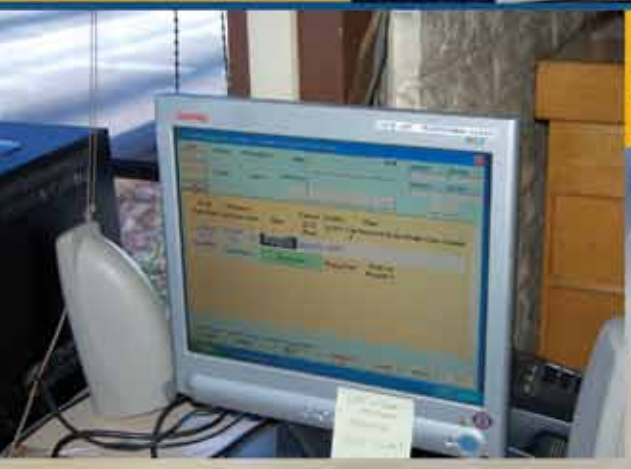
# LICENSE PLATE RECOGNITION (LPR) SYSTEMS

## Function, Performance and Considerations for Law Enforcement Agencies





NLECTC
Small, Rural, Tribal and Border Regional Center

Opinions expressed in this report are those of the author and do not necessarily reflect the official position of the National Institute of Justice, the National Law Enforcement and Corrections Technology Center System, The Center for Rural Development (the host agency for the Small, Rural, Tribal and Border Regional Center) or SRTB-RC.

For more information about the technology, or about this report specifically, contact:

Tod Depp, Project Manager
Small, Rural, Tribal and Border Regional Center
2292 S. US Highway 27, Ste. 300
Somerset, KY 42501
(512) 660–7782
TDepp@SRTBRC.org
http://www.srtbrc.org

Michael K. O'Shea
Law Enforcement Program Manager
U.S. Department of Justice
Office of Justice Programs
National Institute of Justice
Office of Science and Technology
810 Seventh St., Seventh Floor
Washington, DC 20531
Office (202) 305-7954
Fax (202) 307-9907
E-mail: Michael.oshea@usdoj.gov

# CONTENTS

# INTRODUCTION


In 2006, the U.S. Department of Justice's National Institute of Justice (NIJ) funded the Sheriffs' Association of Texas (SAT), as host to the Border Research Technology Center (BRTC), to conduct research, testing and evaluation in operational environments of license plate recognition systems for law enforcement under cooperative agreement # 2006-IJ-CX-K016. (NIJ is the research, development and evaluation agency of the U.S. Department of Justice, and is dedicated to improving knowledge and understanding of crime and justice issues though science. Learn more at http://www.nij.gov).

Beginning in 2010, the National Law Enforcement and Corrections Technology Center (NLECTC) Small, Rural, Tribal and Border Regional Center (SRTB-RC) took on continuing research in this area under cooperative agreement # 2009–IJ–CX–K019 with the development of a self-contained deployable trailer that can be moved to high-traffic areas, allowing officers to continue patrols and still receive immediate information on vehicles of interest. As a follow-on to the research, SRTB-RC has produced this report, which provides an informative overview of the technology generally, including functionality, limitations and other considerations for law enforcement agencies contemplating purchase and deployment of this technology.

# WHAT ARE LPR SYSTEMS?

License plate recognition systems (LPRs) use optical character recognition (OCR) algorithms to allow computer software to read vehicle license plates. (These systems are also known as *automatic license plate recognition systems,* or ALPR.) LPR systems usually consist of a few basic components:

1. A camera designed to take images of license plates (numbers and letters).

2. A computer software package that interprets the numbers/letters from the video captured by the LPR camera.

3. A database of previously stored "hot lists" or previously read license plates.

LPRs come in a variety of formats, including fixed, mobile and portable. This document includes a chapter that goes into more detail on each type, its strengths and weaknesses, and other important considerations. It also discusses performance and capabilities, including uses, speed and accuracy. Vendors often refer to speed and accuracy when promoting their systems, and understanding some of these capabilities will help an agency more fully comprehend the differences between various systems.

