

**Document Title: Evaluability Assessment of
License Plate Reader Technology**

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Evaluability Assessment of License Plate Reader Technology

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NIJ Guidance

The National Institute of Justice (NIJ) has identified some key outcome variables and other parameters of interest for this technology, and has provided some guidance on possible evaluation designs. Applicants may depart from this guidance by providing appropriate rationale.

Technology Summary: LPR (license plate reader or license plate recognition) software is now available that can automate detection of license plates associated with stolen vehicles and other crimes. A mobile camera system mounted on police patrol vehicles recognizes plates in real time, compares them against a database of suspect vehicles, and alerts the officer to any matches.

Scope of Evaluation: The evaluation would entail a randomized assignment of days during which LPR-enhanced and traditional police cars patrol in areas prone to vehicle theft.

Summary of Evaluability Assessment Activity: Documents and evaluations of license plate reader technology were collected from case studies in both Europe and the United States. In addition, experts from NIJ and Appian Technologies were interviewed as well as local law enforcement in the following districts currently using the technology: Pinellas County, Florida; Seattle, Washington; Anne Arundel County, Maryland; Lancaster, Pennsylvania; Mesa, Arizona; and Sacramento, California. A site visit was conducted in Sacramento, California, with members of their vehicle theft unit.

Finding: *License plate reader technology is well suited to a randomized experiment. Benefits in terms of recovery rate, time to recovery, and possibly arrest rate could be measured quantitatively.*

1. Initial Screening

Background

Within the past several years, license plate recognition systems have been piloted extensively throughout Great Britain and, to a lesser extent, in other countries throughout Europe. The promising results of these pilots have led U.S. law enforcement precincts and State highway patrols to consider the possible benefits of LPR technology within the United States. Using license plate recognition technology for other applications is widespread—in many developed countries, including the U.S., for example, plate readers are frequently used to help monitor electronic toll collection networks. Plate readers have also been used as an intelligence-gathering tool and in surveillance operations (Author unknown, date unknown).¹ The pilot studies in Great Britain, however, opened up the possibility of using plate-reader technology as a law enforcement tool with the potential of proactively addressing criminality—especially vehicular crime, including auto-theft (PA Consulting Group, 2004).

License plate recognition technology that is capable of “reading” plate numbers uses a complicated system of algorithms, cameras, databases, and police intelligence to be successful. Foremost, plate recognition technology requires the use of infrared cameras with optical character recognition software. These cameras can be attached to police cars or other mobile units (along highways or other frequently passed roads); or used as hand-held units that police officers can take to a variety of locations throughout a jurisdiction; or placed in fixed locations (along overpasses, for example) connected to closed-circuit televisions (CCTVs) (Ohio State Highway Patrol, 2005; PA Consulting Group, 2004; Civica Platescan, date unknown). Cameras equipped with plate recognition software are capable of recording the license plate numbers of vehicles driving at high speeds. Reports on the uppermost vehicle speeds possible at which plate scanning software can still record accurate results have varied from 65 mph to as fast as 100 mph (Ohio State Highway Patrol, 2005; PA Consulting Group, 2004). The accuracy of plate readers at various speeds is contingent on a variety of factors, including camera quality, weather conditions, and the existence of common obstructions (like dirt and general plate wear-and-tear) that can obstruct the camera’s view.

To read plate numbers accurately, infrared cameras use software with a number of algorithms to identify license plate characters. These algorithms include: Plate Localization (or Image Acquisition), in which a camera identifies a license plate; Plate Extraction and Normalization, in which a camera detects the dimensions of a plate, by compensating for any skewing, adjusting for brightness and contrast, and filtering out any unwanted objects; Character Segmentation, in which a license plate sequence is segmented into individual characters; and Character Recognition, in which the segmented characters are matched to a template of letters and numbers (Kwasnicka and Wawrzyniak, 2002; Parker and Federl, 1996; Valliappan, Sumari, and Kamarulhaili, 2004; Wikipedia, 2006). Typically the software is geared to read plates of a specific State, and even within a State, the software may have limitations when reading atypical plates such as vanity plates. Once a license plate’s characters are identified, the

¹ Closed-circuit television cameras (CCTVs)—a precursor to license plate readers—are common in the U.S. and are used by law enforcement as a surveillance tool that helps provide security within a variety of public venues.

information can be sent to relevant databases within a particular jurisdiction to perform background checks on the vehicle. When a vehicle's license plate is flagged, a patrol officer on site can pursue appropriate action, which usually includes stopping the vehicle's driver for questioning, or requesting assistance with the recovery of a stolen but unoccupied vehicle.

What is the background/history of this technology?

Maturity (i.e., Lab prototype? Field rollout? Multiple generations/manufacturers?)

