RESEARCH

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Utah Department of Transportation - Research Division
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HOT Lane Detection and Management Scan

Prepared For:

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Research and Innovation Division

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16. Abstract

UDOT launched its HOT lane program on I-15 in 2010 and it currently covers 72 miles of I-15. The program charges tolls to drivers of Single-Occupant Vehicles (SOVs) using the HOV lanes as Express Lanes while high-occupancy vehicles use the lanes for free. There are 32 HOT lane agencies in the US and, to date, all of them, including UDOT, rely on state Highway Patrols to enforce occupancy through visual means. Nationwide, HOT lane violations range from 25-40% and violations in Utah are observed to be increasing. Companies are developing two leading technologies for determining vehicle occupancy: 1) camera-based systems; 2) smartphone app-based systems.

This report is a scan of US HOT lane agencies considering new technologies for enforcing occupancy requirements. Camera-based systems have been deployed on the Verrazano Narrows Bridge (NYC) and are being planned for SR92 and I-405 in Orange County, CA and for I-10/I-110 in Los Angeles County. Recent field tests of camera-based systems conducted in the Bay Area concluded, "the relatively low system accuracy rates … suggest the technology is not ready for … a full-scale deployment…" The Dallas-Fort Worth MPO has contracted with Carma for implementing an app-based system for occupancy declaration. UDOT is piloting a smartphone-based occupancy declaration system in 2020. Long-term technologies for occupancy detection include the continued improvement of camera-based and app-based systems, and V2X communication of occupancy which may be linked to emerging connected vehicle technologies or part of road usage charging programs.

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LIST OF ACRONYMS

HOT High-Occupancy Toll

HOV High-Occupant Vehicle

IBTTA International Bridge, Tunnel & Turnpike Association

LACMTA Los Angeles County Metropolitan Transportation Authority

OCTA Orange County Transportation Authority

RCTC Riverside County Transportation Commission

SOV Single-Occupant Vehicle

UDOT Utah Department of Transportation

VES Vehicle Enforcement System

EXECUTIVE SUMMARY

UDOT launched its HOT lane program on I-15 in 2010 and it currently covers 72 miles of I-15. The program charges tolls to drivers of Single-Occupant Vehicles (SOVs) using the HOV lanes as Express Lanes while high-occupancy vehicles use the lanes for free. There are 32 HOT lane agencies in the US and, to date, all of them, including UDOT, rely on state Highway Patrols to enforce occupancy through visual means. Nationwide, HOT lane violations are estimated to range from 25-40%. Violations in Utah are observed to be increasing.

This report is a scan of U.S. HOT lane agencies considering new technologies for enforcing occupancy requirements. Companies are developing two leading technologies for determining vehicle occupancy: 1) camera-based systems; and, 2) smartphone app-based systems. Camera-based systems have been deployed on the Verrazano Narrows Bridge (NYC) and are being planned for in Orange County and Los Angeles Counties in California. Recent field tests of camera-based systems conducted in the Bay Area concluded, "the relatively low system accuracy rates … suggest the technology is not ready for … a full-scale deployment…"

The Dallas-Fort Worth MPO (NCTCOG) has contracted with Carma for implementing an app-based system for occupancy declaration. UDOT is piloting an app-based occupancy declaration system offered by RideFlag in 2020. Long-term technologies for occupancy detection include the continued improvement of camera-based and app-based systems, and V2X communication of occupancy which may be linked to emerging connected vehicle technologies or part of road usage charging programs.

Consideration of new detection technologies in Utah has caused concern regarding privacy issues related to acquired image data. In 2018 SB71 was passed, which amended Title 41 (Motor Vehicles) and Title 72 (Transportation Code). SB71 addresses all data captured in toll enforcement. SB71 amends Subsection 72-6-118(2)(e) to authorize UDOT to utilize technology to monitor and collect tolls, including the use of license-plate-reading technology or photographic-/video-recording technology. The retention and use of any of data obtained from license plate capture or from photographic-/video-recording technology is addressed in Title 72. Such data may only be used in toll enforcement and may only be retained if necessary, to collect the toll or pursuant to a warrant.

1. INTRODUCTION

1.1 Problem Statement

HOT lane agencies in the US, including UDOT, are challenged by validating the occupancy of vehicles using HOT lane facilities for free or at a reduced rate. Technologies are being developed to improve the detection and/or validation of vehicle occupancy. This research is focused on describing these technologies and the state of the practice regarding vehicle occupancy detection. This research also describes how Utah laws are designed to protect individual privacy when imagery is used as part of the occupancy enforcement system.