Although the technology continues to improve rapidly as cameras and software sophistication increase, it does have some limitations that


agencies need to consider. In some cases, these limitations are based on older technology that is still being sold, while other limitations derive from the ways in which LPR systems are used and deployed. This document also includes a chapter that addresses questions such as:

- Where should an agency deploy LPR?
- What type of system is best for a jurisdiction?
- How can an agency get data to/from the field?
- How much does a system cost?
- How does an agency go about selecting an LPR system?

# HOW DOES LPR WORK?

As indicated in the previous section, LPR systems use OCR algorithms to enable computer software to read vehicle license plates. There are several types of systems and it is important to understand the differences between them.

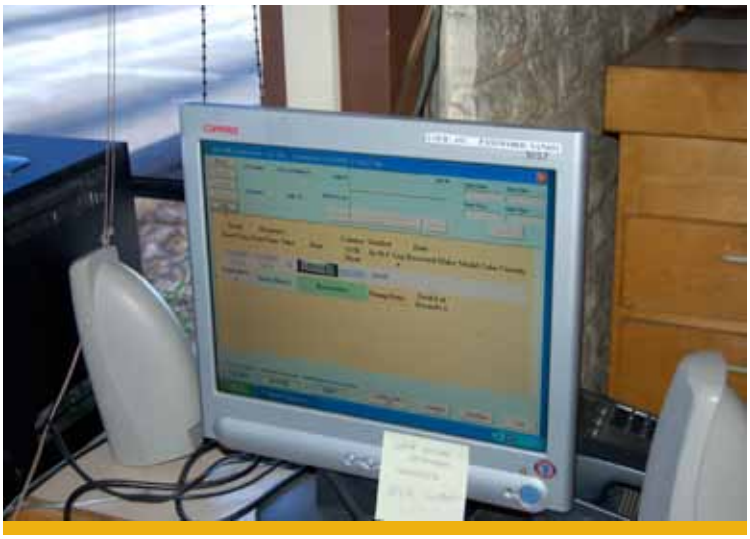
The majority of LPR systems sold in the United States consist of a multi-camera setup wherein a single unit consists of a color overview camera and an infrared (IR) camera. The color overview camera is designed to do exactly what the name implies: provide a color image of the area where the plate was read. This camera has a wide field of view so that users can look at the image and tell if the vehicle is a car, truck, SUV, semi, trailer or something else. Depending on the lighting, this color image can also provide an idea of the color of the vehicle. In many cases, a system may read a high volume of plates in a given time period. When a system reads at a high-density level, and users receive only an image of the plate, it is much more difficult to determine which vehicle has the tag in question. Imagine being in a cruiser and receiving an alarm from the LPR system showing only the plate in question: "ABC-123." Although having the plate number is valuable, the officer may wonder which vehicle he/she needs to locate: "Am I looking for a red car or a black pickup truck?" Therefore, it is extremely valuable to have an overview image of the vehicle to provide the officer with more situational awareness.

Although the color overview camera helps to provide improved situational awareness, the IR camera, in most cases, provides the actual license plate image. The IR camera looks for a series of letters/numbers at all times and most

systems incorporate an illuminator to light up the license plate and make it more readable. This IR illuminator is essentially a pulsing light (with a beam not visible to the human eye). It causes a strong reflection on the license plate that creates a great deal of contrast between the letters/numbers and makes the characters more easily seen by the IR camera. It is important to note that not all LPR vendors use an illuminator in the non-visible spectrum. With these systems, agencies need to determine whether their LPR deployment needs to be covert or if it does not matter if the illuminator creates visible light.

After the IR camera captures an image, computer software analyzes it and uses OCR to determine the characters. The software first looks at the image, then compares the shapes within the image to determine if the shapes look like any of the fonts/letters/numbers in the computer's "dictionary." If the computer knows what "A, B, C" look like, it scans the image for similar shapes to determine if any of these characters are there.