License plate reader technology has been used in Europe since the 1990s, but its use in the United States is significantly more recent. Several departments told us that they had implemented the technology only within the last year, often with only one vehicle in use. The exceptions are departments such as Sacramento Police Department, which has been testing and using the technology for nearly 3 years, and the Los Angeles Police Department, which has 36 vehicles equipped with license plate reader technology. Because police departments often have unique software systems, significant postproduct development has been necessary to incorporate LPR in an easily usable interface into a typical patrol vehicle.

Furthermore, the *application* of the technology could be improved by better use of extant computerized data. For example, the technology is used to enforce motor vehicle laws, including the use of LPR to identify and boot cars with outstanding warrants. However, that process does not communicate data about stolen cars to police. As another example, the LPR is not yet linked with the State's list of stolen vehicles, so that the list must be downloaded into the system once per day rather than being downloaded as stolen vehicle reports are received. These are not limitations of LPR technology; they are current limitations to information flows in Sacramento. LPR remains an emergent technology for law enforcement purposes.

Time in the field?

Although license plate recognition technology has been available to law enforcement since the 1990s, only within the past 5 years have police agencies begun to use such technology as a tool of crime reduction and prevention. A number of jurisdictions in the United States (including those in Ohio, Florida, Washington, D.C., and California, among others) have implemented pilot tests of their own in the past couple of years.

Prevalence in the field? (Is site a first/early adopter?)

The precise number of municipalities in the United States that use license plate recognition technology as a tool of criminal law enforcement is not known. There is reason to believe, however, that the number is relatively small. LPR systems are expensive and only departments that have high auto crime rates have been receptive to the growing number of LPR vendors in the United States. Much of the literature on license plate recognition technology was published within the past 2 years, and most of it references pilot tests in the United Kingdom that were conducted within the past 5 years.

What do we already know about technologies like these?

The evaluations of license plate readers in the United Kingdom yielded several positive results. During the United Kingdom's 6-month pilot, police officers used plate reader technology to recover £2.75 million of stolen vehicles and goods, and seize more than £100,000 of drugs.² In addition to the vehicles recovered during the pilot, eight vehicles were recorded as stolen by plate readers, but were not recovered because police officers were interrogating other drivers at the time of detection (PA Consulting Group, 2004). Teams of patrol officers who used plate readers also achieved an arrest rate that was 10 times the national average, although according to the pilot's evaluators, "it will be essential to know the outcome of arrests made by intercept teams relative to conventional policing"—for example, the number of arrests made during the pilot that go to court and the number of defendants who are convicted compared to the national average (PA Consulting Group, 2004).

Within the United States, the success of license plate recognition technology has been, at times, less apparent. While preliminary pilots in the U.S. have resulted in some positive outcomes, these pilots have also revealed some of the contingencies that software developers must contend with in the U.S.³ Because the size and shape of license plate characters can vary from State to State, plate reader technology can frequently misread license plate numbers. In addition, plate readers frequently register false alarms by matching a license plate number to the plate of another State. According to the Office of Law Enforcement Technology Commercialization (2004), "currently available [plate recognition] systems do not distinguish between States. Therefore, if a system encounters a string of letters and numbers that are wanted in one State on another State's plate, the system will alert. Common vanity plates such as "HELLO" or "GOODBYE" are especially susceptible to this problem."⁴ Other inaccuracies may arise due to common obstructions to license plates, like trailer hitches, ice and snow, and vanity plate covers, which are still legal in a number of jurisdictions (McFadden, 2004).

What could an evaluation of this technology add to current knowledge?

An evaluation of the benefits of this technology could potentially show recovered property equal or greater in value to the cost of the system both in terms of materials and training. If benefits such as these can be proven, then precincts that show high auto theft rates would be more likely to invest in this technology to assist recovery and ongoing investigations.

Moreover, both the technology and law enforcement applications of the technology are emergent. The uses of LPR technology to identify stolen cars and drivers with

² Other recent studies conducted in Great Britain suggest a link between vehicle theft and other serious crime (see Chenery, Henshaw, and Pease, 1999, as cited in PA Consulting Group, 2004).

³ A preliminary field test of plate recognition software conducted by the Washington Area Vehicle Enforcement Unit recovered 8 cars, found 12 stolen plates, and made 3 arrests in a single shift (McFadden, 2004).

⁴ A study conducted by the Ohio State Highway Patrol (2004) concurred with the findings of the McFadden, noting, "standardizing license plates across states would greatly enhance the performance of automatic plate reader technology." In addition, OSHP mentioned, "easier state recognition on the plates would also improve the usefulness of LPR technology...."

outstanding warrants are apparent; so, too, is the use of LPR for enforcing motor vehicle violations. During our site visit to Sacramento, officials discussed the use of LPR technology to monitor the flow of cars at crimes scenes, and they noted the potential for using LPR technology to passively monitor the movement of vehicles associated with suspicious drivers including terrorist suspects.

