponder for SOV Users[7]

5.2.2 Option 2: Separate Transponders for SOVs and HOVs

This option requires all users in the facility to have a transponder. Users declare their occupancy status by installing a HOV or SOV transponder. A customer interested in alternatively using the facility as a SOV or HOV user would have to acquire both transponders. Once a customer enters the HOT lane an automatic vehicle identification (AVI) system detects the type of transponder and the appropriate toll is levied. No HOT lane facility in the U.S. has implemented this configuration.

5.2.3 Option 3: Transponders for SOVs, Pre-Registration for HOVs

This configuration requires all SOVs to display a transponder while all HOV users register their vehicles prior to using the system. HOV pre-registration is required since an automated license plate recognition (ALPR) system is utilized to monitor the traffic in the lanes. Vehicles not

[7] Source: South Bay Express

registered as HOV vehicle and without a transponder receive a citation or fine. This option is currently in place for Miami's I-95 Express Lanes (Section 6.2).

5.2.4 Option 4: Switchable Transponders for SOVs and HOVs

Switchable transponders allow drivers to declare their vehicle occupancy status as either SOV or HOV by toggling a switching mechanism on the unit. Depending on the type of transponder, a user could conceivably declare different levels of occupancy. This type of transponder is also known as a "hard-switch" transponder. With "soft-switch" transponders customers would be able to change their status by calling a service center prior to their trip while the transponder itself does not have a physical mechanism to change to a desired occupancy status. Several HOT lanes projects are planning on adopting switchable transponders in their facilities. Examples include the I-15 Express Lanes in Utah (Section 6.3) and the I-395/Capitol Beltway HOT lanes (Section 6.7).

Figure 11 Switchable Transponders

Figure 11 shows the transponders that are selected for Utah's I-15 Express Lanes - the photo on the right shows a transponder in the SOV status (on) and the photo on the left shows the transponder on HOV status (off)[8] .

Figure 12 Smart Card OBU for the Electronic Road Pricing Scheme in Singapore[9]

5.2.5 Option 5: Smart Card On-Board Units for SOVs and HOVs

[8] Source: Utah Department of Transportation

[9] Source: Transport Issues, UK

A smart card on-board unit (OBU) refers to a transponder capable of reading information contained in a smart card. The device determines the number of occupants in the vehicle by the number of smart cards detected. After the occupancy level is determined, the smart card on-board unit then transmits this information to the AVI system to be charged the appropriate toll. No HOT lane facility in the U.S. currently uses this technology.

5.2.6 Option 6: Separate SOV and HOV Lanes

In facilities with self-declaration lanes, users declare their occupancy status by driving through the designated HOV or SOV lanes at the tolling locations. Vehicles on the SOV lanes must be fitted with a transponder to pay the toll while vehicles using the HOV lane must have the required number of occupants to avoid being stopped by the highway patrol. Prior to the tolling point, users are free to drive in any lane. This type of configuration is used in Denver's I-15 HOV Express Lanes (Section 6.5) and is planned for the METRO HOT lanes project in Houston, Texas (Section 6.6).

Figure 13 Self-Declaration Lanes for the SR-91 Express Lanes in Orange County[10]

5.3 Merits and Constraints of the Available Self-Declaration Systems

Table 17 presents a preliminary overview of the possible merits and constraints of the technological concepts or configurations discussed in the previous.

Table 17 Merits and Constraints of Self-Declaration Systems

Self-Declaration Configuration	User Declaration Action	Merits	Constraints

[10] Source: Orange County Transportation Authority

Option 1: Transponders for SOVs Only	HOV: User takes no action. SOV: By default, the user signals SOV status by installing a transponder.	Only one transponder per vehicle. Simple system that is currently used by many facilities.	Pricing strategies are limited. Without HOV pre-registration and ALPR, toll evasion processing cannot be automated.
Option 2: Separate Transponders for SOVs and HOVs	HOV: User installs a HOV transponder. SOV: User installs a SOV transponder.	All users are detected, may enable pricing and enforcement strategies.	Requiring more than one transponder may conflict with state law. May not be user friendly.
Option 3: Transponders for SOVs, HOV Pre-Registration	HOV: User registers vehicle's license plate. SOV: User installs a transponder.	HOV do not need a transponder.	Resources must be diverted to process the pre-trip registration process and the review of ALPR images.
Option 4: Switchable Transponders	HOV: Switching transponder to the HOV status option. SOV: Switching transponder to the SOV status option.	All users are detected, may enable pricing strategies. Only one type of transponder for all users.	Relatively new technology not in use in any facility. Ease of switching status may present an enforcement problem.
Option 5: Smart Card On-Board Unit	All users must install an OBU. Vehicle occupants must have a smart card.	Smart cards could have multiple functionalities (e.g. paying for transit and parking).	HOV trips maybe prevented if passengers don't have smart cards.
Option 6: Separate SOV and HOV Lanes	HOV: User chooses the HOV lane SOV: User chooses the SOV lane and installs a transponder	Segregation of traffic simplifies the task of verifying the number of occupants in a vehicle by reducing the number of vehicles that need to be inspected.	Requires at least two lanes at observation spots plus the space required by the observation infrastructure at those locations.

5.4 Selection Criteria for Self-Declaration Systems

The goal of the self-declaration systems is to automate some of the enforcement responsibilities currently assigned to highway patrol officers. The question is which of these strategies can best address violation enforcement challenges while meeting the needs of the public, highway patrol, departments of transportation and metropolitan planning organizations. The following discussion will provide an overview of the criteria that must be met by a semi-automated self-declaration system, focusing on five principal areas: enforcement, safety, cost, user comfort, and legal restrictions. For each criterion, the challenges and advantages are discussed. The discussion was informed by the literature review and interviews with HOT facility managers and the California Highway Patrol.

5.4.1 Improvement of Enforcement Effectiveness

Enhancing the enforcement activities currently in place is a fundamental criterion that a self-declaration enforcement system must meet. To realize this objective a system should:

- Minimize the opportunities to subvert the enforcement system
- Decrease the number of vehicles that the officer has to visually inspect
- Reduce the need for interactions between highway patrol officers and customers
- Operate in a reliable and accurate manner

One of the main enforcement priorities is to deter SOVs from purposefully signaling HOV status. In the case of switchable transponders, the ease of changing from SOV status to HOV status presents not only benefits, but also concern for the enforcement officer and the facility operator. Specifically, a SOV with a switchable transponder could intentionally travel on HOV status and quickly revert to SOV status after being intercepted by an officer. In case of being intercepted, the driver could claim that SOV status was rightfully declared and the reader misinterpreted the transponder signal. This enforcement challenge could be addressed if the CHP can officer expediently accesses the status log of the switchable transponder with read/write capabilities.

For San Diego's I-15 Managed Lane Facility, the need for a system that stores transponder transaction history and makes it instantly accessible to CHP officers in the field is further amplified by the multiple access and egress points. As users become familiar with the facility and the enforcement patterns of the CHP, some could decide to falsely declare HOV status at tolling points where they expect no CHP presence. This type of violation could represent a significant loss of revenue if not detected by the enforcement system. Any new transponder technology or arrangement that aims to differentiate between HOV and SOV users must have a strategy to detect users who falsely claim HOV status. This can be accomplished by providing the transponder status (or switch) log history to the CHP officer through a quick and straightforward interface on handheld devices.

Unintentional violations should also be considered in selecting a semi-automated system. Unintentional violations could easily be addressed by design and planning decisions prior to the implementation of the self-declaration system. For example, facilities that employ separate lanes for SOVs and HOVs can minimize confusion by customers accidently selecting the wrong lane with effective signage and pavement markings. Selecting the incorrect occupancy status on a switchable transponder could be avoided with user-friendly design. Regardless of the selected technology, public outreach will play a major role in preventing unintentional violations.

Self-declaration systems have the potential of reducing the number of vehicles that the CHP officers have to visually inspect when combined with an ALPR system. As previously discussed, ALPR systems automate the toll enforcement process. The effectiveness of this strategy hinges on the reliability and accuracy of ALPR technology. The task of inspecting vehicle occupancy is further simplified by self-declaration lanes. Self-declaration lanes offer a unique advantage by segregating traffic into SOV and HOV users. Consequently, a highway patrol officer has to direct his or her attention to only one lane. A possible drawback of self-declaration lanes is that one type of user could be significantly more represented than the other (e.g. significantly more HOV users than SOV users) which could result in different lane speeds at the tolling points. This hypothetical situation could affect the performance of the facility upstream of the tolling points.

The likelihood of this scenario would have to be studied further considering the traffic composition and the geometric realities of the I-15 Managed Lanes.

5.4.2 Risk Minimization

The self-declaration system selected should be reviewed for risk, specifically if unsafe driving could possibly occur when drivers are distracted with their transponders, or if the safety of the highway patrol officers is compromised.

Generally, enforcement systems based on transponder technology do not represent a safety risk. However, some drivers may attempt to change the configuration of their devices while driving, either to correct a declaration mistake or violate the facility rules. Regardless of the reasons, this type of driver distraction represents a risk and consideration should be given to technological features that could preclude the possibility of users changing their occupancy status while the vehicle is in motion.

Another safety consideration is last minute changes in self-declaration lanes at tolling gantries. A serious risk is posed customers who realize, in close proximity to the gantries, that they have to get into the appropriate lane, engaging in unsafe maneuvers to avoid a penalty. Although intuitively possible, experience with self-declaration lanes in Denver's I-25 HOV Express Lanes does not provide any evidence to support this concern (detailed in Section 6.5).[11] Effective signage, pavement markings, and public outreach could greatly reduce any dangerous lane changes at the tolling points.

Highway patrol officers issuing violations also present safety risks. The longer the officer is outside inspecting a vehicle, the greater risk of an accident that could endanger the officer's life. Additionally, the longer the officer has to spend at the roadside with a possible violator, the greater will be the traffic disruption caused by rubbernecking, a phenomenon that also affects safety. Therefore, quick access to a customer's account can minimize risks by reducing the amount of time the officer spends on the shoulder of the facility.[12]

5.4.3 Cost of Self-Declaration Systems

The unit cost of hard case transponders fluctuates between $20 and $25, compared to sticker tags which are usually $5 or less. Customers of Miami's I-95 Express Toll Lanes have the option to buy either type, the hard case transponder (SunPass Portable) at $25 or the sticker tag (SunPass Mini) at $4.99. The availability of both transponders allows choice though sticker tags may limit policy decisions. Sticker tags may not be suitable if switchable transponders and detachability are desired. If cost to the customer is the main reason why stickers are being considered, recent advances in transponder technology and increased demand have steadily decreased the cost of hard case transponders. Other issues related to transponder cost are the device's lifetime, power source (battery or no battery) and the required back office operations.

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[11] Stegman, Stacey. Colorado Department of Transportation. Email Communication. California Center for Innovative Transportation. 24 Jun. 2010.

[12] Keller, John. California Highway Patrol. Telephone interview by the California Center for Innovative Transportation. 21 Jun. 2010.

Georgia's State Road and Tollway Authority September 2009 procurement request received a bid with 5.9 GHz transponder, which is the next generation of dedicated short range communication devices, at $24.80 per unit, a price far below the expected $40 to $50 range.[13] The Virginia Department of Transportation reported that the unit price of the switchable transponder ranges from $20 to $25.[14]

Another cost consideration is how reliant the system is on automated license plate recognition (ALPR) technology. A single ALPR camera costs approximately $20,000 not including the cost of installation, software, computers, fiber optics and other components.[15] Additionally, back office operations required to screen the ALPR images could require significant human resources. However, the benefit of ALPR technologies on enforcement could justify the cost.

5.4.4 User Comfort

The success of a self-declaration system depends in large part on the customer. As previously discussed, the frequency of unintentional violations and the safety of the facility will depend on what type of system is implemented. An additional measure of success is how the users perceive the system, which in part depends on whether the system is easy to use and flexible.

The I-15 Express Lanes requires a user declare SOV status by attaching a FasTrak transponder to the windshield and HOV status with no transponder. Simplifying the process of changing occupancy status could constitute a marginal benefit for the user. Systems based on technologies or concepts familiar to the user present implementation advantages and create a sense of continuity. For example, a switchable transponder would make the declaration process more straightforward with the user toggling a switch to change occupancy status instead of affixing or removing a transponder from the windshield. Self-declaration lanes, on the other hand, only require selecting the correct lane to declare a status.

In the context of this discussion, flexibility refers to the ability to change occupancy status without the need to plan ahead. It implies that if the number of occupants were to change for a particular trip, the driver could change from SOV to HOV or from HOV to SOV with ease. A self-declaration system that involves switchable transponders or self-declaration lanes would only require from the user to toggle a switch or change lanes to update their occupancy status. A multiple transponder configuration would require the user to have both transponders to change status. A HOV pre-registration system would allow a change in occupancy status if the user registers her or his vehicle as HOV and also obtains a transponder. The Smart Card OBU could be considered the least flexible technological option since it requires smart cards from all passengers, a requirement that would be hard to meet in cases where passengers without smart cards are part of the trip.

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[13] "Huge Transponder Price Drop in GA - 6C Sticker $1.59 to $3.05ea, 5.9GHz $24.80ea." *TOLLROAD News*. 20 Sept. 2009. Web. <http://www.tollroadsnews.com/node/4365>.
[14] Boothe, Roger. Virginia Department of Transportation. Email Communication. California Center for Innovative Transportation. 22 Jun. 2010.
[15] Eberline, Andrew. *Cost/Benefit Analysis of Electronic License Plates*. Tech. no. FHWA-AZ-08-637. Arizona Department of Transportation, June 2008. Web. <http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ637.pdf>.

5.4.5 Legal Considerations

Several California legal requirements stipulate how electronic tolling technology must be compliant with Title 21 protocol and interoperable with other tolling facilities in the state.[16] Self-declaration systems that do not meet the state's requirements would confront a complicated bureaucratic process. Therefore, the benefits of a technology that do not meet state standards would have to be weighted by the length of time and effort needed to change the current legal requirements.