Once the software has determined the possible characters on the license plate, it completes several other steps. Agencies can have a database of license tags, often called a "hot list" (can be stolen cars or crimes associated with a specific license tag), downloaded into the LPR software. This list can come from a variety of sources, but most commonly it is a download from the National Crime Information Center (NCIC) database, which contains the national list of stolen vehicles and/or license plates. Please note that systems are rarely set up to do a live query of the NCIC database because of limited bandwidth and the huge strain it would put on the query system of NCIC (to image the ability to run hundreds of tags per minute times the number of deployed systems.) Using a downloaded version of the database allows for increased speed when generating an alert, but opens the door for potential data integrity problems that will be discussed later in this document. Any database with a license plate number field can be incorporated into most LPR systems, which allows the system to scan multiple databases simultaneously. For example, an agency can produce its own "want list" including outstanding



warrants, individuals wanted for questioning, individuals with outstanding fines and so on. Any information that an agency has that is tied to a license plate number can be incorporated into the "hot list." Additionally, agencies may have a separate list for narcotics or undercover investigations where an agency does not want anyone to respond to an alert, but rather to just be aware of a vehicle's being in a given location at a certain time. Individual databases can, in some cases, be set up with their own rules for who is alerted and how they receive the alert.

A rural sheriff's department was going through a demonstration period with a mobile system and quickly realized the benefits of using an LPR system. Late one night, officers were responding to a domestic disturbance involving a firearm. While in route to the scene, the officer operating the LPR system was given the license plate number of the suspect's vehicle. The officer manually entered the suspect's license plate number after learning that the suspect had fled the scene prior to the officer's arrival.

While in route to the scene, the LPR system alerted that the officer had just passed the suspect's vehicle. The officer was able to quickly turn around, stop the vehicle, and arrest the suspect. The responding officer stated that without the use of the LPR system, there is no way that he would've been able to identify the suspect's vehicle in the dark rural roads at high speeds.

# TYPES OF LPR SYSTEMS

As explained earlier, the U.S. law enforcement community primarily uses three types of LPR systems: fixed, mobile and portable. This chapter describes each type and identifies differences between the systems, and their strengths and weaknesses.

## Fixed Systems

Fixed systems are exactly what the name implies: LPR systems used in a fixed location that are designed to be stationary and not moved from where they are installed. This type usually includes some type of overhead mounting structure (overpasses, light poles, etc.) so that the cameras are installed in the optimum position to maximize the number of plates read. By positioning the cameras directly over lanes of interest, the system more easily reads the plates because the vehicles face the cameras directly. This direct angle also cuts down on the chance of another vehicle's or object's blocking the license plate from view.

**Positive Aspects.** A fixed LPR installation runs 24/7. The system can be completely autonomous if hot lists are automatically uploaded. A major benefit is that law enforcement officers do not have to sit right next to it waiting for reads/alerts. With a fixed system, officers can continue to do routine police work. If the system generates an alert, it may either notify a dispatcher or send a series of automatic e-mails and/or text messages to supervisors. Fixed systems also arguably have the highest read volume of any type of LPR system. Most agencies that deploy fixed cameras do so in very busy traffic areas. This maximizes the number of plates read and reduces the number of LPR systems needed in a given area.

**Negative Aspects.** Fixed LPR systems are the most complicated and expensive to install. Sites must have a power supply for the LPR system to work. In many cases, the cameras and computer are housed locally at the installation site, and running power to a new site can be a very expensive and time-consuming process. Some agencies determine the site for the fixed LPR installation based on power availability. Although this saves on cost, the site might not be the best installation point strategically. Obtaining permission to permanently mount cameras to infrastructure also can be problematic. For example, Texas interprets placement of LPR technology in the same manner as red-light camera legislation and currently does not allow any LPR systems to be mounted on state-owned infrastructure.