1.2 Objectives

The objective of this research is to describe the state of the practice among US HOT lane agencies regarding vehicle occupancy detection.

1.3 Scope

The research included six tasks, as follows:

1. Background on the characteristics of HOT lane programs in the US
2. Description of UDOT's HOT Lane Program
3. Near- and Long-Term Express Lane Occupancy Detection Technologies
4. Violation Enforcement Systems
5. HOT Lane Program Economics
6. Recommended Opportunities for Further Investigation
7. Review of Utah Legislation Related to Image Capture for Toll Enforcement
8. Conclusions

1.4 Outline of Report

This report documents the findings of the research and proceeds with the following sections:

- Literature Review
- Research Methods
- Data Collection
- Data Analysis
- Conclusion

2. RESEARCH FINDINGS

2.1 Overview

The research consisted of online research of HOT lane agencies in the United States to determine existing and proposed future occupancy detection systems.

2.2 Background -- Characteristics of HOT Lanes Programs

The International Bridge, Tunnel, and Turnpike Association (IBTTA) defines High-Occupancy Toll (HOT) Lanes as:

"Priced-Managed Lanes that use price, occupancy, and access restrictions to manage the number of vehicles traveling on them, thereby maintaining free-flow traffic conditions, even during peak travel periods. Typically, qualifying HOVs may use these limited-access highway lanes for free or at a reduced cost. Motorists in vehicles that do not meet passenger occupancy requirements may choose between the general-purpose lanes or paying for premium conditions in the HOT lanes."

Currently there are 32 HOT Lanes in operation in the US and 19 Express Toll Lanes (other sources, as shown below, indicate there are 33 HOT Lanes programs in the US). Express Toll Lanes are like HOT lanes, but they do not offer a discount for carpools and therefore do not require occupancy enforcement. Virtually all the HOT Lane agencies contract with their state Highway Patrols for occupancy enforcement.

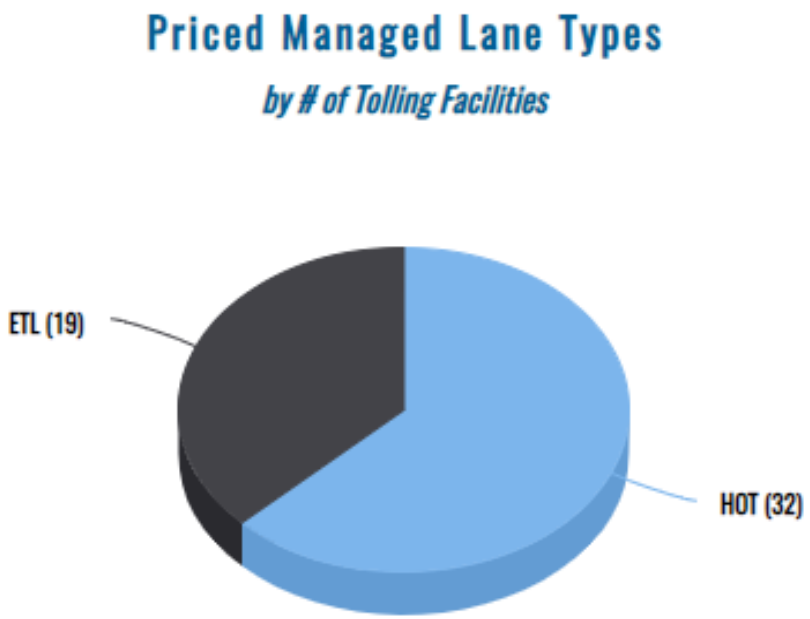

Figure 1: Distribution of Tolling Facilities in the US, by Type of Facility

The majority (22 out of 33) of HOT Lanes programs do not have an exemption for Clean Fuel or Zero-Emission Vehicles. Eleven of 33 agencies, including UDOT, have some type of exemption for clean-fuel vehicles. In two cases (SR 91 managed by OCTA and RCTC), there is a toll discount applied to clean-fuel vehicles. In all other cases, clean-fuel vehicles use the HOT lanes for free.