Which audience(s) would benefit from this evaluation?

- Police precincts
- Highway authorities

What could they do with the findings?

If the evaluation shows real benefit to the departments and potential increases in revenue from tickets and violations or decreases in court costs, police departments could use this data to gain funding for purchases of LPR systems.

At what stage of adoption/implementation is the technology?

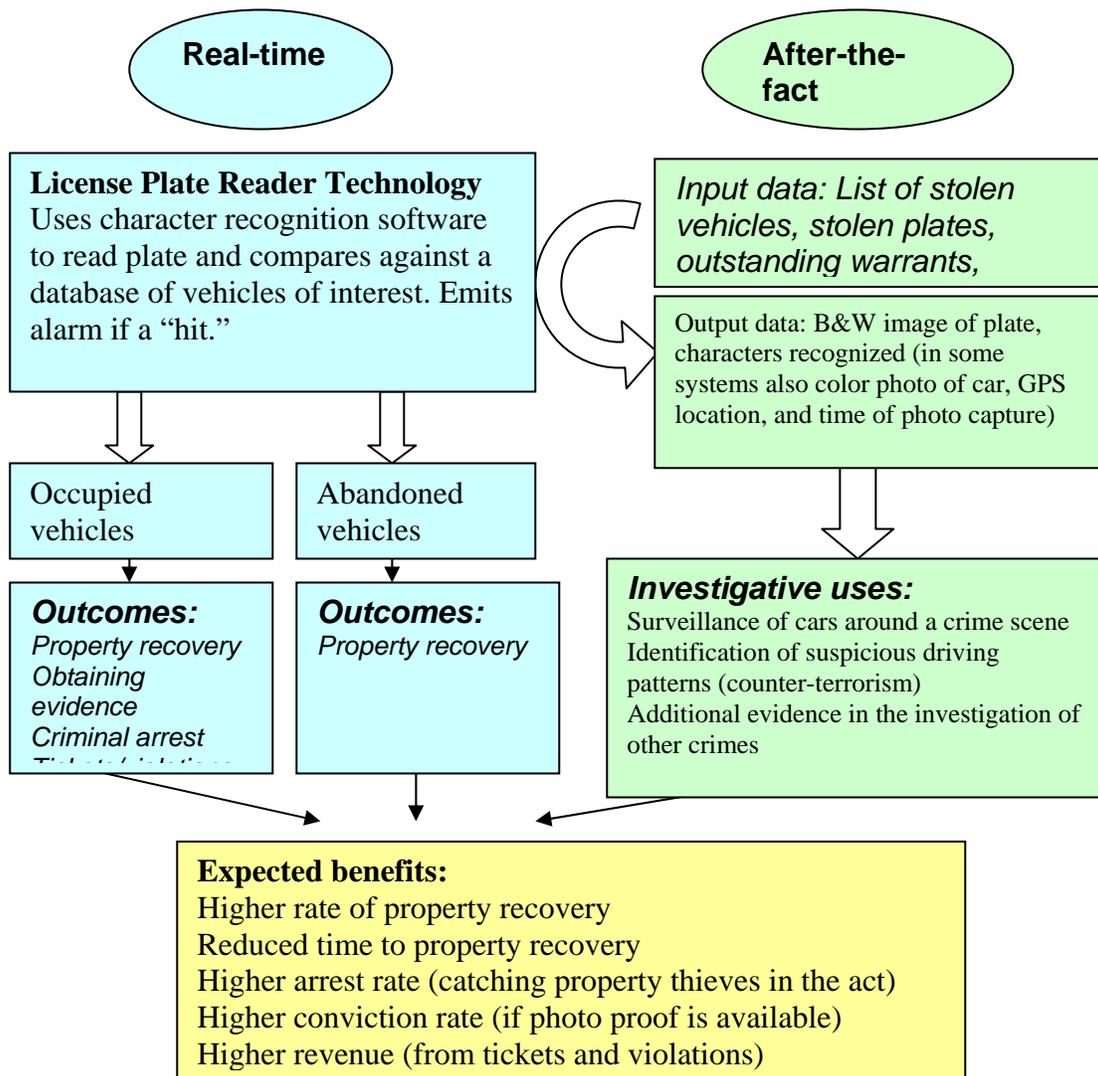
Sacramento Police Department was one of the first field testers of license plate technology and has been testing and using systems for nearly 3 years. However, they continue to work with vendors on improving the user interface and optimizing capabilities. Currently they have only one car and one surveillance van outfitted with license plate reading technology. Few individuals have been trained in its use and the vehicle is taken out approximately once a week. Because the technology is still changing rapidly, documentation has not yet been written for a standard protocol. When fully implemented, the Sacramento Police Department hopes to have several cars (up to six) collecting plate information on both shifts (total of 20 hours), 7 days a week.