Another consideration is how to send/retrieve data to/from a fixed LPR site. All of the data from the field needs to go back to a server. If there is no pre-existing Internet connection, then you need to think about how you will get data

from place to place. Some installations have an Internet provider run a connection to the LPR site. As cellular connections become faster and more affordable, they may provide a good option for the communications backhaul from the LPR site.

## Mobile Systems

Mobile systems mounted on cruisers and other vehicles are designed to have an officer in the vehicle who can instantly see the results of plates being read. This type of system allows for the mounting of cameras in a variety of positions on the vehicle: on the roof, on the trunk deck, on the front bumper mounts and in a variety of covert installations.

**Positive Aspects.** This type of system works well in densely populated, urban environments. Officers can drive to areas of interest and scan a high volume of vehicle plates. Additionally, because officers are always with the system, distance communication relays are of little concern. If the LPR system generates a hit, officers are notified immediately (within one or two seconds).

Mobile systems are less expensive than other types of systems. Whereas the cost for the camera mounting hardware and mobile computing platform may be equal to, or slightly more than, its fixed counterpart, there are no extra construction, mounting or communications expenses. Although prices continue to change along with the technology, costs for mobile LPR capabilities range from around $5,000 to $25,000

| System Type | Positive Aspects | Negative Aspects |
|---|---|---|
| **Fixed Systems** | · 24/7 operation.<br>· Autonomous operation.<br>· Force multiplier.<br>· High volume of reads. | · Complicated installation (mounting structure/hardware, power connection).<br>· Complicated communications link (Internet access).<br>· Potential challenges gaining approval to mount system on infrastructure.<br>· High cost. |
| **Mobile Systems** | · Works well in dense traffic areas.<br>· High volume of reads in a targeted area (malls, hotels, etc.),<br>· Immediate officer notification of "hits."<br>· Easy setup. | · Not as effective in rural, sparsely populated areas.<br>· Officers can become too focused on the LPR system and adjust their patrol habits to maximize the number of reads, rather than focusing on patrolling areas in need.<br>· If permanently installed on a vehicle, the system is only operational when the vehicle is on the road.<br>· Potential power consumption issues in cruisers that already have a large drain on the power supply. |
| **Portable Systems** | · Read volume of a fixed LPR system.<br>· Portability of a mobile LPR system.<br>· No permanent and expensive wiring/site installation expenses. | · Difficult power supply setup (batteries, alternate energy, etc.).<br>· Potentially manpower intensive and expensive if batteries need to be replaced and/or recharged.<br>· Complicated communications link (remote Internet connection).<br>· Lack of "immediate notification." Requires the system to communicate with a server, which then generates the alert and notifies dispatch.<br>· Potentially high cost (may require acquisition of trailer or other mounting device), batteries, dedicated computer, remote Internet connection. |

depending on the number of cameras and the type of system chosen.

**Negative Aspects.** Although mobile systems have several positive aspects, there also are drawbacks. In small communities and more rural environments, mobile LPR systems are not as effective. Since the population is more sparse and spread out, finding a large density of vehicles to scan can sometimes be problematic. Some agencies report that officers with LPR systems focused patrols in areas with more traffic and less in residential areas that may have needed patrolling. It is not uncommon for a system to read several thousand plates in an hour in a densely populated area, whereas in rural/remote areas officers tend to see much lower numbers, sometimes as few as 150 reads in a full shift. Additionally, if a department has a take-home vehicle program, the LPR system is limited to one shift per day or only when that officer is on the street. Lastly, although power is readily available in patrol vehicles, many agencies have problems with the power consumption rate needed by LPR systems. As agencies continue to add more technology to cruisers, the electrical load on the vehicles continues to increase, which can cause problems for the LPR and for other systems as well.

## Portable Systems

Portable systems essentially combine fixed and mobile LPR systems. They are designed to be moved and then left to operate in a given area. Agencies integrate this type system into trailers, traffic control barriers and so on. Some may be covert whereas others are merely set up so that they can be moved to a variety of locations quickly and easily.

