

Front License Plate Market Research: Comparison of Single Versus Dual License Plates



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EXECUTIVE SUMMARY

License plates are a critical element of the transportation system in regards to enforcement and tolling. Additionally, the plates contribute to the effectiveness of parking and homeland security applications. License plates identify vehicles, provide retro reflective characteristics for readability and safety in nighttime conditions, register vehicles for tax purposes as well as indicate the vehicle's origin (state and county in some cases) based on where it is registered. There are 31 states that require two plates (front and rear) on vehicles while the remaining 19 only require a rear plate.

Policy makers as well as individual drivers have strong opinions related to the one versus two plate debate. Law enforcement believes that two plates aide in vehicle identification and the benefits associated with the retro reflectivity is a distinct advantage. With the integration of more automatic license plate reader (ALPR) technology into enforcement, two plates increase the opportunities to identify vehicles (speed detection, stolen vehicles, red-light running, etc.). On the other side of the debate, those who support single plates site the possibility of vehicle fraud, the expense of issuing two plates, and the negative effect on the aesthetics on the front of the vehicle. Interestingly, these discussions are unique to North America since other countries require two plates and it is accepted much like the cultural expectation that individuals do not drive after drinking.

The conclusions drawn in this study were based on the literature review and field studies. The research team collected license plate data in four states: Pennsylvania and Arizona were the one plate states and Maryland and Texas were the two plate states. These states were selected based on geography, proximity to other states or the international border, use of ALPR technology, and presence of tolling. The study results are summarized below:

- Front plates were easier to read in the daytime environment due to the effects of sun glare [1].
- Lack of front plates has significant impact on the generation of photographic evidence related to fining toll violators. With respect to Virginia's toll violations, 23% could not be pursued due to the lack of license plate data (rear plates were unreadable) [2; 3].
- Without front license plates, the E-470 corridor in Colorado would lose at least \$23.1M in toll revenue or 34.5% of their tolls on an annual basis [4].

- The United States Customs and Border Protection (CBP) reports that the number of plates not read (excluded) on vehicle without two plates made a significant impact in their border processing. At the northern border 6% of the plates could not be read and 3.4% across the southern border [5]. The major difference between the international borders is the presence of dual plate states between the US and Mexico. With the volume of vehicles processed everyday along with the homeland security concerns, the front plate allows CBP to operate more effectively.
- Pennsylvania is a one plate state with a 360 mile turnpike that crosses the state east to west. Law enforcement would like to see two plates to improve their ability to read plates, especially large commercial trucks, using ALPR technology. Sixteen percent of the plates through the tolling facilities are not able to be read which impacts the state's ability to pursue toll violators.
- Phoenix's Sky Harbor Airport reports that 10,000 parking transactions per year, an average of \$30/transaction, rely on ALPR plate reads to determine accurate charging. Fifteen percent of those transactions had to be processed manually since the rear plates could not be read due primarily to sun glare.
- Field studies showed a 97% read rate for parked vehicles in two plate states and 76% in one plate states. For moving vehicles, the read rate in Maryland and Texas was 89%, Pennsylvania and Arizona it was 22% and 58% on the roadways connecting Maryland and Pennsylvania. These read rates are based on the opportunity to read a front plate; a vehicle had a license plate mounted on the front bumper.
- For those states with more than 100 miles of toll roads, one plate states account for 55% of the total toll way miles [6]. As fiscal pressures mount, efficiency in the collection of tolls and the pursuit of violators becomes critical. Front plates increase the likelihood of collecting that revenue.

As early as 1925, experts in the transportation field recognized the benefits of standardized placement of license plates and proposed front and rear plate positioning. They believed that this standardization "would help all concerned with their (license plates) observance" [7]. Identification of vehicles is a critical issue for enforcement, tolling, parking, and homeland security. The use of two plates maximizes the opportunity for this identification to be completed efficiently and effectively whether by an individual or through ALPR technology. With the increase in the use of ALPR technology across all of the applications, it is clear that the presence of two plates provides better observation opportunities related to all the applications.

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BACKGROUND

License plates are a critical part of the transportation system for many reasons. Although vehicles can be described according to make, model, color, and/or other distinguishing factors, these general attributes can be subjective and even common. A vehicle’s license plate provides a unique identifier that connects the vehicle to its owner and status. License plates provide:

- identity of vehicles for law enforcement, tolling, parking and other public applications,
- retro reflective elements for readability and as a safety benefit in nighttime conditions,
- a means of registering vehicles for tax and other purposes, and
- designation of the vehicle’s origin (state and sometimes county) based on where it is registered.

License plates have been used on vehicles in the United States since the early days of the twentieth century. Today, each state has multiple versions of license plates that are available to the citizens, although all have a standard size of 12×6 inches. In addition to the differences in appearance, there is another key difference between some of the states – those that use a rear-only (single) license plate and those that use both front and rear (dual) license plates. Table 1 provides a list of states in each category. There are nineteen states that require one license plate while the remaining thirty one are primarily two plate states.

Table 1. Summary of License Plate Use.

States with Rear-Only License Plates		States with Front and Rear License Plates		
Alabama	Michigan	Alaska	Maryland	Oregon
Arizona	Mississippi	California	Montana	Rhode Island
Arkansas	Oklahoma	Colorado	Nebraska	South Dakota
Delaware	Pennsylvania	Connecticut	New	Texas
Florida	New Mexico	Hawaii	Hampshire	Utah
Georgia	North Carolina	Idaho	New Jersey	Vermont
Indiana	South Carolina	Illinois	New York	Virginia
Kansas	Tennessee	Iowa	Nevada	Washington
Kentucky	West Virginia	Maine	North Dakota	Wisconsin
Louisiana		Minnesota	Ohio	Wyoming
		Missouri		

Note: Massachusetts and Nevada require two license plates, but there are exceptions to that requirement based on model and/or year[8].

According to the National Conference of State Legislatures (September 1999), eight jurisdictions responding to a questionnaire were considering changing their license plate requirement (with a majority of these wanting to cut back from two to one) [9]. Indiana has attempted to move from one plate to two, but the legislation was defeated citing a lack of evidence that benefits outweighed costs. In contrast, Utah introduced legislation in 2006 to change their requirements from two plates to one. This revision did not pass.

Many factors impact the advantages of using two versus one license plate. Discussions have focused primarily on the law enforcement aspect of vehicle identification; however over the course of this project, it was determined that enforcement is only one aspect of the debate. Although law enforcement is one of the main proponents of the two plate requirement, they acknowledge that their job could be accomplished if only given one plate per vehicle, albeit a slightly more laborious and less efficient method. A few of the key issues related to single versus dual license plate use from general enforcement and visibility perspectives are summarized in Table 2.

Table 2. Issues Related to License Plate Use.

Advantages of Two License Plates	Disadvantages of Two License Plates
<p>Assists law enforcement officials</p> <ul style="list-style-type: none"> • Vehicle can be identified from either front or rear (by the officer alone or in conjunction with an automatic license plate reader or ALPR) • Could potentially assist in hit and run identification <p>Increases safety in general</p> <ul style="list-style-type: none"> • Retro reflective material on front of car increases visibility at all times • Provides some type of reflection for drunk/inattentive drivers who neglect to turn on their headlights during dark hours [1] <p>Assists with photo and laser radar enforcement</p> <ul style="list-style-type: none"> • Provides two opportunities for photographic evidence • Provides a retro reflective target for laser speed detection 	<p>Increase of possibility of vehicular fraud</p> <ul style="list-style-type: none"> • Relatively lax enforcement of law allows one to take one pair of license plates and distribute it between two cars <p>Expense of adding twice as many plates</p> <ul style="list-style-type: none"> • Some states believe that is significantly more expensive to issue two plates, but interviews indicate that in most states the cost is minimal and passed on to the consumer • Argued that money would be better spent on finding cheaper solutions that would provide equal levels of retro reflectivity/visibility <p>Damage to particular models</p> <ul style="list-style-type: none"> • Even though all models have a location for a front license plate bracket, the equipment is frequently left off of the car when delivered to the dealerships • Owners believe that this may lead to unprofessional alterations that affect the value or appearance of the vehicle • US advertising typically does not include front license plates where as European publications almost always include a front license plate

The early appreciation of having two license plates on a vehicle is evidenced in a 1925 publication of in the Journal of Automotive Engineers [7]. The Division of Simplified Practice, one of the austerity efforts within the federal government, recommended that license plates have standard locations: front and rear. It was thought that front and rear plates can be

obscured or damaged, so requiring specific locations on the vehicle for license plates would help all concerned with their observance and improve proper identification.

