USING THE IBUS SYSTEM TO PROVIDE IMPROVED PUBLIC TRANSPORT INFORMATION AND APPLICATIONS FOR LONDON

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ABSTRACT

iBus is Transport for London (TfL)'s innovative GPS-enhanced Automated Vehicle Location System for improving bus fleet management and giving buses priority at traffic signals. Since 2007, the System has been rolled out to the contracted fleet of 8,000+ buses across London, leading to improvements in bus regularity and punctuality, and a reduction in average waiting times. The System also delivers real-time "next stop" signage and voice announcements for on board passengers, and is now being integrated with the ("Countdown") passenger information system at bus stops, to provide improved real-time predictions of vehicle arrivals. The System's implementation also provides an opportunity to derive other improved public transport information and applications, including profiles of typical journey and bus stop dwell times for management and operational reporting. Dwell times, for example, form an important component in overall bus journey times, and their variability can impact significantly on the effectiveness of systems such as SCOOT to provide bus priority, as well as on overall service performances. The ability to derive typical dwell times therefore helps TfL to optimise the effectiveness of SCOOT (and associated vehicles detectors) in providing bus priority, and their values have potentially wider use in public transport operations, traffic management and simulation modelling. For example, they could provide an improved understanding of the expected delay of vehicles bus stops (and the knock-on impact on other traffic), and help predict more effectively the expected journey times for buses (and other vehicles) in London.

Keywords: Public transport, automated vehicle location, transit operations, bus priority, urban traffic control, fleet management, bus stop design, real-time passenger information, operator headway, bus performance, dwell time.

INTRODUCTION

Transport for London (TfL) is one of the largest public transport "providers" in Great Britain (Department for Transport, 2008). It owns the roadside infrastructure necessary to support bus operations, including traffic signals and priority systems, as well as the franchised contracts allocated to independent transport companies, who operate the bus services. TfL plans the individual routes, specifies the required service frequencies, and monitors the quality of service provided by the contracted operators.

From mid-2007 to the end of 2009, TfL has been rolling out "iBus", a GPS-enhanced Automated Vehicle Location (AVL) System, across its contracted fleet of 8,000+ vehicles throughout London, with the aim of improving bus regularity and punctuality through improved fleet management and operations, and giving these vehicles priority at traffic signals. *iBus* provides Fleet Managers in operators' bus garages with graphical visualisation tools, which help them manage the increasing throughput of vehicles on London's roads. As the location of buses is known at all times, Fleet Managers can "see" their status relative to scheduled frequencies or "headways" (the time between buses), and take pro-active action to improve the overall service, for example by asking drivers to expedite boarding, take adjustments in route, or to alter the speed of their vehicles, where permitted. Such active fleet management has lead to improvements in the bus service regularity, more consistent passenger waiting times at bus stops, and reduces time delays in transit. Additional time savings are achieved (Transport for London, 2006a) by integrating iBus with traffic signal control systems to give buses priority, by either extending the green phase to enable vehicles to pass the signal junction, or curtailing other traffic stages (or "recalling") to reduce the wait time for the signal to turn green for the bus.

THE iBUS SYSTEM

iBus is based on an AVL package, which has been scaled, extended and customised to meet TfL's strategic and operational business needs. The System is complex technically and widely distributed, with software and computer equipment residing in each vehicle, as well as in operators' bus garages, and at TfL's two Bus Network Control Centres in Central and North-East London. The System is essentially made up of four inter-connected components (see Figure 1):

1. an "on-board" unit mounted in each bus (Item L in Figure 1);
2. a "data server" (or large personal computer) at individual bus garages (Item O);
3. a central "system server" (or powerful computer) located remotely (Item K), which holds the master records of bus routes, their timing points, operating frequencies, as well as, for example, the locations of detectors for giving bus priority at signals; and
4. local and user "databases" (Items A and B), together with a "core system", which are used for bus network management and management reporting.