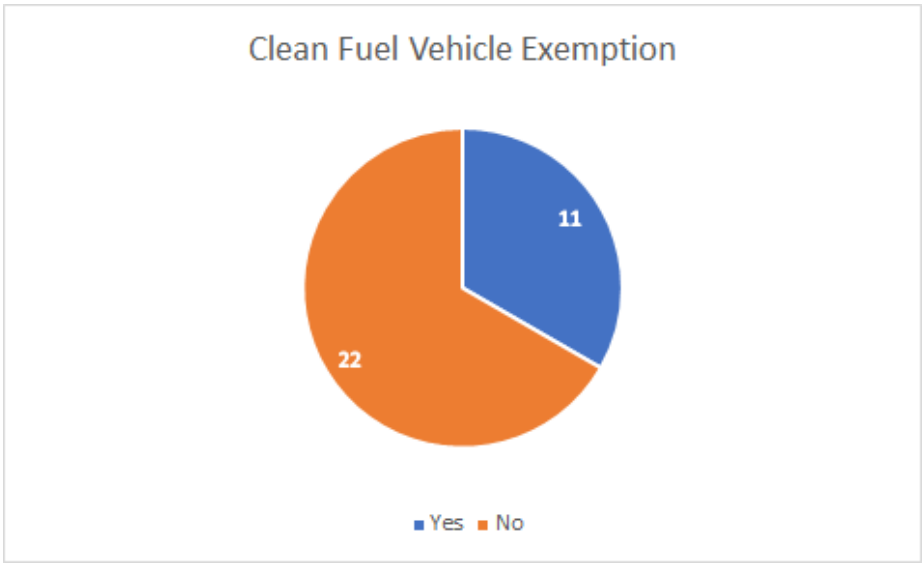

Figure 2: Distribution of HOT Lane Facilities by Clean Fuel Vehicle Exemption

As of now, most HOT Lanes programs (19 out of 33) are based on an HOV2+ occupancy, and this is the case for UDOT. Fourteen programs are HOV3+.

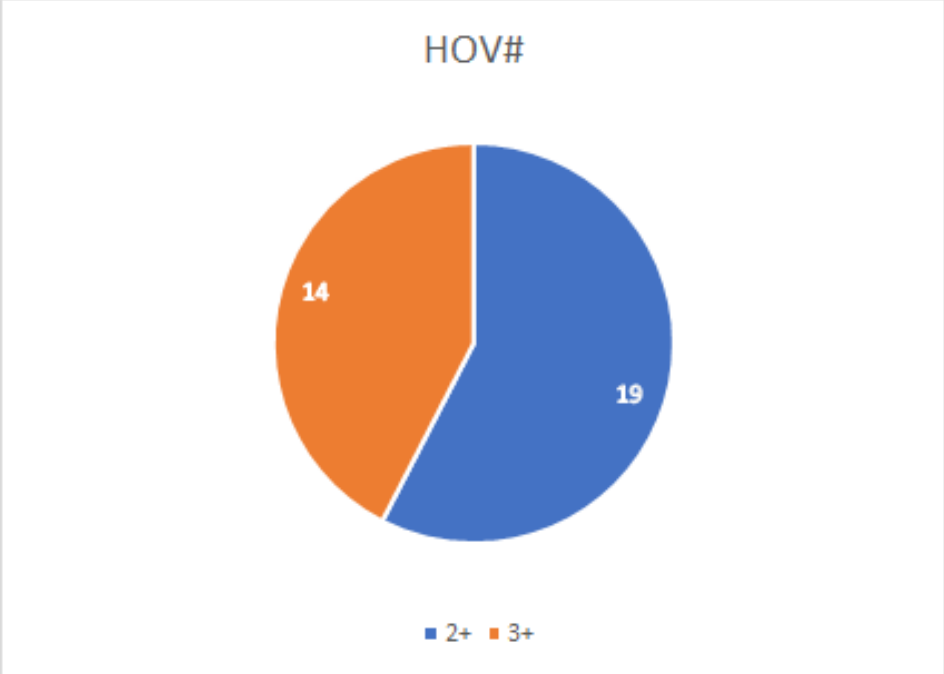

Figure 3: Distribution of HOT Lane Programs by HOV2 and HOV3+

Most HOT Lanes programs (22 out of 30) have dynamic or real-time toll pricing. This is the case with UDOT's program. The remainder (8) have static pricing associated with periods, such as peak-period pricing (e.g. 3pm-6pm).