Currently, the requirements regarding license plates in the United States are largely a political issue, with very little scientific evidence to support the use of one versus two plates. Strong arguments exist on both sides of the issue, but neither has the sufficient amount of quantitative data supporting its premise to reach a definitive conclusion, as can be seen by the United States' distinct split on the issue amongst the states.

When examining the arguments, it generally appears that those in favor of requiring two license plates have a mindset of safety and identification, whereas those in favor of one are coming from a fiscal and aesthetic perspective. The cost of a license plate and the number of license plates issued will vary from state to state, hence making the argument of cost versus safety analysis for each state's scenario different. Interestingly, the fiscal argument appears to be present whether people advocate for one or two license plates. With the increased use of automated license plate recognition (ALPR) technology (enforcement, tolling, parking, etc.), the presence of both front and back plates increases the opportunity to capture revenue especially with respect to securing payment for violations related to tolling and the effective processing of parking fees. It is reasonable to assume that the usage of ALPR technology will continue to expand in terms of the number of units deployed, but also in the diversity of applications. ALPR is only a tool to assist in the reading of license plates; the plates have to be available to read in order for ALPR to work just as when an individual manually reads the plate. When we consider this expectation, the need for front mounted plates seems to be a logical conclusion.

In order to address the lack of quantitative evidence related to one versus two license plate requirements, this project examined vehicle identification based on enforcement/traffic safety, homeland security, tolling, and parking perspectives. In order to address possible geographic issues the data collection was completed in two regions of the country: Mid-Atlantic and Southwest.

This research effort proposed to utilize the scientific approach to identifying critical information and trying to determine quantitative data that can be used as part of an analytical process in assessing the issues related to using one versus two license plates. The following section details the methodology employed to meet the objectives of this project.

STUDY OBJECTIVES

The primary goal of this research project was to evaluate the benefits and challenges associated with the use of dual license plates (front and rear) as opposed to a single license plate (rear-only). The project objectives focused on two areas where license plates are critical: law enforcement and general vehicle identification.

Law Enforcement

- Identify law enforcement practices involving license plates and vehicle identification, including the use of ALPR systems.
- Determine if rear or front plate placement (or both versus rear only) provides higher identification rates when using ALPR systems.
 - Identify the impacts from time of day, direction, lighting, and flash to vehicle identification when using ALPR systems.
- Identify situations and the likelihood of those situations, in which the lack of a front license plate could impede vehicle identification, and whether that identification is attempted by a person visually scanning vehicles or by an ALPR system.
- Assess the probability of vehicle identification by law enforcement officers by sight alone considering the availability of one or two plates.

General Vehicle Identification

- Compare the identification rates related to tolling, parking, and enforcement technology prominent in speed and red light cameras in regards to one or two license plates.
- Identify practices of vehicle identification using one or two plate placement related to homeland security and access entry.
- Determine the impact of the use of license plates for identification of vehicles by witnesses during the investigation of crimes or other incidents.
- Examine the fiscal implications of one versus two plates as they relate to multiple applications.

In addition to the identification aspects of single versus dual license plates, TTI examined the fiscal implications as they relate to multiple applications (enforcement, tolling, parking, etc.).

METHODOLOGY

This project involves diverse stakeholders who may serve as the consumers of the results of this report. In order to illustrate the impact of one versus two license plates, the project team included quantitative as well as qualitative approaches to data collection and analysis. From the quantitative perspective, the research team observed both stationary vehicles and those in motion to determine the rate which the vehicles could be identified according to their license plate. These types of observations could be replicated in different areas by any number of researchers.

The research team was also interested in studying how human behavior affects vehicle identification by law enforcement officers and other transportation professionals. The quantitative data addressed how many vehicles could be identified using front and/or rear plates, but the qualitative data informed the researchers as to how an individual or agency uses this data and articulates challenges associated with vehicle identification using license plates. Although this type of data collection is often considered subjective it is important to interpret the data from a practical perspective. The combination of quantitative and qualitative

methodology provides for a comprehensive analysis that serves the diverse consumers of this type of market study research.

The focus of this project was to assess how vehicle identification using two license plates compares to rear only plates. The intent of the methodology was to examine the identification with respect to all applications not just law enforcement. Based on this approach, the researchers could not ignore the impact that ALPR technology has on the identification process and, subsequently, whether states should consider using two plates on all vehicles registered in their state.

In an effort to represent perspectives from different parts of the country, TTI identified four states in which to collect data. By utilizing four states (two dual plate states and two single plate states); TTI was able to produce a study that was more representative of the identification needs of enforcement and other identification activities. Two regions were identified, Mid-Atlantic and Southwest, as data collection areas for this project. TTI selected states to provide opportunity for observation in diverse environments. Maryland, Pennsylvania, Texas and Arizona were the primary states, but due to their proximity to other states, the observation process included, at a minimum, the selected states as well as the adjacent states. All states had at least minimal deployment of ALPR systems as a means of identification and enforcement.

Based on the preliminary review of publications, TTI determined that it needed to work in states where the ALPR systems were already integrated into enforcement activities. TTI also wanted to ensure that it could readily identify enforcement agencies that would be willing to participate in this project and planned on utilizing existing relationships/partnerships with ALPR providers to enlist that participation. Maryland (two plates) and Pennsylvania (one plate) are geographically located in proximity to New Jersey (two plates), Virginia (two plates), West Virginia (one plate), Delaware (one plate), and the District of Columbia (two plates), therefore observations in these states not only included plates from the selected states, but also a number of plates from the adjoining states. Travel related to conducting the observations in these states was minimized since large population centers as well as rural areas were located close to each other and readily accessible in southeastern Pennsylvania and Maryland (especially in the Baltimore metro area).

The second set of states, Texas (two plates) and Arizona (one plate); represent a significantly different type of area as compared to the mid-Atlantic states. TTI conducted the majority of the observations in these states in the El Paso (TX)/Las Cruces (NM) area, College Station, and Houston. In Arizona, observations focused on Phoenix and Tucson in addition to the rural areas between these metro centers. These locations present unique issues with license plate identification. There is a great deal of interstate transit between Arizona, New Mexico and Texas in this area along with a large military population that included residents from a diverse set of states who are in Texas temporarily for military assignments. There are also significant issues related to border crossings for work (personal and commercial vehicles) as well as recreation.

It was important to attend to issues of diversity in the observation of the license plates (two vs. one plate, design of plates, states, etc.) in order to provide the best data set for analysis. By using states that are adjacent to each other and selecting states that present as many different license plate observations as possible, the analysis was more representative of the issues of license plate recognition. Since data collection represented a significant portion of the project cost, it was critical that this task was performed in such a manner to maximize the amount of data collected.

The work plan was structured to provide useful, practical, and reliable information that can be used to determine whether two license plates are more effective than only a rear plate. It was important to consider perspectives that not only included law enforcement, but also tolling, parking, and homeland security. The following section details the activities used to examine the effectiveness of one versus two license plates on vehicles.

VEHICLE IDENTIFICATION

Intuitively, it makes sense that individuals and/or ALPR technology will be more effective when provided with an increased number of chances to look at a license plate. In order to understand the difference that the use of one plate versus two plates make to the vehicle identification, it is important to understand that recognition process for individuals with and without the assistance of technology.

The ability to recognize a vehicle is critical to a number of applications [10]. Typical vehicle characteristics include body color, make and model, license plates and/or other distinguishing factors such as body damage, window tint, or stickers. A vehicle's make or model has distinct features that are key to human perception. Vehicle type (e.g. truck, sedan, or van) can be recognized even from a significant distance.

In the case of law enforcement, officers may use license plates to identify vehicles for homeland security, auto theft, traffic violations, and other criminal activities. Traffic law enforcement benefits frequently go beyond the traffic stop since many of these stops lead to the identification and/or apprehension of individuals involved in more serious crimes. The National Highway Transportation Safety Administration (NHTSA) and the International Association of Chiefs of Police (IACP) have focused on this opportunity by deploying a training course called Conducting Complete Traffic Stops [11]. The inclusion of license plate information in this process is not only important to identifying criminals, but also to officer safety.

Even though the officers may be searching for a specific license plate number, they often use other factors as a means of identification to reduce the number of options prior to focusing on the plate. These characteristics are easier to see and mentally process, they allow officers to eliminate the vehicles that do not fit the general description, and require minimal interaction with their dispatch [10]. It is difficult for a law enforcement officer to only use the license plate as the primary identifier without the use of ALPR technology since the officer must type in the plate number to their on-board computing system and/or contact dispatch for confirmation. This process can be time consuming and cause delays.