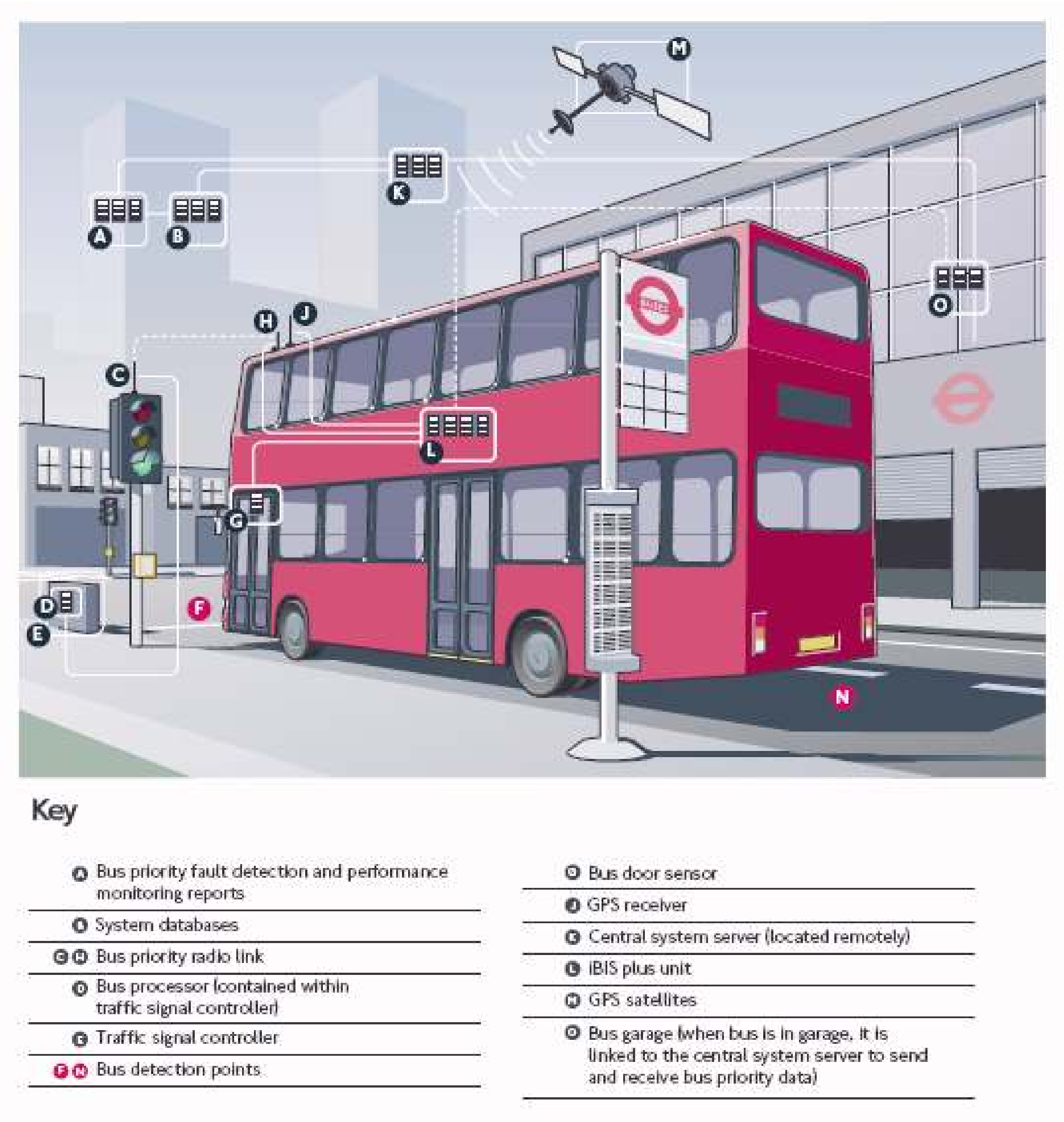

Figure 1 – Overview of iBus System *(Source: Transport for London, 2006a)*

System Components

The *on-board unit* (OBU) essentially comprises a computer chip, with iBus software loaded, which is connected to the vehicle's door sensors (Item G) and a Global Positioning System (GPS) receiver mounted on the roof (Item J). The OBU logs the real-time (second-by-second) GPS location of the vehicle, as well as the occurrence of certain "events", for example, it timestamps when the doors are opened or closed.