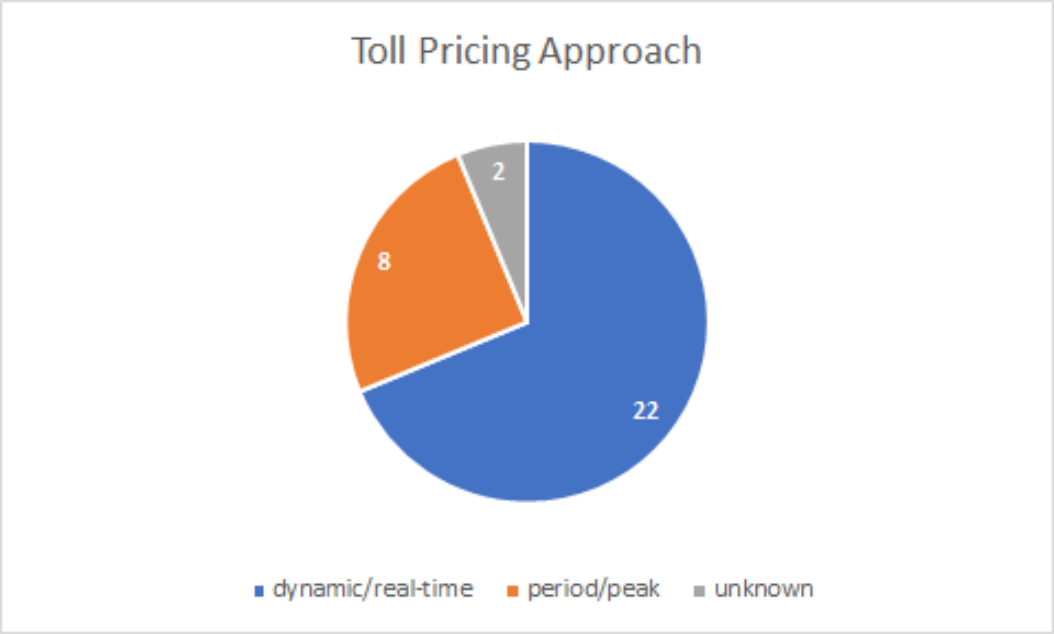

Figure 4: Distribution of HOT Lane Programs by Dynamic/Real-Time Pricing or Period/Peak Pricing

2.3 UDOT's HOT Lanes Program

In 2010, UDOT launched the HOT Lanes program by building an all-electronic system to charge tolls to drivers of Single-Occupant Vehicles (SOVs) using the HOV lanes on I-15 as Express Lanes. The Express Lanes are designed to optimize mobility by offering the unused space in the HOV lanes to SOVs, freeing up room in the general lanes.

The system uses gantries with electronic tag readers on them to charge vehicles with an electronic transponder. The toll price is adjustable based upon the congestion levels of the general-purpose lanes and the HOV lane. The Express Lanes has expanded from approximately 20 centerline miles to approximately 72 centerline miles with 65 gantries. The Express Lanes are separated from the general-purpose lanes by striping.

