



Point-to-Point (P2P) Average Speed Enforcement System

Point-to-point enforcement involves the installation of a series of cameras at multiple (e.g., two or more) locations along a particular section of the road network. As a method of speed enforcement, point-to-point systems capture an image and record the vehicle registration data of each vehicle as it enters the system at the initial camera site. Additional images and data are recorded at subsequent camera sites within the system and matched to the initial data. ANPR and OCR technology are then used to identify vehicle registration details. The average speed of a vehicle is calculated using data collected from at least two points within the system. Specifically, average speed is calculated by dividing the specified distance between those two camera sites by the time taken for the vehicle to travel between these two camera sites. This process is shown in the form of a simple equation below in **Equation. (Distance / Time) x 3.6 = Average speed (km/h)**

If the corresponding average speed of a vehicle exceeds the legal posted speed limit for that section of the road network, image and offence data (e.g., time, date, speed, etc) are transmitted to a central processing unit from the local processor via a communication network. While most systems incorporate an enforcement tolerance, the specific threshold employed varies by jurisdiction. While there are capabilities for the back-office of a system to be fully automated, almost all current installations of point-to-point throughout the world involve some degree of human verification to assess the validity of detected infringements (the closest example of a fully automated system is operated in the Netherlands, see Section 5.3.3). Validated offences are subsequently issued with an infringement notice by the relevant authorities while data on vehicles not exceeding the speed limit are typically erased.

At its most basic, a point-to-point system involves:

- Two or more camera sites along a section of road
- Cameras may be forward or rearward facing (or both) depending on system requirements
- Image and vehicle registration data collected at each point and matched using ANPR technology
- Local processor > Communication network > Back office (Traffic control Centre)
- Average speed calculated by dividing distance between two camera sites by time taken to travel that distance

P2P - ASE System Components

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| • Cameras/Illumination | • Processors |
| • Infrastructure (e.g., camera housing/mounting; cabling; clocks; power source) | • ANPR/OCR engine and software |
| | • Communications network |
| | • Central processing unit/back office. |

Cameras/Illumination

Number of Cameras & Camera Sites – At a minimum, cameras must be installed at the entry and exit points of the enforcement corridor, however contiguous enforcement corridors can also be implemented (e.g., point-to point-to-point). Multi-point systems can also be installed whereby numerous entry and exit camera sites are linked to every other entry and exit camera site. Decisions associated with the use of different systems will typically depend on the length of the enforcement corridor and opportunities for access and egress (e.g., on-ramps and exits within the corridor), as well as budget considerations.

Rearward-Facing Cameras, Forward-Facing Cameras or both – Cameras can be positioned such that they capture the front of a vehicle (forward-facing cameras), rear of a vehicle (rearward-facing cameras) or both. Obviously, there are advantages and disadvantages associated with each approach and decisions regarding which approach is most efficient typically depend on system objectives, the mix of traffic to be enforced and costs. Specifically, while forward-facing cameras allow for driver identification (when cameras are of sufficiently high resolution), these systems are not capable of capturing offending motorcycles whose number plates are on the rear of the vehicle. On the other hand, rearward-facing cameras, while capable of detecting speeding motorcyclists, do not identify motorists. Thus, the use of rearward-facing cameras requires the onus of responsibility to be with the owner of the vehicle, rather than the driver. Other issues include that plate recognition can be complicated or obstructed by trailers or caravans, and there is typically greater heterogeneity in the placement of rear number plates and the presence of bumper stickers and other forms of text may confuse the ANPR/OCR engines. Adverse weather conditions can also impact upon the ability for rearward-facing cameras to capture number plates (e.g., if roads are wet and water is being sprayed by the vehicle's tyres). While having both forward- and rearward-facing cameras provides the benefits of each approach, this is only achieved at a considerable additional cost.