The OBU sends regular location updates (approximately every 30 seconds) via mobile telecommunication messages to the *core system* (not shown in Figure 1), which can be viewed by bus Fleet Managers in operators' garages, as well as in the two TfL Control Centres. The location of every vehicle is displayed against route and geographical maps in the core system, along with their performance relative to the scheduled frequency or headway for that route, e.g. whether "early", "on-time", or "late" (as defined in the system).

In addition to GPS, each vehicle is supported by a traditional "dead reckoning" (i.e. odometer and gyroscope) system, with optimisation and "map matching" software, to improve the detection of the bus' absolute and relative positions. The OBU is also connected to a transmitter mounted on the roof of each vehicle (Item H), which can send radio "telegrams" to request bus priority from individual traffic signal "controllers" (Item E) via their aerials (Item C).

When buses return to their depots (at the end of each "block" of trips), their OBUs are connected to the garage's *data server* through a wireless Local Area Network (LAN). This in turn, provides a link to the remote central *system server* for the purpose of downloading new route and/or detector locations into the OBUs, and to upload their individual event "log" files. The event log files are then consolidated centrally, to provide local *databases* for users, which are used for information storage, historical analysis, and management reporting.

APPLICATIONS OF iBUS INFORMATION

The implementation of iBus and its associated data has already lead to improvements in fleet management and bus operations, and has the potential to provide many further operational and strategic benefits for TfL, bus passengers and operators.

Fleet Management and Operations

According to Transport for London (2010), the deployment of iBus and other associated measures has already contributed significantly to improvements in the operation of the London bus network, including the ability to provide more routes and services. For example, there has been a reduction in the average actual waiting time for "high frequency" services (or those with a frequency of five or more buses an hour), from 5.7 minutes in 2006 to 5.5 minutes in 2009 (see Figure 2). The excess waiting time, representing the additional wait experienced by passengers due to the irregular spacing of buses or those that failed to run, has also reduced slightly over the same period, from an average of 1.14 minutes in 2006 to 1.12 minutes in 2009 (Figure 2). These few seconds may not seem significant, unless taken in the context of the increased traffic congestion in London, as illustrated by the percentage of bus kilometres lost due to this cause, from 1.7% in 2006 to 2.3% in 2009 (see Figure 3), and the year-on-year increases in passenger demand, and the number of bus kilometres operated (e.g. an extra 11 Million passenger journeys, and a further 5.1 Million bus kilometres operated between 2008 and 2009 alone).

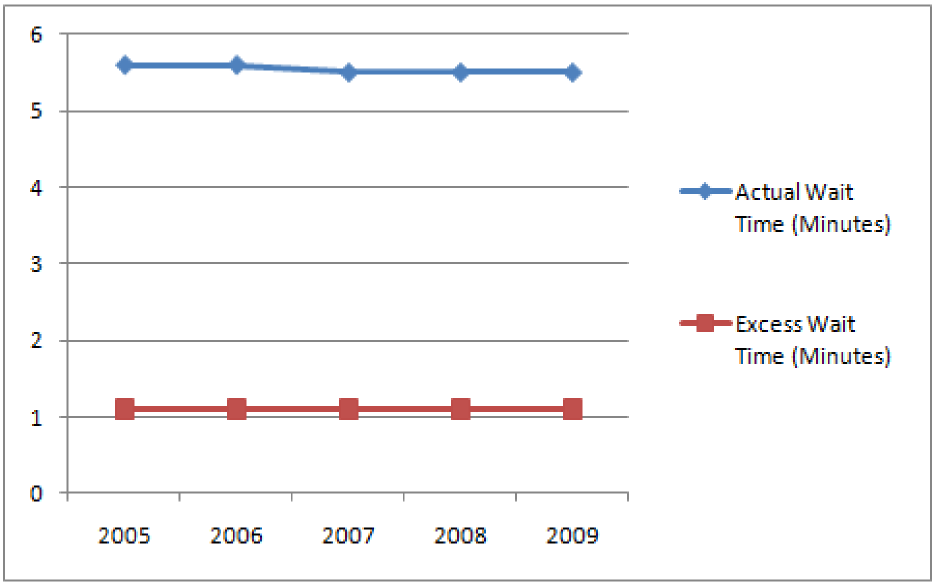

Figure 2 – Percentage of Bus Kilometres Lost Due to Traffic Congestion versus Other Causes for "High Frequency" Services (Source: Transport for London, 2010)

