AVL based Bus Priority at Traffic Signals: A Review and Case Study of Architectures

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Recent developments in technologies such as Automatic Vehicle Location (AVL) and advanced control systems have stimulated new interest in bus priority facilities using traffic signals. The use of AVL systems has generated opportunities for implementing flexible bus-specific priority strategies according to performance. The extent of the opportunities available depends very much on the architecture of a bus priority system, including the location(s) of intelligence determining the priority level and its implementation, and the method of priority request to the traffic signal. These aspects are important from the point of view of bus priority performance, communication requirements and the cost of the system.

This paper draws together and compares the various architectures currently being used for AVL-based bus priority, providing an overall review to supplement other papers which are usually concerned with individual systems. The paper reviews current bus priority systems used across Europe under five different architecture categories. The present bus priority architecture in London is then analysed in more detail as a case study. The paper concludes with a discussion of issues for this application, given the continuing advances in locations and communication technologies, and issues for the future.

1. Introduction

Bus priority remains one of the principal strategies adopted in many towns and cities to improve levels of service for bus passengers and to encourage modal change. With growing interest in the system, continuous research is being carried out to make existing systems more efficient by using new detection techniques (e.g. Hounsell et al., 2004) and new strategies such as intermittent bus lanes (Viegas et al., 2004). Against this background, this paper concentrates on new systems which have been implemented recently, rather than those still within the Research and Development phase.

AVL systems now make it possible to integrate bus priority at traffic signals with other applications such as Real Time Passenger Information (RTPI). This integrated approach has now prompted more bus priority systems around Europe such as Twente in the Netherlands (Witbreuk et al., 2004) and several schemes in the UK (e.g. Glover et al., 2003). The use of AVL systems has generated a wide range of opportunities within bus priority such as using AVL to identify late running buses so that they can be targeted for higher level of priority at traffic signals. In a similar way, AVL can be used to identify levels of headway irregularity in high frequency services, again allowing specific buses to be targeted for higher priority. This method of giving varying levels of priority is sometimes also known as 'Differential Priority'. This type of bus priority is currently in use in many European cities such as London (Hounsell et al, 1999), Toulouse (PRISCILLA, 2002a) and Aalborg (Nor et al., 1998).

With the growing number of differential priority schemes, it is apparent that a wide range of architectures are being employed in different cities to achieve the objectives (PRISCILLA, 2002a). For example, there are differences in priority assessment intelligence, the method of priority request and the means of implementation. Variations in bus priority architectures are usually due to the evolutionary approach of improving a bus priority system in the existing infrastructure (rather than a revolutionary approach). The existing infrastructure influencing the priority architecture mainly include exiting traffic control method and communications facilities.

A comparison of the effectiveness of these different bus priority architectures is complicated because priority benefits depend on a number of factors, such as existing bus delays prior to the bus priority, traffic conditions on the bus network, efficiency of the traffic control systems etc. So, there is some literature (e.g. Hounsell et al., 2002, Jones, 1998) categorising the available priority architectures rather than comparing them to find the best suited one. In this context, this paper attempts to identify the important aspects of bus priority architecture and compare the different options available within each component, thus filling a knowledge gap in this application.

The methodology for the research reported in this paper has been a critical review of international literature on the topic and a comparative analysis of alternatives. This approach has been necessary because of a lack of reported, quantified results of the effectiveness of different architectures, which might otherwise have allowed a more rigorous statistical comparison of them. For the latest published information on performance, readers are referred to Deliverable 4 (Evaluation Results) of the PRISCILLA Project (PRISCILLA, 2002b)