Resolution, Colour & Type of Camera Equipment – The specific resolution of cameras typically depends on system requirements and will invariably be influenced by other system choices, including the number of cameras. High resolution cameras have the benefit of being able to provide wide angle shots at a resolution



large enough to perform the required licence plate recognition, however require greater data processing systems as a function of the larger file sizes of images captured. As a result, many systems employ low resolution cameras specifically designated for each lane of enforced traffic. In addition, cameras can be digital or analogue. While digital cameras offer higher resolution, analogue cameras typically have higher capture rates given that a greater number of photos can be taken in an equivalent period of time. Reduced system requirements are also associated with analogue cameras due to the smaller size and resolution of each captured image. Finally, cameras can be monochrome or colour. Monochrome cameras have a number of advantages, including the capability to be used with infrared illumination and the fact they are more sensitive and require lower levels of ambient light. For this reason, monochrome cameras are most commonly used in point-to-point systems.

Illumination – Given that point-to-point enforcement systems are operated continuously (e.g., 24 hours a day), it is important for systems to have the capability to provide additional illumination during low-light and night-time conditions. A number of options are available, including continuous illumination, triggered illumination and infrared illumination. Continuous illumination is the most expensive approach and increases the likelihood of maintenance requirements, while triggered systems, such as flashes, have the potential to distract motorists. Infrared illumination is most commonly employed, particularly when monochrome cameras are used. The most popular approach is the use of pulsed infrared light emitting diode (LED) illuminators. In addition, the illuminator is typically offset to prevent reflection directly back to the camera, allowing the system to accurately identify number plates with reflective fonts or surfaces.

Camera Activation System – Cameras can be activated in a number of different ways, including continual video-streaming to capture images, or vehicle-activated methods such as lasers, radars or induction loops. Trials conducted have suggested that vehicle capture rates are higher when cameras are triggered by induction loops, however such an approach can have a relatively short working-life and thus increase maintenance requirements.

P2P - ASE System Infrastructure

Camera Housing – There are various options for camera housing. The specific level of enclosure typically depends on the degree of protection required from various weather conditions or anticipated tampering or vandalism. Typically, the most protective housing involves a closed system that does not ingest external air, allowing for the use of the technology in even the harshest of environmental conditions.

Mounting – There are two main approaches to the installation of point-to-point systems: permanent or mobile/temporary. Permanent systems are typically mounted to roadside structures, such as poles, or on existing or purpose-built infrastructure such as gantries, bridges or overpasses. Conversely, mobile systems are typically vehicle- or trailer-mounted versions of the same technology and are most commonly installed as a temporary application of the enforcement method during road works.

Cabling – The amount of cabling required for a point-to-point system, and the complexity of the cabling, largely depends on the degree to which the system is integrated. As Wiggins (2006, p.4) explains: 'Systems that utilize separate cameras, illuminators and processors will require the most complicated cabling scheme. A simpler cabling arrangement would be required where combined camera and illuminator units are connected to a separate processor. Fully integrated systems employing combined cameras, illuminators and image processors may only need power to be connected'.

Time clocks Point-to-point camera systems must include time clocks that can provide date and time stamps associated with captured images. Such a process creates a vital evidentiary basis for enforcing infringements detected by the systems. The most common approaches are the use of Global Positioning Systems (GPS) technology and/or Network Time Protocols (NTP).

Power Source – There is the ability for point-to-point systems to operate on both AC mains and DC power sources. In many instances, systems will be capable of operating via either, with permanent installations typically requiring mains power and mobile systems having a necessity to be able to support DC power supply. Access to appropriate power sources can represent a substantial cost when implementing a system, and thus can affect the specific location of camera sites.

Processors & Servers – The primary processing requirement for point-to-point camera systems is that of the ANPR and OCR software, discussed in greater detail in the following section. That is, the primary processing requirement is the capturing and recognition of vehicle number plates and other associated data. According to Orozova-Bekkevold, point-to-point systems typically work in the following manner: images are captured at each camera site and converted into a specific file format (e.g., JPEG, TIFF, bitmap) for additional processing by the ANPR/OCR software. At the time the image is captured, information is also collected regarding the date, time and location of the offence, as well as the system parameters. These data, commonly referred to as a 'fingerprint' are collected at each camera site, with data from exit cameras systematically compared to entry fingerprints for the purpose of matching and the identification of offending vehicles. While early point-to-point systems involved relatively extensive computer hardware, more recently, ANPR/OCR processing systems typically involve nothing more than small industrial PCs or laptop computers. Systems also differ in relation to whether they are PC-based or embedded. Embedded systems, typically implemented as part of an overall device including hardware and mechanical elements, are designed to perform a single (or small number) of specific and dedicated functions. Conversely, PC based systems are designed to be more flexible and to meet a broader range of end-user requirements.