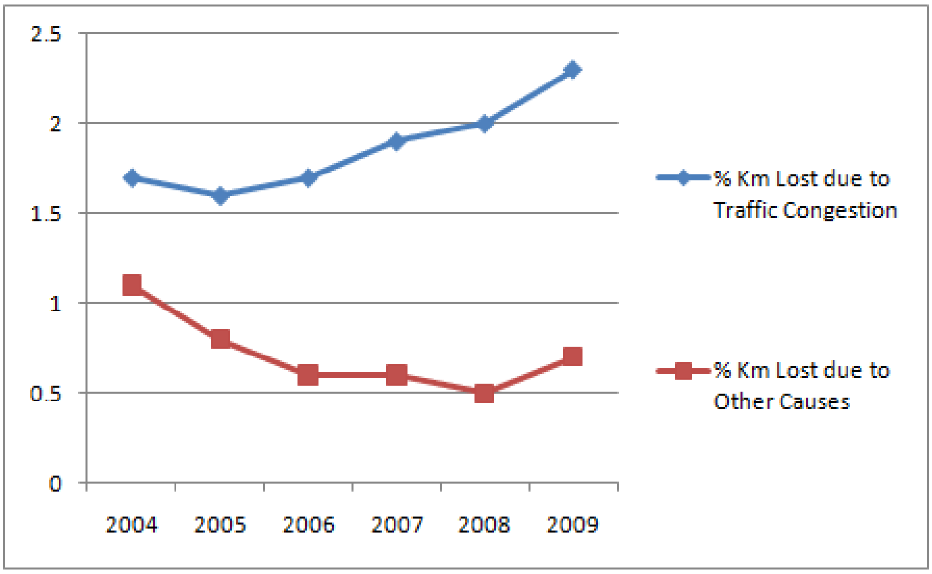

Figure 3 – Percentage of Bus Kilometres Lost Due to Traffic Congestion versus Other Causes for "High Frequency" Services (Source: Transport for London, 2010)

Similarly (Transport for London, 2010), for "low frequency" services (or those with a frequency of four or less buses an hour), the percentage of vehicles running "on-time" has improved (see Figure 4), from e.g. 79.1% in 2008 to 80.8% in 2009, and all these trends are expected to continue in 2010.

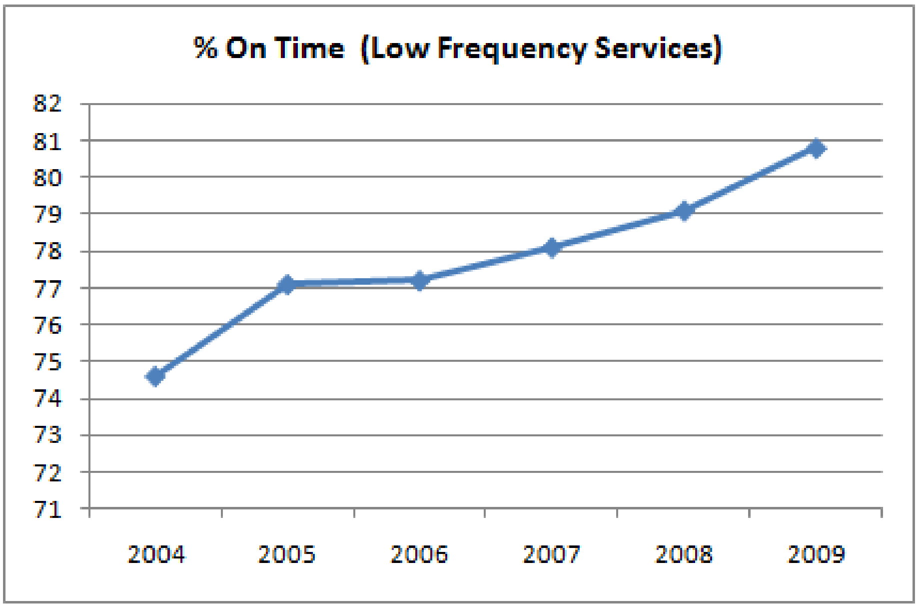

Figure 4 – Percentage of Buses “On Time” for “Low Frequency” Services
(Source: Transport for London, 2010)