Human recognition verses ALPR technology

When ALPR technology is employed in the enforcement environment, the technology performs the visual identification by reading and processing the plate in order to alert the officer to a potential offender or stolen property. The technology allows an officer to assess hundreds of plates per hour and automatically alerts the officer to those plates that are known to be stolen or belong to individuals involved with other criminal activity [12]. The ALPR process is very efficient, but, like a police officer, it cannot read what it cannot see. If license plates are affixed to the front and rear of vehicles, the technology, as well as identification solely by a law enforcement officer, can work more efficiently whether the vehicle in question is moving or in a stationary position. Dual plates allow an officer to specifically identify a vehicle from the safety of their police car regardless of whether the vehicle is in motion or stationary.

Vehicles require identification in other applications in addition to enforcement. Government and private entities are looking for ways to make processes more efficient/cost effective and less dependent on human interaction especially in regards to repetitive activities related to tolling, parking, and automated enforcement such as red light violations and speeding. License plates serve as unique identifiers in all of these applications and directly affect accurate identification of the vehicle involved in the violation and, in some cases, revenue generation.

Although the concept of identifying a motor vehicle seems simple, it can be complex and time consuming. Once the vehicle itself is identified, the vehicle has to be connected to the driver or the owner in order to pursue an enforcement issue of seeking payment for a traffic (red-light cameras and speeding) tolling or parking violation. The ability to identify the vehicle from the front as well as the rear increases the opportunity to recognize and compare the plate to a known database of vehicle information. Even without the benefit of quantitative data related to license plate identification, it is reasonable to conclude that the use of front and rear license plates increase the probability to accurately identifying a motor vehicle in multiple and diverse situations. Clearly, with the advent of ALPR technology and its relevance to various applications, there is or will be a significant benefit to government, private entities, as well as enforcement.

The following section of this report provides data and case studies from the literature as well as the field studies conducted specifically as part of this project.

APPLICATIONS IN LICENSE PLATE IDENTIFICATION

In order to address the objectives of this project, the research team reviewed existing literature and collected data from specific states to determine the impact of utilizing dual license plates (front and rear placement) verses only using a single rear plate. Initially, the research team was focused on enforcement, but found that the enforcement community has little incentive to collect data related to the identification of vehicle via the license plate. Most of the existing data is anecdotal. The enforcement related data included in this report was collected by the research team in each of the four states with moving vehicles and those that were stationary. Although the enforcement data demonstrates a difference in the recognition of vehicles with

dual plate, the researchers found an even more profound impact when they examined the fiscal impact in tolling as well as an improvement in recognition in security applications.

The impact of ALPR technology cannot be ignored as a critical factor in regards to the current and potential benefits of requiring a front license plate. As the use of ALPR technology increases across a diverse set of applications, front plates will become even more beneficial. This section details the cases studies found in the literature as well as the data analysis based on the field studies that were conducted as part of this project.

Case Studies from the Literature

As part of the literature review, the research team selected examples related to the identification of vehicles either manually or by using ALPR technology. These examples have been summarized in the form of case studies related to enforcement and tolling. The intention was to highlight practical insights gleaned from the existing literature as a means of informing the methodology, data collection, and the formation of conclusions related to the debate of one versus two plates.

California: Automated Photo Enforcement Countermeasures

A study was conducted in California to examine the effect of two countermeasures: photo spray and license plate shields [1]. Field tests examined the impact of plate treatments on the readability of the front and rear license plates in different directions (east and west) in both daylight and darkness. The study also provides some insight on the recognition of the plate placement. In the darkness setting, there was not a noticeable difference between the readability of either the front or rear plates. Observations made during in daylight environment did produce a difference between the readability of the front verses rear plates. The presence of sun glare had a noticeable effect on the readability of the rear plates, but not those placed on the front of the car. These results are consistent with observations made by the staff at Phoenix’s Sky Harbor Airport parking facilities.

Although this study was conducted exclusively using ALPR technology, it is reasonable to assume that the sun glare would also affect an individual’s ability to recognize and read the plates regardless of the treatment.

Virginia: Report of the Tolling Legislation Working Group

Virginia has a number of toll roads including those that are part of the general roadway that serve as HOT lanes. These roadways are a critical part of the state’s transportation infrastructure and serve as a critical element to address mobility issues in Virginia’s most congested areas.

“The HOV lanes move more people in carpools, vanpools, buses, motorcycles, clean fuel vehicles, and trucks from Virginia to the core areas of Arlington and Washington DC than the regular highway lanes, Metrorail, and the Virginia Railway Express. Our transportation network could not function without HOV lanes [2, p2].”

Electronic toll collection technology has improved the transportation environment so that high-occupancy and tolling facilities can be expanded. The challenge associated with electronically monitoring these facilities is the enforcement of the occupancy and toll violations with minimal impact to those facilities [2; 3]. Manual enforcement, individual officers alone or as part of saturation patrols, is expensive, frequently inefficient, and diverts resources [2; 3; 13]. Additionally, this type of enforcement only results in short term impact on violation rates and disrupts traffic flow on roadways that are intended to improve mobility. Along with the growing demand for efficient travel, tolling authorities and government entities need to recoup the revenue that is used to justify the construction of such facilities. With that in mind, it is important to maximize the opportunity to identify vehicles via license plates. Although Virginia is a two plate state, not all of their tolling facilities are equipped with ALRP cameras that read the front plate which significantly contributes to the 539,000 violations (23% of total violations) which are not pursued due to the lack of photographic evidence. It is easy to imagine the financial impact that this has on the revenue generation in Virginia [3].

Table 3. Virginia Toll Transactions and Violation Disposition [3]. (Year Ending 6/30/2011)

	Total toll transactions	200,000,000
	Toll violations	1,914,000
	Violations not resulting in a court summons	1,871,000
Paid Violations	Violations processed through V-tolling	647,000
	Violations pursued through notices	445,000
	Violation paid after 1st notice	164,000
Unpaid Violations	Violation not paid, but disregarded since a third violation did not occur during the calendar year	173,000
	Returned to sender	65,000
	Violations not processed due to lack of photo	539,000
	Violator (1st time violator) with no additional violations during the calendar year (no fine)	283,000
	Violations resulting in court summons (6,750 individual violators)	43,000

From these statistics, it is evident that improving the capability to identify and photograph license plates could significantly improve reclamation of fees for violations. Adding cameras positioned to capture front plates in addition to the rear-plate cameras currently in service could significantly increase the number of vehicles that are successfully photographed.

Georgia: Enforcement Strategies for High-Occupancy Toll (HOT) Lanes in Atlanta

The metro Atlanta area is well known for its congestion. With three major interstates (I-20, I-75, and I-85) converging in its downtown area along with the population growth in its suburbs, the city is seeking ways to improve their transportation infrastructure while relieving its congestion

challenges. Atlanta is currently utilizing HOT lane corridors without complete barrier separation as a means of addressing the significant congestion challenges along its most travelled roadways [13]. Effective enforcement presents several issues when addressing toll violations, lane integrity, and occupancy restrictions. In order to augment traditional enforcement by individual officers, the HOT lanes are equipped with enforcement cameras that capture the license plates of violators. The ALPR equipment is directed only at the rear plate. This application is not solely due to the fact that Georgia is a one plate state, but rather because the violation has to occur (i.e. vehicle must pass the gantry/reader without a valid transponder) before the camera needs to capture the image of the plate. If reading front plates was an option, there may be other available approaches to enforcement (occupancy and other tolling violations).

Denver, Colorado: E-470 and How Front License Plates Impact Tollway Efficiency

The E-470 roadway in the Denver-Aurora Metropolitan Area serves an excellent example of how much front license plates can impact the efficiency of our transportation infrastructure in the tolling application. E-470 is a 47-mile-long, controlled-access road with fully electronic tolling. The toll way intersects significant highways (I-25, I-70, and I-76) and serves as an outer beltway for the Denver-Aurora Metropolitan Area [14]. E-470 is not a state road and is managed by the E-470 Public Highway Authority; therefore it is critical that the system generate the expected revenue since tolling authority receives no state or federal funding or local taxes.



Over a twelve month period, E-470 Public Highway Authority tracked the number of transactions and tolls due based on which license plate was used to generate the toll. There were a total of 23,798,636 transactions resulting in more than \$67.2 million in revenue [4]. Front plates accounted for 8,007,895 toll transactions and \$23.1 million in revenue. Based on feedback directly from E-470 staff, the ability to capture front plates is critical to the success of the toll way. Thirty-four percent (34%) of the tolling revenue would have been lost without the ability to read a front license plate.