**Positive Aspects.** The capability to quickly and easily move this type of LPR system between locations is its strongest suit. The fixed location provides performance and read volumes similar to those of permanently mounted fixed LPR systems, but by comparison, costs less. Depending on the power supply used, a portable system may be able to operate 24/7 without officer involvement.

**Negative Aspects.** One of the biggest concerns with a portable system is how to power it in the field. Solutions range from deep cell marine batteries to standard automotive batteries, from capacitor banks to pulling up in an area where power is already available. Depending on the power supply, this type of system could be manpower-intensive if officers or support staff must, for example, change batteries often. And like fixed LPR systems, communications backhaul also can become problematic. Because portable systems move from place to place, microwave point-to-point systems are not as feasible. Cellular connectivity is probably the most suitable method, but depending on its location, an agency may not have sufficient bandwidth to get immediate notifications. Depending on the proposed LPR site, another possibility is to form a partnership with a local business that may have an existing Internet connection and use that Internet connection to send the data from the field.

# PERFORMANCE AND EXPECTATIONS

## Uses

The most commonly referenced use for an LPR system is using the technology to find stolen vehicles, often using the NCIC download list of stolen vehicles from around the country. However, LPR systems also have many other uses. For example, LPR can be a phenomenal investigative tool. While conducting a demonstration in a rural south Texas county, a deputy using the system on patrol was called to assist at the scene of a homicide. On arriving at the scene, the deputy left the vehicle running and thus the LPR continued to function. When he returned to his vehicle, he searched the reads to see if he had missed anything while working the crime scene and noticed several reads of the same vehicle. The owner of this vehicle that passed the crime scene several times was the primary suspect in the homicide.

LPR technology is also commonly used in support of arson investigations. Arsonists often return to the scene of the crime to "see their work," and the ability to quickly scan neighborhoods around a suspected arson site may yield results. If a particular license plate is consistently read in the neighboring area of several suspected arsons, then the owner of that vehicle may be a person of interest.

In short, LPR can be an extremely powerful investigative tool. Agencies that have operational experience with this technology routinely praise its ability to support investigations, validate/deny suspect alibis and so on.

## Light Conditions

How systems perform under varying light conditions is what separates many of the available LPR systems. There is a wide range of prices between various LPR manufacturers and performance in a variety of lighting conditions often impacts price.

A prior section discussed IR cameras and illuminators. However, some LPR systems do not use IR cameras or illuminators; they use color daylight video cameras only. The performance of this type of system is limited, however, in low light conditions. Some may perform in daylight only. Rather than purchasing a system simply because it costs less, the need for low-light performance should be considered. IR-based systems should be able to capture plates in complete darkness. The plate's reflection will be very bright to the camera because of the illuminator, even though human beings see no light.

## Speed

Video cameras have the ability to capture images from vehicles passing at a high rate of speed. It is not uncommon for LPR cameras to capture plate reads at speeds of 150 mph, or in some cases even higher. It is critical that systems, especially mobile systems, be able to read at this speed. If a vehicle using a mobile LPR is traveling at 70 mph, and oncoming traffic is traveling at speeds of 80 mph, the camera will still need to capture reads.

## Accuracy

Many vendors may use system accuracy as a selling point: "Our system is 98 or 99 percent accurate..." Although this sounds great, these numbers simply are not realistic. A manufacturer might record those numbers in a laboratory testing environment, but performance in the real world is very different. In a laboratory, lighting, distance, contrast and so on are all controlled. Unfortunately, everything in the real world is variable. In operational deployments with agencies, 80-85 percent accuracy is typical. Even at those rates, LPR systems are exponentially more efficient than manual reads by an officer on the street.

Numerous variables can affect LPR system performance including rain, snow, dirt/dust, custom plates, special characters/logos, license plate covers and plate occlusion. An operational demonstration in Alaska determined that the system would be useless for a large portion of the year due to snow, slush and road grime's often partially or fully obscuring plates. Additionally, plastic license plate covers may cause issues with the system's ability to read the license plate. The plastic covering may cause the license plate to not reflect light as it normally would, thereby reducing the ability for the LPR system to read the plate.