2. Bus priority architecture

The performance of a bus priority system and the facilities available for priority depend on the architecture of the system. The priority architecture shows the overall picture of how a bus gets priority at traffic signals. In its most simple form, a bus approaching a signalised junction is detected upstream of the junction and a priority request is communicated to the traffic signal controller. In this case, both the bus detection and the traffic signal priority is undertaken locally on a route. Here, all detected buses are eligible for priority and may get priority at all signals. In a more complex form, the signals may be operated under UTC (Urban Traffic Control), and bus location is implemented by an AVL system. This adds two further 'centralised' dimensions to the bus priority system. In such a case, the priority decision may be taken fully or partially by the central UTC taking account of the coordination with adjacent traffic signals and other factors as specified. Additionally, the location information of buses available at the AVL centre is used to determine their priority need. These 4 main components (Bus, AVL centre, Traffic controller and UTC) of an AVL-based bus priority system at traffic signals are linked by communication systems to pass information from one to another. A simple representation of this bus priority architecture with typical links between different components is shown in Figure 1.

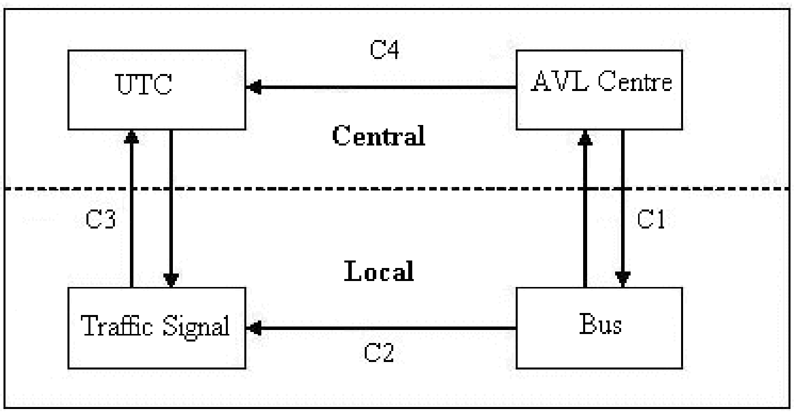


Figure 1. A simple illustration of bus priority architecture

In Figure 1, 'C#' represents a communication link between two components. The 'C1' link is necessary to monitor bus locations from the AVL centre and to pass a priority request level (PLR) if this is assessed at the AVL centre. Communication link 'C3' keeps a traffic signal under the control of the UTC system. The linking between the AVL centre and UTC (C4) and the linking between each bus and each traffic signal (C2) are necessary to pass priority requests to the traffic signals. Some of these links may be one way or two way and some may not be used depending on the way of working of the priority system i.e. the priority architecture. The key questions leading to different architectures include:

- Where is the priority request determined? – Location of 'intelligence'
- How is a priority request passed? – Priority request method
- Where is the priority decision taken? – Location of priority control

These three aspects of bus priority architecture can affect bus priority performance, communication requirements and the cost of the priority system. These aspects are discussed in the following sections.

3. Review of main aspects of bus priority architectures

3.1 Location of 'Intelligence'

The 'intelligence' termed here is the component that determines the priority requirement of a bus based on predefined criteria using bus locations available from the AVL system. For example, differential priority used in London determines the priority level request (PLR) on the basis of the gap between buses (headway) relative to the scheduled frequency. The 'intelligence' may be located at central level (e.g. multi purpose AVL centre) or local level (bus or traffic controller). There are some advantages and disadvantages of both locations of 'intelligence'. These are described and discussed in subsequent sub-sections.

'Intelligence' at local level
At the local level, the 'intelligence' equipment can be located either inside each traffic signal controller or inside each bus. For this discussion, equipment in the traffic signal controller will be termed the 'in-controller priority processor' (ICPP) while that inside a bus will be termed the 'on-board priority processor' (OBPP). In the first case, the ICPP stores the priority criteria required to determine the PLR. It needs also to store the detection time of earlier buses to determine headways. Once a bus is detected on the approach of a traffic signal, the ICPP calculates the headway with the last bus and decides the PLR. The PLR is then passed to the signal controller for implementation. This is a simple system and is capable of providing headway based priority similar to the one used in London. This is for high frequency services where regular headways are sought; the priority in this example is based solely on the ratio of the headway to the bus in front to the scheduled headway. The higher this ratio, the higher is the priority level.

