A REVIEW OF BUS LANE ENFORCEMENT TECHNOLOGY IN THE UK

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SUMMARY

In the UK, bus lanes are regarded as a key weapon by transportation planning engineers in encouraging the shift from private car to public transport. Their effectiveness is greatly reduced when non-permitted vehicles illegally use them, hence the need for bus lane enforcement systems. This review of current and emerging bus lane enforcement technologies in the UK describes the components employed in such systems, various methods of implementation and their relative advantages/disadvantages. All five UK bus lane enforcement systems are covered. In order for the evidence produced by a bus lane enforcement system to be admissible in court, it must first be Type Approved by the Home Office. The paper discusses existing published guidelines and the revisions that are expected to be made to them.

INTRODUCTION

Within the last 48 years, the amount of traffic on Britain's roads has increased by over 24 million. This represents a massive 600% increase from the 1950 value of 4 million vehicles. However, it is not just the number of vehicles on our roads that has increased during this period - we also travel five times further today than we did in 1950. The average daily journey has increased from 8km to 40km and it is forecast to reach 100km by 2025 (1).

In urban areas, 85% of road traffic consists of cars, hence any traffic reduction measures must be aimed primarily at these drivers (2). The fact that there were 15 times more passenger kilometres travelled by car than by bus during 1995 only serves to demonstrate the potential contribution buses could make in achieving this aim (1). Persuading car drivers to leave their pride and joy at home and travel instead by bus is no easy task.

One potential measure that has already been introduced by transportation planning engineers is that of dedicated bus lanes. These are normally operated part-time during peak hours, although full-time operation can serve as a further incentive for switching modes of travel. Bus lanes offer three major benefits: quicker bus journeys; more consistent bus journey times; slower journeys for other traffic (3).

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In London alone, it has been estimated that the illegal use of bus lanes results in delays costing both the operators and passengers around £15 million per year (4). In the UK, illegally using a bus lane is still a criminal offence, *i.e.* only the police have the authority to enforce them. An already over-stretched police force cannot justify wasting valuable time and resources manually enforcing bus lanes. The Road Traffic Act 1991 enabled more effective use of automatic detection devices in the enforcement of road traffic law, particularly speeding and traffic light offences (5). It is only within the last 3 years, however, that automatic bus lane enforcement technology has been employed within the UK.

UK SYSTEMS

There are four UK bus lane enforcement systems currently in operation: one in Birmingham and the other three in London. The Birmingham system is owned by the City Council, but is operated by its supplier Golden River Traffic Ltd. One of the London systems is owned and operated by BAA Heathrow, whilst the other two are owned by the Traffic Director for London, who also operates the systems in close co-operation with the Metropolitan Police.

BIRMINGHAM

The Birmingham Bus Lane Enforcement System depends on video camera and image processing equipment mounted either within an operational bus or at the roadside. The system digitally photographs vehicles in the bus lane 20m ahead of it and transmits the registration number of those vehicles to a Variable Message Sign (VMS) near the end of the bus lane. The digital images are stored and can be used for subsequent enforcement procedures (where the legal framework exists), whilst the VMS advises the driver that he/she has incorrectly used a bus lane and displays the offending vehicle's registration number. Both systems are fully automatic and therefore require no user intervention (6).

There are three common components used for both the Bus Mounted and Roadside Mounted Systems. Each of these components is further described below.

Automatic Number Plate Reader (ANPR)

The ANPR is an industrial Personal Computer (PC) based image processor. A colour video camera provides a wide-angle view of the offending vehicle, whilst a monochrome video camera gives a close up view of the vehicle's number plate. An Infra-Red (IR) illuminator enables operation in poor lighting conditions.

During the bus lane operating hours, the ANPR reads the number plates of all vehicles travelling 20m ahead of the cameras. The ANPR provides real time operation with

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automatic triggering during all lighting conditions. In order to minimise the recording of redundant information and thus speed off-line processing, a 'whitelist' of exempted vehicles (*e.g.* buses, taxis and emergency vehicles) is employed.

All number plate identifications that match those in the whitelist are discarded, along with the associated graphical images. If a number plate identification does not have a corresponding entry in the whitelist, it is recorded in a 'blacklist' of bus lane offenders, along with the associated date/time stamp and graphical images. The ANPR then sends a command via a radio modem to the VMS in order to display the number plate identification.
After the bus lane operating hours, the blacklist is automatically transferred to the Instation. A copy of the latest whitelist is then transferred from the Instation to the ANPR.