A problem unique to the United States when compared to many other countries that use LPR technology is the prevalence of hundreds of plate variations. Every state has a variety of license plates from which citizens can choose. These plate differences make it much more difficult for the LPR software to know all of the fonts, colors and so on, and therefore many specialty plates are misread. Additionally, some plates use special images or logos. For example, a handicap symbol on the license plate may sometimes be interpreted as a "G" or a "6."

Occlusion also causes problems. If anything blocks part of the license plate, then the system will get only a partial read. Trailer hitches, custom bumpers and so on all can cause problems by blocking some of the characters on the plate (unless the camera is looking down on the plate from above). Because of this, fixed sites with their elevated viewpoints have the best accuracy rates because there is less chance of anything blocking part of the license plate.

# CONSIDERATIONS

Before deploying LPR technology, an agency should consider how to best deploy the technology in its jurisdiction.

## Location

Location is of critical importance, especially for an agency considering a fixed or portable LPR system. Power and communications availability are prime considerations. It is also extremely important to make sure that the system is installed at a natural choke point (e.g. controlled access highways, long bridges, any other road that limits the number of routes a vehicle can take) where drivers do not have a way to change course or direction. This gives officers a chance to respond to generated alerts. If drivers have several options to turn off the main road, it is much harder for responding officers to locate and interdict a wanted vehicle. Long stretches of road with controlled access make the most suitable LPR installation sites.

Mobile systems are a different matter because they constantly move from one place to another. During operational deployments, mobile systems appear more suited to small and rural areas. However, officers indicate that if they want a higher volume of plates, they have to park on the side of the road and wait for vehicles to pass. Although this approach works, it goes against the notion of LPR systems being a force multiplier for agencies. If a small agency (with limited manpower to begin with) has an officer pulled off to the side of the road focused on maximizing the LPR read rate, then that officer has effectively been removed from normal patrol work.


## Communications

Communications also should be considered prior to making a decision to purchase an LPR system. If an agency wants to run the LPR against known databases such as NCIC, then it must be able to load that list into the computer with the LPR software. Many vendors say the easiest way to do this is by having an officer download the database to a USB storage drive and use that drive to install the information. Although this system works, many agencies find it ineffective because officers often lack training in uploading the information or simply forget to do it. An automated download usually works best.

Update frequency also impacts system effectiveness. The Texas Crime Information Center database is updated hourly and the state has developed a software program to automatically download and save the updated file every hour. For this to work in a mobile system, the state's software needs to be installed on a vehicle's mobile data terminal with Internet connectivity; updates can then occur automatically. With fixed

and portable systems, however, data needs to be sent to the remote site without officer involvement. This can be accomplished in a variety of ways such as a cellular air card or local Internet service provider. An agency should conduct testing prior to setting up any of these sites in order to understand traffic volume and the available Internet connection speed. If the agency can only get access via a slow Internet connection, but the site has a high volume of vehicles, it may take several minutes for the data to be sent from the LPR system back to dispatch or a patrol officer.

In one case, SRTB-RC and a manufacturer worked on developing a prototype portable LPR system to be completely autonomous. This system has a built-in power supply and solar panels, making it capable of recharging itself. Thus, it never needs human intervention. However, during a demonstration, the communications link between this trailer and a centrally housed server proved extremely problematic. The server was located inside a building and on a private network, and when the agency tried to connect via an outside air card, firewall problems surfaced.

Given the complexity of some communications networks and how crucial it is that the LPR and software communicate, an agency should involve IT staff in discussions of system setup. Vendors often say cameras in the field may easily be linked to a server in an agency office, but it may not be that simple, especially without the involvement of IT staff.