Another legal matter that must be considered is the admissibility of violation evidence. Enforcement systems with relatively large margins of error (relative to court standards) could render inadmissible any evidence of violation. Back-office operations that provide ways to reduce error margins and transmit information quickly to patrol officers can help produce sound evidence to the violator.

5.4.6 Additional Requirements to Consider

The factors listed below are not critical requirements for implementation though they could be taken into consideration when deciding among similar systems.

- *Detailed information on the level of vehicle occupancy*: This benefit refers to the capability of a self-declaration technology to indicate if there are one, two, three or more vehicle occupants. This feature enables the agency to introduce additional policies, or different tolls depending on levels of occupancy (i.e., a SOV toll, a HOV 2 toll and a HOV 3+ toll) to promote ridesharing. The switchable transponder may be better suited for accomplishing this objective.

- *Potential to integrate the Compass Smart Card*: The Compass Smart Card is a transit pass that is reusable and accepted on all transit systems in San Diego. The Compass card can be used for HOT lane tolls by inserting it into a Smart Card OBU. The advantage is that all transportation payments could potentially be made by one card.

- *Accurate traffic counts in managed lanes*: The vehicle detection systems could provide traffic counts useful for planning purposes.

- *Reduced education campaigns*: If customers feel comfortable with a new self-declaration technology due to previous experience, SANDAG could minimize the scale of the education campaigns.

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[16] Title 21 refers to open compatibility specifications for two way communications protocol for automatic vehicle identification precluding the vehicle owner from installing more than one device to use toll facilities statewide. The Title 21 standard is an open specification. Source: Caltrans Department of Transportation.

6. SURVEY OF SELF-DECLARATION SYSTEMS AND IMPLEMENTATIONS

This chapter describes the violation and enforcement technologies used in HOT lane projects planned or in operation in the United States.

6.1 HOT Lanes Projects in the United States

Between March and June 2010 the research team contacted transportation agencies with HOT lane facilities in planning, construction or operational phases. Project managers and agency officials associated with of HOT lanes facilities were interviewed on the physical characteristics of the lanes, the selected electronic payment systems, and the technologies and strategies used to enforce occupancy and toll evasion violations in the facilities.

The interviews revealed that current enforcement approaches can be categorized into three groups:

- Enforcement of occupancy and toll violations relying solely on visual inspection of the occupancy of vehicles that do not complete a valid transponder transaction. Highway patrol officers rely on transaction status indicators (TSI) or mobile enforcement readers (MER) to verify if a vehicle completed a valid transponder transaction.
- Implementation of self-declaration lanes and automatic license plate recognition (ALPR) systems. The ALPR system is used to automate the enforcement of toll evasion in the SOV lane and highway patrol officers visually inspect the occupancy of the HOV lanes
- Requirement of HOV pre-registration and implementation of an ALPR system. The ALPR system is used to automate the enforcement of toll evasion and highway patrol officers verify the occupancy of vehicles with a HOV decal.

The interviews identified several factors that defined current violation enforcement practice in HOT lanes facilities. These factors include the following:

- State laws regulating electronic tolling and enforcement technologies;
- Budget and scheduled constraints;
- Desire to automate the enforcement process;
- Physical dimensions of the facility;
- Climate conditions; and
- Transponder options that best fit the needs of the HOT facility and its customers.

This section presents an overview of the violation enforcement strategies of nine HOT lanes projects in the United States. A total of ten transportation agencies were contacted, of which nine were able to participate in the study. Of the nine HOT lanes facilities studied, the following five are currently in operation:

- SR-167 HOT Lanes Pilot Project — Seattle, Washington
- I-95 Express Toll Lanes — Miami, Florida
- I-15 Express Lanes — Salt Lake City, Utah

- I-394 MnPASS Express Lanes — Minneapolis, Minnesota
- I-25 HOV Express Lanes — Denver, Colorado

The remaining four projects were either in planning (P) or planning and construction (P/C) stages at the time the respective interviews were conducted. These projects are:

• METRO HOT Lanes Project	(P/C)	Houston, Texas
• I-495/Capitol Beltway HOT Lanes	(P/C)	Fairfax County, Virginia
• Los Angeles Express Lanes Project	(P)	Los Angeles, California
• Bay Area Express Lanes Network	(P/C)	San Francisco Bay Area, California

The following subsections are divided in three parts: 1) key findings, 2) background, and 3) description of violation enforcement strategies.

6.1.1 SR-167 HOT Lanes Pilot – Seattle, Washington

Key Findings

- Transponders have read-write capabilities which assist enforcement efforts
- Random assignment of patrol shifts to shape the public's perception of the enforcement activities
- Concerns over legacy sticker tags

Project Overview

The SR-167 HOT lanes facility is a four-year pilot project in Washington State. One of the primary objectives is to demonstrate the effectiveness of the lanes in reducing congestion. A dynamic pricing algorithm based on real-time speed data from the lanes is among the technologies being tested.[17] The dynamic pricing system varies the tolls from $0.50 to $9.00 every five minutes depending on the traffic levels in the HOT lanes. The goal is to maintain a free flow speed of 45 mph on the HOT lane the entire period of operation, from 5:00 am to 7:00 pm.

HOV to HOT conversion was completed on May 3, 2008 with one lane per direction for nine miles. Currently, the HOT lanes are separated from the general purpose lanes by solid double white lines that create a two foot buffer (eight inches for each painted line and eight inches for the unpainted space between the lines). Profile plastic raises the lines so that drivers feel a bump when driving over them. Six northbound and four southbound access zones are identified by dashed lines.[18]

An electronic toll collection system is used in the facility. Customers have the option of using hard-case transponders or sticker tags, both of which have read-write capabilities. The sticker tag

[17] Patterson, Tyler. Washington Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010.
[18] Ibid.

was selected because of its low price while the hard case transponder was not phased out to maintain consistency with other electronic toll facilities in the state. As part of the pilot project, 5.9 GHz transponder technology is being tested for a possible transition in the future. Other technologies being studied include switchable transponders and smart card on board units.[19]

HOT Lanes Violation Enforcement Overview

Toll and vehicle occupancy violations are enforced manually by state patrol officers. The Washington State Department of Transportation (WSDOT) pays the full cost for enforcement of approximately 250 personnel hours per month. Troopers locate themselves in shoulder bump-outs along the lanes to enforce the toll and vehicle occupancy requirement. They are assisted by handheld devices and transaction status indicator (TSI) lights to verify toll payment. The TSI flashes a white light when a valid transponder is detected and no flash when a transponder is not read. Officers must visually inspect the vehicles when no light flashes to determine if the users are complying with the occupancy requirements of the lane (2+ occupants).[20] Officers have reported difficulty in seeing TSI lights on occasion due to glare. Also, the officers maintain mixed opinions on the effectiveness and ease of use of the hand held devices.

The Washington State Patrol uses a strategy known as “emphasis patrols” to enforce the occupancy requirement. On emphasis patrol, the number of officers on duty is significantly increased. The practice, used randomly, is intended to draw the public’s attention to the enforcement effort (“emphasis”) and discourage potential violators. Another strategy used to discourage violation is the installation of regulatory signs along the route informing drivers should enter and exit the HOT Lanes at the appropriate locations as crossing the double white lines is illegal.

Sticker tags offer customers a low cost alternative but have also presented some enforcement challenges. An increasingly common occurrence involves drivers claiming to have an active tag when in fact they are attempting to use an inactive account inherited from the previous owner of the vehicle who did not remove the tag. When stopped by highway patrol, some drivers challenge the accuracy of the officers’ handheld devices or the TSI lights. These challenges require officers to contact the back office operations to verify the claim, a process that consumes time. This problem is of concern to WSDOT since they expect the number of inactive sticker tags to continue to grow given that detaching a sticker tags from the windshield renders it useless. Consequently people leave it attached in the windshield even when they cancel their account or transfer ownership of their vehicle to another driver.[21]

6.1.2 I-95 Express Toll Lanes – Miami, Florida

Key Findings

- ALPR used for automated enforcement of toll evasion

[19] Ibid.

[20] WSDOT. "SR 167 HOT Lanes - Commonly Asked Questions." w*ww.wsdot.wa.gov/*. WSDOT. Web. 21 Apr. 2010. <http://www.wsdot.wa.gov/Tolling/SR167HotLanes/faq.htm>.

[21] Patterson, Tyler. Washington Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010.

- HOVs must pre-register and affix a HOV decal
- Officers check the occupancy of vehicles with HOV decal

Project Overview

The I-95 Express Toll lanes project encompasses two phases: Phase 1 was completed early 2010 and replaced two existing HOV lanes for both northbound and southbound directions. A HOT lane corridor for the east/west direction is part of Phase 2, which is expected to be completed by 2011. The primary objective of these express lanes is to increase and manage the capacity of the corridors.[22]

The eight mile express lane facility is separated from the general purpose lanes by a buffer zone delineated by double solid lines with plastic divisors in the middle. Travel on the express lanes is free for registered vanpools, HOVs of three or more and hybrid vehicles. The registration process requires all HOV participants to provide their name, home address, work address, work schedule and license plate number, among other information. Once registered, each HOV member receives one I-95 Express decal. HOT lane vehicles that do not meet the toll exception criteria must obtain a Sunpass transponder or sticker tag to electronically pay the toll. Dynamic pricing varies the toll from $0.25 to $7.50, although the maximum toll is typically $3.50.[23] The goal is to maintain speeds of 55 mph in the express lanes. Since the implementation of the HOT lanes the speed has doubled in the corridor as a whole.

RFID transponders are required of all toll paying customers. The users are given the choice to purchase a portable device (hard case transponder, $25.00 plus tax) or a more inexpensive fixed device (sticker tag, $4.99 plus tax). Both devices are compatible will all other toll roads in Florida.

HOT Lanes Violation Enforcement Overview

The Florida Department of Transportation (FDOT) funds manual enforcement by the Florida Highway Patrol (FHP) for $300,000 per year. The FHP provides spot enforcement during peak traffic periods of the day.[24] The primary responsibility of the FHP is monitoring the occupancy of registered vehicles. Officers can identify registered HOVs by the decal provided during the registration process. Those registered vehicles using the facility without the required number of people are subject to a citation.[25]

An automatic license plate recognition system, formally known as the Florida's Turnpike Enterprise (FTE) automatic violation enforcement system, is used to automatically enforced toll

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[22] Santana, Rory. Florida Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 2 Mar. 2010

[23] FDOT. "Tolling." *www.95express.com*. FDOT. Web. 21 Apr. 2010. <http://www.95express.com/home/tolling.shtm>.

[24] Santana, Rory. Florida Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 2 Mar. 2010

[25] FDOT. "Registration Process." *www.95express.com*. FDOT. Web. 21 Apr. 2010. http://www.95express.com/home/registration.shtm

violations. The system takes a photograph of the license plate of vehicles without a valid transponder or sticker tag and a citation is subsequently mailed to the vehicle owner.[26]

FDOT considered charging users the toll using ALPR technology, but determined that the use of transponders was the cheapest and most accurate way to toll. Currently ALPR is used only for toll violation enforcement. FDOT also considered switchable transponders. Since HOV users do not represent a large majority (one percent of the express lanes users) this option was not pursued. Moreover, the switchable transponder models presented some logistical challenges, particularly for verifying if the transponder was in SOV or HOV mode.[27]

6.1.3 I-15 Express Lanes – Salt Lake City, Utah

Key Findings

- Transition from a decal system to an electronic system
- Transponder will have a sliding tab to declare SOV or HOV status
- Officers enforcement activities will be assisted by handheld devices and TSI lights

Project Overview

In 2006, the Utah Department of Transportation (UDOT) implemented a decal system allowing SOV customers use of the HOV lanes for $50.00 per month. This system is in the process of being upgraded to an electronic toll collection system, scheduled to open Fall 2010. The new system will require customers to use a transponder, branded Express Pass. The primary objective of the I-95 HOT lanes is congestion mitigation; the current lanes have reduced delays by four minutes.

The corridor has one 60 mile lane in each direction. The lanes are separated from the general purpose lanes by a two foot buffer zone demarcated by a solid double white line. Access points are shown by dashed lines. The lanes have a standard 10 feet wide shoulder along most of the corridor.[28]

Dynamic pricing will be used to adjust the tolls according to traffic conditions as well as which and how many of the four tolling zones the customer drives through. Tolls will change with the goal of maintaining a target speed for the express lanes of 55 mph. Buses, HOVs with two more passengers, motorcycles, emergency vehicles and C plate (Clean Fuel-Clean Air license plate) vehicles are and will continue to be exempt from the toll.[29]

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[26] FDOT. "FAQ." *www.95express.com*. FDOT. Web. 21 Apr. 2010. http://www.95express.com/home/FAQ.shtm

[27] Santana, Rory. Florida Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 2 Mar. 2010

[28] Cutler. Catherine. Utah Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010

[29] UDOT. "FAQ - Express Lanes." h*ttp://www.udot.utah.gov*. UDOT. Web. 21 Apr. 2010. <http://www.udot.utah.gov/expresslanes/faq.php>.

While UDOT considered 5.9 GHz, they concluded that the technology still needs development and is currently too expensive.[30] In the interim, all users will have to purchase a switchable transponder with an up/down switch to indicate HOV or SOV.[31]

HOT Lanes Violation Enforcement Overview

UDOT pays $120,000 per year for two officers during weekday peak hour enforcement. The officers are responsible for both toll and occupancy violations. State mandate does not permit cameras and other automatic license plate readers to be used as an enforcement tool.[32]

TSI lights will be located in lane overhead signs to assist officers. The TSI lights will flash one color for valid transponder reads, another color for no funds in the transponder account and a third color for no transponder. Handheld devices will assist officers in the verification of toll payment. With the handheld devices officers can read a transponder's information and verify the customer's activity in the facility.