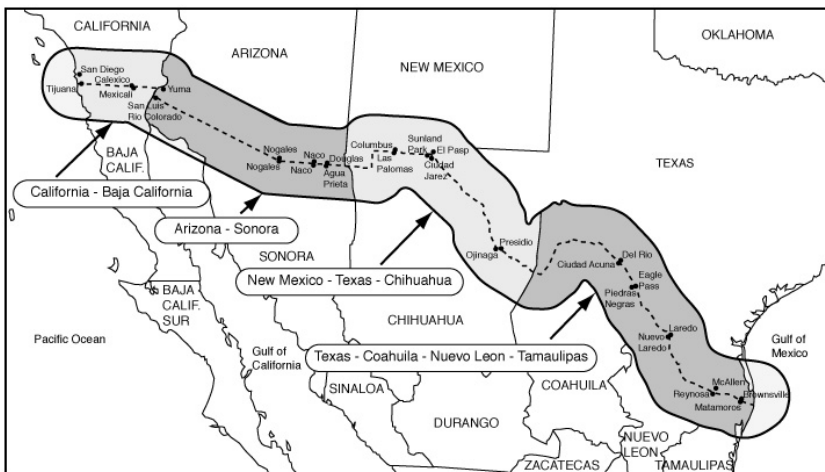
Table 4. E-470 Transactions for 12-Month Period [4].

Plate Side	Transaction Count	Toll Due	% of TOT
FRONT	8,007,695	\$ 23,062,441	34.3%
REAR	5,389,926	\$ 14,577,152	21.7%
UNKNOWN	10,401,015	\$ 29,589,750	44.0%
TOTAL	23,798,636	\$ 67,229,342	

According to Dave Kristick of the E-470 Public Highway Authority, front plates are even more important in the capture of large, long-haul truck revenue [4]. Due to the prevalent use of apportioned plates with the trailers, the ability to capture the front plates of large trucks is crucial. The operation of the E-470 toll way provides a strong case for why front plates will be a critical element of tolling as either a means of generating the toll and/or pursuing violations.

U.S. Customs and Border Protection: Effects of License Plate Placement on ALPR at Border Crossings

The U.S. Customs and Border Protection (CBP) utilize ALPR technology on both the northern and southern borders of the United States [15]. The border facilities process a significant number of vehicles each day, so efficiency of the identification process is paramount. U.S Customs and Border Protection in conjunction with RTR technologies studied the effectiveness of ALPR applications on at northern and southern border crossings and the results of that investigation are summarized in this case study.



Authorities at the international borders relied on ALPR technology for this investigation. The agency defined a valid read as one that is read (correctly or erroneously) and excluded several instances since the issue was beyond the capabilities of the ALPR system due to limitations in the field of view. In order to be included, the plate’s number and state must be visible. Those vehicles with obstructions such as a trailer hitch, part of the plate being out of the field of view, temporary plates, towed vehicles, motorcycles, as well as commercial vehicles with more than one specific plate were excluded.

The Canadian and Mexican states that border the United States have the following requirements for license plates:

Table 5. International States Bordering the United States [8].

	Dual Plates	Rear Plate Only
Canada	British Columbia Saskatchewan Manitoba Ontario New Brunswick	Yukon Territory Alberta Quebec Nova Scotia
Mexico	Baja California Norte Baja California Sur Chihuahua* Coahuila* Sonora* Tamaulipas*	Nuevo Leon

Note: In Mexico, the front plate requirement only applies to privately owned vehicles. The () indicates that in these Mexican states, a front plate is only required on vehicles that are registered to owners who live within 20 miles of the U.S. border.*

At the northern border crossings, vehicles with rear-only plates had significantly more exclusions (e.g. the rear plate was obscured by something and there was no front plate to read) than those with dual plates and the read rates were lower [5]. The general traffic lanes had approximately 6% of their vehicles excluded and the commuter lanes had a 4% exclusion rate. Seventy-five percent of the read rates for rear-only plates were below the average of the dual plate reads. The southern border exclusions were better with only 3.4% of the general lane traffic excluded and 1.3% of the commuter lanes vehicles were excluded. This is likely due to the fact that most of the traffic across the southern crossings have two plates since the two most populous states in the U.S., Texas and California, are dual plate states and have significant cross traffic on a daily basis. Additionally, the Mexican states adjacent to these borders require two plates for those most likely to cross into the U.S. on a frequent basis. Finally, at the southern border, the read rates for those plates with license plates mounted only on the rear of the vehicle were all lower than those with dual plates.

The ability to efficiently process vehicles at border crossings is not only an issue of congestion, but also homeland security. It would be impossible to process all of the crossings effectively without the use of ALPR technology. Additionally, the technology allows the U.S. Customs and Border Protection to load license plates that are known to be connected to security risks as well as criminal activity [16]. In July 2012, the federal government issued a request for information (ALPR technology) in support of the Drug Enforcement Administration (DEA), along with CBP, National License Plate Reader (LPR) Initiative [17]. This provides further proof that ALPR technology is the wave of the future in terms of vehicle identification. Checking each plate manually would not be possible without long lines and additional personnel. Since ALPR technology is a critical tool in border security, it stands to reason that states should give the

federal enforcement officers any practical tool that can improve the efficiency and effectiveness of their operations. Dual plates seem to be a low cost tool to address these issues.

Revenue Collection: Tolling and Parking

Although there were not specific examples in the literature related to vehicle identification from the revenue generation perspective, it is important to note that license plates do serve a critical need in the tolling and parking industries. ALPR can be used by tolling agencies to track violators and to automatically collect tolls, though regular toll collection is more commonly accomplished using toll tags/transponders. ALPR systems are generally positioned to the side of or above roadway lanes just past tolling plazas/checkpoints to photograph vehicle plates. Similarly, parking facilities that charge by the hour or day can use ALPR to verify when vehicles enter and leave a facility.

Case Studies and Data Analysis from the Field Studies

The research team travelled to the Mid-Atlantic and Southwestern states to interview stakeholders related to law enforcement, tolling, and homeland security. Given the close proximity of the states in that region, the research team was able to visit other areas adjacent to the target states. The research team surveyed multiple parking lots, garages, and other locations in several jurisdictions in Arizona, Maryland, Pennsylvania, and Texas. The team tabulated the number of cars in those facilities and the percentage of those cars with visible license plates. There were more than 9000 vehicles observed during this task verses the 2500 originally projected at the beginning of this study.

The research team tested the ability of ALPR systems to identify vehicles based on front and rear license plates under various conditions. The observations utilized ALPR systems currently deployed by the law enforcement agencies that participated in the project - researchers rode-along with selected officers to conduct some of the observations. Care was taken to include officers who primarily deal with traffic related enforcement (e. g. state patrol) as well as those officers who engage in more general patrol activities (municipal and county). As part of this task, the researcher recorded how vehicles were identified (front license plate, rear license plate or both) during the officer's shift. During this process qualitative data was gathered from the officers and other stakeholders to augment the quantitative data.

The following section provides data from specific states and jurisdictions. The research team collected data and interviewed individuals related to enforcement, tolling, parking and homeland security. These observations serve as practical examples of those applications that were found in the literature.

General Enforcement

The law enforcement agencies interviewed in this study that use ALPR systems did not use the technology on all patrol vehicles at the time of this report due to the expense of the systems, though several indicated that they would be in favor of expanding their agency's ALPR capabilities, based on the benefits that have been realized from the units they have. The purchase and maintenance of ALPR units are often funded through competitive grants that are

specifically focused on reducing certain types of crimes, such as stolen vehicles. Other funding sources that were mentioned by law enforcement agencies include homeland security funding, especially for agencies close to Washington, D.C., and a local community grant that was repaid via the increased collection of parking fines. The specific funding source for a law enforcement-operated ALPR unit often dictates the unit's primary use/assignment within that agency – e.g., an ALPR system purchased with a stolen-vehicles grant will be installed on a patrol vehicle within the agency's stolen-vehicle unit, and ALPR units purchased with Homeland Security funds are likely to be positioned at locations where vehicles will be crossing a defined border or perimeter.

However, in nearly all cases, ALPR units are used to alert officers and agencies to license plates associated with other outstanding crimes as well. The interviewed agencies have made use of ALPR systems, individually or networked across regions or states, to track Amber and Silver alerts, to find vehicles and people connected with crimes that have been reported locally or listed in the National Crime Information Center (NCIC), and for enforcement of suspended vehicle registrations, insurance violations, and outstanding traffic and parking warrants. As ALPR becomes more widespread and technology costs decrease, it is likely that agencies will adopt the units more widely across their patrol and roadway surveillance operations.