Roadside VMS

The VMS displays information about vehicles that are illegally using the bus lane using Light Emitting Diode (LED) technology. There are three lines of display with up to eight 140mm high characters in each. The first two lines are a fixed text message saying "BUS LANE OFFENCE" and the bottom line displays the alpha numeric text from the number plate of an offending vehicle. A typical legend is shown in Figure 1 opposite.

Figure 1 - Variable Message Sign

On transmission of a number plate identification from the ANPR via the radio modem link, there is a delay of no more than 2 seconds before the VMS displays the corresponding message. The legend display time is user configurable to suit local traffic conditions.

Instation

The Instation consists of a PC running application software under Windows 95. An attached colour printer facilitates images of offending vehicles being printed, a sample of which is shown in Figure 2 overleaf.

For each violation, the ANPR transfers a single Bus Lane Offence (BLO) file to the Instation PC. These sequentially numbered files contain the following information: text format number plate identification with a date and time stamp, Windows bitmap format

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graphical image of the vehicle registration plate and JPEG format graphical image of the vehicle.

The BLO file is separated into three files by the Instation application. The source file is then deleted. For each number plate identification transferred from the ANPR, the Instation compares the registration against the whitelist.

Any number plate identification that matches a record in the whitelist is discarded, along with the associated graphical images. Although this check is also performed by the ANPR, the Instation repeats this comparison as a double-check, particularly in case the whitelist has changed since the copy held by the ANPR. If a number plate identification does not have a corresponding entry in the whitelist, the three files are written to the blacklist database. The Instation allows the whitelist to be edited and makes it available to the ANPR.

Figure 2 - Printed Bus Lane Offence Record

Bus Mounted System

The Bus Mounted System is unique in that it is the first time an ANPR has been installed in a moving vehicle. It is also the first UK bus lane enforcement system to employ digital video technology. There are other components unique to the Bus Mounted system and each of these is further described below.

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A Power Conditioning and Control Unit (PCCU) carries out DC/DC conversion for the purposes of supplying power to the other Bus Mounted System components. It also features a 30 minute Uninterruptable Power Supply (UPS), in the event of the bus battery failing. The ANPR is informed whether or not the bus is in the bus lane by locating semi-passive microwave tags attached to street furniture alongside the bus lane. A wireless Local Area Network (LAN) provides a connection between the ANPR and Instation, allowing automatic transfer of data at speeds of up to 3Mbps.

Roadside Mounted System

The Roadside Mounted System employs a Public Switched Telephone Network (PSTN) modem connection for the transfer of blacklists to and whitelists from the Instation. All equipment is AC mains powered. The cameras are mounted on an existing lamppost, whilst the ANPR and associated modems are enclosed within a roadside cabinet.

Evaluation

In order that the effectiveness of the Bus Lane Enforcement System could be assessed, various surveys were undertaken before and after its installation. These were as follows: current bus lane offence levels, queue lengths, bus journey times and junction turning movement counts. The level of bus lane offences committed decreased by 60% between the before and after surveys. Average bus journey times decreased by 32% and, not surprisingly, reduced queuing in the bus lane was observed.

In addition to the before and after surveys, a survey of driver's attitudes was conducted. Of the 1150 postage-paid questionnaires distributed, a total of 120 were returned completed, i.e. 10.4%. 71% of the respondents used the Stratford Road bus lane every day and 88% were familiar with its operating rules. 73% of the respondents were already aware of the Bus Lane Enforcement system and 44% had seen it in operation.

At time of writing, the Roadside Mounted System surveys have yet to be completed. These results will be published at a later date, when available.

HEATHROW

The Heathrow Bus Lane Violation Detection & Deterrent (BLVDD) is very similar to the Roadside Mounted System in Birmingham, in that it is digital and employs the same ANPR to display the registration of offending vehicles on a VMS. BLVDD is installed on the 1.4km spur linking Junction 4 of the M4 motorway to Heathrow Airport. The bus lane won this year's British Construction Industry Small Project Award. As can be seen from Figure 3 overleaf, unlike the bus lane restrictions operating in Birmingham, taxis are not exempt from them (7).