In the second case, the OBPP stores the priority criteria required to determine the PLR. However, even in this case, the detection time of an earlier bus still needs to be stored at the ICPP. This is easier than requiring the bus to store the time of the previous bus for the headway calculation. Once a bus is detected at the approach of a traffic signal, the ICPP sends the detection time of the earlier bus to OBPP. The OBPP then calculates the headway and determines its PLR depending on the priority logic. The PLR is then transmitted to the signal controller for implementation. This is more complicated than intelligence in the ICPP in the case when the headway based priority is given to the buses. However, in the case of low frequency services, a bus may calculate its deviation (i.e. lateness) from the scheduled timetable on-board and determine its PLR. This is more efficient method of calculating priority requirement of buses operated under a timetable service.

With the use of 'intelligence' at the local level, the priority requirement is calculated inside a bus or signal controller depending on the system architecture. Hence, no communication link is necessary between buses and the AVL centre (if there is any) to transmit priority level requests. This may also avoid the requirement of an AVL centre for this application if buses can locate themselves with onboard navigation equipment (e.g. GPS receiver). However, it should be noted here that AVL is often implemented for other functions, particularly bus fleet management and real time passenger information (RTPI).

With intelligence at the local level, lateness will be based on the last bus/buses only. The approaching bus with a higher headway will get priority even if the headway of the bus following it is much higher than that. In such a case, the headway between these buses may worsen. Additionally, the priority requirement of buses is determined based on the predefined criteria. Any recent changes in the network affecting performance of the buses and requiring an alteration in the bus priority criteria is not possible. Additionally, it restricts the change of bus fleet from one to another bus route as it requires buses to have route related criteria and coding to calculate the priority need. If a change in fleet on a route occurs, then the buses would need to have all the new route related data to get priority at traffic signals. This requires careful checks to be carried out to make sure that the bus on the route has the correct priority information. This may induce a bigger operational cost burden on the bus operators.

Intelligence at central level
With 'intelligence' at the central level, an AVL centre monitors bus locations in real time. This gives an overall view of the performance of the buses in the whole network. This provides an opportunity to devise priority strategies based on the buses in the whole route or even the whole network.

The main advantage of having central intelligence is the availability of up to date information of bus locations in a network at one place. This provides opportunities for more control on the bus priority at traffic signals and multi-purpose use of the AVL data. With intelligence at the central level, a 'Dynamic' priority (time varying) action can be implemented. 'Dynamic' here is in the sense that the priority criteria may be altered in real time to favour a bus or buses on a whole route or a part of the route. The alteration of the priority criteria can be done instantaneously and the duration of the altered criteria can vary depending on the network performance. Moreover, the availability of central AVL data makes system integration with a Real Time Passenger Information (RTPI) system easier: As RTPI is a main driving force for using AVL in public transport within the UK, there is a greater prospect for using bus priority also if intelligence is at the central level, alongside the RTPI system.

Using intelligence at the central level, a reliable and frequent communication is required to transmit data to buses within a short span of time. This can require a significant communication capacity and cost and may necessitate a particular type of dedicated radio communication system. The capital and operating cost of this would need to be compared against the advantages (for priority) of being able to implement more flexible priority strategies.

3.2 Priority request method

Once the priority requirement is determined, the request needs to be sent to the traffic controller for its implementation. The traffic signal then changes its timings in favour of the approaching bus. If the intelligence for determining priority is at the local level, the priority is requested by the bus to the traffic controller. However, if the intelligence is at the AVL centre, then there are 2 ways of requesting priority for the approaching bus at a traffic signal. The control centre may send the priority request directly to UTC for processing onward implementation at the traffic signal controller or priority may be requested via the bus onwards to the local traffic controller. These two methods of requesting priority are sometimes also categorised as centralised and decentralised communication systems (Hounsell et al, 1999) as discussed below.