What efficiencies or primary/secondary outcomes are expected?

Sketch the logic by which technology use should affect goals (see exhibit 1).

Is the technology well suited and appropriately specified given these goals?

Exhibit 1. LPR Technology Logic Model



Are there operational alternatives that could be used for comparison?

The operational alternatives to LPR are sending officers out to run plate information on a plate-by-plate basis for suspicious vehicles (clearly abandoned vehicles). Generally a police department is only aware of vehicles stolen in its area and may not recognize plates as stolen if the vehicle in question was stolen in another area of California.

Is the site interested in being evaluated?

The Sacramento Police Department would be happy to be part of an evaluation of this technology.

Is the site planning an evaluation?

No evaluation is yet planned.

Data Sources

What data systems exist that would facilitate evaluation?

There are two types of data that would facilitate evaluation: the data generated by the LPR system itself and the CrimeConnect database. (See the discussion below.) Additional information on outcomes can be gleaned from the Sacramento Police records management system (RMS).

What key data elements are contained in these systems?

The Platescan reader (the LPR system used in Sacramento) automatically records the number of plates read in each session and the number of positive hits. It does not distinguish between true and false positive hits, but license plates are routinely double-checked by the officer on duty and false positives will be noted. No outcome information is contained in Platescan, so for additional information on the number of recovered cars, the value of recovered cars, and the number of arrests, one would have to go through the Sacramento RMS system to trace each case.

In addition to the LPR reader, there is the database CrimeConnect containing all images of license plates, cars, and global positioning system (GPS) position and time of photo for each vehicle. (The system shows the reading made by the LPR, a picture of the plate, and a picture of the car.) This database is used for further investigation of cases. Usage of this system could be fairly simply tracked to

show how often the vehicle theft group uses the database for investigative purposes. At the time of our visit, usage was limited by staff availability.

Are there data to estimate unit costs of labor and capital?

The specific capital expenditure for each system is between \$20,000 and \$25,000. Beyond that there are costs for maintenance and support with the vendor as well as for a technology consultant to manage the equipment and address local user concerns. Training costs are unknown as the system is still very much in flux and no final training protocol has been developed. In general, costs for this system have not been separated from other costs to the department.

Are there data for possible comparison technologies or other solutions?

In the absence of an LPR system, stolen cars are likely to be recovered during traffic stops resulting from other enforcement activity and as a consequence of citizens reporting abandoned vehicles. Thus, the “other solution” is traditional enforcement. As we discuss later, the use of this technology to recover stolen cars could be evaluated using a random assignment design. The “treatment group” would be an area patrolled using LPR technology; the “control group” would be an area patrolled by traditional policing.

Going beyond automobile theft recovery to examine the role of LPR as a crime-solving tool, we are less certain about suitable comparison groups. An evaluator would have to investigate how LPR was used in crime investigation settings, the type of data that it generated, and how those data were used. An outcome analysis would probably be premature prior to understanding the process.

In general, how useful are the data systems to an impact evaluation?

The data automatically generated by the Platescan system will be very useful in an impact evaluation, but is not a complete picture. In order to do an impact evaluation, data on additional outcome measures will need to be generated through searches of cases in the RMS system. Furthermore, if the evaluation extended to investigating prosecution and conviction rates, an evaluator would have to match arrests with prosecutions and court data.

2. Site Visit Screening

The Intervention

Has the organization implemented a policy or training for the technology’s use?

The Sacramento Police Department has trained a few users within the department in the use of the LPR-enabled vehicle. A protocol for the real-time

capture of license plates calls for different responses depending on whether the vehicle is occupied or unoccupied and whether the police officer is available. The protocol follows these guidelines:

- ❑ *Alarm sounds*
- ❑ *Is officer occupied with another call?*
 - *If yes, he or she radios the information to another officer for confirmation and follow-up*
 - *If no, he or she confirms plate information*
- ❑ *Is vehicle occupied?*
 - *If yes, officer attempts to pull over vehicle*
 - *If recently occupied, officer may wait for return of driver*
 - *If abandoned, officer calls tow truck and completes paperwork*

Who are the users?

The vehicle theft unit currently manages the system, though the database can be accessed for investigative purposes in other crimes. Officers in the vehicle theft unit drive the test vehicle and surveillance van.

Who/what are the targets?

The license plate reader system used by Sacramento has been tailored to read standard California auto license plates. Three target databases are currently loaded into the system: stolen vehicles, stolen license plates, and a relatively small group of vehicles associated with other crimes. All of these represent only California vehicles. The system has the capability to use other databases including parking violations and unlicensed drivers, but these have not yet been implemented.

Who/what gets excluded as a user or target?