## Cost

System costs vary widely. The complexity and features of the systems can contribute to the final costs. As the technology continues to develop and the number of manufacturers has increased, the overall costs of the systems have decreased. At the 2010 Annual International Association of Chiefs of Police conference, one vendor offered a two-camera mobile LPR system for under $10,000. Meanwhile, some companies sell mobile systems for between $18,000 and $20,000 apiece. The price often varies based on how many cameras (two, three, four) an agency needs. As discussed previously, pricing a fixed LPR system has a large number of variables and the price ultimately depends on the installation site.

A police department has been using a prototype portable LPR system with great success as part of a system evaluation. The municipality has less than 50,000 residents, and in a four-month period, the LPR system read more than 900,000 license plates. Of these 900,000 plates, there were approximately 700 alarms, which resulted in 11 arrests. The vast majority of alarms were merely notifications of registered sex offenders and did not warrant any type of interdiction. All of these plates were read by the portable system and allowed officers to continue their routine patrols. Whenever an alert is generated, a dispatcher notifies officers of the last location and the make/model of the vehicle. The agency using this system is currently in the process of permanently acquiring their own system.

# CONCLUSIONS

## What Type of System Is Best for My Agency's Jurisdiction?

All agencies are unique and must determine the solution that best meets their needs. For example, an agency with a major traffic route somewhere in its jurisdiction might want to consider a fixed LPR system. An agency without a high-volume road might consider a portable or mobile solution. In small and rural areas, a portable solution might be the most suitable.

Contact several LPR vendors and take a look at different systems. Vendors should be willing to come to a jurisdiction and show an agency the technology. Most vendors will loan equipment for an evaluation project and in many cases, vendors will want to give a demonstration of the technology in their own vehicles. This will provide some idea about system performance, but it is critical to have a demo system in a departmental vehicle. This will allow an agency to see if there are any power, communications or software issues that need to be resolved. Request an equipment loan for a few weeks so that officers can use the system without intervention from a salesperson. This will give the agency a chance to identify areas in need of further clarification. Additionally, it provides a good opportunity to assess the technical support available from the LPR vendor. It is important that the system you purchase include good technical support to ensure that the system remains operational for its intended purpose. The degree of technical support that a manufacturer provides a product should be a factor in the purchase of this technology. A system that is inoperable can be a drain on both manpower and financial resources. In some cases, the technical support team can make the difference in an agency's decision of which vendor to choose.

It is important to note that this report does not cover every detail of LPR systems because there are many differences between product models and manufacturers. If you have questions about a specific piece of technology, do not hesitate to ask the vendor to provide further documented information. If a vendor makes a specific claim that is important to your purchase decision, consider having the vendor conduct a demonstration to support the claim as well as making this statement part of the purchase agreement.

Also, ask the vendor for contact information for other agencies in the area that use a similar system. Contact those agencies directly and get their honest feedback: Ask them how the system works for them, if they've had any technical problems and whether those problems were resolved in a timely fashion.

If you have more questions about LPR technologies or want to inquire about specific uses and goals, the NLECTC System serves as a free resource for state and local law enforcement agencies. For more information on the NLECTC System in general, please visit JUSTNET, the system website (www.justnet.org).

The authors of this report would like to thank the Sheriffs' Association of Texas, The Center for Rural Development and the law enforcement agencies whose contributions made this report possible.

# List of Sample Questions to Ask Vendors

Vendor Name: _____

Vendor Point of Contact: _____

Name: _____

Phone: _____

E-mail: _____

System Name: _____

System Cost: _____

What is the warranty on the equipment? _____

Is technical support available 24/7? _____

Is there a cost for technical support after the end of the warranty period? If so, what is the cost?

_____

Is training included in the cost of the system? Will you train our staff on-site?

_____

Can you do an "in-person" system demonstration for my agency?

_____

Are you willing to do this demonstration by setting up the equipment on a departmental vehicle (Mobile Systems Only)? If so, what are the vehicle requirements? _____
_____
_____

How long will you allow us to demo the system before requiring a purchase decision?

_____
_____

What other agencies are using your system? Who is the LPR contact with those agencies so that I can inquire about system performance, technical support and LPR effectiveness? _____
_____
_____
_____