Vehicle Detection and Traffic Signal Priority

Historically (Hounsell et al, 2005), bus priority in London has been achieved using infrastructure-based systems, which engage, for example, in-road inductive loops or physical road-side beacons with associated vehicle transponders to identify buses on approach, and provide them with a green time extension or recall at the signal. However, these physical infrastructure-based “Selective Vehicle Detection” (SVD) systems are becoming increasingly outdated, as they are relatively expensive to install and maintain, so are no longer being applied to London’s signal junctions (Transport for London, 2006a). The inductive loops, for example, typically provide vehicle detection in one direction only, and are permanently embedded into the road, so are difficult to modify or remove. They are also subject to the effects of road works, or whenever the road is dug up for other reasons. Typically, these systems also do not provide for the detection of separate buses for assigning priority, and therefore do not differentiate between those vehicles that are running “late” (i.e. warranting priority), and those that are “early” or “on time” (for which priority is squandered).

With iBus, SVD is triggered through the use of “virtual” detectors. These pinpoint, using a set of GPS longitude and latitude coordinates, the designated detector locations associated with each signal junction (such as a bus stop on approach), and are loaded regularly onto the OBU of vehicles. When a vehicle travels past a designated area, e.g. two metres upstream of the associated virtual detector, its system generates a bus priority telegram and transmits this request by radio to the traffic signal controller. The iBus virtual detectors may therefore be used at many more new junction sites to detect vehicles for triggering bus priority, or to replace (or supplement) existing physical SVD detector locations, as they do not require road-side infrastructure changes.

The execution of the bus priority request at the signal can be made locally or centrally (Hounsell and Shrestha, 2005). At “stand-alone” junctions, for example, a “bus processor” or computer chip typically resides within the traffic signal controller, which takes the priority request sent by the vehicle, and acts with the controller to determine “locally” whether an extension or recall could be granted. However, where the signal forms part of a wider SCOOT Urban Traffic Control (UTC) network, the request “message” is usually relayed to the “central” SCOOT software (or “kernel”), which then determines whether priority can be granted by the signal.

Because the status of vehicles relative to scheduled headways is also determined by iBus, the System offers TfL (Hounsell and Shrestha, 2009) the potential to implement “differential” bus priority at signals, whereby priority is given according to the individual needs of vehicles, e.g. depending on differing thresholds of regularity or being “late”. This form of priority helps to reduce the impact on other traffic, and leads to more regular and improved journey times for buses overall.

Real-Time Arrivals/Stop Information for Passengers

Increasingly, the accessibility and exchange of information to transport users (e.g. Marsden et al, 2010), must be seen as important (and sometimes even more so), as the mode of travel itself, and people’s choices can be influenced by the accuracy, availability and timeliness of the information they are given. For this reason, iBus provides real-time route, destination and next-stop signage (and associated voice announcements) for the benefit of passengers on board (See Figure 5a). It is also being integrated with the “Countdown” information displays at bus stops (Transport for London, 2009), to provide improved real-time predictions of vehicle arrivals (see Figure 5a), and (from 2010) passengers will be able to obtain details of upcoming bus arrivals at a bus stop by text message through their mobile phones (see Figure 5c).

Figure 5a - Real-time Signage “On Board” Vehicles

Figure 5b - “Countdown” Sign of Predicted Arrivals at Bus Stop

Figure 5c - Upcoming Arrivals by Text Message for Bus Stop 24356

(*Source: Transport for London, 2010*)

Management Information and Reporting

The iBus databases also provide a rich source of bus network management information for reporting. The bus event log files and databases provide a vast repository of operational information collected by London's buses, including vehicles' real-time GPS locations and messages of their interactions with traffic signals, as well as trip journeys times, relative headways, and average speeds on route.

The System has already been used by TfL to provide data on average (route) journey times and to show, for example (Hardy, 2009), how time delay savings could be achieved through the use of integrated bus/signal priority measures. The data can also be analysed to provide, for example, a chronology of vehicles trips or reports of bus journey times between specific signal junctions and bus stops. The journey time performance of individual links, operators, or even parts of the network, can also be established over time, and this information used to identify where problems persist (e.g. links where buses are frequently delayed), and/or where priority at additional signals could help reduce delays further.