Maryland State Police: Dual Plates and ALPR Creates an Effective Enforcement Partnership

Maryland is a two-plate state that is bordered by three single-plate states, Pennsylvania, West Virginia, and Delaware, and two dual-plate states, Virginia and the District of Columbia. This geographic location makes for some challenges for enforcement and security concerns. Maryland is a small state with many challenges including the proximity of the state to the District of Columbia (critical homeland security issues), areas of high crime rates, and a diverse set of vehicles that utilize their roadways. There is a great deal of interstate traffic between Maryland, Virginia, and the District of Columbia so the state depends on both front and rear plates to address these challenges.

The Maryland State Police (MSP) department currently operates 20 vehicles equipped with ALPR units, and will be adding more units to its fleet soon, with the goal of having at least one ALPR mobile unit per barrack/district. In addition, several fixed ALPR units are mounted to scan traffic lanes at selected high-traffic locations in the state. The state police use ALPR to assist in locating stolen vehicles, stolen license plates, Silver and Amber alerts, Gold alerts (adults who are vulnerable due to mental illness or other impairment), other missing people, and people wanted in connection with a crime. Several local jurisdictions in Maryland also use ALPR to look for suspended registrations, insurance violations, and outstanding traffic warrants.

The MSP's mobile (vehicle-mounted) units include two forward-facing cameras, one each on the right and left sides on top of the vehicle. The left-hand camera reads two lanes to the left of the police vehicle to read plates of oncoming traffic; the right-hand camera reads one lane to the right, to widen the camera's detection field and maximize the ability to identify parked vehicles on the right side of the road.

The state police mobile units, the fixed units, and any ALPR units being operated by municipal and county police jurisdictions in Maryland are all centrally networked. Mobile units can monitor fixed ALPR units in real time. Each unit downloads an updated list of plate numbers twice daily from the National Crime Information Center (NCIC) and the state Motor Vehicle Administration; in addition, emergency notifications (such as Amber, Silver, or Gold alerts) can be manually entered and pushed by the networking center to all ALPR units in real time rather than waiting for the next NCIC download.

Beyond the immediate alerts to officers in the ALPR-equipped vehicles, the collected license plate data has been of enormous benefit to criminal investigations. Suspects and witnesses to crimes can be found much more quickly, based on previous reads of their vehicles during routine patrols. Vehicles that may be connected with Homeland Security alerts can be tracked as they cross highways monitored by the fixed ALPR units. The ability to push emergency alerts out to all ALPR units is valuable as well; a vehicle associated with a recent Amber alert was tracked within 40 minutes of the alert being posted.

Lancaster, Pennsylvania: A Small Town with Many Tourists

Pennsylvania is a single plate state with a major turnpike running east to west. There are a number of cities in Pennsylvania, but there are also a considerable number of rural roadways in the state. The South Central town of Lancaster has approximately 60,000 people with several major tourist destinations in the immediate area so there is a great deal of traffic created beyond the local community. Although the enforcement resources in Pennsylvania have adapted to only having one license plate for the majority of the vehicles they encounter, it is still a challenge to identify oncoming traffic and many of the vehicles parked in the local area.

The local police department has two vehicles that are equipped with ALPR cameras: one unmarked car that is used by Community Service Aids who patrol for parking-violation scofflaws, and one car that is used by the auto theft unit (regular patrol car as seen on the right).



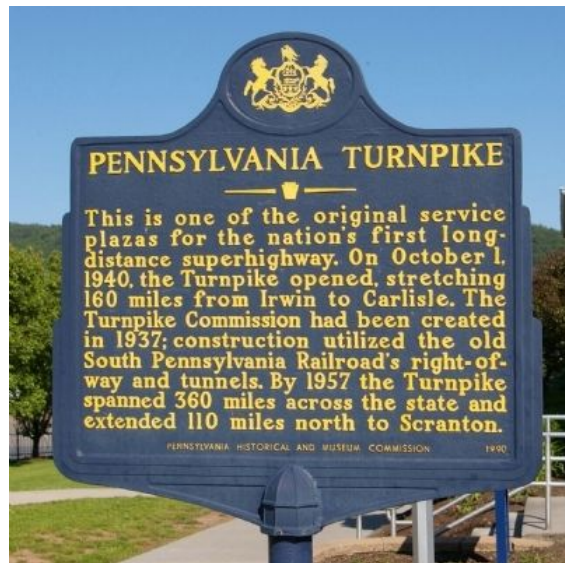
Each of the two ALPR-equipped cars has two cameras mounted on the left and right; the cameras lock into place at a 45-degree angle forward or a 45-degree angle backward, but can also be positioned, unlocked, to a 90-degree angle to more easily read plates in a parking lot. The two cameras have slightly different fields of view – the left (driver) side camera has a narrower field but a longer range that is useful for scanning the farther-away left side of a road, and the right (passenger) side camera has a wider field but a shorter range. The cameras are also fairly effective at scanning multiple lanes of traffic.

Each day an updated list of license plate numbers associated with stolen cars and parking violation scofflaws is received from the Commonwealth Law Enforcement Assistance Network (CLEAN) and uploaded to the ALPR system. Between January 1, 2012 and late April 2012, over 300,000 plates were read by the two ALPR-equipped vehicles; the Lancaster Bureau of Police has a total of 1.3 million images stored (those read since October 2011).

It is difficult to pinpoint differences in the number of vehicle thefts before and after the introduction of the ALPR systems in Lancaster; this is in part due to other crime-prevention cameras implemented throughout the city in recent years by the Lancaster Community Safety Coalition. These combined efforts have greatly decreased the overall crime rates in the city. However, the theft of license plates has decreased sharply since the ALPR systems began operation. The ALPR system used for parking enforcement paid for itself in three months because of increased collection of outstanding parking fines.

Pennsylvania Turnpike Commission: How Front Plates Could Assist in Tracking Violations

The Pennsylvania Turnpike uses ALPR systems for revenue collection and to track tolling violations. Vehicles that have traveled the Turnpike without paying the toll are tracked and their owners contacted for payment, though the Turnpike currently has no real authority to enforce payment. The Turnpike's ALPR cameras are positioned so that pictures can be taken of the front and rear of a violating vehicle (approximately vehicle width) from a distance of 17 feet. Typically, when a vehicle crosses detection points on the Turnpike without an EZ Pass transponder, or without paying a toll at one of the tollbooths, the cameras are triggered. Several images are taken of a single plate so that the system has multiple opportunities to scan and interpret the plate's number; the system usually captures at least two pictures of the vehicle's front (for trucks) and four to five pictures of the rear plate, and may take 16 or more images of a given plate.



For passenger vehicles, the Turnpike Commission tries to obtain a readable picture of the rear plate (to avoid including the driver in the photograph); for trucks the practice is to obtain a readable picture of the front of the vehicle, since the plate of concern is on the tractor rather than the trailer. The clearest picture is then selected to copy and include with the violation notice that is sent to the vehicle owner.

Even with the multiple images, it is not always possible to see or read a given vehicle's plate. The position of the plate, especially on trucks, may be out of the camera's capture window (often due to deliberate placement by truck drivers to circumvent toll collections), and the plate itself may be difficult to read because its surface condition or because the image is too dark, particularly at night.

The ALPR system confidence level is configured at 85%. In all, an average of 16% of plates captured by the cameras as potential violations are voided during the identification process, and another 3% are voided during the appeals process. This level of accuracy is achieved using both plates when available.

International and Multi-State Influence: El Paso and Horizon City Police

The second most populous state, Texas requires two license plates. The state is home to five of the twenty largest cities in the United States and also has the longest international border of any state. One of the areas the project wanted to focus on was the El Paso region which is unique based on its significant international, military, and bi-city relationship with Las Cruces, New Mexico. Texas is a major transportation hub with several sections of interstate roadways connecting the east and west coasts as well as I-35 which runs north and south directly through the center of the country connecting from Canada to Mexico.

The El Paso Police Department has used ALPR since 2006, and currently operates 23 mobile units with ALPR. Besides the mobile units, the El Paso Police also own six ALPR-equipped trailers that can be parked alongside a roadway. The trailers include a radar system and “your speed is” display that faces approaching traffic, while the ALPR camera is positioned on the opposite side to read rear license plates as vehicles pass it. While the license plate reads from the trailer-mounted cameras do not provide instant feedback to patrol officers as do the vehicle-mounted ALPRs, they provide additional data to the department’s analysts.

Nearby Horizon City has one ALPR-equipped patrol car in its 20-vehicle police fleet. Information from NCIC and the Texas Crime Information Center (TCIC) are downloaded daily, and can also be refreshed wirelessly on demand while the vehicle is patrolling. License plate reads from Horizon City are uploaded to the El Paso Police database for storage and analysis.