The technology currently recognizes about one in three or four plates as the unit is being driven past a series of cars. This does not reflect the technological barriers to character recognition on a visible plate, but rather the number of plates that are obscured or otherwise unreadable. It has difficulty reading plates that are:

- ❑ *Bent*
- ❑ *Dirty or obscured (for instance parked too close to another car for a full plate read)*
- ❑ *Covered (illegally) with reflective material*
- ❑ *Positioned high (as on an SUV) or at a high angle to the camera*
- ❑ *Older plates*
- ❑ *On cars traveling at high speeds*

It also has difficulty reading plates that have stacked characters (some State license plate designs, handicapped license plates).

Stolen cars that may not be identified are those without plates, or with borrowed or altered plates. Cars without plates will not appear on the system but are in obvious violation of the law for other reasons. Borrowed plates may allow a stolen car to pass unnoticed as long as those plates have not been reported stolen. Altered plates may also pose a difficulty, but California plates have raised letters and thus are more difficult to alter.

In addition to the technological difficulty of reading plates, the system will not recognize stolen autos from other States because only California stolen vehicle and stolen plate information is entered into the system. The system sometimes reads a partial plate, allowing an investigator to do wildcard searches to match those partially observed plates with a list of plates used for crime detention.

Have the characteristics of the user or target population changed over time?

The characteristics of the target population have changed and continue to change over time. The system is designed to read current California plates (within the last 25 years). These will make up a larger proportion of the total California plates observed as time goes on. Sacramento continues to work with state and local authorities to gain access to other databases of both input and output data. Input data include data on outstanding warrants for arrest while output data include the database of license plates gathered by the Sacramento Parking Authority that may prove useful in investigative efforts.

In the future, the users are likely to change as well. The department may enlist the help of retired officers to drive the vehicle, and observe and report any hits to an active officer. Alternately, the officer driving the vehicle may use a community service officer. These approaches free police from completing paperwork on abandoned vehicles and being out-of-service during the time required for towing.

What values/outcomes do users see/envision in the technology?

The current system is used in a patrol car to identify stolen vehicles and in a surveillance van to support long-term investigations. The Sacramento Police Department envisions other uses, such as using the LPR to track vehicle travel patterns across the county. Presumably this would work by identifying certain cars as worthy of being tracked, and then recording the geographic position of "hits" to establish driving patterns of suspicious individuals. Artificial intelligence system might be used to identify patterns worthy of enforcement attention. As they characterized the technology: LPR can be used to collect data; the police then need to develop the means to analyze those data to provide information of use to enforcement.

What are the limitations/obstacles to using the technology?

The benefits from real-time license plate recognition are only as good as the database used. For the police to identify stolen vehicles, the LPR system must have fresh and accurate information. Currently the data regarding stolen cars, plates, and outstanding warrants are downloaded before using the outfitted patrol car, so that the data become dated as the day progresses. If the system were implemented more widely, multiple downloads in a day would enhance the officer's ability to identify stolen vehicles quickly and ideally while still occupied. (This data update could happen by driving a car through a "hot spot" that would allow an automatic download.) Obtaining access to data requires developing partnerships within the state. Some of these partnerships have already been developed, but access to additional databases will have to be worked out on an individual basis.

The investigative benefits to the system would be significantly enhanced with more widespread use of the technology. The investigative database currently contains some 50,000 plate images, many of which are duplicates. (The system is intended to include duplicates, as one use of the system is to record multiple occurrences of the same car.) As the system is used more frequently and as other patrol cars are outfitted with the system, the database will be greatly increased. This will make it more likely that a vehicle of interest has been viewed and tagged with a location.

It should be noted that some popular systems capture neither the GPS location nor a color photo of the vehicle. These simple systems are valuable for real-time recognition of stolen vehicles but are much less useful for investigation purposes. The records for these systems are typically not kept and may be purged from the system after 2 weeks or less.

What outcomes could be assessed? Using what measures?

Using LPR to identify and recover stolen cars provides the clearest measure of outcomes. Cars are stolen for two generic purposes. The first motivation is to either sell the car or to strip its parts and market those parts for resale. It seems unlikely that an LPR would be effective at identifying cars stolen for commercial theft purposes, because the thief has an incentive to move the stolen car from the point of the theft to a hidden location before the owner files a stolen car report. Thereafter, there is little reason for the thief to drive the car into an area where it might be detected by the LPR.

The second motivation is for a thief to acquire a car for instrumental purposes. These may range from joyriding by teenagers to using the car as a temporary conveyance to or from a crime. Cars stolen for such purposes are usually recovered, although the car may have been damaged.