6.1.4 I-394 MnPASS Express Lanes – Minneapolis, Minnesota

Key Findings

- Only SOVs need transponders
- The locations available for enforcement make TSI impractical
- Officers rely on Mobile Enforcement Readers for enforcement

Project Overview

The I-394 MnPASS Express Lanes project opened in 2005 with the conversion of existing HOV lanes into HOT lanes. A second facility, the I-35W Express Lanes, opened on October 2009, although some sections are slated to open late 2010, with all extensions completed by 2012. Both facilities converge in Minneapolis. The Minnesota Department of Transportation (MnDOT) implemented the I-394 MnPASS project to enhance the efficiency of the corridor, preserve the performance of the HOV lanes and provide an option to SOV drivers. The project has increased throughput by approximately five percent in the corridor.[33]

The I-394 MnPASS Express Lanes consist of two sections for the eleven mile stretch. The first section is a single lane in each direction running for eight miles. The lanes are located in the inner section of the four lane freeway and they are separated from the general purpose lanes by double white lines. The second section consists of two reversible lanes separated by concrete barriers from the general purpose lanes. Five intermediate access points are located on the first

[30] Cutler. Catherine. Utah Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010

[31] UDOT. "FAQ - Express Lanes." h*ttp://www.udot.utah.gov*. UDOT. Web. 21 Apr. 2010. <http://www.udot.utah.gov/expresslanes/faq.php>.

[32] Cutler. Catherine. Utah Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010

[33] Buckeye, Kenneth. Minnesota Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010.

section, officially called the diamond section because of the HOV lane symbol. The second section doesn't have intermediate entry points.

The system uses dynamic pricing to set the tolling rate according to traffic conditions with the objective of maintaining speeds around 50 mph. The tolls usually range from $0.50 to $8.00 and are applied in the peak direction and hours: from 6:00 am to 10:00 am in the eastbound direction and from 2:00 pm to 7:00 pm in the westbound direction. HOVs with two or more passengers and vanpools are not required to have a transponder to use the Express Lanes.[34] Additionally, pricing varies according to the segment of the facility.[35]

A transponder (called the MnPASS) is required to pay the tolls. The selected transponder is manufactured by Raytheon and has read/write capabilities, an important criterion in the selection process. Additionally, the transponder can easily be turned on and off by placing it on or removing it from its cradle. The transponder was selected through a competitive bid process.

HOT Lanes Violation Enforcement Overview

MnDOT funds two state patrol shifts: one shift from 6:00 am to 10:00 am and the other from 2:00 pm to 7:00 pm. This is a supplemental service to the standard service provided by the state patrol. Additional enforcement is provided by city police and Metro Transit police.[36]

The officers use handheld devices to verify toll payment and if a transponder was read. The enforcement of toll violations and occupancy violations is done entirely by the patrol officers due to a ruling by the state's Supreme Court banning the use of video tolling.

As described above, the I-394 MnPASS lanes consist of two sections, one of which is separated from the general purpose lanes only by a striped buffer and has multiple access and egress points. This configuration represents a challenge from a toll enforcement perspective since vehicles could enter the lane at unauthorized points. An additional challenge is that users could disconnect their transponders while using the lanes in order to go undetected by the RFID readers. These challenges were one of the main reasons why MnDOT selected a transponder with read/write capabilities. With this type of transponders officers can query a user's transponder and determine its activity in the facility. For example, given that the enforcement is usually done at the end of the reversible section, a driver could decide to deactivate the vehicle's transponder while passing thorough previous tolling locations only to reactivate it again when entering the reversible lanes section. However using MER, officers could read the user's transponder activity and detect questionable activity.[37]

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[34] Scott, Brian. "HOT Lane Design Overview." Webinar. 21 Apr. 2010.
<http://www.ntoctalks.com/webcast_archive/to_jun_13_07/to_jun_13_07_bk.ppt#256,1,MnPASS I-394>.
[35] Buckeye, Kenneth. "High-Occupancy Toll Lane Innovations: I-394 MnPASS." *Transportation Research Board 85th Annual Meeting* (2006): p18.
[36] Scott, Brian. "HOT Lane Design Overview." Webinar. 21 Apr. 2010.
<http://www.ntoctalks.com/webcast_archive/to_jun_13_07/to_jun_13_07_bk.ppt#256,1,MnPASS I-394>.
[37] Buckeye, Kenneth. Minnesota Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 3 Mar. 2010.

Kenneth Buckeye, project manager of the Express Lanes project, commented that the self-declaration lanes concept is a good idea, but the space available in the highways under consideration is limited. The corridor's narrow space and limited enforcement positions have also made TSI impractical. According to Mr. Buckeye, relying on TSI requires watching the beacon through a vehicle's rear-view mirror, doing a visual inspection in case a violation has taken place and then finding a gap to pursue the suspected violator. Compared with the efficiency and robustness of transponder reader technology, employing TSI in the enforcement process is too complicated in I-394 MnPASS express lanes. Consequently, patrols rely on the transponder reader technology installed on their vehicles. [38]

6.1.5 I-25 HOV Express Lanes – Denver, Colorado

Key Findings

- The facility has self-declaration lanes at tolling locations
- ALPR used for automated enforcement of toll evasions
- License plate tolling gives SOVs the option of not having a transponder

Project Overview

The Colorado Department of Transportation (CDOT) I-15 HOV Express Lanes consist of two reversible lanes that extend for seven miles. The lanes, which replaced two existing HOV lanes, are located in the middle of the corridor separated from the general purpose lanes by concrete barriers. The primary objectives of the project were to better utilize the capacity of the HOV lanes and mitigate the congestion in the corridor. The project costs were approximately $8 million, of which $2.8 million were paid with a federal grant.[39,40]

The toll in the I-15 HOV Express Lanes varies between $0.50 and $3.50 according to the time of the day, not traffic conditions. There are two tolling periods: the morning peak period from 5:00 am to 10:00 am and the afternoon period from noon to 3:00 am.[41] Unique to the lanes is a policy allowing SOV users the option of installing the facility's transponder. Those users without a transponder are billed at the end of the month on the basis of the number of times the ALPR system detected the vehicle's license plate number. SOVs with a transponder are not required to register their license plates. Vehicles with two or more occupants do not need a transponder and use the lanes for free. Users self-declare their status by driving in the designated HOV or SOV lane.

CDOT plans to transition to a new type of transponder that meets the state's interoperability requirement. Under consideration are sticker tags.

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[38] Buckeye, Kenneth. Minnesota Department of Transportation. Email communication to the California Center for Innovative Transportation. 22 Apr. 2010.

[39] "Toll Violations on the I-25 Express Lanes." *ExpressToll*. Web. 30 June 2010. <https://www.expresstoll.com/Default.aspx?pn=TollViolationsontheI-25ExpressLanes>

[40] Stegman, Stacey. Colorado Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 22 Jun. 2010.

[41] CDOT. "Toll Rates/Violations". *CDOT*. Web. 30 June 2010. <http://www.coloradodot.info/travel/tolling/i-25-hov-express-lanes/rates-violations#howmuch>.

HOT Lanes Violation Enforcement Overview

The self-declaration lanes and the ALPR system allow the patrol officers to concentrate on the HOV lane only. The task of the officer is to inspect the level of occupancy in the HOV. CDOT pays the full cost at an overtime rate of $75 per hour. One officer patrols the lanes for 50 percent of the peak time periods (approximately 20 hours).[42] The CDOT has plans to provide handheld devices to assist the patrol officers.

The E-470 Public Highway Authority is responsible for the operations of the ALPR system. On average two cameras per lane capture front and back images of vehicles. A total of eight images are taken: two are infrared images and six are visible light images. The experience of the I-25 HOV Express Lanes shows that the accuracy of the ALPR system is affected primarily by the following issues:

- Plates with no DMV record
- Vehicles not aligned in the lane
- Temporary or car dealership plates
- Out-of-state plates with special formatting
- Glare, bad lighting and weather

Images with alphanumeric characters not initially recognized by the ALPR software are examined manually. Images are rejected if the manual inspection cannot decipher the characters. License plates not in the database are cross-referenced with DMV records from Colorado and other states, a challenging task given imperfect license plate records. A final control check is carried out after the images are rejected to ensure quality of the human inspection process.[43]

6.1.6 Metro HOT Lanes Project – Houston, Texas

Key Findings

- All users will need to have a transponder
- Self-declaration lanes are planned for enforcement purposes
- Toll evasion processing will be automated using ALPR

Project Overview

The Metropolitan Transit Authority (METRO) of Harris County, Texas is in the process of converting the existing HOV lanes on IH-45 North, US-59 North, IH-45 South, US-59 South and US-290 into HOT lanes. As with the HOV lanes facility, a single reversible HOT lane in the middle of each corridor will be separated from the general purpose lanes by concrete barriers.

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[42] Stegman, Stacey. Colorado Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 22 Jun. 2010

[43] Kristick, Dave. E-470 Public Highway Authority. Telephone interview by the California Center for Innovative Transportation. 30 Jun. 2010.

The METRO HOT lanes are intended to counteract the congestion problem in the region and improve the usage of the HOV lanes.[44]

The lanes will be available free of charge to vehicles with two or more occupants. SOV users will use a transponder to pay the toll that will be detected by a RFID reader. Tolls will dynamically change based on traffic conditions in the HOT lanes. Ultimately, the pricing mechanism of the lanes is intended to maintain a level of service of 1,500 vehicles per hour (vpr), or approximately 50 mph.[45,46]

On March 19, 2009, METRO signed a $38.7 million contract with TransCore to design, supply, and install the HOT lanes system with an additional $8.46 million per year to operate and maintain the facilities. When completed, the facilities will have a total of 52 toll and 47 access/egress points.[47]

HOT Lanes Violation Enforcement Overview

The METRO HOT lanes violation enforcement strategy centers on the use of self-declaration lanes. At tolling locations, the single reversible lane will diverge into two lanes: one lane will be designated for SOV users and the other lane for HOV users.[48] An ALPR system will be used to enforce SOV toll violations; highway patrol personnel will not need to intercept SOV toll violators. The license plate photograph taken by the ALPR system will be used to send a violation notice to the vehicle owner.

Users of the HOV lane will not be charged a toll. At the tolling location an observation booth will be staffed with METRO occupancy verification personnel. Users in violation of the 2+ occupancy requirement will be intercepted by the METRO's patrol officers.

METRO decided to implement this enforcement system configuration because it automates the toll violation enforcement, and by creating the observation booths at each tolling location, the manual occupancy enforcement process is given better vantage.[49]

6.1.7 I-495 Capitol Beltway HOT Lanes – Fairfax County, Virginia

Key Findings

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[44] Lobron, Rich. Metropolitan Transit Authority of Harris County. Telephone interview by the California Center for Innovative Transportation. 9 Mar. 2010.
[45] Ibid.
[46] METRO. "HOV & HOT Lanes." *Http://www.ridemetro.org/Services/HOV_HOTLanes.aspx*. METRO, 2008. Web. 19 Apr. 2010
[47] "TransCore Has $38.7m Construction, $8.46m/yr Ops for 5 HOV-HOTs Houston TX." *TOLLROADS News.* 22 Oct. 2009. Web. 19 Mar. 2010. <http://www.tollroadsnews.com/node/4413>.
[48] Lobron, Rich. "BRT on Managed Lanes or Park-and-Ride on HOV Lanes." Priority Bus Conference, Washington Plaza Hotel, Washington DC. National Capital Region Transportation Planning Board. Web. 21 Apr. 2010. <http://www.mwcog.org/uploads/committee-documents/aV5bXVpW20090625164813.ppt>.
[49] Lobron, Rich. Metropolitan Transit Authority of Harris County. Telephone interview by the California Center for Innovative Transportation. 9 Mar. 2010.

- All users will be required to install switchable transponders
- Long term plans for an automatic occupancy enforcement system
- The facility will be compatible with 5.9 GHz technologies

Project Overview

Construction on the Capitol Beltway HOT lanes began in late 2008 and is expected to be completed in late 2012 or early 2013. The primary objective in implementing the HOT lanes is congestion mitigation and the replacement of aging infrastructure in the corridor.[50] To finance this project, the Virginia Department of Transportation (VDOT) entered into a public-private partnership with the concessionaire, Capitol Beltway Express LLC, a group form by two companies, Transurban and Fluor.[51]

The project consists of two HOT lanes per direction running a length of 14 miles. The express lanes are separated from the general purpose lanes by a four foot striped median with plastic channelizers. The project requires rebuilding 50 bridges and ten interchanges, and the construction of three new interchanges. Drivers will be able to enter and exit the toll lanes in a number of locations.

An electronic tolling system will be installed that will use dynamic pricing to set tolls based on real-time traffic information. The system will manage traffic in the HOT lanes to maintain speeds of 55 mph by dynamically varying the toll between $0.10 per mile and $1.00 per mile. HOVs with two or more occupants are exempted from the toll. All users of the HOT lanes facility will be required to obtain a switchable transponder to declare their status.

VDOT is developing a new advanced transportation management system (ATMS) that will be compliant with 5.9 GHz technologies when the facility becomes operational. Another planned VDOT innovation is the implementation of an automated vehicle detection/classification system for tolling.[52]

HOT Lanes Violation Enforcement Overview

Currently the Virginia State Police (VSP) pays for the enforcement of the HOV lane occupancy requirements, collecting fines for traffic violations. The planned enforcement system will initially depend on manual enforcement by VDOT, but long term plans call for automatic enforcement. In fact, the terms of the agreement with the concessionaire specify that an automatic enforcement system must be in place within 5 to 10 years. While the concessionaire works on the automatic enforcement system, officers will be provided with an alarm system (which has not yet been defined) that will inform the officer if a transponder executed a valid transaction. Occupancy violation will be enforced by visual inspection.

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[50] Boothe, Roger. Virginia Department of Transportation. Telephone interview by the California Center for Innovative Transportation. 8 Mar. 2010.
[51] VDOT. "Project History." *Virginia HOT Lanes*. Web. 23 July 2010. http://www.virginiahotlanes.com/beltway/project-info/history.php
[52] Ibid.