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Figure 3 - M4 Spur Bus Lane

This additional restriction enables the system to clearly identify potential offenders by means of vehicle length. The only short vehicles exempt from the bus lane restrictions are those operated by the emergency services. These are filtered out using a whitelist, *i.e.* exactly the same way as is employed in Birmingham. The monochrome camera used to read the vehicle's number plate is also used to determine its length and speed. Previous investigations reviewing the length of Heathrow bound vehicles constructed to carry more than 8 passengers has resulted in a threshold value to be determined.

Both the monochrome and colour cameras are mounted on an overhead gantry. Just under 800m downstream, a customised version of a standard Highways Agency approved Enhanced Message Sign (EMS) is mounted on another gantry. This EMS employs LED technology to form two lines of twelve 320mm high characters and is shown opposite in Figure 4. The first line displays the registration of the offending vehicle, whilst the second line contains the fixed text message "IN BUS LANE". On detection of a bus lane offender, display of the corresponding number plate identification is delayed until the vehicle is calculated to have reached the EMS.

Figure 4 - BLVDD in Operation

In accordance with current Home Office requirements (8), all evidence is recorded onto a local Write Once Read Many (WORM) drive. Instead of just one colour image, two time-lapsed pictures are taken in an attempt to determine whether or not there was a valid reason for the driver straying into the bus lane. This does not, however, meet current Home Office requirements (5).

Despite the deployment of advance warning signs, bus lane offences are still observed during peak periods. As with the Birmingham systems, the VMS acts a very strong deterrent, by notifying both the actual and potential offender that an illegal act has been

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recorded. The effect this has had is to minimise the actual level of bus lane violations and eradicate occurrences of any repeat offences.

LONDON AREA SCHEME

The Traffic Director for London is presently employing two different bus lane enforcement systems as part of its Bus Lane Enforcement Cameras Project London Area Scheme (4). One of the Traffic Director's systems is roadside mounted, whilst the other is bus mounted. Both rely on SVHS Video Cassette Recorder (VCR) technology, rather than digital video images, as employed in the Birmingham and Heathrow systems. The main effect this has is to generate redundant information, because there is no way of distinguishing a valid bus lane user from a potential offender.

In common with all the current UK bus lane enforcement systems, the London Area Scheme uses dual CCD video cameras to provide both a context view of the scene and a close-up view enabling a vehicle's number plate to be read. Unlike any of the other systems, however, the SVHS recordings are continuous. The images from both cameras are multiplexed onto a single videotape to produce integral evidence. Both the Bus Mounted and Roadside Mounted Systems employ Rugby Clock receivers to determine the correct time.

Bus Mounted System

Both Bus Mounted System cameras are colour and do not rely on any additional illumination beyond that supplied by the existing bus headlamps. The SVHS VCR operates at 25 frames per second. Although the Bus Mounted System is connected to the bus battery, this is only used to recharge its own battery power source. Whilst recording, the Bus Mounted System is isolated from all bus power sources.

All the Bus Mounted Systems utilise an existing Automatic Vehicle Location (AVL) system installed by London Transport in order to determine whether or not the bus is in a bus lane and therefore whether or not to record data onto videotape. This works on a similar principle to the Birmingham system, in that it employs semi-passive microwave tags, although this time the tags are attached to the buses and the readers are located on the roadside at least once every 2.5km. The present location of the bus ±10m is overlaid onto the video recording and therefore forms part of the evidence.

Roadside Mounted System

The Roadside Mounted System has an identical camera arrangement to that employed in Birmingham, *i.e.* colour context camera and monochrome close-up camera with an IR illuminator. A time-lapse VCR automatically records the multiplexed camera signals at

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5 frames per second during the operating hours of the bus lane. This results in approximately 15 hours of continuous footage being generated per videotape.

Offence Viewing and Decision System

In common with the Birmingham Instation, the London Area Scheme employs a single Offence Viewing and Decision System (OVDS) capable of processing data generated by both the Bus and Roadside Mounted Systems. Whereas in Birmingham and Heathrow, the vast majority of data is evidence of bus lane offences having taken place, the OVDS requires the operator to manually playback all the videos retrieved, despite the fact that only a minority of the data is potentially evidence of an offence.