It seems unlikely that a LPR would increase the eventual recovery rates, but nevertheless, a LPR could have three distinct advantages:

- 1. Because an LPR operates in real-time, the LPR system may increase the probability that the police detect a stolen vehicle that is occupied. The occupant may be the thief, or at least, the occupant may be someone linked to the thief. Thus some form of clearance rate (arrest, prosecution, conviction) would provide a metric of the outcome from using an LPR system.*
- 2. The LPR might cause the earlier recovery of stolen cars. Even if all cars stolen for instrumental purposes were eventually recovered, the time from theft to recovery may be material and costly to the car's owner. A simple metric is the length of time from theft to recovery, which might be monetized by using the dollar-cost of the rental of an equivalent car.*
- 3. The LPR might reduce the damage to a stolen car. Stolen cars are often vandalized. For example, opportunistic thieves may remove the tires from an abandoned car. Hence, reducing the time until recovery might reduce the damage. We are uncertain that the police would record the damage amount, but owners could estimate those damages if asked. Otherwise, one might rely on a proxy estimate of damage as a function of time until recovery using insurance claims to estimate. This would require the cooperation of insurance companies.*

These outcomes are measurable and, as we discuss below, an evaluator could use a strong research design to evaluate the effectiveness of LPR at reducing the cost of automobile theft and, perhaps, at increasing the capture rate of automobile thieves.

As noted above, the LPR system might be used in the investigation of major crimes. At the least, this use could be converted to a counting exercise—how frequently was the system queried to detect driving patterns useful for an investigation? How often did these queries yield useful information? Since these queries must be done at a central source, they would be countable. Then an evaluator might track how those results were used in an investigation and in support of a prosecution. The Sacramento Police Department also uses an LPR-equipped van to monitor traffic at crime scenes. This latter use of LPR technology is unlikely to lend itself to random assignment experiments or even to quantification. Although the police might be convinced to use random assignment of the van to major crimes, we suspect that they would demand to assign the van to crimes where the van's utility would be the greatest. In either case, we expect that there would be a fairly small number of such events, so that statistical analysis would be precluded. An evaluator might better use a qualitative plan to

study the use of a van equipped with LPR technology to augment other investigation resources.

Designing a Study

Are there other operational environments for which the technology is well suited?

What are the constraints in such environments?

The technology is also well-suited for use in fixed locations, as has been shown in European usage of the technology. These sites could be placed on major traffic arteries to alert the police to stolen vehicles entering or leaving the city. However, these systems are of little use unless paired with law enforcement backup. The great benefit of the mobile systems in place in Sacramento is the ability for the alert to be immediately acted upon.

Do the technology “events” permit randomly generated applications of the technology?

If not, can comparison samples be formed? With what difficulties?

Random design experimental studies seem practical for evaluating the use of LPR to reduce the cost of automobile theft. One approach would be to allow the police to select an area to be patrolled and then to randomly select a day to use LPR technology to patrol that area. The same area would be patrolled routinely (without LPR technology) during the previous 6 days. The one-day patrol would be the experimental period; the 6-day patrol would be the control period.⁵ Outcome measures would be cars recovered during the experimental period and cars recovered during the control period (prorated to a daily recovery basis). The principal metrics are the average length of time required to recover cars during the experimental period compared with the control period and the average damage to the car during the experimental period compared with the control period.

Two elements of this design require discussion. First, the experimental period must follow the control period rather than the reverse. Reversing this order would bias the treatment effect. Specifically, suppose that the LPR technology does not necessarily increase the recovery rate but that it does reduce the time to recovery and the damage done to recovered cars. Although the eventual recovery rate would be the same whether or not LPR technology were used, the LPR technology will cause more stolen cars to be recovered on a day when LPR is used than on a day when it is not used. Thus, there would be fewer stolen cars on the street in the 6 days that follow the day when LPR is used, so an evaluator would not want to use that subsequent 6-day period as a control period. Second,

⁵ There is nothing special about the length of the control period. A longer period increases the sample size. Give that the recovery rate would be smaller during the control period, we would want the control period to be longer to provide a sufficient sample.

we assume that the patrol areas should be stratified, and the experiment would pertain to a selected stratum. This is not a necessary step, but it does provide some assurance that the experiment would be limited to those patrol areas where stolen cars (occupied or unoccupied) are prevalent. Furthermore, the stratification assures that an experimental condition will not be repeated too quickly in a stratum, because a quick repetition will tend to reduce the recovery rate.⁶

There is a second approach. If the patrol car equipped with LPR were only used on one day per week, then that car might be used to simulate patrol on other days. Specifically, the patrol car could be driven by a retired police officer or by a community-service officer who would simply record stolen cars as they are identified by the LPR system. (Recording of both is automatic. In this variation of the random assignment, the retired officer/community service officer would simply be collecting data rather than performing enforcement.) If the retired officer/community service officer reported those stolen cars when detected, this would be little different in theory from having an on-duty officer driving the LPR-equipped car.