Video tolling was evaluated but it was ultimately dismissed given the available options for implementation, namely allowing any vehicle without a transponder to use the lanes or requiring customers to pre-register. It was determined that the first option complicated enforcement activities and the second option is not compatible with current practice in the E-ZPASS region.[53] Implementing a self-declaration lanes strategy was also considered but it was rejected since it would have affected facility throughput given the traffic composition in the corridor. [54]

The ease with which a user could change occupancy status presents an enforcement challenge. To address this issue Transurban has established the following performance requirements:

- The switchable transponder must be able to record the position of the switch, specifically the last toll point that the vehicle crossed
- Back office operations must be able to monitor suspicious activity (such as a customer frequently changing the transponder switch) and to package this information and make it easily available to the officer in the field

The project's costs and schedule were the primary reasons for the selection of the enforcement technologies. Transponders were selected given that the HOT lanes are set to open in 2012 and the concessionaire will take several years to develop the fully automated occupancy verification system.[55]

6.1.8 LA Express Lanes Demonstration Project – Los Angeles, California

Key Findings

- Switchable transponders are under consideration
- ALPR and TSI will be part of the enforcement system

Project Overview

The Los Angeles Express Lanes Demonstration Project is a one-year pilot project that will convert the HOV lanes on the I-10 and I-110 to HOT lanes. The I-10 corridor will have two HOT lanes per direction that will run for approximately 14 miles while the I-110 will have one HOT lane per direction for 11 miles. This project is being undertaken by the Los Angeles County Metropolitan Transportation Authority (Metro) and Caltrans, along with regional partners, after receiving a $210 million grant from the U.S. Department of Transportation. Once completed, the project is intended to tackle the congestion problem in both corridors. Construction began in 2010 and will extend until 2012.[56, 57]

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[53] Kohr, Dean. Transurban. Telephone interview by the California Center for Innovative Transportation. 14 Jul. 2010.
[54] Kohr, Dean. Transurban. Email communication to the California Center for Innovative Transportation. 21 Jul. 2010.
[55] Ibid.
[56] Metro. *Express Lanes Frequently Asked Questions*. Web. 7 May 2010. <http://www.metro.net/projects_studies/expresslanes/images/10-1680_ntc_ExpressLanes_FAQ_web.pdf>.
[57] Metro. "Projects: Express Lanes." Web. 17 May 2010. <http://www.metro.net/projects/expresslanes/>.

The HOT lanes will be separated from the general purpose lanes mostly by striping, although some segments will be physically separated. Traffic conditions in the HOT lanes change tolls will be adjusted to maintain a minimum speed of 45 mph (LOS C). If speeds fall below 45 mph for more than 10 minutes SOVs will be informed by dynamic message signs that entry is restricted only to HOVs. Tolls will range from $0.25 per mile to $1.40 per mile.

Vehicles with two or more occupants will have toll free access to the I-110 HOT lanes. For the I-10 corridor, vehicles with three or more occupants will be exempt during the peak hours (5:00 am to 9:00 am and 3:00 pm to 7:00 pm) only; all other times, vehicles with two or more occupants will be exempt from the toll. Users will need to install a switchable transponder in order to declare occupancy of one, two or more than two. However, customers will have the option of paying with cash at service centers where users will also be able to replenish their accounts. This cash option is a requirement of California state law.

HOT Lanes Violation Enforcement Overview

Currently the CHP provides random enforcement of the HOV lanes. Once the HOT lanes become operational, METRO will pay $500,000 per year for four patrols during the peak hours. The officers will have limited or no shoulder throughout both corridors, though strategic zones for enforcement have been planned. The CHP will be responsible for toll and occupancy enforcement.[58]

Given that the project is in its initial stages, certain details of the enforcement strategy still need to be determined. The selected technologies and strategies for enforcement process respond to the fact that the USDOT grant established required timely receipt of deliverables, limiting the time for considering newer technologies or strategies. The HOT lanes will use ALPR to assist in the enforcement of toll violations. The system, which will serve as a backup to the CHP, will read the license plate of vehicles without a transponder and subsequently determine if the vehicle's account is in good standing. Metro is currently considering which type of handheld devices will be helpful to the CHP in verifying toll payments.[59]

6.1.9 Bay Area Express Lane Network – San Francisco Bay Area, California

Key Findings

- Switchable transponders are being evaluated
- Automated enforcement of toll evasion using ALPR
- CHP will be assisted by TSI to enforce the occupancy requirements

Project Overview

Besides the goal of reducing congestion, the primary objective of the Express Lane Network project is to generate funds to expedite the completion of the HOV network in the Bay Area. As

[58] Wiggins, Stephanie. Los Angeles County Metropolitan Transportation Authority. Telephone interview by the California Center for Innovative Transportation. 9 Apr. 2010.
[59] Ibid.

presented in its Transportation 2035 Plan for the San Francisco Bay Area, the Metropolitan Transportation Commission (MTC) plans to convert 400 miles of existing HOV lanes into express lanes and build an additional 100 miles of express lanes in the next few years. The funds generated by the express lanes will then be used to construct 300 miles of express lanes to complete connections throughout the Bay Area. When project is completed, the express lane network will span 800 miles.[60] An estimated $4.8 billion will be needed to complete the network, of which $1.4 billion will be used to convert the HOV lanes to HOT lanes and $3.4 billion will be spent on expanding the network and closing its gaps.[61] Express lanes for I-680 is became operational in September 2010.

The regional express lane network is a single lane system (one express lane per direction). However, two express lanes per direction are being considered for the US-101 in Santa Clara. The HOT lanes will be separated from the general purpose lanes by double yellow stripping. The shoulder available to the CHP varies from corridor to corridor ranging from two to four feet.

HOVs of two or more occupants will be exempt from the tolls except on bridges. MTC is currently evaluating switchable transponders for the network. All users will have to install a switchable transponder and self declare occupancy of one, two or more than two persons. The switchable transponder is planned to be introduced initially on I-580 in 2011. Although customers will need a switchable transponder to pay the toll at the tolling locations, a pay by cash option will be available at service centers.[62] Switchable transponders are being considered because they allow flexible pricing and enforcement strategies.

HOT Lanes Violation Enforcement Overview

The CHP will be responsible for the enforcement of the HOT lanes rules, assisted by an ALPR system that will read the license plate of all vehicles. If a transponder is misread, the user will be charged the toll based on the image captured by ALPR cameras, which will work in conjunction with the toll system and back-office operations. Since the ALPR system will detect and process situations related to transponder misreads, the CHP will concentrate on detecting vehicles that declare an HOV status without the required number of occupants. Technologies being considered to help the CHP are overhead lights or transaction beacons to determine which vehicles declare HOV status. The CHP will have enforcement pockets along the shoulders or median barriers to park and monitor traffic.[63]

6.2 Summary of Implemented Enforcement Strategies

As the case studies show, occupancy and toll violation enforcement in HOT lanes facilities currently depend on manual enforcement by law enforcement officials. However, the projects differ on the type of enforcement technologies implemented and on the level of reliance on these

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[60] Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area. Rep. 2009.
[61] "Tolling to Be Huge in SF Bay Area with 1300km (800 Miles) Network Committed." *News | TOLLROADSnews*. 24 Apr.
2009. Web. 07 May 2010. <http://www.tollroadsnews.com/node/4122>.
[62] Wolf, Stephen. Bay Area Toll Authority. Telephone interview by the California Center for Innovative Transportation. 16 Apr. 2010.
[63] Ibid.

technologies. On the basis of the interviews, the following enforcement approaches were identified:

- Enforcement of occupancy and toll violations, relying largely on visual inspection of vehicles that do not complete a valid transponder transaction
- Implementation of self-declaration lanes and an ALPR system
- Requirement of HOV pre-registration and implementation of an ALPR system

The most noteworthy enforcement technologies implemented that rely solely on manual enforcement are TSI and handheld devices. Two of the HOT lanes facilities studied (Washington's SR-167 and Minnesota's I-394) have implemented TSI and their experiences suggest that the effectiveness of this technology in the field is limited. Obviously, the problems experienced with TSI in these facilities may be site-specific and not translatable to the conditions of the I-15 Managed Lanes. Minnesota's I-394 highway patrol officers have had a positive experience with handheld devices, a device that allows the officers to check vehicles for the presence of a transponder and query the devices to verify their transaction history. The ability to access the transponder transaction history is important in the I-394 HOT lanes since each of the multiple tolling points cannot have the presence of a highway officer. Transponders will need to have read/write capabilities to deploy this technology in the I-15 Managed Lanes.

In facilities with self-declaration lanes (e.g. Denver's I-25 HOT lanes), customers are required to choose a lane in accordance to their vehicle occupancy prior to going through the tolling points. The facility's ALPR system enforces toll violation in the SOV lane while highway officers monitor the occupancy of vehicles that choose the HOV lane. The benefits of this strategy are automated enforcement of toll evasion and simplified inspection of vehicle occupancy since officers are required to observe only one lane where all vehicles are expected to meet the HOV requirement. Questions that could aid in a future evaluation of this strategy for San Diego's I-15 Managed Lanes are:

- How accurate and reliable are current ALPR systems?
- Is the enforcement of toll evasion using ALPR cost-prohibitive given the back office operations required to implement a quality-controlled image review?
- Could the throughput of the facility be compromised by requiring vehicles to segregate themselves prior to going through the tolling points?
- How would customers perceive this strategy?

HOV pre-registration entails customers, among other requirements, to register their vehicle's license plate so that the ALPR system is able to distinguish between HOV and SOV users. HOV pre-registration in conjunction with an ALPR system can automate the enforcement of toll evasion. This strategy has only been implemented in Miami's I-95 HOT lanes where HOV users have to attach a decal to their vehicles so that officers can identify them as HOVs. As in the case of self-declaration lanes, an evaluation of this strategy for the I-15 Managed Lanes would have to consider the merits and constraints of ALPR systems. Additional preliminary questions are:

- Would the HOV pre-registration process affect efforts to encourage users to rideshare dynamically?
- How would HOV preregistration affect interoperability in the state?

6.3 Synthesis of Relevant Factors in the Selection of Self-Declaration Systems

Several factors have defined current violation enforcement practices in HOT lanes facilities around the United States. The following list presents a synthesis of the factors of the decision-making process.

- *Legislation.* Interoperability requirements have guided the selection of electronic payment systems in all the HOT lanes facilities studied. Additionally, state laws can define which technologies can be deployed for enforcement and tolling purposes. Utah and Minnesota state laws have prohibited the use of cameras for vehicle violation enforcement process, thus requiring the state DOTs to rely entirely on manual enforcement. In the case of Salt Lake City's I-15 Express Lanes, long term enforcement plans have explicitly considered rapid conversion to camera enforcement system in the event that a change in state laws occurs.

- *Cost and schedule constraints.* Several project managers expressed that their agencies had considered technologies such as automated violation enforcement or 5.9 GHz technologies. However, these technologies were not considered mature or too expensive to be implemented in a large scale project. Instead, the second-best solution given budget and project schedules were chosen in lieu of the more advance options. The case of the Capitol Beltway Express Lanes in Virginia provides an example. Given the projects schedule and budget, the lanes are planned to begin operation with manual HOT lane enforcement strategies while the long term plan is to transition to an automated enforcement system interoperable with 5.9 GHz technologies.

- *Automation of toll violation enforcement.* Although fully automated vehicle occupancy enforcement systems have not been implemented in any HOT lane facility, several project managers interviewed expressed interest in them as an ideal method for enforcement. However, the interviewees considered the technology not currently viable. Only Virginia's I-495 HOT lanes project have required the private partner to implement an automated enforcement system before the end of a ten year period. In place of the fully automated vehicle occupancy enforcement, two of the cases studied use ALPR systems to partially automate the enforcement of toll violations, namely Miami's I-95 Express Lanes, Denver's I-25 HOV Express Lanes and Houston's METRO HOT lanes. These facilities require HOV users to declare their status by either selecting the HOV lane in a self-declaration lane arrangement (Denver and Houston) or by pre-registering as a HOV (Miami).

- *HOT lane facility layout.* Multiple entry and exit points in long corridors represent a challenge to enforcement efforts. The I-394 MnPASS Express Lanes is an example of how an agency has addressed this enforcement challenge by selecting appropriate technologies. Officials selected a transponder with read/write capabilities and officers were provided with monitoring technology imbedded in handheld devices to query the transaction history of the transponder throughout the corridor. This arrangement allows officers to determine if a user has deactivated his or her device at tolling points upstream of the enforcement location.

- *Spatial and climate constraints.* Narrow corridors limit the number enforcement spots available for highway patrol and make self-declaration lanes infeasible. This was the situation faced by officials of Minnesota's I-394 MnPASS Express Lanes project. Additional site-specific constrains include the weather, which could influence the type of barriers used to separate the HOT lanes from general purpose lanes.

- *Transponder options and the user*. The idea of providing the user with transponder choices when using the HOT lane facility was mentioned in the interviews. For example, officials of Miami's I-95 Express Lanes allowed customers to continue using their traditional hard case transponders even though the FDOT had introduced a new sticker tag. This decision provided a sense of continuity and options to the customers. Denver's I-25 HOV Express Lanes allows users the choice between of affixing a transponder or relying on video tolling.