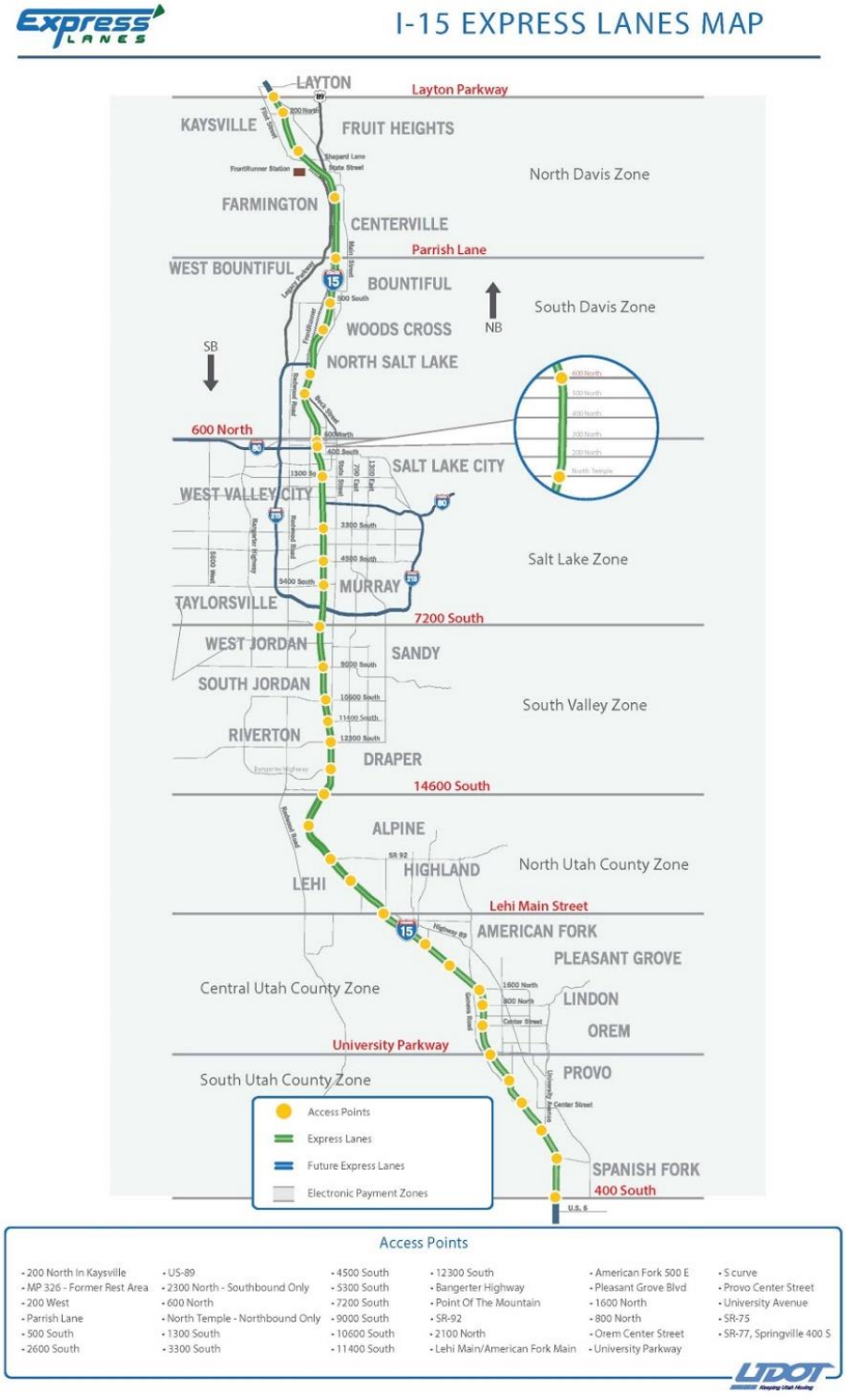

Figure 5: UDOT's I-15 HOT Lanes System on I-15

The system relies on drivers purchasing an Express Pass and setting it to toll mode to charge their accounts for use of the Express Lanes. UDOT's Express Lanes generate approximately $2 million in revenues annually with 21,000 prepaid accounts. A total of 6,650 clean-fuel vehicles can use the lanes without a toll.

Vehicles without a tag are assumed to be carpoolers and are not tolled by the system. UDOT relies on the Utah Highway Patrol to ensure that vehicles without an Express Pass are carpoolers. In recent years the number of SOVs that use the HOT Lanes without an Express Pass has continually increased. To that end, there are several companies offering technologies for determining vehicle occupancy, for the purpose of reducing or eliminating HOT Lane-occupancy violations.

2.4 Near- and Long-Term Express Lane Occupancy Detection Technologies

Occupancy violators reduce the ability to efficiently operate HOT lanes and impact revenue collection. The challenge has always been with occupancy enforcement. Most systems, including UDOT's, have relied on visual enforcement by law enforcement officers to determine the correct number of occupants. This manual enforcement method has difficulty determining occupancy, is often expensive, and inevitably presents safety concerns.

Most facilities that have manual enforcement still have a significant amount of occupancy violators using the lanes. Occupancy violations are estimated to range from 25%-40% of vehicles in HOT lanes across the country.

There are two leading technologies for determining vehicle occupancy: camera-based systems and smartphone app-based systems. Both approaches are being piloted now and should improve in the future, so they are addressed in the section on "Long-Term" technologies as well.

Automated Occupancy Detection – Camera-Based Systems

Camera-based automated occupancy detection systems have been in development for the past 15 years including several field tests. The most recent results from a 2018 pilot test sponsored by the Metropolitan Transportation Commission (MTC, Bay Area MPO) of three different systems showing Vehicle Occupancy Detection (VOD) show system accuracy of 77%-

89% based on manual image review and 37%-75% based on controlled test runs. The three systems tested were from Conduent, Transcore (with NEC) and Indra.

The MTC concluded that "the relatively low system accuracy rates seen from the pilot suggest the technology is not ready for use in issuing … citations in a full-scale deployment…" MTC is currently developing an RFP to pilot app-based occupancy declaration systems.