If the retired officer or community-service officer did not report the stolen car to on-duty police⁷, there are two problems. The first problem is that we would not have a metric for how long is required to recover a stolen car detected by the LPR system. This is a minor problem, however, because we can estimate that time based on the average time observed for the real-world use of the LPR system. The second problem is that the resulting data will not provide any information about the damage to the car that resulted from the delay between theft and detection. However, this can be estimated by studying damage as a function of recovery time. If the retired officer or community service officer reported the stolen car, these concerns would be moot.

Finally, we note that the value of using LPR to locate stolen cars depends on the frequency with which LPR is used to patrol an area. The more frequent the patrol, the greater the value, because LPR causes cars to be recovered more quickly than they would otherwise be recovered. Of course, the more frequent

⁶ Suppose that a patrol area receives LPR patrol on day 1. The effectiveness of another LPR patrol would be less on day 2 than it would on day 3; it would be less on day 3 than it would on day 4; and so on. This follows because a patrol on day 1 would remove cars that otherwise would be identified on day 2, while a new patrol on day 3 would provide some opportunity for stolen cars to be replenished. There is no need to test how the effect diminishes with the frequency of patrol, because this can be inferred from the length of time that a car had been reported as stolen at the time that it was recovered.

⁷ The Sacramento Police Department considered the prospect of hiring retired police or using community service officers to simply drive the LPR-equipped car. This would allow on-duty officers to perform regular police work until called by the surrogate officers. If Sacramento adopted this procedure, even for an experimental period, then the random assignment evaluation could be done with this configuration. From an evaluation standpoint, this would provide the same data as having on-duty officers drive the LPR-equipped car.

the patrol, the higher the cost. Presumably the cost of patrolling with LPR increases linearly while the benefit increases at a decreasing rate. The breakeven point can be inferred from the experimental evidence.

A random assignment experiment seems unnecessary for determining whether or not LPR increases the frequency with which an officer detects an occupied stolen vehicle. Even without random assignment, one could observe the frequency at which a routine patrol car identifies an occupied stolen car and the frequency with which a LPR-equipped patrol car identifies an occupied stolen car. Nevertheless, the same randomized design as was suggested for estimating how LPR reduces recovery time and reduces vehicle damage would apply to judging whether LPR-equipped vehicles identify more occupied vehicles per patrol period than non-LPR-equipped vehicles.

When researching the issue of identifying occupied vehicles, however, we suggest that the evaluator also perform a qualitative process analysis of what happens to people who are observed occupying stolen vehicles. How often are they prosecuted? Convicted? How often are their cases dismissed (or no charges filed) because they were in fact authorized to drive the vehicle?

We recommend the use of qualitative methods to investigate the use of LPR for collecting evidence from crime scenes and for monitoring the driving patterns of suspicious persons.

How many times would the technology be applied in 1 year?

The technology would be applied multiple times. When fully implemented, the application would be continuous.

Will modest but statistically significant effect sizes be detectable given sample sizes?

Although we are uncertain of estimates, it appears that a LPR patrol car will discover 1–2 stolen cars per shift. (We posed this question during our site visit to Sacramento.) If an LPR patrol car were to patrol on one shift per week, then the LPR car would detect 52–104 stolen cars per year. Patrols during the longer control periods might detect about the same number of cars. The question is whether or not the LPR patrol would identify stolen cars sooner and with less damage. Given the expense of an LPR system, only large effects are likely to be of interest. However, we cannot tell what is large and small, so any power calculations would be suspect.

However, an experimental condition with as few as 52 observations is small, and we seek ways to expand this number. If the LPR-equipped car could be driven 7 days per week, then the sample would be between $7 \times 52 = 364$ for one shift or $7 \times 104 = 728$ for two shifts each day. The size of the control sample would be about the same. This would certainly appear to be a sufficient sample to detect

even a modest treatment effect. If not, the experiment might add an additional LPR-equipped car to the study.

We know that discovering an occupied stolen vehicle is a relatively rare event, but unless it is very rare, a sample of 364–728 stolen cars for the LPR-equipped and non-LPR-equipped recovered cars should provide sufficient power to judge whether or not LPR-equipped cars have a material effect on increasing the arrests and prosecutions of car thieves.

How many units—if any—would have to be procured for an evaluation?

If a single LPR-equipped car were available for seven shifts per week, the sample size would be adequate, and there would be no need for additional equipment. However, we are uncertain that the car could be put into service for that period because of unavoidable equipment failures. The cost of the LPR reader is about \$20,000–\$25,000, so the purchase of one unit would not be a prohibitive expense. This presumes that the agency would pay for the patrol car, and as noted, someone has to drive this car: using retired officers or community service officers to drive the LPR-equipped car would require payment that is less than the cost of a patrol officer. If they were acting as data collectors (rather than as police adjuncts), their cost might be paid by a grant.