Table 18: HOT Lane Facility Policies and Technologies

Facility	Length (miles)	Lanes per direction	Range of toll	HOV requirement	HOV transponders	TSI?*	Handheld devices?	MER?*	ALPR?*
SR-167 (Seattle, WA)	9	1	$0.50 to $9.00	2+	No	Yes	Yes	No	No
I-95 (Miami, FL)	8	2	$0.25 to $7.50	3+	No	No	No	No	Yes
I-15 (Salt Lake, UT)	60	1	Decal: $50 per month; ETC: $0.10 to $1.00 per zone	2+	Planned (Switchable transponders)	Planned	Planned	No	No
I-394 (Minneapolis, MN)	1st section: 8	1	$0.25 to $8.00	2+	No	Yes	Yes	Yes	No
	2nd section: 3	2							
I-25 (Denver, CO)	7	2 reversible lanes	$0.50 to $3.50	2+	No	No	Planned	No	Yes
Non-operating Facilities									
I-495 (Fairfax County, VA)	14	2	$0.10 to $1.00 per mile	2+	Yes (Switchable transponders)	No	No	No	No
METRO Hot Lanes (Houston, TX)	87	1 reversible lane	-	2+	Yes	No	No	No	Yes
I-10 and I-110 (Los Angeles, CA)	I-10: 14	2	$0.25 to $1.40 per mile	Peak: 3+ Non-Peak: 2+ 2+	Yes (Switchable transponders)	Yes	Asking bidders	No	Yes
	I-110: 11	1							
BA Express Lane Network (SFBA*, CA)	800	1 (with 2 lane exceptions)	-	Varies between 2+ and 3+ (majority 2+)	Yes (Switchable transponders)	No	Yes	No	Yes

**TSI: transaction status indicator, MER: mobile enforcement reader, ALPR: automatic license plate recognition, SFBA: San Francisco Bay Area*

Table 19: Enforcement in HOT Lanes Facilities

Facility	Enforcement Approach	Future enforcement plans
SR-167 (Seattle, WA)	• Manual enforcement of all violations • Use of handheld devises and TSI	• WSDOT is considering fully automated verification systems, switchable transponders and smart card on board units
I-95 (Miami, FL)	• Manual enforcement of vehicle occupancy • Automated enforcement of toll evasion relying on ALPR • HOV must pre-register prior to using lanes	• Use of handheld devices
I-15 (Salt Lake, UT)	• Manual enforcement of all violations • SOVs must have a decal	• Transition to electronic payment system • Use of TSI and switchable transponders
I-394 (Minneapolis, MN)	• Manual enforcement of all violations • Use of handheld devices, MER and TSI	• No changes envisioned
I-25 (Denver, CO)	• Manual enforcement of vehicle occupancy • Automated enforcement of toll evasion relaying on ALPR • Use of self-declaration lanes	• Use of handheld devices
Non-operating Facilities	Planned Enforcement Approach	
I-495 (Fairfax County, VA)	• Initially, the lanes will be manually enforced with the help of technology • An alarm system will inform the troopers if a valid transaction was executed • Private partner is required by contract to implement an automatic enforcement system • Switchable transponders will be used	
METRO Hot Lanes (Houston, TX)	• Enforcement revolves around self-declaration lanes • Toll evasion enforcement will be automated with an ALPR system	
I-10 and I-110 (Los Angeles, CA)	• Manual enforcement assisted by TSI and a ALPR system • Switchable transponders will be used	
BA Express Lane Network (SFBA, CA)	• Manual enforcement assisted by handheld devices and a ALPR system • Switchable transponders will be used	

7. POLICY CONSIDERATIONS ON SELEF-DECLARATION SYSTEMS

This section presents political, legislative, legal and other policy aspects that could influence the decision-making process defining the I-15 Managed Lane vehicle occupancy enforcement system.

7.1 Regulatory and Legislative Issues for the Deployment Self-Declaration Systems in San Diego

7.1.1 Title 21 Specifications of RFID Technologies

The Compatibility Specifications for Automatic Vehicle Identification Equipment standard was created by Caltrans. Part of the California Code of Regulations as Title 21, Division 2, Chapter 16, Article 1 through 4. Title 21, as this standard is commonly called, stipulates transponder specifications for automatic vehicle identification systems used for electronic toll collection (ETC) in highways. As the standard's name suggests, its general objective is to ensure statewide compatibility of ETC technologies. Table 4 presents a summary of key transponder compatibility specifications.

Table 20: Transponder Compatibility Specifications

Item	Specification
Technology Type	Modulated Backscatter
Transponder Antenna Polarization	Horizontal
Field-of-View	Operation within 90° conical angle
Location	Front of Vehicle
Send Mode (Uplink) Carrier Radio Frequency	915 ± 13 MHz
Subcarrier Modulation	Frequency-shift keying with a center frequency of 900 kHz and frequency deviation of ± 300 kHz
Subcarrier Frequencies	600 kHz ± 10% and 1200 kHz ± 10%
Data Bits Rate	300 kbps
Receiver Field-Strength Threshold	500 mV/m ± 50 mV/m (minimum)
Activation Timing	Within 1 millisecond entry into the reader's modulated radio frequency field
Reader's Message Decoding Time	Within 100 microseconds of a 33 microsecond long modulated RF trigger pulse from the reader

Source: CCR, Title 21, Division 2, Chapter 16, Summary and Article 1 through 4

Title 21 specifications may prevent the adoption of newer technologies, such as 5.9 GHz transponders. If a non-Title 21 transponder is identified as a potential element of an I-15 occupancy verification system, Caltrans could be petitioned to amend or repeal Title 21 by the procedure described in the Government Code sections 11340.6 and 11340.7. Section 11340.6 states that "any interested person may petition a state agency requesting the adoption, amendment, or repeal of a regulation." The petition must state:

- The substance or nature of the regulation, amendment, or repeal requested;
- The reason for the request; and

- Reference to the authority of the state agency to take the action requested.[64]

Caltrans has 30 days to either deny the petition or schedule a public hearing on the matter. The denial of a petition requires a written explanation to the petitioner indicating the reasons for the decision. The petitioner can ask the agency to reconsider the denial within 60 days of the determination. The process for requesting the reconsideration has to follow the aforementioned procedure. Additionally, the petitioner must explain the reasons why the agency must reconsider the previous decision. The petitioner also must be notified if the state agency decides to grant the petition in whole or in part.

7.1.2 Interoperability and Limit on the Number of Transponders per Vehicle

Section 275664 of the California Streets and Highways Code requires that "all automatic vehicle identification systems and technology used by all toll facility operators are compatible with one another" in the state.

In Section 27565(a) of the California Streets and Highways Code, the Legislature establishes that "vehicle owner[s] shall not be required to purchase or install more than one device to use on all toll facilities." Therefore, this provision could represent a legal challenge any enforcement or tolling strategy that requires the use of multiple transponders.

7.1.3 Safety

In Section 5.3.2 of this report, safety is discussed in terms of its implications to the selection process of a self-declaration system, highlighting distracted driving and CHP safety. The method used to separate the HOT lanes from the general purpose lanes is another important safety and enforcement consideration. For example, HOT lanes can be separated from general purpose lanes by using specialized striping, plastic delineators or concrete barriers. Five of the nine facilities presented in the case studies section stripe the length of the facility. The rest used either fixed plastic delineators or concrete barriers.

An enforcement concern associated with striping based separation is that drivers could enter or exit the HOT lanes in unauthorized zones with ease. This type of maneuver not only represents a violation of the facility rules but may also cause accidents. Possible methods for preventing these types of maneuvers are installing concrete barriers or fixed plastic delineators. However, these solutions also have their disadvantages. Concrete barriers are expensive, require additional lane space and could cause traffic problems in case of an incident in the HOT lanes traffic.[65] Plastic delineators are cheaper and require less space but require more maintenance.

7.1.4 Privacy and Related Legal Issues

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[64] Government Code Section 11340.6

[65] FHWA. "Strategies for Improving Safety at Toll Collection Facilities: Reducing Unsafe Merging and Lane Changing." *FHWA Operations*. Web. 01 July 2010. <http://ops.fhwa.dot.gov/tolling_pricing/resources/report/toll_summary/s5.htm>.

Several concerns associated with electronic vehicle identification systems can be grouped into three broad classifications related to privacy issues:[66]

- *Big Brother government concerns*: Besides being useful to monitor terrorists and criminals, theoretically the technologies used in ETC facilities could be used to track and persecute government dissenters.
- *Unauthorized appropriation of records*: Criminals could breach the ETC database system to extract the user records for financial gains.

- *Leaking or disclosure of secret records*: The data collected by the ETC (e.g., person's location at certain a time) could be leaked or disclosed which could cause embarrassment, anguish or harm to the individual.[67]

Given these possible privacy concerns the authors emphasize the need for public agencies to have public outreach programs to market the benefits of the systems and alleviate any concerns.

Researchers at UC Berkeley found evidence that privacy concerns have an impact on the usage of transponders. The study was based on a survey with 558 participants who were asked, among other questions, the reasons why they do not use FasTrak. Privacy concerns were the third most selected option after "I don't think I would use [FasTrak] often enough" and "I haven't had the time [to sign up]". The researchers concluded that perceived reduction in privacy explains the lower FasTrak adoption rate in the San Francisco Bay Area relative to other urban regions with similar electronic toll collection systems.[68] This research suggests that some drivers in California place a higher value on privacy than on time saved by the use of the FasTrak transponder, which may indicate that this is an issue that needs to be explicitly addressed.

The perception that transponders impact privacy could be explained in part by the number of cases for which lawyers have subpoenaed transponder transaction records for criminal and civil cases. Lawyers have used transponder transaction records as incidence in civil cases related to marital disputes, child custody, and employee/employer cases. In California, these concerns resulted in the 2008 RFID "Skimming" Ban law, which makes it illegal to read or record information embedded on RFID-enabled ID without consent. The handling of data collected by government agencies in California has been regulated since the passage of the Information Practices Act of 1977. These statutes stem from the fact that the right of privacy is explicitly guaranteed in Article 1 of the Constitution of the State of California.[69]

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[66] Persad, K., C. M. Walton, and S. Hussain. *Electronic Vehicle Identification: Industry Standards, Performance, and Privacy Issues.* Texas Department of Transportation, Austin, 2007. www.utexas.edu/research/ctr/pdf_reports/0_5217_P2.pdf.

[67] Persad, K., C. M. Walton, and S. Hussain. *Electronic Vehicle Identification: Industry Standards, Performance, and Privacy Issues.* Texas Department of Transportation, Austin, 2007.< www.utexas.edu/research/ctr/pdf_reports/0_5217_P2.pdf >.

[68] Riley, Patrick. The tolls of privacy: An underestimated roadblock for electronic toll collection usage. Computer Law & Security Report 24 (2008) 521-528.

[69] Ozer, Nicole, *Rights "Chipped" Away: RFID and Identification Documents,* Stanford Technology Law Review, 2008. Available at: stlr.stanford.edu/pdf/ozer-rights-chipped-away.pdf.

Concerns have also been raised about the constitutionality of ETC automated law enforcement systems. Some have argued that these systems could infringe on the "right of free association (First Amendment), the right of equal protection (Fourth Amendment) [*sic*], the right to present a defense (Sixth Amendment), and the right for due process (Tenth Amendment)".[70]

7.2 Conclusions

Lessons learned from the literature review and case studies show that partially-automated systems may not capture all violations but they have proven to be the most reliable for the level of technology that is currently available. Several options for technologies and physical design of the facility are available and can be selected according to the I-15 Managed Lanes specifications and customer preference.

[70] UCD (2005): *Virtual Commercial Vehicle Compliance Stations: A Review of Legal and Institutional Issues.* Caroline Rodier, Susan Shaheen, and Ellen Cavanagh, Institute of Transportation Studies, University of California at Davis.

Appendix I Technology Provider Evaluation Form/Selection Criteria

SAN DIEGO ASSOCIATION OF GOVERNMENTS (SANDAG)

CONSULTANT SHORT LIST EVALUATION FORM

Consultant: ______________________________

Contract No.: ____________________ Description: ____________________

Criteria	(a) Weight	(b) Score (0-10)*	(a) x (b) Weighted Score
1. FIRM'S CAPABILITIES • Nature, quality, and relevance of completed projects • Previous demonstrations of technology • Other ongoing project commitments and priorities • Quality and cost control measures in place • Evidence of overall corporate resources available • Financial stability and strength of the company • Experience, technical competence and role of key staff / subcontractors.	2.0		
2. PRODUCT / SERVICE CAPABILITIES • Use of components proven in service on similar projects or related applications • Innovative approaches to design, integration and use of equipment • System design: logic, advantages, proven approach • System Integration: logic, advantages, proven approach • System performance and reliability: proposed system performance and actual documented performance • System flexibility and upgradeability • Test Plan: logic, applicability to data reporting requirements • Potential for interoperability with existing or planned systems in the region	3.0		
3. APPLICABILITY TO PROJECT OBJECTIVES • Applicability of product/services to Project objectives • Potential benefits to SANDAG of proposed solution	3.0		
4. COMMITMENT TO PROJECT • Evidence of corporate resources committed to the Project • Availability/experience of key members and senior staff for this Project • Demonstrated knowledge of work required • Logic, clarity and specificity of work plan • Evidence of willingness to exceed the requirements of the RFP and the Scope of Work • Quality of plan and schedule for implementation, including planned coordination	2.0		
		Total	

Comments (continue on reverse if necessary):

I certify that I have performed an independent evaluation of the above named consultant. I further certify that I have not engaged in discussions within the last year with the above-named consultant regarding my future employment with said consultant and that neither I nor anyone in my household has received income from any of the bidders/proposers during the last 12 months.