Integration of End-to-end Passenger Journey Times

Intuitively, the origin-destination pair of many bus passenger journeys do not lie solely on a single route. For example, bus services from the main shopping districts (e.g. the "West End") or the business districts (e.g. the "City") do not cover many popular residential parts of London (e.g. Wimbledon). These passengers must either change services to go shopping/get to work, or use other modes of transport (e.g. underground, rail or tram). Historically, journey time information has been individual route based, and it has not been possible to provide multi-bus passengers with end-to-end journey times, except based on the concatenation of published schedules between recognised "timing points", where these are available. However, with real-time journey information now being stored by iBus, the potential for *whole* journey time information integration (and estimation) for passengers across different routes, e.g. as suggested by Potter (2010), becomes a technical possibility, which in itself may provide further information for the effective design of commonly-used bus interchanges (e.g. at Clapham Junction or Vauxhall).

Bus Stop Dwell Times

Discussions with TfL have also indicated that the iBus information could be used to develop profiles of typical bus stop dwell times in London, which are needed for a variety of purposes. Dwell time values have wide applications in public transport operations, traffic management and simulation modelling, and could provide an improved understanding of the expected delay of vehicles at London bus stops, and therefore their impact on other traffic, and help predict more effectively the expected journey times for buses and other vehicles. Dwell time profiles could also help TfL to optimise the location *and* effectiveness of vehicle detectors in providing bus priority. For example, it has been TfL's policy traditionally (Hounsell and McLeod, 1998) to site bus priority detectors at 60 metres *upstream* of the signal stop line, to provide the maximum benefits in terms of time delay savings. However, where a bus stop lies close to the traffic signal, detectors have been sited *downstream* of the bus stop, i.e. short of 60 metres upstream to the stop line, to avoid the need to account for the unpredictability (both duration and variability) in the bus stop dwell time, which impacts the effectiveness of SCOOT in providing priority or time delay savings to a given vehicle. The delay savings from priority are therefore limited (Hounsell et al, 2004) where stops are closed to signals, and although there is the option to relocate bus stops further *upstream* to the junction, this is not always feasible (e.g. because of road layout) or desirable for passengers. Although SCOOT has the capability to support detectors sited *upstream* of bus stops, its effectiveness is limited by the ability to accurately predict a “BUS VARY” parameter, or the variability in the bus stop dwell time due to various factors, such as the type of stop, and the time of day. In the past, this has required the use of *additional* detectors, e.g. downstream of the bus stop or near the signal stop line, to compensate for inaccurate vehicle journey time predictions derived from the upstream detector. The effectiveness of SCOOT to implement bus priority using detectors *upstream* of bus stops can therefore be improved significantly by providing *BUS VARY* values which are obtained from live data at each site, and the development of typical dwell time profiles from iBus provides an opportunity to supply SCOOT with improved indicative values.

Indeed, bus stop dwell times for London have not been analysed publicly for nearly 20 years (York, 1993), and many contributory parameters, such as the composition of vehicle fleets, population density/demographics (or passenger demand), ticketing arrangements, and road traffic conditions/congestion have all changed in that time (Transport for London, 2006b). Day-to-day bus operations are now almost unrecognisable from before, e.g. with the retirement of all “Routemaster” buses and other vehicle changes (all vehicles now have low floors, and no steps), the move solely to one-man operations, and the introduction of the Oyster card and other “cashless” boarding initiatives (e.g. ticket machines at bus stops), which are likely to have effects on typical passenger boarding and/or alighting times. Therefore, on-going profiling of bus stop dwell times could also be used to provide “before” and “after” indicators for assessing the performance of new boarding, ticketing and other innovative technology measures aimed at reducing dwell (and therefore overall bus journey) times, and improving the attractiveness of this mode of public transport.

CONCLUSION

The introduction of iBus has already resulted in tangible improvements to the operation of the London bus network, including a reduction in waiting times. The System is now being used to provide further public transport information and applications for Fleet Managers and bus passengers, including improved real-time bus travel information, as well as more effective vehicle detection and operation of priority for buses at signals; and it has the potential to provide other bus-related operational information, including reports of bus journey times for management reporting, and the derivation of typical bus stop dwell times, which has many uses in public transport operations, traffic management, and simulation modelling.

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