

Background Information: Enforcement Strategies and Approaches

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Introduction

The purpose of this memorandum is twofold: (1) to document background information collected by the research team (through project site visits, literature review, and contacts) regarding the processes and technologies used to enforce HOT lane compliance, and (2) to identify potential enforcement objectives for the QuickRide program.

Southern California Site Visits

In fall 2002, a team including TTI researchers and project sponsors visited two operating HOT facilities in southern California, for the purpose of observing successful practices in value pricing enforcement that could be applied to the Katy and Northwest facilities. These site visits occurred September 17-19, 2002, with the following members attending: David Fink, TxDOT Houston District; James Kratz, TxDOT Traffic Operations Division; Vera Bumpers, METRO Police and Traffic Management; Scott Cooper, representing HCTRA; and Bill Stockton and Ginger Goodin, TTI. The results of the visits are summarized by facility. Information in addition to that obtained at the time of the site visits has been included where helpful.

I-15 FasTrak, San Diego

The visit to the I-15 Express Lanes was conducted September 19, 2002 at the FasTrak Customer Service Center in Kearny Mesa. The following FasTrak representatives met with the research team: Heather Werdick, SANDAG; Lynn Barton, Caltrans; Fares Ibrahim, TransCore, and Officer Kevin Duncan, CHP.

Basic Description

The I-15 Express Lanes are an existing eight-mile, two-lane, reversible high occupancy vehicle (HOV) facility in the median of Interstate 15. Barriers separate the Express Lanes from the regular traffic lanes, and access to the Express Lanes facility is available only at its north and south ends. Carpools and vanpools with two or more occupants, buses, motorcycles are allowed to use the I-15 Express Lanes for free. Authorized FasTrak program participants also may use the Express Lanes for a per-trip toll. The I-15 Express lanes are open on weekdays only, with the following regular hours of operation: southbound 5:45 a.m. to 11:00 a.m. and northbound 1:00 p.m. to 7:00 p.m. The San Diego Association of Governments (SANDAG) contracts with TransCore for software and hardware maintenance. Transcore also runs a customer service center (CSC) staffed by 2-3 people. As of late 2002, enrollment in the FasTrak program stood at 14,600, for which 21,000 transponders had been issued.

Enforcement procedures

Enforcement along this HOT facility is conducted by California Highway Patrol (CHP) officers. At the time of the site visit in September 2002, SANDAG had a \$60,000 contract with CHP for twelve four-hour shifts per month.

CHP officers check for proper vehicle occupancy and the visible presence of a toll transponder. For vehicles involves an AVI activated overhead light mounted on the toll reader gantry to indicate when a toll is paid. The enforcement/tolling zone is located at readers toward the southern end of the project. CHP officers in a patrolling or stationary police vehicle downstream from the reader count the number of occupants in vehicles passing through the tolling zone, and can identify lower occupancy vehicles that don't get this fare paid signal as violators. CHP issues a ticket if transponder is not displayed, as is required by state law. The minimum fine for unauthorized used of the HOT lanes is \$271, and all revenue generated by fines reverts to the state.

Enforcement challenges

A disadvantage of the current enforcement approach is the need for enforcement personnel to look at both oncoming vehicles and the toll indicator light, and to remain within line of sight of the tolling zone. The latter restriction provides opportunity to motorists who, in the absence of enforcement agents near the tolling zone, will be tempted to shield their tags. [1]

CHP officers also indicated difficulties in their dual role of having to identify both valid FasTrak single occupant vehicles (SOV's) and verify correct occupancy for high occupancy vehicles (HOV's). Officers find it difficult to correctly discern the number of vehicle occupants in low-lighting conditions. In winter months, full daylight hours only begin halfway through the morning peak period and end before the evening peak period expires. Small children in the rear seats of vehicles are often hard to see as well, as officers are often at too low a vantage point to see down into vehicles. Anecdotal reports suggest nearly 50 percent of occupancy-related vehicle pullovers by CHP personnel result from officers not being able to see children in the backseat. These problems are only exacerbated by the prevalence of window tinting in vehicles, especially mildly reflective semi-metallic or metallic tint films, and the increasing proportion of SUV's on the roadways.

Lessons learned and suggested improvements

In the first two years of the FasTrak program there was a separate SOV lane at the tolling zone to aid occupancy enforcement. This configuration caused difficulties for SOV's when they had to merge back into the two HOV lanes, as merge distances were not sufficient. For this reason, the SOV-only lane was eliminated.