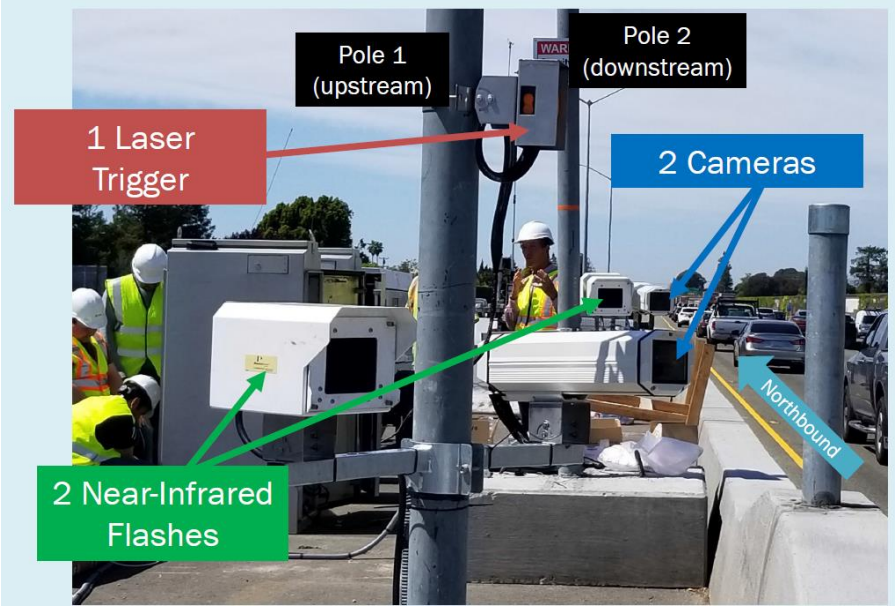

Figure 6: Indra occupancy detection system as installed for MTC pilot

Kapsch is also developing a camera-based VOD system but was not part of the MTC pilot test.

Current/Planned VOD Camera-Based Systems:

In 2017, the Metropolitan Transportation Authority (MTA, New York City) installed a vehicle occupancy detector system on the Verrazano Narrows Bridge to confirm vehicle occupancy for vehicles using carpool tags (HOV 3+). This system was installed by Conduent and is not currently integrated into the Open Road Tolling system.

In 2020, LA Metro will be implementing an automated occupancy detection system on the I-10 and I-110 Express Lanes. This will be the first Conduent VOD system fully integrated into the Express Lanes tolling system.

The Orange County Transportation Authority (OCTA) has contracted with Kapsch to implement an integrated express lanes system on I-405 and SR91 by 2023. This contract includes installation of a complete electronic toll and traffic management system, including a laser-based vehicle detection and classification system.

The I-66 Outside-the-Beltway project (Virginia) contracted with Indra to implement a fully integrated dynamic tolling system for the 22-mile Express Lanes on I-66. The system will feature dynamic tolling in an Open Road Tolling system and will include vehicle occupancy detection. Completion is expected in 2022.

Camera-based occupancy detection systems are usually deployed with a Violation Enforcement System enabling license plate capture so that the occupancy detected from the VOD system can be linked to the transaction.

Automated Occupancy Detection – App-Based Systems

Smartphone-based apps are being considered for occupancy verification systems and are currently being deployed as pilots. MTC is planning to test app-based technology in 2020 to understand operations, costs, and accuracy. RideFlag and Carma are two companies that have smartphone apps developed for occupancy declaration.

Central Texas Regional Mobility Authority in Austin and the Texas Department of Transportation both tested the Carma smartphone-app between 2012 and 2014. Carma has been awarded a contract to deploy their app in the Dallas- Fort Worth Metroplex area in 2020. In a four-month pilot conducted in 2017, NCTCOG reported a 98% exact match in reported occupancy.

UDOT is planning a 2020 pilot deployment of RideFlag on I-15.

Figure 7: *RideFlag Occupancy Validation App*

Both companies are still developing and testing their apps and are working to move from demonstrations and pilots to fully deployed occupancy declaration systems.

Long-Term Express Lane Occupancy Detection Technologies

For camera-based systems the cameras and algorithms are continuing to improve. Artificial Intelligence (AI) is being used to train the systems to more accurately determine the correct license plate numbers. Fingerprinting is also being used to assist systems to determine the correct plate number. Various approaches can be used to reduce the operational costs for manual image review such as offshore reviews, using prison labor for image reviews, and crowdsourcing. Privacy issues and quality control remain primary concerns and must be addressed for both the camera images and the manual image review.

Occupancy declaration smartphone apps are also just moving from the pilot stage to the deployment stage. The industry is closely monitoring them to determine how they perform on a larger scale. Messaging to the public will be critical for the success of full-scale smartphone occupancy app deployments. The first deployments will be closely monitored to determine if people still violate the system and if the app-based enforcement is accurate.