Signature of Evaluator: ____________________ Date: ____________

Printed Name of Evaluator: ____________________

Checked by: ____________________ Date: ____________

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SAN DIEGO ASSOCIATION OF GOVERNMENTS (SANDAG)

CONSULTANT INTERVIEW EVALUATION FORM

Consultant: ____

Contract No.: ____________________ Description: ____________________

Criteria	(a) Weight	(b) Score (0-10)*	(a) x (b) Weighted Score
1. FIRM'S CAPABILITIES • Nature, quality, and relevance of completed projects • Previous demonstrations of technology • Other ongoing project commitments and priorities • Quality and cost control measures in place • Evidence of overall corporate resources available • Financial stability and strength of the company • Experience, technical competence and role of key staff / subcontractors.	1.0		
2. PRODUCT / SERVICE CAPABILITIES • Use of components proven in service on similar projects or related applications • Innovative approaches to design, integration and use of equipment • System design: logic, advantages, proven approach • System Integration: logic, advantages, proven approach • System performance and reliability: proposed system performance and actual documented performance • System flexibility and upgradeability • Test Plan: logic, applicability to data reporting requirements • Potential for interoperability with existing or planned systems in the region	1.5		
3. APPLICABILITY TO PROJECT OBJECTIVES • Applicability of product/services to Project objectives • Potential benefits to SANDAG of proposed solution	1.5		
4. COMMITMENT TO PROJECT • Evidence of corporate resources committed to the Project • Availability/experience of key members and senior staff for this Project • Demonstrated knowledge of work required • Logic, clarity and specificity of work plan • Evidence of willingness to exceed the requirements of the RFP and the Scope of Work • Quality of plan and schedule for implementation, including planned coordination	1.5		
5. INTERVIEW QUESTIONS • Demonstrated knowledge of the work required • Appropriate responses to questions	1.0		
6. REFERENCES** • Record of producing a quality product on similar projects on time and within budget • Overall experience and technical competence of the firm in performing work of a similar nature • Key personnel reference quality	0.5		
7. COST OR BEST VALUE • Evidence of financial commitment to proof-of-concept • Ranking of comparative costs among proposed firms, providing the best value for services offered)	3.0		
***** All panel members must enter a zero (0) for all interviewed Consultants if time did not allow for reference checks or if the reference checks were not completed on <u>all</u> the Consultants.***		Total	

Comments (continue on reverse if necessary):

I certify that I have performed an independent evaluation of the above named consultant. I further certify that I have not engaged in discussions within the last year with the above-named consultant regarding my future employment with said consultant and that neither I nor anyone in my household has received income from any of the bidders/proposers during the last 12 months.

Signature of Evaluator: ______________________________ Date: ________________

Printed Name of Evaluator ______________________________

Checked by: ______________________________ Date: ________________

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Appendix II Sample Size Calculation with Expected Performance Level

In the case studies under consideration, it is desirable to select a sample size or the number of test samples needed to assess whether the selected instrument can achieve the expected or hypothesized level of performance in accuracy.

Assume that the accuracy performance of the instrument is γ_i ($0 \le \gamma_i \le 1$) for the conditions that there are i (where $i = 1, 2, 3$) occupants in the vehicle. For a given confidence level (1-α) and margin of error d, we will estimate the sample size needed for the experiments.

Suppose we take n times experiments, and the results are denoted $X_1, X_2, \cdots, X_n$, and the random variable X_i takes two values 1 or 0, with probability γ_i or $1-\gamma_i$. So we have $EX_i = \gamma_i,\ DX_i = \gamma_i(1-\gamma_i)$, where EX_i is the expected value of test i and DX_i is the variance of test i.

Let's denote $\bar{X} = (\sum_{i=1}^{n} X_i)/n$, then $\bar{X}$ is the unbiased estimation for γ_i, and

$E\bar{X} = \gamma_i,\ D\bar{X} = \gamma_i(1-\gamma_i)/n$.

The probability of the unbiased estimation is then expressed as:

$$P(\bar{X} - \gamma_i \ge d) = \alpha \tag{1}$$

Assuming that the standard deviation of $\bar{X}$ can be approximated by a normal distribution Z ratio, then equation (1) becomes:

$$P(\bar{X} - \gamma_i \ge d) = P\left(\frac{\bar{X} - \gamma_i}{\sqrt{\gamma_i(1-\gamma_i)/n}} \ge \frac{d}{\sqrt{\gamma_i(1-\gamma_i)/n}}\right) \approx P\left(Z \ge \frac{d}{\sqrt{\gamma_i(1-\gamma_i)/n}}\right) = \alpha$$

Since $P(Z \ge Z_\alpha) = \alpha$, where Z_α is the α quantile for normal distribution, then

$$\frac{d}{\sqrt{\gamma_i(1-\gamma_i)/n}} = Z_\alpha \tag{2}$$

This implies that

$$n = \frac{Z_\alpha^2 \gamma_i (1-\gamma_i)}{d^2} \tag{3}$$

Based on Equation (3), we can then calculate the sample sizes for various hypothesized performance levels, confidence levels and margin of errors. In the examples below, the sample sizes are generated with for case studies with the following parameters:

(a) Margin of errors at $d = 0.05,\ 0.03, 0.025$

(b) Confidence levels at $1-\alpha$, where $\alpha = 0.2, 0.1, 0.05, 0.01$, and α denotes significance level.

(c) Expected performance accuracy at $\gamma_1 = 0.99$, $\gamma_2 = 0.95$, $\gamma_3 = 0.9$.

Case Study I: $\gamma_1 = 0.99$ (99% accuracy)

Table A1 $\gamma_1 = 0.99$

sample size n / confidence level $1-\alpha$ / margin of error d	0.80	0.90	0.95	0.99
0.05	3	7	11	22
0.03	8	19	30	60
0.025	12	26	44	86

Case Study II: $\gamma_2 = 0.95$ (95% accuracy)

Table A2 $\gamma_2 = 0.95$

sample size n / confidence level $1-\alpha$ / margin of error d	0.80	0.90	0.95	0.99
0.05	14	32	52	104
0.03	39	87	144	287
0.025	55	126	207	413

Case Study III: $\gamma_3 = 0.9$ (90% accuracy)

Table A3 $\gamma_3 = 0.9$

sample size n / confidence level $1-\alpha$ / margin of error d	0.80	0.90	0.95	0.99
0.05	27	59	99	196
0.03	73	164	273	543
0.025	105	236	393	782

From the estimated samples for difference case studies, it can be seen that for the same confidence level and the same margin of error, a lower expected performance level will require a larger sample size and vice versa.

Validation of Hypothesized Performance

The analysis above provides a needed sample size for a given hypothesized level of performance. After the experiments are conducted, the results can be used to validate the hypothesis.

For example, a set of experiments is carried out to observe if there is only one single occupant in a vehicle. If the outcome of the experiment indicates that there is one occupant, we denote the observation as 1 (true), and 0 (false) otherwise. Suppose that we have a random sample of n observations, and n_1 is the times when the outcome is 1, and n_0 for outcome 0, where obviously $n_0 = n - n_1$. Then we would like to test the following hypothesis where

$$H_0 : p_1 = \gamma_1, \quad p_0 = 1 - \gamma_1 \qquad H_1 : p_1 \neq \gamma_1, \quad p_0 \neq 1 - \gamma_1 \tag{4}$$

By the theory of K. Pearson[1] , the appropriate statistics can be denoted as

$$D = \frac{(n_1 - np_1)^2}{np_1} + \frac{(n_2 - np_2)^2}{np_2} \tag{5}$$

Where D is Karl Pearson Statistics, So when hypothesis H_0 is true, we can express D as follows:

$$D = \frac{(n_1 - n\gamma_1)^2}{n\gamma_1} + \frac{(n_2 - n(1-\gamma_1))^2}{n(1-\gamma_1)} \sim \chi^2(1) \tag{6}$$

For a confidence level α , we can get the corresponding quantile $\chi^2_\alpha(1)$ from the χ^2 distribution table. By the observed result we can then determine if $D \geq \chi^2_\alpha(1)$, we can reject H_0, otherwise we can accept H_0.

Case Study I:

For example, we want to verify the performance accuracy of 99% for the instrument under the condition of one single occupant inside a vehicle. The results of 100 experiments showed that 98 observations were true (with an outcome of 1) and two were false (outcome is 0). Based on Equation (6) above, with a confidence level $\alpha = 0.05$, and $\chi^2_{0.05} = 3.84$, and the calculated $D = 1.01$, so we accept H_0. If there were only 97 observations of true outcome, then $D = 4.04$. Since $D = 4.04 > \chi^2_{0.05} = 3.84$, we then reject H_0, which means that the hypothesized performance of 99% accuracy is not valid.

Case Study II:

We want to verify the performance accuracy of 95% for the instrument under the condition of two occupants inside a vehicle. If the results of 100 experiments showed that 91 observations were true (with an outcome of 1) and 9 were false (outcome is 0). Based on Equation (6) above, with a confidence level $\alpha = 0.05$, and $\chi^2_{0.05} = 3.84$, and the calculated $D = 3.36$, so we accept H_0 . But if there were only 90 observations of true outcome, then $D = 5.26$. Since $D = 5.26 > \chi^2_{0.05} = 3.84$, we then reject H_0, which means that the hypothesized performance of 95% accuracy is not valid.

Case Study III:

We want to verify the performance accuracy of 90% for the instrument under the condition of two occupants inside a vehicle. If the results of 100 experiments showed that 85 observations were true (with an outcome of 1) and 15 were false (outcome is 0). Based on Equation (6) above, with a confidence level $\alpha = 0.05$, and $\chi^2_{0.05} = 3.84$, and the calculated $D = 2.77$, so we accept H_0. But if there were only 84 observations of true outcome, then $D = 4.01$. Since $D = 4.01 > \chi^2_{0.05} = 3.84$, we then reject H_0, which means that the hypothesized performance of 90% accuracy is not valid.

Appendix III Controlled Testing Sequence

Record	Test Date	Time of Day	Test Step (Run)	Position	Vehicle Type	# Occupant	Occupant Types	Seat Assignment	Speed
1	7/30/10	NT01	1	1	Sedan	2 ~~1~~ + 1 dummy	1 adult, 1 dummy, 1adult	Driver, dummy on passenger seat, adult 2^{nd} row passenger side	10
2	Friday			2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	10
3	Night			3	Truck	2	2 adults	Driver and 1 passenger	10
4				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	10
5				5	Sedan	2 ~~1 + 1 dummy~~	1 adult, 1 adult ~~dummy~~	Driver, adult ~~dummy~~ on passenger seat	10
6				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row ~~middle~~ passenger side	10
7				7	Truck	2	2 adults	Driver and 1 passenger	10
8				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	10
9			2	1	Sedan	2 ~~1~~ + 1 dummy	1 adult, 1 dummy, 1adult	Driver, dummy on passenger seat, adult 2^{nd} row passenger side	30
10				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	30
11				3	Truck	2	2 adults	Driver and 1 passenger	30
12				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	30
13				5	Sedan	2 ~~1 + 1 dummy~~	1 adult, 1 adult ~~dummy~~	Driver, adult ~~dummy~~ on passenger seat	30
14				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row ~~middle~~ passenger side	30
15				7	Truck	2	2 adults	Driver and 1 passenger	30
16				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	30
17			3	1	Sedan	2 ~~1~~ + 1 dummy	1 adult, 1 dummy, 1adult	Driver, dummy on passenger seat, adult 2^{nd} row passenger side	45
18				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	45
19				3	Truck	2	2 adults	Driver and 1 passenger	45
20				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	45
21				5	Sedan	2 ~~1 + 1 dummy~~	1 adult, 1 adult ~~dummy~~	Driver, adult ~~dummy~~ on passenger seat	45
22				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row ~~middle~~ passenger side	45
23				7	Truck	2	2 adults	Driver and 1 passenger	45
24				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	45
25			4	1	Sedan	2 ~~1~~ + 1 dummy	1 adult, 1 dummy, 1adult	Driver, dummy on passenger seat, adult 2^{nd} row passenger side	65
26				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	65
27				3	Truck	2	2 adults	Driver and 1 passenger	65
28				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	65
29				5	Sedan	2 ~~1 + 1 dummy~~	1 adult, 1 adult ~~dummy~~	Driver, adult ~~dummy~~ on passenger seat	65
30				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row ~~middle~~ passenger side	65
31				7	Truck	2	2 adults	Driver and 1 passenger	65
32				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	65
33			5	1	Sedan	2 ~~1~~ + 1 dummy	1 adult, 1 dummy, 1adult	Driver, dummy on passenger seat, adult 2^{nd} row passenger side	80
34				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	80
35				3	Truck	2	2 adults	Driver and 1 passenger	80
36				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	80
37				5	Sedan	2 ~~1 + 1 dummy~~	1 adult, 1 adult ~~dummy~~	Driver, adult ~~dummy~~ on passenger seat	80
38				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle passenger side	80
39				7	Truck	2	2 adults	Driver and 1 passenger	80
40				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	80
41		NT02	6	1	Sedan	2	2 adults	Driver, passenger on front row	10
42				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	10
43				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	10
44				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	10
45				5	Sedan	2	2 adults	Driver, passenger on front row	10
46				6	Minivan	4 ~~3~~	1 adult, 2 children, 1 adult	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle, adult on 3rd row driver	10
47				7	Truck	1 ~~+ 1 dummy~~	1 adult, ~~1 dummy~~	Driver~~, dummy on passenger seat~~	10
48				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	10
49			7	1	Sedan	2	2 adults	Driver, passenger on front row	30
50				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	30
51				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	30
52				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	30
53				5	Sedan	2	2 adults	Driver, passenger on front row	30
54				6	Minivan	4 ~~3~~	1 adult, 2 children, 1 adult	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle, adult on 3rd row driver	30
55				7	Truck	1 ~~+ 1 dummy~~	1 adult, ~~1 dummy~~	Driver~~, dummy on passenger seat~~	30
56				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	30
57			8	1	Sedan	2	2 adults	Driver, passenger on front row	45
58				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	45
59				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	45
60				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	45
61				5	Sedan	2	2 adults	Driver, passenger on front row	45
62				6	Minivan	4 ~~3~~	1 adult, 2 children, 1 adult	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle, adult on 3rd row driver	45
63				7	Truck	1 ~~+ 1 dummy~~	1 adult, ~~1 dummy~~	Driver~~, dummy on passenger seat~~	45
64				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	45
65			9	1	Sedan	2	2 adults	Driver, passenger on front row	65
66				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	65
67				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	65
68				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	65
69				5	Sedan	2	2 adults	Driver, passenger on front row	65
70				6	Minivan	4 ~~3~~	1 adult, 2 children, 1 adult	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle, adult on 3rd row driver	65
71				7	Truck	1 ~~+ 1 dummy~~	1 adult, ~~1 dummy~~	Driver~~, dummy on passenger seat~~	65
72				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	65
73			10	1	Sedan	2	2 adults	Driver, passenger on front row	80
74				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	80