What does a control/comparison group receive?

The control group would receive routine patrolling.

What kinds of data elements are available from existing data sources?

Existing data elements would list stolen cars, when they were reported as stolen, and when and where they recovered. We are uncertain if the reports include estimates of damage. We would also know when the LPR-equipped car was in service and where it patrolled. And, we would expect the records to record arrests, while prosecution records would tell about prosecutions and convictions.

What specific input, process, and outcome measures would they support?

We are uncertain that the data would provide estimates of damage. This part of the evaluation might have to be based on insurance claims by year, model, and time until recovery. Various insurance institutes collect these data and could probably be persuaded to provide estimates. There might be a data processing cost.

How complete are data records? (Attain samples if possible)

We have not collected samples, but the data needs are minimal.

Can user and/or target populations be followed over time?

Yes, a license plate can be followed over time (this is in fact one potential application suggested by the Sacramento police), although this does not seem to be an important element of the research design.

Can the dosage of technology used be identified?

Yes, the dosage (frequency of patrol with a LPR-equipped car) is an observable metric. We think that the more important question is whether this study could provide an estimate of the relationship between dosage and benefit. We have sketched how that relationship could be established with a simple mathematical model.

Can data systems help diagnose implementation problems?

Yes. A problem with the LPR technology is that the technology cannot always read a plate. This failure rate can be estimated for abandoned cars by examining the period following patrol by the LPR-equipped car. Cars that were stolen before the LPR patrol, abandoned in the area patrolled by the LPR-equipped patrol, yet not detected would represent a potential failure to detect a plate.

There is a potential problem. The car may have been stolen before the LPR patrol but abandoned (in the LPR patrol area) after the LPR patrol. But if that were true, then there would be a pattern to the cars missed by the LPR patrol: Those stolen most recently would have a higher rate of being missed by the LPR patrol, and one could adjust the statistics based on that observed pattern.

The CrimeConnect data could be reviewed to identify the rate at which the system reads partial plates.

What threats to a sound evaluation are most likely to occur?

We see no reason to suppose that LPR equipment will increase the rate at which stolen cars are recovered. We do expect that LPR equipment will reduce the time until recovery; we do expect that LPR equipment will reduce damage to recovered vehicles, and we do expect that the use of LPR technology will increase the apprehension rates of car thieves. Measuring the time until recovery is straightforward; measuring the damage to recovered vehicles is more demanding. We suspect, however, that the principal benefit from LPR-equipped patrols comes from reducing damage. Furthermore, the rate at which LPR-equipped patrol vehicles apprehend suspects from occupied vehicles is observable and supports an inference that LPR technology increases the rate at which car thieves are identified driving cars that they have stolen.

What changes is the site director willing to make to support the evaluation?

The evaluation is not disruptive of operations provided the Sacramento police would be willing to randomly assign LPR-equipped patrol cars to patrol on some days and not on others. An alternative plan of using retired officers or community service officers as data collectors would reduce the burden.

3. Overall

Would you recommend that the technology be evaluated? Why or why not?

Cars, especially those that are attractive to thieves, are remarkably expensive. The cost to the victim of an automobile theft is commensurate. Although theft for profit (for resale and for chop-shops) imposes the largest per-unit losses, the inconvenience of waiting for a stolen car to be recovered and the expenses of repairing a seriously damaged car are consequential. A technology that promises to reduce recovery time and to reduce the damage from car theft has the potential to be cost-effective. Increasing the rate at which thieves are apprehended is also beneficial.⁸

Restricting an evaluation to the benefit from reducing the cost of automobile theft would miss an important point, however. LPR is an emerging technology. Its use to recover stolen cars is obvious and an evaluation would be straightforward. But as an emerging technology, the LPR is in an early stage as a crime tool. The Sacramento Police Department believes that LPR can be used as a more general crime-fighting tool. If that proves to be true, then the cost of LPR technology would fall, increasing its value as a means for reducing the costs of automobile theft. We do not see how this emergent aspect of the technology would be evaluated experimentally, but a study of reducing the cost of automobile theft should include a process analysis of LPR as an emergent technology.

Furthermore, LPR has other extant applications. It is used to identify cars with outstanding tickets, leading to booting of the cars of offending owners. The sharing of equipment and data could both reduce the cost of equipment used for a single application and increase the effectiveness of that application. This sharing is not practical at this time in Sacramento, but consideration of sharing should be part of a process analysis.

What type of evaluation design would you recommend?

As noted above, random assignment—with or without expanding patrols—is recommended. Evaluating this technology lends itself readily to random assignment, and given the benefits of random assignment, it should be used.

⁸ The eventual benefit would come from increased deterrence.

Qualitative analysis should be used to extend the evaluation of emerging uses of LPR technology.

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