The I-15 Congestion Pricing Project initially used gantry-mounted video cameras to provide a record of SOV violators on the carpool-only lanes of the Express Lanes facility. CSC staff were required to review the videotape and provide a count of SOVs using the Express Lanes. In their 2001 report on enforcement effectiveness, San Diego State University researchers reported that CSC staff could not reliably distinguish SOV violators on the videotapes, and found it difficult to discern the number of vehicle occupants, especially for those in back seats. [2] These problems led to the elimination of video monitoring in late 1998.

Motorcycle-based enforcement has been judged superior to that of car-based enforcement for the project. Motorcycle units are able to maneuver better than cars within the barrier-separated Express Lanes facility. Patrol cars provide stationary enforcement, but have less ability to enter and exit the facility at intermediate points and instead need to drive the length of the facility to cruise or pursue a potential violator. [2]

During the site visit, CHP officers suggested reinstating the SOV/HOV split in the tolling zone, and creating higher vantage points for enforcement personnel for better views of backseat occupants. TransCore representatives would like to see signs erected along the facility stating the legal requirement that all vehicles must display transponders.

An alternative presented in the I-15 Phase II Concept Plan [1], proposed an AVI querying capability for enforcement agents. This approach uses a terminal consisting of a portable PC equipped with a microphone, a speaker, a speech synthesizer, speech recognition software, and a cellular wireless connection mounted within the patrol vehicle. An officer could verbally query the toll billing system by calling out license plate numbers, and would receive confirmation of tolls paid. Since the vehicle would be downstream of a tolling zone the lack of a report of paying the toll would provide evidence of a violation. Such a system would solve the problem of motorists shielding transponders. Further investigation of the feasibility of this approach has been deferred to Phase III of the Express Lanes study.

SR-91 Express Lanes, Orange County, California

The visit to the SR-91 Express Lanes was conducted September 18, 2002 at the offices of California Private Transportation Corporation (CPTC) in Anaheim. The following CPTC representatives met with the research team: Greg Hulsizer, General Manager; John Ramirez, Operations Manager; as well as a Customer Service Center manager and Customer Assistance Program Operator.

Basic Description

The section of California State Route 91 (SR 91) containing the express lanes is located between the SR 91/SR 55 junction in Anaheim and the Orange/Riverside County Line. The project provides two extra lanes in each direction, separated from the adjacent freeway by a "soft" barrier consisting of a painted buffer with pylons. The lanes run for approximately 10 miles in the median of SR 91 and access points to the express lanes are provided only at each end of the facility. The SR 91 Express Lanes operate as a toll facility, and users are required to be registered customers and to carry transponders. Registered users are allowed to move their issued transponder among all vehicles whose license plates are already on file with the user's account. Carpooling groups of three or more people may register as such to qualify for a 50% discount to the nominal toll rate. The CPTC operates a traffic management center (TMC) that is staffed 24 hours a day, 7 days a week. Incident response time along the Express lanes is 5 minutes; the Express Lanes may also authorize general traffic in the event of an accident in the adjacent general purpose lanes (GPL).

Enforcement procedures

Enforcement along the SR-91 Express Lanes is greatly facilitated by the fact that user vehicles must be registered in the FasTrak program and carry transponders. As such, automated enforcement procedures can be employed to a high degree. A combination of AVI readers and photo license plate monitoring handles billing and violations such as lack of a transponder, while contracted CHP officers monitor HOV occupancy violations. CPTC reports overall violation rates of 2 to 4 percent for the facility.

All vehicles using the facility have their transponders read upon entering and again at the toll plaza. If the toll readers fail to detect a transponder for a vehicle, photo cameras along the facility capture images of the vehicle's license plate; approximately 4000 license plate images are generated per day. License plate numbers of potential violators are checked against a FasTrak customer database. If a potential violator is not in the FasTrak customer database, then the license plate is checked with other partnering toll authorities (currently there are five) and billed. Note that approximately 80% of potential violators turn out to be customers registered with FasTrak or a partnering toll authority. If still no license plate match is found, the license number is checked with DMV records, and within 24 hours a notice of violation is issued by mail. Automated violation processing incurs an additional \$20 charge over the nominal violation fine. Recalcitrant violators' vehicle registration can be placed on hold for non-payment of assessed fines.

Occupancy enforcement for HOV's is conducted visually by CHP contract law enforcement. Two officers are present on the facility in the peak periods, with one officer present in off-peak periods. At night, the lone CHP officer splits duties between the Express Lanes and the free lanes. Service patrol operators also assist in enforcement by noting violators at the tolling zone and radioing officers downstream. Fines for occupancy violations are \$271; total cost including court fees exceeds \$300.