3.2.1 Centralised communications

In this architecture, the control centre (determining the priority requirement) directly passes requests to the UTC system to give priority to an approaching bus at a particular traffic signal. The UTC then calculates the possibility of implementing changes in the stage. This information about changes in signal timings is then transmitted to the local controller to implement. The local controller where the bus is approaching will change the traffic signal to favour the bus, depending on the UTC instruction. This type of system is adopted in Toulouse (France).

The main advantage of this type of system is the reduced infrastructure cost. Since priority is requested directly from the AVL centre to UTC, this architecture does not need on-street infrastructure for bus detection to activate a priority request. Communication costs can also be reduced as there is no communication of priority information from the centre to each bus. This type of system can also reduce the communication delay while implementing priority where the priority decision is taken at UTC level only. In such a central control system (section 2.3.1), the time needed to pass information to and from the local controller to UTC can be avoided using centralised communications. The savings may be in the range of 5 seconds which may be very beneficial for buses arriving towards the end of the green period.

Bus location may be achieved using GPS, with virtual detectors (VD) being programmed into the on-board processor such that, when the bus reaches each VD it communicates its location/time to the AVL centre. Priority requirements are then determined centrally. The other common way of determining bus location is through sequential ‘polling’, where the AVL centre communicates regularly with each bus in sequence to request its location. This may be sufficient for fleet management/passenger information purposes, but it is not ideal for bus priority purposes. In general, the AVL centre polls buses every 10-30 seconds to get its latest position in the route. During that time interval, the AVL centre has to rely on the bus location at its last polling to estimate when a bus is approaching the traffic signal. If the bus is at a bus stop during this time interval, then it is extremely difficult to estimate its arrival time at the signal accurately. In the worst case, the bus may miss the awarded priority and the priority is completely wasted. However, the centralised system works efficiently if the journey time of buses can be predicted quite accurately and locational updates are frequent. The system used in bus priority lanes in Toulouse, France (PRISCILLA, 2002a) is a good example of such system.

3.2.2 Decentralised communications

In this method, the control centre sends the priority request to a bus approaching a traffic signal after determination of its priority requirements. The bus then communicates to the traffic signal just before approaching the traffic signal for priority implementation. This type of communication architecture was trialled first in London and is adopted generally in recent systems in the UK. Such a method of requesting priority in conjunction with a GPS based AVL system is used in places such as Cardiff (Hill, 2000) and Leicester (Gillam and Wright, 2000).

The main advantage of a decentralised system is the accuracy in estimation of bus arrival time at the signal. Since the priority is requested when a bus is detected on the approach, its location is precisely known and hence its estimated arrival time can be more accurately calculated. In this process, any local effects on a link affecting journey time of a bus, before the detection point, are reduced. This more accurate estimation of arrival time than from a centralised system reduces the wastage of the priority given. Furthermore, this system can also be implemented at isolated signal-controlled junctions.

This type of system requires a detection system to activate priority for a bus approaching a traffic signal. The detection system may require field infrastructure such as loop detectors or beacons which induce extra costs for installation and maintenance. Alternatively, detection may be carried out with 'virtual' detectors (i.e. co-ordinates of the required bus detection location) if GPS is used. This has the advantages of flexibility and reduced cost (of infrastructure) with the further potential of providing multiple detection points to monitor bus progress more accurately. There may be some reduction in benefits as GPS locational accuracy (typically ±10 metres) is not as good as for fixed detectors/beacons, but the loss should be relatively small. This architecture needs communication links to transmit priority requests from the AVL centre to the bus and from the bus to the signal, making it relatively more expensive compared to the centralised alternative.