75			3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	80
76			4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	80
77			5	Sedan	2	2 adults	Driver, passenger on front row	80
78			6	Minivan	4 ~~3~~	1 adult, 2 children, 1 adult	Driver, child on 2nd row driver side, child on 3rd row middle, adult on 3rd row driver	80
79			7	Truck	1 ~~+ 1 dummy~~	1 adult, ~~1 dummy~~	Driver~~, dummy on passenger seat~~	80
80			8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	80
81	NT03	11	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	10
82			2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	10
83			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
84			4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	10
85			5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	10
86			6	Minivan	3 ~~2~~	1 adult, 1 child, 1adult	Driver, child on 3rd row middle, adult on 3rd row passenger side	10
87			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	10
88			8	SUV	2 ~~+ 1 dummy~~	2 adults, ~~1 dummy~~	Driver, passenger on front row~~, dummy on 2nd row middle~~	10
89		12	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	30
90			2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	30
91			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
92			4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	30
93			5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	30
94			6	Minivan	3 ~~2~~	1 adult, 1 child, 1adult	Driver, child on 3rd row middle, adult on 3rd row passenger side	30
95			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	30
96			8	SUV	2 ~~+ 1 dummy~~	2 adults, ~~1 dummy~~	Driver, passenger on front row~~, dummy on 2nd row middle~~	30
97		13	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	45
98			2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	45
99			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
100			4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	45
101			5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	45
102			6	Minivan	3 ~~2~~	1 adult, 1 child, 1adult	Driver, child on 3rd row middle, adult on 3rd row passenger side	45
103			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	45
104			8	SUV	2 ~~+ 1 dummy~~	2 adults, ~~1 dummy~~	Driver, passenger on front row~~, dummy on 2nd row middle~~	45
105		14	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	65
106			2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	65
107			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
108			4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	65
109			5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	65
110			6	Minivan	3 ~~2~~	1 adult, 1 child, 1adult	Driver, child on 3rd row middle, adult on 3rd row passenger side	65
111			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	65
112			8	SUV	2 ~~+ 1 dummy~~	2 adults, ~~1 dummy~~	Driver, passenger on front row~~, dummy on 2nd row middle~~	65
113		15	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	80
114			2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	80
115			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
116			4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	80
117			5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	80
118			6	Minivan	3 ~~2~~	1 adult, 1 child, 1adult	Driver, child on 3rd row middle, adult on 3rd row passenger side	80
119			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	80
120			8	SUV	2 ~~+ 1 dummy~~	2 adults, ~~1 dummy~~	Driver, passenger on front row~~, dummy on 2nd row middle~~	80
121	NT04	16	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	10
122			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	10
123			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
124			4	SUV	1	1 adult	Driver	10
125			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	10
126			6	Minivan	2 + ~~1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side~~, dummy on 3rd row passenger side~~	10
127			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	10
128			8	SUV	1	1 adult	Driver	10
129		17	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
130			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	30
131			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
132			4	SUV	1	1 adult	Driver	30
133			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
134			6	Minivan	2 + ~~1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side~~, dummy on 3rd row passenger side~~	30
135			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	30
136			8	SUV	1	1 adult	Driver	30
137		18	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	45
138			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	45
139			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
140			4	SUV	1	1 adult	Driver	45
141			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	45
142			6	Minivan	2 + ~~1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side~~, dummy on 3rd row passenger side~~	45
143			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	45
144			8	SUV	1	1 adult	Driver	45
145		19	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	65
146			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	65
147			3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
148			4	SUV	1	1 adult	Driver	65
149			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	65
150			6	Minivan	2 + ~~1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side~~, dummy on 3rd row passenger side~~	65
151			7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2nd row middle	65
152			8	SUV	1	1 adult	Driver	65
153		20	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	80

154				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2^{nd} row driver side, dummy on $3r^{d}$ row passenger side	80
155				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
156				4	SUV	1	1 adult	Driver	80
157				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2^{nd} row passenger side, 1 passenger on 2nd	80
158				6	Minivan	2 + ~~1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2^{nd} row driver side, ~~dummy on $3r^{d}$ row passenger side~~	80
159				7	Truck	3	2 adults, 1 teen	Driver and ~~passengers~~ adult on front row, teen on 2^{nd} row middle	80
160				8	SUV	1	1 adult	Driver	80
161	**7/31/10**	**DT01**	1	1	Sedan	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	10
162	**Saturday**			2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	10
163	**Morning**			3	Truck	2	2 adults	Driver and 1 passenger	10
164				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	10
165				5	Sedan	2 ~~1+1 dummy~~	2 ~~1~~ adult, ~~1 dummy~~	Driver, ~~dummy~~ adult on passenger seat	10
166				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	10
167				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	10
168				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	10
169			2	1	Sedan	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	30
170				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	30
171				3	Truck	2	2 adults	Driver and 1 passenger	30
172				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	30
173				5	Sedan	2 ~~1+1 dummy~~	2 ~~1~~ adult, ~~1 dummy~~	Driver, ~~dummy~~ adult on passenger seat	30
174				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	30
175				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	30
176				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	30
177			3	1	Sedan	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	45
178				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	45
179				3	Truck	2	2 adults	Driver and 1 passenger	45
180				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	45
181				5	Sedan	2 ~~1+1 dummy~~	2 ~~1~~ adult, ~~1 dummy~~	Driver, ~~dummy~~ adult on passenger seat	45
182				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	45
183				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	45
184				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	45
185			4	1	Sedan	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	65
186				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	65
187				3	Truck	2	2 adults	Driver and 1 passenger	65
188				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	65
189				5	Sedan	2 ~~1+1 dummy~~	2 ~~1~~ adult, ~~1 dummy~~	Driver, ~~dummy~~ adult on passenger seat	65
190				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	65
191				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	65
192				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	65
193			5	1	Sedan	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	80
194				2	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	80
195				3	Truck	2	2 adults	Driver and 1 passenger	80
196				4	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	80
197				5	Sedan		2 adult,	Driver, on passenger seat	80
198				6	Minivan	4	2 adults, 2 children	Driver, front passenger, 2^{nd} row driver side, 2^{nd} row middle	80
199				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	80
200				8	SUV	3	2 adults, 1 teen	Driver, 2^{nd} row driver side, teen on 2^{nd} row passenger side	80
201		**DT02**	6	1	Sedan	2	2 adults	Driver, passenger on front row	10
202				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	10
203				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	10
204				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	10
205				5	Sedan	2	2 adults	Driver, passenger on front row	10
206				6	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	10
207				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	10
208				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	10
209			7	1	Sedan	2	2 adults	Driver, passenger on front row	30
210				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	30
211				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	30
212				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	30
213				5	Sedan	2	2 adults	Driver, passenger on front row	30
214				6	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	30
215				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	30
216				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	30
217			8	1	Sedan	2	2 adults	Driver, passenger on front row	45
218				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	45
219				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	45
220				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	45
221				5	Sedan	2	2 adults	Driver, passenger on front row	45
222				6	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	45
223				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	45
224				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	45
225			9a	1	Sedan	2	2 adults	Driver, passenger on front row	65
226				2	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	65
227				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	65
228				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	65
229				5	Sedan	2	2 adults	Driver, passenger on front row	65
230				6	Minivan	3	1 adult, 2 children	Driver, child on 2^{nd} row driver side, child on $3r^{d}$ row middle	65
231				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	65
232				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2^{nd} row driver side, 2^{nd} row passenger side	65

233			10	1	Sedan	2	2 adults	Driver, passenger on front row	80
234				2	Minivan	3	1 adult, 2 children	Driver, child on 2nd row driver side, child on 3rd row middle	80
235				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	80
236				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	80
237				5	Sedan	2	2 adults	Driver, passenger on front row	80
238				6	Minivan	3	1 adult, 2 children	Driver, child on 2nd row driver side, child on 3rd row middle	80
239				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at rear driver side	80
240				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	80
241			9c	1	Sedan	2	2 adults	Driver, passenger on front row	65
242				2	Minivan	3	1 adult, 2 children	Driver, child on 2nd row driver side, child on 3rd row middle	65
243				3	Truck	1 + 1 dummy	1 adult, 1 dummy	Driver, dummy on passenger seat	65
244				4	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	65
245				5	Sedan	2	2 adults	Driver, passenger on front row	65
246				6	Minivan	3	1 adult, 2 children	Driver, child on 2nd row driver side, child on 3rd row middle	65
247				7	Truck	3 ~~2~~	3 ~~2~~ adults	Driver and 1 passenger, adult at read driver side	65
248				8	SUV	4	3 adults, 1 teen	Driver, passenger on front row, teen on 2nd row driver side, 2nd row passenger side	65
249		DT03	11	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	10
250				2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	10
251				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
252				4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	10
253				5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	10
254				6	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	10
255				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
256				8	SUV	1	1 adult	Driver	10
257			12	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	30
258				2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	30
259				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
260				4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	30
261				5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	30
262				6	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	30
263				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
264				8	SUV	1	1 adult	Driver	30
265			13	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	45
266				2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	45
267				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
268				4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	45
269				5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	45
270				6	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	45
271				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
272				8	SUV	1	1 adult	Driver	45
273			14	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	65
274				2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	65
275				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
276				4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	65
277				5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	65
278				6	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	65
279				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
280				8	SUV	1	1 adult	Driver	65
281			15	1	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	80
282				2	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	80
283				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
284				4	SUV	2 + 1 dummy	2 adults, 1 dummy	Driver, passenger on front row, dummy on 2nd row middle	80
285				5	Sedan	3	2 adults, 1 child	Driver, child on 2nd row driver side, adult on 2nd row passenger side	80
286				6	Minivan	2	1 adult, 1 child	Driver, child on 3rd row middle	80
287				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
288				8	SUV	1	1 adult	Driver	80
289		DT04	16	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	10
290				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	10
291				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
292				4	SUV	1	1 adult	Driver	10
293				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	10
294				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	10
295				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	10
296				8	SUV	1	1 adult	Driver	10
297			17	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
298				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	30
299				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
300				4	SUV	1	1 adult	Driver	30
301				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
302				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	30
303				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	30
304				8	SUV	1	1 adult	Driver	30
305			18a	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	45
306				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	45
307				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
308				4	SUV	1	1 adult	Driver	45
309				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	45
310				6	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	45
311				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45

312				8	SUV	1	1 adult	Driver	45
313			19a	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	65
314				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	65
315				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
316				4	SUV	1	1 adult	Driver	65
317				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	65
318				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	65
319				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
320				8	SUV	1	1 adult	Driver	65
321			20a	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	80
322				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	80
323				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
324				4	SUV	1	1 adult	Driver	80
325				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	80
326				6	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	80
327				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
328				8	SUV	1	1 adult	Driver	80
329			20b	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	50
330				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	50
331				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	50
332				4	SUV	1	1 adult	Driver	50
333				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	50
334				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	50
335				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	50
336				8	SUV	1	1 adult	Driver	50
337			20c	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	55
338				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	55
339				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	55
340				4	SUV	1	1 adult	Driver	55
341				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	55
342				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	55
343				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	55
344				8	SUV	1	1 adult	Driver	55
345			20d	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	45
346				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	45
347				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
348				4	SUV	1	1 adult	Driver	45
349				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	45
350				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	45
351				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	45
352				8	SUV	1	1 adult	Driver	45
353			20e	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	65
354				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	65
355				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
356				4	SUV	1	1 adult	Driver	65
357				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	65
358				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	65
359				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	65
360				8	SUV	1	1 adult	Driver	65
361			20f	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	80
362				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	80
363				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
364				4	SUV	1	1 adult	Driver	80
365				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	80
366				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	80
367				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	80
368				8	SUV	1	1 adult	Driver	80
369			20g	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	50
370				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	50
371				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	50
372				4	SUV	1	1 adult	Driver	50
373				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	50
374				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	50
375				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	50
376				8	SUV	1	1 adult	Driver	50
377			20h	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	55
378				2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, child on 2nd row driver side, dummy on 3rd row passenger side	55
379				3	Truck	3	2 adults, 1 teen	Driver and passengers on front row	55
380				4	SUV	1	1 adult	Driver	55
381				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	55
382				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, child on 2nd row driver side, ~~dummy on 3rd row passenger side~~	55
383				7	Truck	3	2 adults, 1 teen	Driver and passengers on front row	55
384				8	SUV	1	1 adult	Driver	55
385	**07/31/10**	**DT05**	1	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	40
386	**Saturday**			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2rd row passenger side, child on 3rd row passenger	40
387	**Afternoon**			3	Truck	2	2 adults	Driver, passenger on front row	40
388				4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
389				5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2rd row passenger side, 1 passenger on 2nd	40
390				6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2rd row passenger side~~, child on 3rd row passenger	40

391			7	Truck	2	2 adults	Driver, passenger on front row	40
392			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
393		2	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
394			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	50
395			3	Truck	2	2 adults	Driver, passenger on front row	50
396			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
397			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
398			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	50
399			7	Truck	2	2 adults	Driver, passenger on front row	50
400			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
401		3	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
402			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	60
403			3	Truck	2	2 adults	Driver, passenger on front row	60
404			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
405			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
406			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	60
407			7	Truck	2	2 adults	Driver, passenger on front row	60
408			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
409		4	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
410			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	70
411			3	Truck	2	2 adults	Driver, passenger on front row	70
412			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
413			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
414			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	70
415			7	Truck	2	2 adults	Driver, passenger on front row	70
416			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
417		5	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	40
418			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	40
419			3	Truck	2	2 adults	Driver, passenger on front row	40
420			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
421			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	40
422			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	40
423			7	Truck	2	2 adults	Driver, passenger on front row	40
424			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
425		6	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
426			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	50
427			3	Truck	2	2 adults	Driver, passenger on front row	50
428			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
429			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
430			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	50
431			7	Truck	2	2 adults	Driver, passenger on front row	50
432			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
433		7	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
434			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	60
435			3	Truck	2	2 adults	Driver, passenger on front row	60
436			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
437			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
438			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	60
439			7	Truck	2	2 adults	Driver, passenger on front row	60
440			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
441		8	1	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
442			2	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	70
443			3	Truck	2	2 adults	Driver, passenger on front row	70
444			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
445			5	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
446			6	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	70
447			7	Truck	2	2 adults	Driver, passenger on front row	70
448			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
449		9	1	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	30
450			2	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
451			3	Truck	2	2 adults	Driver, passenger on front row	30
452			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	30
453			5	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	30
454			6	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	30
455			7	Truck	2	2 adults	Driver, passenger on front row	30
456			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	30
457		10	1	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	40
458			2	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	40
459			3	Truck	2	2 adults	Driver, passenger on front row	40
460			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
461			5	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	40
462			6	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	40
463			7	Truck	2	2 adults	Driver, passenger on front row	40
464			8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	40
465		11	1	Minivan	2 + 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	50
466			2	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
467			3	Truck	2	2 adults	Driver, passenger on front row	50
468			4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
469			5	Minivan	2 ~~+ 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	50