Enforcement challenges

As the SR-91 Express Lanes were operated by a private company at the time of the site visit, it is perhaps understandable that no substantive information on enforcement shortcomings was obtained.

Lessons learned and suggested improvements

Given the near ideal operating conditions and very low violation rates which the SR-91 Express Lanes enjoy, it is not surprising that no obvious improvements were suggested or recommended during the site visit or presented in published literature. It may only be speculated that occupancy enforcement is subject to many of the same visibility problems identified for the I-15 Express Lanes facility. However, since HOV3+ traffic constitutes a mere 15 percent of the total using the SR-91 Express Lanes, the practical implications of any such difficulties would be se difficulties would be expected to be minor.

Technology Review

The presence of mixed toll and carpool vehicle traffic on High Occupancy Toll (HOT) lanes present special challenges to effective enforcement. Regular toll lanes are amenable to automated enforcement techniques, such as license plate recognition (LPR) in combination with automated vehicle identification (AVI). However, usage of toll transponders on HOT lanes is not required for high occupancy vehicles (HOVs), while additional verification of vehicle occupancy is needed. Enforcement personnel face both the normally difficult task of determining the number of occupants in a fast-moving vehicle and the additional complication of having to verify proper toll payment.

Verification difficulties rank among the principal problems facing enforcement efforts along the I-10 and US 290 HOT lanes. Enforcement officers have no way of definitively verifying the presence of valid QuickRide transponders in vehicles, and find it difficult to accurately count vehicle occupants in all but the most favorable lighting conditions. A comprehensive review was therefore undertaken to identify existing or emerging technologies that may reduce or eliminate these difficulties. Most of the technologies encountered in the course of the review fall within two general application categories: 1) transponder verification and 2) vehicle occupancy detection.

Transponder verification

Transponder verification refers here to any technologies or methods by which enforcement personnel can receive real-time information on the transponder status of vehicles. An investigation of existing and proposed verification systems identified several scenarios, incorporating different levels of sophistication. All of these systems are evaluated relative to their ability to address the following problems facing any verification system:

- 1) No transponder
- 2) Malfunctioning transponder
- 3) Invalid transponder
- 4) Transponder shielding

Two types of transponder verification approaches are described below. A summary of the advantages and disadvantages of the approaches is provided in Table 2.

AVI Reader with Indicator Signal

The simplest scheme for transponder verification is comprised of a stand-alone AVI reader/controller actuating an indicator signal. The AVI controller would have a database of valid QuickRide transponder ID's, and would compare transponders from passing vehicles with the database. Valid matches to the stored database transponder ID's would cause the controller to actuate the indicator signal. Such a system would be situated at the enforcement area, and would notify enforcement personnel that a vehicle either possessed a valid transponder or had an invalid/missing transponder. A disadvantage of this configuration is that the database of valid ID's on the AVI controller must be manually updated.

Hand-held Technologies

With the placement of portable readers at selected sites along the HOV lanes, handheld technologies for transponder identification will become a viable option for enhancing enforcement effectiveness. This stems from the fact that enforcement officers will have the ability to examine toll transponders from vehicles already pulled over.

Three scenarios are proposed below for incorporating Personal Digital Assistant (PDA) type devices as an enforcement tool. The scenarios are ordered according to increasing ability of the PDA to communicate with various computer networks.

Scenario A

This scenario assumes that an enforcement officer possesses a stand-alone Personal Digital Assistant (PDA) device. The PDA stores information on valid QuickRide transponder ID's and the name(s) and license plate number(s) corresponding to these ID's. In practice, an officer would need to read off the transponder ID physically printed on the transponder casing, and input this ID into the PDA. The ID would be compared to a database of valid QuickRide transponder ID's stored in the PDA's memory. If the transponder ID was not found in the database, then the officer could perform additional searches by the name of the registered QuickRide user(s), or the vehicle license plate(s). Failure to obtain a match to a valid QuickRide record would provide near conclusive proof of an invalid transponder.

Convenience of data input could be enhanced by a progressive search function, in which successively entered characters of the identification information automatically winnow the search results to a short list of matches. The correct match would then be selected by cursor or touch screen.

Another useful feature could be incorporated whereby the enforcement officer can input notes or codes to be attached to each identification record. For example, if identification information input by the officer fails to match a database record, the officer could be presented with menu options to store the license plate and driver name from the vehicle, and associate a brief annotation such as "Warning Issued" or "Ticketed". A more comprehensive notation system could record a more detailed record of enforcement actions against a particular data record. A possible schema could include the following:

Action	Reason
Warning	No displayed QuickRide identification hang-tag
Warning	Transponder not valid
Warning	No transponder present
Ticketed	No displayed QuickRide identification hang-tag
	...
	Etc.