The ALPR technology used by both of these agencies is equipped with one camera per unit; the camera can be mounted anywhere and facing any direction, but the most common orientation for a vehicle-mounted camera is to the forward right of the patrol vehicle, for reading plates on parked cars. The orientation of Horizon City’s ALPR unit can only be changed manually from outside the car; the units in El Paso can be panned and tilted electronically from inside the vehicle. Future ALPR systems for the El Paso Police department are going to include two cameras per unit to be able to read forward and backward simultaneously.

Both departments use ALPR to track stolen vehicles, vehicles associated with other crimes, and vehicles belonging to sex offenders. The units can also help track uninsured vehicles or vehicles with expired registrations.

Phoenix Metro Area, Arizona: Local Police Agencies and the Impact of Vehicle Identification

Arizona is a single plate state with two major metropolitan areas, Phoenix and Tucson. Like Texas, Arizona has a significant international presence based on its border with Mexico. It is also bordered by New Mexico, California, Nevada, Utah, and shares its northeast corner with Colorado. The state has several international crossings as well as major interstate thoroughfares running east and west.

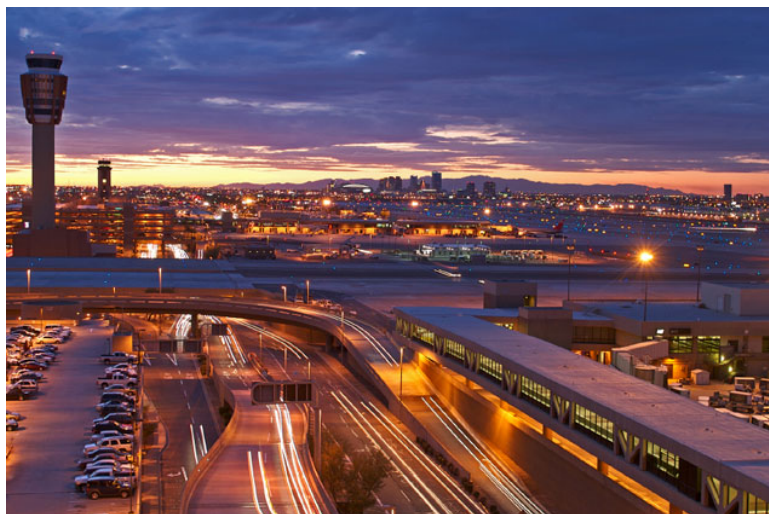
The Phoenix Police Department has been using ALPR since 2004 and currently has a total of four ALPR units; one is assigned to the Auto Theft unit, one to parking enforcement, and two to general patrol. The Phoenix ALPR units each include three vehicle-mounted cameras, two facing forward to the left and right, and a third facing to the right of the patrol vehicle for reading plates in a parking lot. The two forward-facing cameras can read up to two lanes on either side of the patrol vehicle (three lanes are possible, but accuracy diminishes). The side-facing camera scans approximately six to nine feet, or a little less than one lane width, to the right of the patrol vehicle.

Glendale's department originally acquired ALPR units in 2006, specifically to track stolen vehicles; the department is now using its second generation of four ALPR units, and their use has expanded to general patrol activities as well as continuing to track stolen vehicles and stolen license plates. Glendale's mobile units each have two forward-facing and two backward-facing cameras. The cameras can be placed in different configurations, but are usually set up to read plates on parked vehicles to the side of the patrol vehicle.

In both cities, anywhere between a few dozen and a few thousand plates may be read by an ALPR unit on a given day, depending on the vehicle's patrol pattern. In April 2012, the four ALPR-equipped vehicles in Phoenix read a total of 62,833 license plates, averaging 523 plates read per unit per day. The Phoenix PD currently has about two million plates in its database; Glendale purged its old data in 2010 after getting new software for its ALPR system which could not read the previously collected data, and currently has approximately 280,000 plates in its database.

Phoenix Sky Harbor Airport: Reading License Plates Translates to Revenue

Parking revenues are the second-highest revenue source for Sky Harbor, following only airline revenues. Before the economic downturn in 2008, Sky Harbor reached \$80 million per year in parking revenues, and revenues are beginning to climb back toward that level again as of 2012. Each of the 65 entry and exit lanes for airport parking at Sky Harbor are monitored with an ALPR camera, positioned to photograph the vehicle's rear plate. The objective is to provide a visual record of every vehicle entering and leaving the parking facilities in order to prevent fraud and ensure that correct parking revenues are collected from each customer.



On average, 10,000 parking transactions per year (at an average value of \$30 per transaction) rely on the ALPR reads to determine accurate charges; most of these are due to lost tickets, and

with the record provided by the ALPR read of a given vehicle upon entry, the correct charge can be determined. Less commonly, attempted fraud, falsely lost tickets and swapped tickets, can be detected and prevented. Also because of the ALPR system, the number of vehicles stolen from Sky Harbor parking facilities has decreased significantly in recent years.

The system accuracy on plates that are read is 85% (rear plates only in the current configuration). Typically, 10-15% of license plates entering or exiting the facilities cannot be read by the system, most often because of sun glare. To remedy the problem, canopies are placed over the reader location to minimize early-morning and late-afternoon glare off of rear plates as vehicles enter the facility. Currently, because so few vehicles entering the parking facility display a front license plate, it is not cost-effective to add a second camera to each entrance/exit lane.

To back up the information provided by the entry/exit ALPR reads, a manual license plate inventory (LPI) is conducted of one of the airport's four parking facilities each week. On an average night 14,000 vehicles are parked in the airport's four parking facilities. In a typical LPI, approximately 200 plates can be inventoried per man-hour. Depending on the size and vehicle occupancy of the facility being inventoried, an LPI can take between two and 15 man-hours. Typically, one out of every eight vehicles (12.5%) is parked tail-in, generally requiring the person conducting the LPI to walk around to the rear of the vehicle to read the rear plate because most vehicles in the area do not have a front plate. Because of the significant percentage of vehicles without visible plates due to tail-in parking, the parking facility staff cannot perform their audit using the mobile ALPR unit to double-check inventories.

VEHICLE IDENTIFICATION: ESTIMATING THE EFFECTS OF FRONT PLATES

As can be seen in the case studies, agencies will adjust their vehicle identification procedures and their use of ALPR (where applicable) to accommodate existing conditions as much as possible. In states where a majority of vehicles do not have front plates, ALPR systems are more likely to be set up to capture rear plates. Furthermore, the law enforcement agencies interviewed in both one- and one plate states do not tend to track the number of front plates versus rear plates that are captured during patrols. For these reasons, the exact benefit of front plates in improving vehicle identification is difficult to calculate. However, two vehicle identification scenarios that are common to most of the interviewed agencies were simulated by the research team's counts of license plates on parked and moving vehicles in each of the four case study states.

Identifying Parked Vehicles

The first scenario is the identification of vehicles that are parked perpendicular to a driving lane in a parking lot. Because some percentage of vehicles are likely to be parked tail-in, the presence or absence of front plates will help to determine the percentage of vehicles that can be identified using a mobile ALPR unit. For the parking lot vehicle counts in this study, the research team counted the total number of vehicles as well as the total number of license plates that faced the driving lanes between the rows of parking spaces (rear or front plates,

depending on whether each vehicle was parked tail-out or tail-in), simulating the ALPR camera configurations and ranges used by most of the law enforcement agencies to read plates on parked cars.

Based on the parking lot plate counts (See Table 6), ALPR-assisted patrols of the parking lots sampled in Maryland and Texas would have the opportunity to read license plates on 97% of the vehicles parked there. In contrast, similar patrols of the sampled lots in Pennsylvania and Arizona would be able to capture the plates of (on average) only 76 % of the parked vehicles.

Table 6. Parked Vehicle Counts. (Mixed front and rear plates)

State	City/Location	Date/Time	Total Vehicles	Vehicles with Visible Plates	% with Visible Plates
MD	Jessup	Wednesday, 4/11/12, 10:34 a.m.	211	205	97%
MD	Hanover Lot #1	Wednesday, 4/11/12, 2:43 p.m.	198	196	99%
MD	Hanover Lot #2	Wednesday, 4/11/12, 2:53 p.m.	1855	1794	96%
TX	El Paso	Tuesday, 4/24/12, 4:15 – 4:40 p.m.	1129	1049	93%
TX	College Station Lot #1	Saturday, 6/23/12, 12:15 p.m.	167	165	99%
TX	College Station Lot #2	Saturday, 6/23/12, 12:40 p.m.	271	268	99%
TX	College Station Lot #3	Saturday, 6/23/12, 1:15 p.m.	261	258	99%
TX	College Station Lot #4	Saturday, 6/23/12, 1:45 p.m.	1298	1276	98%
Total for Maryland and Texas (2-plate states)			5390	5210	97%
PA	Lancaster Lot #1	Thursday, 4/12/12, 11:30 a.m.-12:15 p.m.	332	259	78%
PA	Lancaster Lot #2	Thursday, 4/12/12, 1:30 p.m.-2:30 p.m.	1812	1288	71%
AZ	Tempe	Tuesday, 5/22/12, 1:25-2:30 p.m.	1607	1317	82%
Total for Pennsylvania and Arizona (1-plate states)			3751	2864	76%

When law enforcement or parking personnel assess a parking lot for stolen vehicles, parking violations, etc., they can either use staff resources to personally conduct the audit or ALPR technology. Regardless of the methods, the license plate must be visible in order to be read. It

is evident that the use of front plates increases the opportunity for these individuals to perform their work tasks and, in some cases, increase their revenue.