ANPR/OCR Engine & Software – Average speed cameras use our own Optical Character Recognition (OCR) engine, which is widely recognized as the most advanced in the industry.

ANPR/OCR engine and software One of the most fundamental technologies employed in point-to-point systems is the ANPR or OCR software, used to identify the letters and numerals on vehicle number plates. As noted above, the system processor extracts information from the data collected from this software, using a

relational database. However, it is critical that the software, operating system and database are compatible to ensure adequate system functionality.

System Speed Accuracy – The accuracy of point-to-point speed enforcement systems can be assessed in two ways:

The capability to capture a vehicle number plate, and the accuracy in which ANPR/OCR engines read the number plate. All systems should be designed to have high vehicle detection rates, such that all (or at least almost all) vehicles travelling along the enforced section are monitored. However, the degree to which the plate recognition software can read the number plate can be affected by variations of plate styles (e.g., different plates used within the one jurisdiction or different plates used by other jurisdictions which may not be easily recognised by another jurisdiction's system) or plate condition (e.g., dirty, damaged). This latter point highlights the need for road authorities to encourage and enforce correctly placed and legible plates, as well as the importance of ensuring that all new plate styles can be detected by system cameras. The most important element of number plate reading is that, when errors are made by the ANPR/OCR engine, they are consistent at both the entry and exit site. Such errors still allow for the enforcement of that vehicle, although highlight the need for some degree of manual verification at the back-office. When errors differ between the entry and exit sites, offending vehicles are not detected, thus reducing the enforcement effectiveness of the system.

Communications Network – There are a variety of options for transmitting 'fingerprint' information from the local processor to the back-office. These include Ethernet, wireless technologies (e.g., WiFi, GSM, GPRS, CDMA or 4G) and fibre optic cables. Often fibre optic communication networks are already installed along motorways and thus this can provide a cost-effective approach.

Given the sheer volume of data to be processed, most systems are capable of saving and transmitting fingerprint data in very small (e.g., as little as 1KB each) file sizes. However, initial images captured by the point-to-point system will vary depending on other system components. For example, analogue cameras generate images of a smaller size (up to 50kB) compared to digital cameras (500kB to 2MB). Therefore, traffic flow and processor capabilities of the system must be considered (Wiggins, 2006). In addition, the amount of information sent to the central processing unit differs depending on the type of processor employed. There are also numerous options regarding the level of detail of information included in the data block. Indeed, outlines the various elements of content that can be included in the data block, including speed limit (which might include enforcement tolerance), capture speed, lane information, date and time of the infringement, location of the infringement, image and operator details. Typically, to address issues associated with data security, information transmitted through the communication networks is encrypted. Numerous other security protocols can also be developed.

Back Office/Central Processing Unit – The back office represents the central processing unit whereby data from the local processor are transmitted, via a communication network. As stated in the previous section, the amount of data transmitted to the back office varies from system to system. However, point-to-point systems generally perform a number of processing tasks at the local

processor, transmitting only data and images associated with offending vehicles to the central processor. The back-office may be fully automated or involve varying degrees of human verification to assess the validity of detected infringements. Validated offences are subsequently issued with an infringement notice by the relevant authorities while data on vehicles not exceeding the speed limit are erased. Generally, some level of human verification is recommended to ensure the validity and reliability of detections. Moreover, in the instance of system malfunctions, human verification may represent the quickest and most efficient means of identifying the anomaly and ensuring incorrect infringements are not issued. Such a practice may serve to safeguard against reductions in the perceived legitimacy of the system.