One drawback to the stand-alone scenario is that the accuracy of the database would need to be maintained by continually updating the PDA. The onus of updating could be substantially eliminated, however, if some interface between PDA and the onboard computer of the police cruiser could be developed, where the vehicle computer in turn is linked to a central QuickRide

user database. Such an interface would ideally provide up-to-the-minute database accuracy, as well as allowing information from all PDA's to be shared and combined.

Scenario B

In this scenario, the PDA is linked to the computer aboard the enforcement vehicle via a wireless 802.11b interface. The PDA functions as a satellite of the police cruiser computer. The QuickRide user database is stored primarily on the vehicle computer, where it can be updated periodically via the vehicle's wireless data network. In this scenario, search functions could be run by the more powerful vehicle computer, which would also accommodate a larger information database. Text input or alphanumeric searches could be optionally conducted on the full-size keyboard of the vehicle computer. In this case, the PDA would operate more as a terminal display for out-of-vehicle activity.

Scenario C

This scenario resembles Scenario B, except the vehicle computer is capable of interfacing with the QuickRide billing system. With this added capability, enforcement personnel could ideally verify whether a particular transponder had been read at the upstream billing reader. Under this scenario, there would be very little indeed that the enforcement officer could not directly verify; this would eliminate virtually all doubt on the part of the officer. If, as in Scenario B, detailed notes of past violations and warnings were readily available to the enforcement officer, serial scofflaws would very quickly identified and dealt with.

Feasibility issues

The most substantial hurdle to implementation of any of the above scenarios is networking capability; i.e., how much information can be provided based on the systems and technologies currently in use by enforcement personnel. If no interfacing is possible, the PDA database would have to be manually updated by physically connecting it to a computer and running an update program. A minimally viable setup should include the following network capabilities:

1. The PDA must be able to interface (by wire or wirelessly) with the in-vehicle computer system.
2. The in-vehicle computer system must be able to interface wirelessly with a central QuickRide user database on at least a scheduled periodic basis.

Table 2: Comparison of technologies for transponder verification

Technology	Advantages	Disadvantages
Stand-alone reader with indicator light	<ul style="list-style-type: none"> • Verifies QuickRide enrollment • Detects absence of transponder • Easiest to implement • Compatible with existing transponder technology 	<ul style="list-style-type: none"> • Cumbersome updating of database • Cannot immediately verify billing status of transponder • Enforcement must be located close to enforcement reader
Stand-alone reader with wireless link to PDA	<ul style="list-style-type: none"> • Verifies QuickRide enrollment • Detects absence of transponder • Easier database updating via PDA • Greater flexibility in enforcement sites • Compatible with existing transponder technology 	<ul style="list-style-type: none"> • Cannot verify billing status of transponder • Enforcement must be within line-of-sight of enforcement reader
Enforcement reader and PDA linked to billing system	<ul style="list-style-type: none"> • Verifies billing status of transponder • Verifies QuickRide enrollment • Detects absence of transponder • Database automatically updateable • Enforcement sites can be anywhere along facility • Compatible with existing transponder technology 	<ul style="list-style-type: none"> • Requires modification to billing system back office operations • Requires either additional communications infrastructure or expensive cellular contract

Vehicle Occupancy Detection

Similar to license plate recognition (LPR) systems, a vehicle occupancy detection system utilizes one or more cameras and illumination sources to collect images from the interior of passing vehicles. Systems range in complexity from operator-monitored video cameras though sophisticated infrared composite images evaluated by a neural network.

Photo/Video systems

Video and machine vision technologies seek to assist and automate the task of vehicle occupancy counts. Video methods are typically used when areas for enforcement along the HOT facility are limited, and are not as reliable as live visual inspection. The HOVER system in Dallas employed 3-way views of vehicle cabins and license plate recognition (LPR) to record occupancy and vehicle identification. Enforcement agents reviewed the archived images to identify HOV violators. An effectiveness study of the HOVER system revealed that the video

and LPR implementation failed to achieve the necessary image quality and accuracy for effective enforcement screening. [3]

In another application of video enforcement, the I-15 Congestion Pricing Project initially used gantry-mounted video cameras to provide a record of SOV violators on the carpool-only lanes of the Express Lanes facility. CSC staff were required to review the videotape and provide a count of SOVs using the Express Lanes. In their 2001 report on enforcement effectiveness, San Diego State University researchers reported that CSC staff could not reliably distinguish SOV violators on the videotapes, and found it difficult to discern the number of vehicle occupants, especially for those in back seats. [2] These problems led to the elimination of video monitoring in late 1998.