Connected and automated vehicles continue to develop standards and move into the demonstration and pilot phase. They bring the possibility of many changes in the tolling industry including the possibility of providing occupancy information directly from the car, VIN information, and automatic toll charging.

Road Usage Charging (RUC) also has the possibility of significantly changing how funds are collected to maintain our infrastructure. At this time, it is not known if occupancy will be a consideration in road usage charging or how they would declare and enforce occupancy.

LA Metro is preparing to test changing occupancy requirements to 5+ on their HOT lanes on the I-10. They want to evaluate the effect on operations and the use of vanpools to improve throughput during peak periods. This is a significant increase in requirements that moves complying vehicles to vanpools and transit. It will be important to monitor the test results as it may, if deemed successful, indicate a future direction other HOT Lane agencies may take if HOT Lane performance degrades in the future.

Summary

Occupancy violators reduce the ability to efficiently operate HOT lanes and impact revenue collection. Occupancy violations are estimated to range from 25%-40% of vehicles in HOT lanes across the country. Occupancy enforcement methods have been a focus of operating agencies and toll vendors for over a decade. Occupancy detection technologies have been field tested for several years and current deployments are considering either camera-based VODs or smartphone app-based systems.

The main obstacles to full deployments are cost and accuracy for camera-based VODs and accuracy and public acceptance for smart-phone based apps. With the improvement in camera-based VOD systems agencies are trying to deploy them to support existing systems and are starting to require them for new systems. As more systems are deployed, the cost of both the capital investment and the ongoing operational costs should become more reasonable. Smartphone apps for occupancy are also being tested in larger scale pilots and are going to be fully deployed in the next couple of years.

2.5 Violation Enforcement Systems

For violation enforcement, tolling systems and priced-managed lanes systems are most likely to have a license plate Violation Enforcement System (VES) to catch violators that are using the system without having a valid account. Violation Enforcement Systems take an image

or multiple images of the vehicle license plate, perform Optical Character Recognition (OCR), and then process the violation through the back-office system.

There are several different variations of VES that are currently deployed. Systems can deploy just a front or rear license plate camera or utilize both a front and rear camera to improve accuracy.

Newer systems use a “finger printing” system to identify vehicles by other identifying marks in addition to the license plate. After the system automatically performs OCR it determines the confidence level of the results. If the confidence is low the image is sent to manual review to verify the license plate number. Once the license plate number is determined the information is sent to the DMV to look up the owner’s name and address and a violation notice is sent to the owner. Similar systems are used for pay-by-plate, where a toll bill is sent to the owner instead of a violation notice. These systems have been deployed for years and are used in most All Electronic Toll (AET) systems. They are also often installed in HOT lanes and Express Lanes and are required for all pay-by-mail toll facilities.

2.6 HOT Lane Program Economics

Annual financial reports from three HOT Lane agencies were reviewed: I-15 (San Diego), SR91 (Orange County) and I-10 (Los Angeles County). The financial reporting varies among the three agencies. In one case, LACMTA, the Express Lanes Operating Expenses were reported as one line item within a larger enterprise fund which also included transit operations. The following tables provide high-level revenue and expense numbers for each agency for 2018:

I-15 FasTrak (San Diego, 2018) 19 centerline miles

Operating Entity	SANDAG
Declaration Method	Switchable or no transponder (like Utah)
# of Accounts	
Min Toll	$0.50
Max Toll	$4.00

Operating Revenue	$13,400,000
Operating Expenses	
FasTrak Operating Expenses	$4,800,000
Payroll	$600,000
Administrative Costs	$500,000
Professional Services	$266,000
Depreciation	$2,600,000
Total	$8,766,000
Operating Income	$4,634,000

SR91 (Orange/Riverside Co., 2018) 19 centerline miles

Operating Entity	OCTA/RCTC
Declaration Method	Specific lane
# of Accounts	140,694
Min Toll	$3.55
Max Toll	$28.50

	OCTA (11 miles)	RCTC (8 miles)
Operating Revenue	$57,600,000	$58,400,000
Operating Expenses		
Management and Operational Services	$6,400,000	$10,450,000
Administrative Overhead	$2,400,000	$570,000
Professional Services	$6,200,000	$1,100,000
General and Administrative	$500,000	$600,000
Depreciation	$3,400,000	$10,700,000
Total	$18,900,000	$23,420,000
Operating Income	$38,700,000	$34,980,000

I-10/I-110 Metro ExpressLanes 25 centerline miles in 2 segments

Operating Entity	LA Metro
Declaration Method	Switchable transponder
# of Accounts	702,500
Min Toll	$2.75
Max Toll	$21.00

Operating Revenue (from tolls)	$69,900,000
Operating Expenses	
Toll Operations	$22,200,222
California Highway Patrol Enforcement	$9,700,000
Total	$31,900,222
Operating Income	$37,999,778

2.7 Recommended Opportunities for Further Investigation

If Utah state officials wish to learn more about HOT lane management, several of the agencies mentioned in this report would be worth contacting and/or visiting to understand how such agencies evolve to manage revenues and enforcement issues, and what technologies are being deployed.