3.3 Location of priority control

The priority request from a bus is only implemented when the traffic signal controller 'decides' to do that. The decision to implement the priority request is very important in terms of the performance of a bus priority system. This issue of priority control location comes into the picture particularly when traffic signals are controlled under a UTC system. In this case, the decision may be taken at the central level (UTC) or at the local level (signal controller) depending on the type of signal controlling system available. (The choice of having the decision at the local or central level only occurs when the priority is requested via decentralised communication (3.2.2)). In the case of centralised communication (3.2.1) the AVL centre directly sends the priority request to UTC where the priority decision is taken. The implication of these two choices of priority control on the bus priority system is discussed below.

Central control

This is applicable to the case when traffic signals are controlled under coordinated UTC system such as SCOOT. In coordinated systems, the priority decision is normally taken by the central UTC to take account of the adjacent network of signals. In such a system, the priority request is passed directly to the UTC centre. The central UTC system calculates the possibility of providing the required priority based on the various parameters such as signal timings, degree of saturation and signal coordination. It then sends the changed signal timing (if any) to the local controller. The local controller changes the stage timing according to the instruction from the UTC.

The main advantage of such a system is that the priority decision is taken on a more coordinated approach. The impact of bus priority on general traffic is minimised by taking a network of junctions into account rather than a single junction at which a bus is approaching. The optimisation by UTC makes sure that the overall delay in the network is a minimum as a result of bus priority.

The main drawback of a central control system is the communication time necessary to send the priority request from a local controller to the central UTC and the decision to be made and returned. This communication delay could restrict buses arriving at the end part of the green in gaining a priority green extension depending on the location of the bus detector. This reduces the bus delay savings from bus priority where bus detection is closer to the junction. It may appear that this problem could be minimised by detecting buses further upstream from the signals. However, that ‘solution’ can make bus journey time (detector to stopline) more variable and difficult to predict, particularly in congested conditions or where bus stops exist.

Local control

In this method, the local signal controller has authority to give priority to the approaching bus once the bus requests priority. This type of control is applicable to the traffic signals whether they are coordinated or isolated. However, in coordinated systems, there may be a partial facility for a local decision on priority. For example, the SCOOT UTC system has the facility to provide a green extension at the local level within a given regime determined previously in the cycle by the central UTC. However, even in this case, the decision of a priority recall is carried out by the UTC itself.

Local control removes the communication delay problem between the priority request and its implementation. This is particularly useful for buses arriving towards the end of the green period. Buses detected at the end part of the green, which would not get extension in the case of central control, are able to get an extension in local control. This increases the bus delay savings from priority at traffic signals. Field trials in London have shown that the use of local extensions can increases bus delay savings in the range of 1 - 2 seconds per bus per junction (Bowen et al, 1996).

3.4 Summary

Based on the above discussion, options available within different aspects of bus priority architecture are summarised in table 1.

Table 1. Options available within different aspects of bus priority architectures

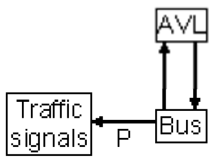
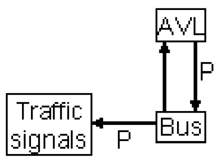
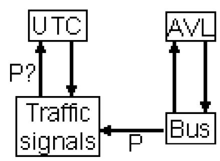
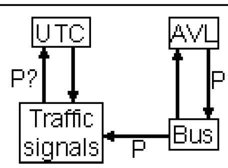
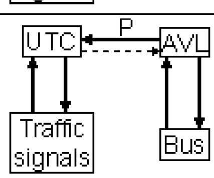
Aspect	**Comments**
Intelligence	
Local	Simple and efficient method Less communication requirement More suitable for timetable service e.g. Architecture category A1 and B1 (Table 2)
Central	Possibility of network based bus priority (e.g. dynamic priority) Compatible with multi purpose use of the data (e.g. RTPI) More suitable for headway based service. e.g. Architecture category A2, B2 and B3 (Table 2)
Priority request	
Decentralised	More accurate priority request Applicable to both UTC controlled as well as isolated junctions Needs extra infrastructure and communications e.g. Architecture category A1, A2, B1 and B2 (Table 2)
Centralised	Needs lesser infrastructure Applicable to signals under UTC system and central level 'intelligence' only. e.g. Architecture category B3 (Table 2)
Priority decision	
Local controller	Instant implementation gives higher potential delay savings Often more complex to implement in signals under UTC system e.g. Architecture category A1, A2 and B2 (Table 2)
Central UTC	Takes account of signal coordination and hence lesser impact to the general traffic Applicable to the signals under UTC system only. e.g. Category B1, B2 and B3 (Table 2)