Identifying Moving Vehicles

The second scenario is identification of vehicles that are in motion— on a roadway, crossing through a toll plaza, crossing over a border, or entering or leaving a parking facility. ALPR cameras may be mounted on patrol vehicles, to portable trailers, or to stationary structures.

The moving-vehicle license plate counts conducted by the research team were of oncoming traffic, comparing the total number of vehicles to the number of front license plates (with the assumption that virtually all vehicles in all four states would be equipped with rear plates). As can be seen in Table 7, the highest percentages of vehicles with front plates were seen on roadways that began and ended within the one plate states of Maryland and Texas. This high percentage of front plates is seen even at the border crossing bridge between Texas and Mexico. The highways spanning the one plate state of Maryland and the one plate state of Pennsylvania, not surprisingly, carried a mixture of vehicles from both states, as well as several other neighboring states. This mixture resulted in varying percentages of vehicles with front plates (39% up to 66%), with an average of 58% of observed vehicles across the three highways displaying a front plate. Researchers observed that these percentages tended to shift up and down on these highways depending on the location relative to the Maryland-Pennsylvania state line. The roadways that were contained within Pennsylvania and Arizona carried the lowest percentage of vehicles with front plates, averaging 22%.

Among the agencies interviewed for the case studies, the overall accuracy of the ALPR systems (i.e., the percentage of accurate reads of plates that are captured by the cameras) ranges from 85 to 92 percent. The law enforcement agencies that were interviewed in the case study states do not generally track the numbers of vehicles that are photographed from the rear versus the front or the percentage of vehicles that are not captured at all by ALPR systems due to a lack of a front plate.

Phoenix Sky Harbor Airport is, however, able to compare the total number of vehicles that enter its four parking facilities to the number of plates that are successfully read. The ALPR cameras at each entrance are set up to capture rear plates only, and approximately 10 to 15 percent of those plates are not captured by the cameras. Since the ALPR system achieves approximately 85% accuracy on plates that are captured, this missing percentage of captured plates lowers the actual accuracy of the plate reads to between 72 and 77 percent. The vast majority of these unread plates are due to the limitations of the single camera arrangement dictated by the absence of front plates on most local vehicles. If all vehicles entering Sky Harbor's facility had front plates as well as rear plates, a second camera placed to capture front plates would help to achieve nearly 100% capture and thus raise the overall accuracy of the system to the desired level.

Even if a majority of vehicles entering Sky Harbor's parking facilities had a front plate (such as the 85 to 94 percent of vehicles observed on roadways in Texas and Maryland), the added reads from a two-camera configuration could significantly improve the capture rate for vehicle

identification. It is likely that the ability to capture both front and back plates would similarly improve the capture rate in other moving-vehicle environments such as law enforcement patrols.

Table 7. Moving Vehicle Counts. (Front plates only)

State	City/Roadway	Date/Time	Total Vehicles	Front Plates	% with Front Plates
MD	City of Elkridge, W. Nursery Rd @ Winterson Rd	Monday, 4/9/12, 9:50-10:55 a.m.	652	578	89%
MD	I-97, Baltimore to Annapolis to Baltimore	Monday, 4/9/12, 9:30-11:00 a.m.	2,123	1,822	85%
TX	Horizon City, Horizon Road	Monday, 4/23/12, 9:57 – 10:15 a.m.	250	229	92%
TX	El Paso, San Paulo St.	Monday, 4/23/12, 2:20-2:50 p.m.	718	634	88%
TX	El Paso, Stanton St. International Bridge	Tuesday, 4/24/12, 11:50 a.m. -12:20 p.m.	180	161	89%
TX	College Station, Texas Ave.	Saturday, 6/23/12, 6:30-7:30 p.m.	1009	952	94%
Total for Texas and Maryland (2 plates)			4932	4376	89%
MD/ PA	Highway 97, Gettysburg to Baltimore	Monday, 4/9/12, 6:07-6:29 p.m.	615	407	66%
MD/ PA	I-83, Baltimore, MD to York, PA	Tuesday, 4/10/12, 11:25-11:45 a.m.	241	127	53%
MD/ PA	Highway 272, Lancaster to Baltimore	Tuesday, 4/10/12, 5:08-6:10 p.m.	220	86	39%
Total for Roads Spanning Maryland and Pennsylvania			1076	620	58%
PA	I-30, York to Lancaster	Tuesday, 4/10/12, 11:55-12:10	584	188	32%
AZ	I-10 Phoenix to Tucson	Monday, 5/21/12, 9:30- 10:30 a.m.	2285	662	29%
AZ	Phoenix, 7 th Ave @ Washington St.	Tuesday, 5/22/12, 8:30-8:50 a.m.	683	22	3%
AZ	Glendale, 57 th Ave @Glendale Rd.	Tuesday, 5/22/12, 10:30 – 11:00 a.m.	488	18	4%
Total for Pennsylvania and Arizona (1 plate)			4040	890	22%

Law enforcement, tolling and homeland security applications process data from moving vehicles. Based on the data from the field studies it is evident that the lack of a front plate has an adverse affect on the ability to identify vehicles that are moving.

STATE LICENSE PLATE POLICIES – RESULTS OF DMV INTERVIEWS

Departments of Motor Vehicles (DMVs) in each state were contacted by telephone and/or e-mail. Responses were obtained from 33 states – 21 states that mandate two license plates per vehicle and 12 states that mandate only a rear plate. Table 8 lists the states represented by the interview responses.

Table 8. States Requiring One vs. Two Plates.

States Requiring Two Plates	State Requiring Rear Plate Only
Alaska California Colorado Hawaii Idaho Maine Maryland Minnesota Missouri Nebraska New Hampshire Nevada* Oregon South Dakota Texas Utah Vermont Virginia Washington Wisconsin Wyoming	Alabama Arkansas Delaware Georgia Indiana Kansas Louisiana New Mexico North Carolina Oklahoma Pennsylvania Tennessee

Note: The () indicates that although two plates are issued in Nevada, vehicles without a designated space for a front plate do not have to display the front plate.*

Reasons for License Plate Policies (One plate and One plate)

Of the DMV respondents from the 21 states that currently require two plates, 16 (76%) indicated that a primary reason for the establishment and/or retention of the one plate requirement was greater ease of vehicle identification by law enforcement. In 2006-2007, Utah considered changing from a two plates to a one plate, but this change was not approved by the legislature. Of the 12 DMV respondents from one plate states, five attributed the policy to cost considerations. In New Mexico, the difficulty of enforcing two plates per car (at one point labeling plates with front and rear to prevent vehicle owners from splitting one set of plates between two cars) also factored into the decision to begin requiring only one plate.

License Plate and Vehicle Registration Costs

Stated production costs per plate ranged from \$0.50 to \$5.65. These costs are passed on the vehicle owner, usually as part of the vehicle registration fees. Registration fees and the basis for them varied widely from state to state, from a low of \$21.05 in Indiana to a high of \$202 in California. Several states charge a base registration fee, with additional fees levied by individual counties.

States considering a change in license plate requirements

Of the 21 respondents from states currently requiring two plates, only Maine indicated that legislative proposals are currently under consideration to change the requirement to one plate. Another ten of the responding one plate states have had similar legislation introduced in past years. The objective of the proposed legislation in all of these cases is to reduce production costs to the state. In most of these states, the cost issue has been overridden by the needs and preferences of law enforcement. Two states, Nevada and Wyoming, have passed or are considering a different modification to the one plate requirement for vehicle models that do not have a designated space for a front plate. Nevada still issues two plates to every vehicle owner, but exempts owners of these types of vehicles from displaying the front plate. Wyoming is considering legislation which would allow owners of qualifying vehicle models to apply for a similar exemption, replacing the front plate with a front windshield sticker.