470				6	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	50
471				7	Truck	2	2 adults	Driver, passenger on front row	50
472				8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	50
473			12	1	Minivan	2 – 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	60
474				2	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
475				3	Truck	2	2 adults	Driver, passenger on front row	60
476				4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
477				5	Minivan	2 ~~– 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	60
478				6	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	60
479				7	Truck	2	2 adults	Driver, passenger on front row	60
480				8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	60
481			13	1	Minivan	2 – 1 dummy	1 adult, 1 child, 1 dummy	Driver, dummy on 2nd row passenger side, child on 3rd row passenger	70
482				2	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
483				3	Truck	2	2 adults	Driver, passenger on front row	70
484				4	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
485				5	Minivan	2 ~~– 1 dummy~~	1 adult, 1 child, ~~1 dummy~~	Driver, ~~dummy on 2nd row passenger side~~, child on 3rd row passenger	70
486				6	Sedan	4	3 adults, 1 child	Driver, 1 passenger on front row, child on 2nd row passenger side, 1 passenger on 2nd	70
487				7	Truck	2	2 adults	Driver, passenger on front row	70
488				8	SUV	2	1 adult, 1 teen	Driver, passenger on front row	70
489	**07/31/10**	**NT05**	1	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	40
490	**Saturday**			2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	40
491	**Night**			3	Truck	2	2 adults	Driver and front passenger	40
492				4	SUV	3	2 adults	Driver and front passenger	40
493				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	40
494			2	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	50
495				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	50
496				3	Truck	2	2 adults	Driver and front passenger	50
497				4	SUV	3	2 adults	Driver and front passenger	50
498				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	50
499			3	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	60
500				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	60
501				3	Truck	2	2 adults	Driver and front passenger	60
502				4	SUV	3	2 adults	Driver and front passenger	60
503				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	60
504			4	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	70
505				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	70
506				3	Truck	2	2 adults	Driver and front passenger	70
507				4	SUV	3	2 adults	Driver and front passenger	70
508				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	70
509			5	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	40
510				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	40
511				3	Truck	2	2 adults	Driver and front passenger	40
512				4	SUV	3	2 adults	Driver and front passenger	40
513				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	40
514			6	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	50
515				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	50
516				3	Truck	2	2 adults	Driver and front passenger	50
517				4	SUV	3	2 adults	Driver and front passenger	50
518				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	50
519			7	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	60
520				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	60
521				3	Truck	2	2 adults	Driver and front passenger	60
522				4	SUV	3	2 adults	Driver and front passenger	60
523				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	60
524			8	1	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	70
525				2	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	70
526				3	Truck	2	2 adults	Driver and front passenger	70
527				4	SUV	3	2 adults	Driver and front passenger	70
528				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	70
529			9	1	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	40
530				2	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	40
531				3	Truck	2	2 adults	Driver and front passenger	40
532				4	SUV	3	2 adults	Driver and front passenger	40
533				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	40
534			10	1	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	50
535				2	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	50
536				3	Truck	2	2 adults	Driver and front passenger	50
537				4	SUV	3	2 adults	Driver and front passenger	50
538				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	50
539			11	1	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	60
540				2	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	60
541				3	Truck	2	2 adults	Driver and front passenger	60
542				4	SUV	3	2 adults	Driver and front passenger	60
543				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	60
544			12	1	Minivan	4	2 adults, 1 dummy	Driver, adult front passenger, dummy on 2nd row passenger side	70
545				2	Sedan	4	2 adults, 2 children	Driver, adult on passenger seat, 2 children at the back driver and pass side	70
546				3	Truck	2	2 adults	Driver and front passenger	70
547				4	SUV	3	2 adults	Driver and front passenger	70
548				5	Truck	3	2 adults, 1 teen	Driver and adult front passenger, teen on back passenger side	70

549			13		Minicar	2	1 adult, 1 child	Driver and child front passenger	30
550					Minicar	2	1 adult, 1 child	Driver and child front passenger	35
551					Minicar	2	1 adult, 1 child	Driver and child front passenger	40
552					Minicar				45

Appendix IV: HOT Facility Project Manager Interview Questionnaire

A SURVEY OF APPROACHES AND STRATEGIES BY AGENCIES NATIONWIDE -QUESTIONNAIRE

Study Overview

The San Diego Association of Governments' I-15 Managed Lanes project is a three stage implementation of High-Occupancy Toll (HOT) lanes. This project will result in four bi-directional lanes for twenty miles and multiple intermediate access locations. Completed Stage 1 has the middle segment (8 miles long) and 18 toll locations operational since March 2009.

Enforcement of vehicle occupancy is currently provided by the California Highway Patrol (CHP) with officers patrolling during a limited number of hours. The facility expansion to the full 20 miles, the move to 24/7 operations in a concurrent traffic flow environment, and the incorporation of many intermediate access points are expected to substantially increase the complexity of violations enforcement on the I-15 Managed Lanes facility.

California Center for Innovative Transportation (CCIT) at University of California Berkeley is undertaking a survey of agencies operating HOT lanes to learn about their violation enforcement strategies and lessons-learned. This will help SANDAG identify Violation Enforcement Systems (VES) for the I-15 Managed Lanes.

CCIT

CCIT accelerates the implementation of research and the deployment of technical solutions by practitioners to enable a safer, cleaner and more efficient surface transportation service. As part of the SANDAG I-15 Managed Lanes VES Technology Assessment, CCIT is assisting SANDAG assess, test and implement Violation Enforcement Systems (VES) for existing and proposed HOT lane facilities.

Survey Questions

The survey questions have been grouped into three categories for simplicity.

HOT LANE Operations

1. What is the primary objective of your agency's implementation of HOT lanes (e.g., congestion mitigation, revenue generation, etc.)?

2. How would you describe the level of congestion on your corridors with HOT lane operations? (e.g., heavily congested, moderately congested, average commute delays more than 30 minutes, etc.)

3. What is the occupancy requirement for HOV users (i.e., 2+ or 3+ persons)?

4. Are there incentives / charge-free access for carpools, vanpools and or hybrid vehicles to use the HOT lanes? (Yes / No)
    a. If yes to above, what are the incentives?

Facility and Infrastructure

5. How many HOT lanes are in use or planned in each direction?

6. How are the HOT lanes separated from the all-purpose lanes? (e.g., physical barriers, striping, in-pavement reflectors, etc.)

7. What is the shoulder width, if present that can be used by the highway patrol?

8. Can HOT lane users pay by cash at your facility? (Yes / No)

9. Please indicate which of the following electronic payment systems are currently used on your HOT lanes:

Electronic Payment Systems	**In Use? (Yes / No)**	**Manufacturer, communication frequency/protocol, cost per unit, specific to SOV users, etc.**
Transponders (e.g., EZPass)		
Sticker Tags		
Video tolling using Automated License Plate Reader (ALPR) and / or Automated Vehicle Classification		
Other		

10. Please indicate which of the following technologies are currently used on your HOT lanes (exclude the ones indicated to be in use above in question 6):

Technology	**Planned in short term? (Yes / No)**	**Planned over Long Term (3-5 years)? (Yes / No)**	**Manufacturer, communication frequency/protocol, cost per unit, specific to SOV users, etc.**
Transponders (e.g., EZPass)			
Sticker Tags			
Smart Cards On-Board Unit			
Automated Vehicle Detection /Classification			
Other			

11. Please indicate the reasons for your use of the given combination of technologies?

12. Are your electronic payment systems interoperable with other systems in the region and have you planned for a transition to 5.9 GHZ?

13. If electronic payment method(s) is/are used, what percentages of tolls are collected through electronic transponders in your jurisdiction (HOT lane and Non-HOT lane tolling)?

14. What are the state laws or agency policies that regulate or affect your selection and the use of electronic payment methods (e.g., number of devices required in the vehicle)?

HOT Lane Violation and Enforcement

15. What is your current level of manual enforcement with highway patrol? (e.g., 40 total personnel hours per month, etc.)

16. Does your agency pay full or partial costs of manual enforcement by highway patrol?

17. What is the estimated rate of HOT lane violations at your facilities?

18. According to the current law in your state/region, what are the penalties for a HOT lane violation (civil/criminal)?

19. What does your agency consider an acceptable level for HOT lane violations? (e.g., less than 5 %)

20. What are your current and planned enforcement methods on HOT lanes?

Enforcement Method	In Use? (Yes / No)	Planned in short term (1-2 years)? (Yes / No)	Planned over long term (3-5 years)? (Yes / No)	Description of the Method Used or Planned (manufacturer, costs per unit, communication frequency / protocol, interoperability)
Enforcement through highway patrol personnel with enhanced detection.				
Handheld devices to verify toll payment				
Mobile Enforcement Transponder (MET) used in patrol cars to identify valid transponders				
Overhead lights indicating toll payment				
Fully automated occupancy verification systems				
Violation Enforcement System Cameras (infrared or near infrared)				
Other automated occupation verification systems				
Self occupancy declaration systems with enforcement				
Switchable transponders				
Carpool sticker tags				
Smart card on board units				
License plate detection				
Photo enforcement				
Other automated enforcement				

Others (e.g., gates, etc.)				

21. Please describe the reasons for the selection of planned violation enforcement strategies in the short term and long term?

(For questions 23 and 24, answer only if they are relevant)

22. If fully automated occupancy verification systems are being used or planned, who will be responsible for processing citations and the evidence package?

23. If self-declaration systems are in use or planned, elaborate on the enforcement technologies and strategies in use or planned.

24. For enforcement methods in use at your agency, please provide an estimate of the initial and on-going costs if available.

Enforcement Method	**Initial Capital Costs**	**Ongoing Operations and Maintenance Costs**	**Estimated Effectiveness (documented before after violation rates)**
Enforcement by highway patrol personnel (Manual)	N/A		
Enforcement through highway patrol personnel with handheld devices to verify toll payment.			
Fully automated occupancy verification systems (e.g., infrared or near infrared cameras with automated occupancy identification)			
Self occupancy declaration systems (e.g., switchable transponders, carpool sticker tags, smart cards, etc) with enforcement (e.g., license plate detection/photo enforcement)			
Others (e.g., gates)			

Thanks you for your participation!

Appendix V: CHP Questionnaire

Survey Questions
The survey questions have been grouped into four categories for simplicity.

A. Background Information

1. What types of violations are officers expected to enforce while patrolling a HOT lanes facility? (e.g., toll evasion, occupancy violation, speed violations)

2. Do officers assigned to HOT lanes facilities complete additional training for HOT lane enforcement?

3. Do one or more entities pay CHP for the enforcement of HOT lanes? (e.g., SANDAG pays for overtime for CHP personnel)

B. Enforcement Technologies

4. What technologies are currently used in HOT lane enforcement by CHP?

5. Which agencies participate in the selection process of technologies used in the field by CHP officers for the purposes of detecting occupancy and toll violations in HOT lane facilities?

6. Which agency (or agencies) determines the technologies used by CHP officers for the purposes of detecting occupancy and toll violations in HOT lane facilities?

7. Please indicate which of the following enforcement technologies are in use, planned or have been considered but not deployed in the field by CHP (refer to Table 1).

Technology	**In use? (Yes/No)**	**Planned? (Yes/No)**	**Considered?* (Yes/No)**
Mobile Enforcement Transponder			
Mobile Transponder Reader			
PDA			
Portable Transponder Reader			
Transaction Status Indicator (Beacon)			
Other			

[For questions 8 through 10 please consider your answers in question 7.]

8. How would you describe the experience of CHP officers with the technologies in use in HOT lanes facilities? (For example, highway patrol officers in Minnesota avoid using the transaction status indicators due to the locations available for enforcement and the availability of other technologies.)

9. If a technology was considered but not selected, please explain the reason(s) for the decision of not utilizing the technology.

10. Has the CHP considered the possible impacts of 5.9 GHz DSRC technologies? If so, are there any enforcement related advantages or disadvantages of 5.9 GHz DSRC technologies over its predecessors?

11. Has the CHP considered the possible impacts of switchable transponders in its enforcement efforts? If so, are there any enforcement related advantages or disadvantages of switchable transponders? How best to mitigate the challenges?

12. What is the CHP's assessment of sticker tags?

13. Are transponder misreads in HOT lanes facilities frequent enough to cause enforcement problems?

14. Are there certain types of transponder technologies that cause concern given the CHP experience with drivers that engage in toll or occupancy violations?

15. What are the other challenges of transponder technologies? What is the best way to mitigate the challenges?

C. SPATIAL CHALLENGES TO THE CHP ENFORCEMENT EFFORTS

16. Are the enforcement locations available along the I-15 corridor adequate for observing vehicles and joining the traffic stream in case of a possible violation?

17. How have the multiple access and egress points of the I-15 corridor project affected the enforcement strategies of the CHP?

18. What additional challenges does the CHP face with the new I-15 Managed Lanes geometric configuration (e.g. shoulder width reduction, added lanes)?

D. Policy

19. What Title 21 amendments, if any, would be beneficial to CHP's violation enforcement efforts in HOT lanes?

20. What amendments, if any, should be considered to the appeal process of toll or occupancy fines given the special features of the I-15 managed lanes?

Thank you for your participation!

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