Table 1 shows that the available options within the different aspects of priority architecture have advantages as well as disadvantages. Beside the trade-off between advantages and disadvantages, the appropriateness of an option is also dependent on the facilities in the existing traffic control system. For example, if there is no UTC system, the priority request needs to be 'decentralised' and the priority decision needs to be taken at the 'local controller'. The choice of a traffic control system may or may not be influenced by the bus priority facility it can support. Hence, there are different bus priority architectures used across Europe depending on the requirement and the existing resources available. Possible priority architectures as a combination of different options available are described and discussed in the next section.

4. Comparison of bus priority architectures available

Depending on the different options available within each aspect discussed earlier, different AVL based bus priority systems used across Europe can be categorised into 5 different bus priority architectures. These architectures are based on 8 bus priority system architectures identified earlier by European funded PRISCILLA project (Hounsell et al, 2002a). These 5 bus priority architecture categories are diagrammatically represented and categorised in table 2.

Table 2: Examples of different AVL based bus priority architectures

Category	Architecture (P = priority request)	Priority intelligence	Priority request	Priority decision
A1		Local	Decentralised	Local
A2		Central	Decentralised	Local
B1		Local	Decentralised	Central/Local
B2		Central	Decentralised	Central/Local
B3		Central	Centralised	Central

These architectures are summarised and reviewed as follows:

4.1 Category A1

This architecture involves bus priority at isolated junctions, without the use of UTC. The architecture uses the AVL system to locate buses and the location information is then used by local 'intelligence' to determine bus-specific PLR. The PLR is then transmitted from the bus to the approaching traffic signal controller (decentralised communication method). With no UTC involved, the priority decision is taken by the traffic controller at the local level. The role of the AVL is limited to providing the locational information to determine the PLR. This AVL-based bus priority architecture at isolated traffic signals is more suitable for the places where buses are operated under a timetable service.

4.2 Category A2

This architecture is also related to isolated traffic signals. The AVL system is used to locate buses to determine their individual priority requirement. This is assessed by intelligence at the central AVL centre and passed to the bus. The bus then passes the request to the signal controller once it is detected at the approach to a traffic signal (decentralised communication). With no UTC involved, this architecture also takes the priority decision at the local level. The system allows implementation of all possible bus priority systems such as differential bus priority. A similar system is used at isolated junctions in Helsinki (Sane, 1999).

4.3 Category B1

This architecture involves traffic signals controlled under UTC. The role of AVL in this architecture is limited to providing locational information only for bus priority purposes. The priority requirement is determined at the local level (OBPP or ICPP) based on the lateness of the bus and defined priority criteria. The bus transmits the priority request to the traffic controller once it is detected at the signal approach. The priority implementation decision may be taken at UTC level or at local level depending on the facility in the control system. This type of system is more suitable for the places where buses are operated under a timetable service. Examples of this architecture are the GPS-based Cardiff system (Hill, 2000) and Leicester system (Gillam and Wright, 2000) which use onboard timetable information to determine the priority needs of each bus.