The following agencies are recommended:

- SANDAG (I-15 San Diego)
- Orange County Transportation Authority/Riverside County Transportation Commission (SR91)
- LA Metro (1-10/I-110)
- TxDOT/NCTCOG (8 managed lanes in Dallas-Fort Worth area)
- Metropolitan Transportation Authority (Verrazano Narrows Bridge)
- Virginia DOT (I-66, I-495/I-95)

In addition, the IBTTA is holding a Technology Summit in April 2020 (https://www.ibtta.org/events/technology-summit) in San Diego, CA that will involve vendors of occupancy detection technologies. This conference represents an opportunity to investigate the most recent advances in this technology.

2.8 Review of Utah Legislation Regarding Privacy Issues (SB71)

In 2018 SB71, also known as the Road Tolls Provision, was passed. SB71 amended Title 41 (Motor Vehicles) and Title 72 (Transportation Code).

SB71 addresses all data captured in toll enforcement. SB71 amends Subsection 72-6-118(2)(e) to authorize UDOT to utilize technology to monitor and collect tolls, including the use of license-plate reading technology or photographic-/video-recording technology (lines 142-159 of SB71).

The retention and use of any data obtained from license plate capture or from photographic-/video-recording technology, is addressed in Title 72 [subsections 72-6-118(10) and (11)]. Such data may only be used in toll enforcement and may only be retained if

necessary, to collect the toll or pursuant to a warrant. Aggregated data may be used for planning and statistical purposes so long as specific license plate data is not preserved or disclosed.

Title 41, Chapter 6a, Part 20 deals with other uses for license plate readers, not just for tolling purposes. It specifically addresses the use and retention of that data but provides a limited exception for tolls. This Part doesn't address other data such as imagery. Titles 41 and 72 are two separate statutory schemes, addressing different uses of similar technologies by various government entities.

3. CONCLUSIONS

The key findings of this research are:

- Annual revenues from UDOT's HOT Lanes program is approximately $2 million.
- In Utah, the occupancy violation rate in the HOT lanes, is increasing year to year. Nationwide, HOT lane violations are estimated to range from 25-40%.
- Nationwide, there are 32 HOT Lane and 19 Express Lane systems. Virtually all the HOT Lane systems contract with state Highway Patrols for occupancy enforcement which still does not eliminate the violations.
- Near-term technologies to detect vehicle occupancy include camera-based systems and smartphone apps.
- Camera-based vehicle occupancy systems have been deployed on the Verrazano Narrows Bridge (New York City) and are being planned for SR91 and I405 (Orange County, CA) and for I-10/I-110 in Los Angeles County.
- The accuracy of camera-based occupancy detection technologies from a 2018 pilot test of three systems conducted by MTC (Bay Area MPO) ranged from 77%-89% based on manual image review and 37%-75% based on controlled test runs.
- MTC concluded that "the relatively low system accuracy rates seen from the pilot suggest the technology is not ready for use in issuing … citations in a full-scale deployment…" MTC is currently developing an RFP to pilot app-based occupancy declaration systems.
- UDOT is piloting a smartphone-based occupancy declaration system in 2020 with RideFlag.
- NCTCOG (Dallas-Fort Worth MPO) has contracted with Carma for implementing their app-based system for occupancy declaration. In a 2017 pilot, NCTCOG reported a 98% accuracy rate.
- Long-term technologies for occupancy detection include the continued improvement of camera-based and app-based systems, and V2X communication of occupancy which may be linked to emerging connected vehicle technologies or part of road usage charging programs.
- SB71 (2018 legislative session) modified language in Titles 41 and 72 that further protect personal privacy. SB71 modified Title 41 to address limitations for retention of data from license plate readers. SB71 modified Title 72 to specifically authorize the use of license-plate reading technology and photographic- or video-recording technology for automatically monitoring a tollway and collecting a toll. Prior to SB71, Title 72 already

addressed limitations for retention and use of captured images so there was no need to address this again in SB71.