Automated systems for detecting vehicle occupancy on HOV/HOT lanes are an emerging technology, as no systems implemented thus far operate fully autonomously in real-time. Over the last several years, two systems primarily geared towards vehicle occupancy detection have been developed at least to the point of enabling limited field tests.

Infrared systems

Georgia Tech Research Institute (GTRI) engineers have developed a new technology for the Georgia Department of Transportation for counting the number of occupants in vehicles passing by at highway speeds [4]. The project consists of a computer-assisted infrared imaging system, utilizing a single near-infrared camera illuminated by an infrared light source. The system is contained in a roadside-mounted camera/processing unit that captures side views of passing vehicles; both the camera and illumination are triggered by radar. GTRI researchers conducted a successful field trial of the system over a period of a few months in 1998. The system demonstrated the ability to capture images of vehicles at speeds up to 80 mph. A qualitative assessment of system accuracy involved a real-time comparison with visual observation. Upstream observers would pick out certain vehicles and count occupants, while an observer at the camera location would tag the corresponding vehicle image. From approximately 200 vehicles selected in this fashion, researchers found that the system was superior to visual inspection at identifying rear passenger occupants. GDOT ultimately declined to further fund the project.

Differential Infrared systems

Researchers at Honeywell and the University of Minnesota are developing a machine vision system for vehicle occupancy detection utilizing a pair of synchronized near-infrared cameras to capture dual-band near-infrared images [5]. The system exploits the infrared reflection characteristics of human skin, which display an abrupt change near 1.4 μm . The change in reflectance is explained by the high water content of tissues immediately under the skin; i.e., other warm objects not primarily composed of water will not display this behavior. By imaging two infrared bands above and below this wavelength and generating a differential image (the difference in brightness between corresponding pixels of the two images), the system can isolate the signature of human skin from that of other materials in the vehicle cabin.

In the current configuration of the test system, the infrared cameras are mounted above the roadway to provide a single view through the windshield of oncoming vehicles. A computer-controlled near-infrared lighting source provides optimal illumination of the target vehicle. All

image-processing hardware and illumination control is performed on-site in a roadside unit, which is linked to a remote computer. The camera mounts are computer-controlled for remote positioning capability. In operation, the synchronized IR cameras take snapshots of the road scene when triggered by vehicle-detection radar. The pair of dual-band infrared images is differenced, and the result is “thresholded” to generate a two-color (black and white) image. A fuzzy neural network occupancy classification system then processes the image to count the number of vehicle occupants.

Researchers conducted a field test of the system in February 2000. Vehicles containing one or two occupants were driven at 50 mph under both daylight and nighttime conditions. Images captured by the prototype were stored to compare occupancy counts between visual inspection and the results of the occupancy classification system. Researchers reported 100% correct identification of the number of occupants by the system for a randomly selected subset of 100 thresholded images. No further development has occurred since the limited field test.

Table 3: Comparison of technologies for vehicle occupancy detection

Technology	Advantages	Disadvantages
Photo/Video	<ul style="list-style-type: none"> • Commercially available systems 	<ul style="list-style-type: none"> • Poor resolution • Inferior to visual inspection • Cannot operate autonomously • Unusable in low lighting
Infrared	<ul style="list-style-type: none"> • Usable under all lighting conditions 	<ul style="list-style-type: none"> • Not developed past custom prototype • Cannot penetrate metallic window tint • Cannot operate autonomously • Cannot distinguish human skin from other objects of similar temperature • Expensive
Differential infrared	<ul style="list-style-type: none"> • Can distinguish unique IR signature of human skin • Usable under all lighting conditions • Can potentially operate autonomously 	<ul style="list-style-type: none"> • Not developed past custom prototype • Cannot penetrate metallic window tint • Extremely expensive

Initial Enforcement Objectives for QuickRide

Based upon the current operation of QuickRide, the following enforcement issues have been identified:

1. Unauthorized HOV2s impossible to detect
2. Accurate occupancy count difficult
3. Enforcement resources stretched
4. Fine structure and judicial support insufficient
5. Level of allowable law enforcement SOVs
6. Majority of customer complaints: violators

In order to improve compliance during QuickRide periods, TTI will be working with TxDOT and METRO to explore technologies and procedures to address the above issues. The following objectives and MOEs have been developed to evaluate alternative enforcement strategies and assess the success of enforcement measures that will be applied:

- Improve effectiveness: reduce violation rate to 10%
- Improve efficiency: reduce cost of violation rate monitoring
- Improve customer satisfaction: reduce number of complaints

References:

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