Footage that is deemed by the operator to have shown a bus lane violation must contain the following images to be admissible as evidence in the courts: a start image, followed by enforcement images, then an end image, plus a distance validation image (for the Bus Mounted System only). The enforcement images must contain the following data: day of week, date, time, sequential field counter, sequential recording number, site description, identity of last AVL beacon (for Bus Mounted System only) and distance in 0.01km (ditto). The start and end images must contain additional data to that already stated. For a start image: “start of recording” message, recording type and fleet number of the bus (for Bus Mounted System only). For an end image: “end of recording” message, recording type and reason for the termination. The distance validation image is recorded after the end image when the bus reaches the next AVL beacon. In addition to the data recorded as part of an enforcement image, the following must be recorded: “distance validation” message, the identity of the last AVL beacon passed and the result of the validation.

TYPE APPROVAL

At present, the only UK bus lane enforcement system to have been Type Approved by the Home Office is the Bus Mounted System provided as part of the London Area Scheme. Type Approval ensures that the evidence produced by the system is sufficient to achieve prosecution of the offending drivers. Guidance on the requirements and procedures for obtaining Type Approval have been published by the Police Scientific Development Branch (PSDB) (5). While it is a legal requirement for the equipment which detects, measures and records the evidence of a traffic offence to have Home Office Type Approval, this does not extend to the rest of the system (8).

For a bus mounted system, Type Approval procedures must be undertaken for every different model of bus onto which the equipment is installed. This involves taking a fully instrumented bus to an approved independent test house, where a series of rigorous environmental and Electro-Magnetic Compatibility (EMC) tests are undertaken. Installing extra electronic or electrical equipment on the bus could potentially invalidate any prior Type Approval granted for a particular bus mounted system (5).

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Although the two London Area Scheme bus lane enforcement systems were designed to meet the published Type Approval requirements, these will be revised to take into account the practical experience gained during the project. The requirements outlined below are expected to be included in the next issues of the relevant PSDB publications.

The minimum duration for an evidential recording is 20 seconds at 5 frames per second (9). Electronic or digital images are acceptable, as long as they are of sufficient quality to prove the offence. In order to reduce data transmission and/or storage costs, these images may be compressed in accordance with the ISO/IEC 10918-1 JPEG standard.

Even if a bus lane enforcement system employs a remote instation link for the retrieval of data, there is still a requirement for on-site Write Once Read Many (WORM) data storage as the primary evidential source (8). All data stored must employ a 16 bit Cyclic Redundancy Check (CRC) in accordance with the CCITT V41 standard.

In addition to the error checking facilities, data protection methods as used in the financial industry have to be applied to the offence data transmitted over a public or private data network (9). Authentication and encryption processes are in accordance with the Data Encryption Standard (DES) specified in ANSI X3.92 – 1981 or NBS FIPS 46, where the same block cipher is used for both authentication and encryption. The authentication process also follows the ANSI X9.9 and ISO/IEC 9797 – 1989 standards. The encryption process employs 64 bit Cypher Block Chaining (CBC) in accordance with ISO/IEC 10116. The security of the bus lane enforcement system is obviously dependent on the fact that both the authentication and encryption keys remain unknown by any third party (8).

CONCLUSION

In order to encourage more people to use buses, the UK Government has recently committed itself to giving buses greater priorities and improving information and networks. Police and local authorities are being asked to work together so that bus lane restrictions will be enforced on a route by route basis. The London Area Scheme Bus Lane Enforcement Cameras Project will be expanded throughout the city (10).

Both inside and outside London, the police do not possess the resources to enforce the bus lanes. Despite the fact that the Birmingham and Heathrow systems are not Type Approved by the Home Office, they have demonstrated that it is still possible to deter a bus lane violator from re-offending without actually enforcing the regulations.

The only Type Approved bus lane enforcement system employs analogue technology. It is envisaged that digital bus lane enforcement systems will gain Type Approval in the near future. Digital systems offer a number of advantages over their analogue counterparts. They open up the possibility of automatically transmitting evidence from the point of capture to an administrative centre, thereby saving both the time and money associated with manual collection. By employing ANPR, digital systems can also filter

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out redundant information via a whitelist of exempted vehicles. The addition of a VMS deterrent has been proven to be an effective means to increase the availability of a bus lane.

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