P2P - ASE System Cameras & Illumination

Camera Resolution	1.4 Megapixels
Digital or Analogue	Digital
Monochrome or Colour	Both. Front scene image in colour (based on infra-red illumination), front plate image in monochrome
Forward or Rearward Facing	Both. However only forward facing cameras are currently used
Illumination Approach	Infra-Red

Infrastructure

Camera Mounting Approach	Pole Mounted to Side of Road. One pole mounts the camera while another is used to mount the Flash
Purpose Built or Existing	Purpose built. Guardrails were also constructed to protect vehicles from hitting the poles should they crash at the site
Camera housing approach	Standalone enclosure
Power Source	AC

System Software & Processors

Software Characteristics	OCR/ANPR matching of front plate image
Location of Processor	OCR processor is located at the roadside (alarmed to prevent tampering). Central processor is located in TCC.
System Hardware	PC
Clock Synchronization	GPS units at each site used to ensure all clocks are synchronised to a common time source; secondary measurement system currently being installed incorporates alternative GPS time source
Size and type of image data file	approx. 1MB/Redflex proprietary INC format. Data is encrypted
Data storage approach	Data is retained for 7 days before deletion at the roadside processor

Communications Network & Back Office

Communication network approach	Fixed line, 4G
Data sent to back office	Data for all vehicles are sent to back-office. Data is encrypted at the source prior to communication to the back-office. The vehicle image and data block are rasterized into a new JPEG image
Data included on data block	Time, date, location, direction, lane, offence type, speed zone, vehicle speed, device type, device serial number
Degree of back-office automation	All incident records are checked and processed by human verifiers. Process involves two
Arbitrators	- in case of a disagreement, a third moderator is used.

This System also include:

- 2 megapixel camera file size 200KB per image
- 11 megapixel camera file size 1MB per image (spot-speed-enforced camera)
- 4G or hardwired communications
- 2 images and offence data per potential infringement file
- Plate cameras to provide a localised image of the vehicle
- Scene cameras to provide a location shot to help identify the enforcement site
- Capacity to include 'blacklist' searches of database files
- Offset infrared flash to capture image.
- Image size between 5KB and 50KB
- Data file size approximately 20KB depending on information transferred
- Cameras capture 95% to 97% of vehicles detected
- Night-time images are typically captured using infrared illuminator, therefore pictures are grey scale.

The capture of vehicles accessing the P2P enforcement is affected by the

- Positioning of the camera
- Provision of a vehicle trigger
- Number plate reflectivity
- Weather conditions
- Front- and rear-facing cameras.

P2P - ASE System Features

- Cameras are installed at the entry and exit points to a corridor of known length.
- A photo is taken of the vehicle as it passes over a detection loop, or similar, at the entry or exit point.
- Vehicle images and time stamps captured at corridor entry and exit points are saved to a local server.
- ANPR software reads number plates and saves a data file to a local server.
- Data files from the entry and exits points are transferred over the communications network either fixed or wireless to a central processing computer.
- Central processing computer determines if a speeding offence has been committed by matching entry and exit point data files and calculating the travel time.
- Average speeds are calculated using travel times over the known distance to confirm if the average speed along the corridor was greater than posted speed.
- Local server image files are requested by and sent to the central processor via the communications network.
- An infringement file is created and it contains the image files and all necessary information captured at the entry and exit points for matching and enforcement purposes.
- The infringement file is sent to enforcement adjudication for verification and issuing.

P2P - ASE System Benefits

- **Advanced Technology:** Based on the OCR and high-resolution cameras.
- **Flexible:** Can be used for stationary or mobile applications.
- **Effective & Cost-Efficient:** Monitor one long section of road using only one system.
- **Documentation that can be used as Evidence:** Driver and tailgate photos guarantees an identification without doubt.
- **Reliable Data Protection:** Use anonymized (encrypted) measurement data. Personal data is recorded only once the measurement is complete and only in the event of a speed violation.
- **Customer-Specific Features:** Can be enhanced with customer-specific modules as required.
 - Speed Enforcement on Dangerous Sections of Road
 - Greatly improved traffic management when combined with variable-message signs
 - Can be combined with ANPR and toll applications
 - Reduction of Fuel Consumption
 - The systems are effective in reducing both the number and severity of crashes
 - The systems are able to improve speed compliance within the enforced area and often reduce speed limit
 - The systems produce smoother traffic flows and reduce speed differentials between vehicles
 - Infringement rates are typically low
 - There is an observed reduction in crash and casualty rates.