Of the 12 respondents from one plate states, only one has recently had a bill introduced to require two plates. A bill was introduced in North Carolina's state legislature in the 2006-2007 session but was unsuccessful. Law enforcement in New Mexico has requested that similar legislation be introduced in that state's legislative sessions, but no such bill has ever made it to the floor for a vote.

CONCLUSIONS

Based on the literature and the project field studies, the identification of a vehicle is a critical need for law enforcement as well as tolling authorities, parking applications, and homeland security. The manual identification process is dependent on the license plate, but the individual, especially law enforcement officers, must use other means to reduce the pool of potential vehicles. This is accomplished by using the color, make, and/or model to reduce the number of cars that will have to be assessed before identifying a particular license plate. It helps to have two license plates in the manual process; it is not the primary means of identification. With the advent of the ALPR technology, the license plate becomes a primary and highly efficient means of vehicle identification. ALPR eliminates some of the manual steps involved with identifying and verifying vehicles that may be involved with traffic and tolling violations, Amber or other similar alerts, homeland security concerns and/or stolen vehicles. By utilizing front and rear plates, the opportunity for correct identification increases. This is the reasoning that law enforcement uses to support issuance of two plates versus one.

A large part of policy making depends on its fiscal aspects. This study examined multiple applications: enforcement, tolling, and parking related to the location of the license plates on

vehicles. In order to understand the financial impact that license plates have on enforcement, the research team developed a scenario to illustrate how the use of front plates can help to support the implementations of the ALPR. If a state requires front plates and law enforcement can utilize ALPR technology, the officers can observe more vehicles than they can without the cameras.

In Chicago, over 25K vehicles stolen every year and an average of thirty are recovered each month [18]. The ALPR technology can read up to 10,000 license plates during an eight hour shift compared to an officer being able to run between 10-40 vehicle plates after designating a vehicle as suspicious.

Table 9. Chicago: Recovery of Stolen Vehicles with and without ALPR Technology.

Details	Recovery of Stolen Vehicles/Year	
	Without ALRP	With ALPR
Labor costs/year	\$ 40,000	\$ 40,000
Cost of ALPR equipment/car 3 camera unit	\$	\$ 16,550
# of plates read/year	10-40 plates/8 hr shift	10,400
	10,000 plates/8 hr shift	2,600,000
# of stolen cars/year	25,000	25,000
# of stolen cars recovered 30 vehicles/month	360	90,000
% of stolen cars recovered	1.44%	

The data included in the table above is based on information available from ALPR vendors and jurisdictions. There are approximately 25,000 vehicles stolen in Chicago (Illinois is a two-plate state) each year with an average of 30 recovered each month. It is estimated that an individual officer can read and identify 10-40 during an 8 hour shift while a patrol car equipped with ALPR technology can identify approximately 10,000 vehicle plates during that same shift. If we assume that these estimates are reasonable, then ALPR technology can increase the number of plate reads exponentially annually which will give officers the potential to identify and recover significantly more stolen vehicles. This scenario is not intended to promote the use of ALPR technology, although it does assist in identification in a number of different applications, but rather illustrate that front license plates provide more opportunities to identify vehicles. These opportunities are not limited to enforcement, but also include tolling and parking revenue.

Half of the fifty states have at least one mile of toll road. Those states are evenly split between those that require one or two plates [6]. Of those states with at least 100 miles of toll roads, the one plate states represent 55% of the total toll miles. As fiscal pressures mount, automating the tolling process with ALPR technology will soon become the only efficient method of collecting tolls and identifying violators. The toll collection focuses on a transponder interaction between the facility and the vehicle. In contrast, the identification of violators and the pursuit of lost revenue depend on the ability to capture the license plate information. Based on the literature,

interviews and field studies, it can be concluded that two plates offer significant fiscal and process benefits to enforcement and tolling in terms of revenue. These benefits outweigh the cost associated with issuing additional license plates due to assuming the cost of plates is passed on to the owner of the vehicle. One of the concerns related to the use of front plates is the placement of vehicles that are not manufactured with a place to attach a front plate. Individual states could deal with this issue based on the vehicle type.

The number of miles of toll roads has increased across the United States on interstate and non-interstate highways. General toll roads and high-occupancy tolling facilities are becoming popular means of improving mobility and helping to pay for construction of new roads or upgrading of existing roadways (See Figure 1) [6]. With the advent of this approach to transportation infrastructure, it seems that states should reconsider their plate policies in order to ensure the efficiencies of the improvements of our highway infrastructure.

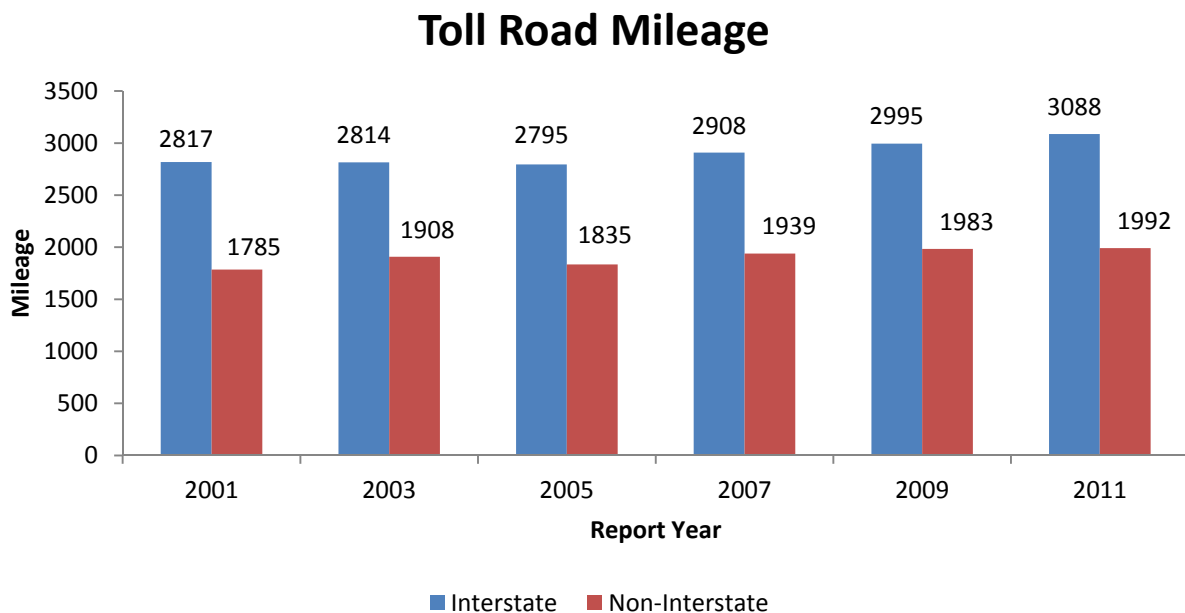


Figure 1. Toll Road Miles in the United States [6].

In addition to the ramifications of one versus two plates in regards to toll roads, efficiency related to homeland security should also be considered. In a two week period, the border patrol assessed the read rates on the northern border between the United States and Canada. In this application the read rates, using ALPR, across seventeen lanes were between 86.9% and 94.3%. The lanes where only the rear plates were read had a range of 86.9%-90.8% while the lanes where both plates were read resulted in a range of 90.8%-94.7%. Clearly the use of the front and rear APLR cameras, made a significant difference in the read rate. Considering how many cars are processed through the border, it is important for this process to be as efficient as possible.

The criticality of front plates in the tolling process was echoed by Dave Kristick who is the Director of Operations for E-470 Public Highway Authority in Colorado. In an interview as part of this study, he indicated:

“Colorado is a two plate state and it makes a huge difference. The two plate environment is crucial for public safety and revenue purposes. You cannot accomplish mileage based funding without a two plate vehicle since you must be able to identify the vehicle when other vehicle identification technologies fail. Cashless, all electronic toll systems rely completely on ALPR systems- at that point; you can’t just say it is about deterrence anymore, it is about how you will best assure your toll revenue [4].”

Initially the premise of this project focused on vehicle identification in general as it relates to one versus two license plates. As the research team progressed through the literature review and field work, the augmentation of the ALPR technology became a central consideration. The team understands that not all states have tolling to consider and many parking facilities still rely exclusively on people to manage the business aspects. Most law enforcement resources (officers and vehicles) are not equipped with ALPR technology. That being said, as budgets (private and public) are reduced and/or come under increased scrutiny, all of these applications will have to consider alternate means of enforcing traffic, pursuing violations, maintaining homeland security, addressing stolen vehicles, and using automation as a means of deterrence to preserve safety and ensure fiscal responsibility. Using two license plates seems to be a small issue when you examine it in a vacuum, but in reality the specific identification of a vehicle is a critical part of how the United States will address their transportation infrastructure in the near future through enforcement and tolling applications.

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