4.4 Category B2

This architecture involves traffic signals controlled under UTC. In this architecture, the AVL centre gathers locational information of buses and uses the information to determine the priority requirement of the buses. Since there is no communication between AVL and UTC, bus-specific priority requests are then routed from the AVL centre to UTC via the bus and traffic signal controllers. The AVL centre passes the priority level request (PLR) to the bus at the time of polling. The bus transmits the priority request to the traffic controller once it is detected at the signal approach. The decision of priority implementation may be taken at the UTC level or at the local level depending on the facility in the control system. In London, the decision is taken at two levels depending on the type of priority: At the local level for priority extension and at the UTC level for recalls. The differential priority system used in London (Hounsell et al, 1999) is an example of this architecture. The system in London is further reviewed as a case study in Section 5.

4.5 Category B3

This is a fully centralised type of priority architecture with a bigger role of the AVL centre. In this architecture, the AVL centre locates buses, determines their requirement and transmits the priority requirements directly to UTC. This removes the need of a detection system on the approach to each traffic signal (e.g. loops or beacons) as well as the communication links between bus and the traffic controller. However, since the priority decision and activation is totally dependent on the bus locations available at the AVL centre, the architecture is vulnerable to the accuracy of the AVL system used. The systems used in Southampton (Wren, 1996) and in Toulouse (PRISCILLA, 2002a) are examples of this architecture. A slight modification to this architecture, as used in some French cities, involves two-way communications between the AVL centre and UTC. In this case, UTC plays an active role in informing the AVL centre of each proposed stage change and requesting the location of any bus that needs priority, which would then delay this stage change.

These different architectures just required illustrate that there are a wide range of solutions being adopted for bus priority in Europe, depending on the existing systems (traffic control, detection, etc.), available resources (costs/benefits) and other city/country specific factors.

5. A case study: London

London has been the leading city in the UK for the development and implementation of bus priority at traffic signals. Systems were first implemented in the 1970's at isolated junctions controlled under the UK 'D-system' of Vehicle Actuated (VA) control. Bus detection involved self-contained transponders mounted on the underside of buses, with data transfer to an inductive loop bus detector in the road surface typically 70-100m upstream of the junction. Priority was granted to all buses through a green time extension or a green time recall, with (optional) compensation facilities included for non-priority stages. Successful early trials led to a larger implementation at 50 junctions in the SELKENT area of south east London (University of Southampton, 1988), and then to wider implementation, with many isolated junctions now equipped for bus priority.

London has been involved in two major EC- funded projects concerning bus priority at traffic signals. The first of these, PROMPT (Hounsell et al., 1996), involved the development and evaluation of bus priority in the SCOOT UTC system. Of some 4000 signal installations nearly 50% operate under isolated VA control, while the remainder operate under UTC. Approximately 50% of these are under fixed time control (e.g. TRANSYT plans), while the remainder are under traffic responsive SCOOT control. Priority strategies include green extensions and recalls with benefits dependent on the 'spare green time' available at the junction which can be re-allocated to detected buses. The amount of spare green depends on the difference between the actual degree of saturation (DOS) on the non-priority stage(s), which is estimated by SCOOT in real time, and target DOS values set by the operator according to policy (e.g. the higher the target DOS, the higher the priority for buses, but the greater potential disbenefit for non-priority traffic). Bus priority is now operational at most of the SCOOT controlled junctions, in this way (Category B2 Architecture).

The implementation of a beacon-based AVL system, for real-time passenger information at bus stops (COUNTDOWN), provided the basis for enhancing the bus priority system in the 1990's. The system relies on the bus odometer, calibrated by roadside beacons, to provide the bus location data, with two-way communication with the AVL centre using a ~30 second frequency radio polling system. The new bus priority system using this AVL system was developed in the EC-funded INCOME project (Rochez et al., 2000). The key features of this architecture, illustrated in figure 3, are that it:

- Builds on the existing AVL hardware (e.g. using beacons to replace road loops), providing a cost-effective system evolution.

- Allows differential priority to be provided according to 'adherence to schedule' (This implies improving headway regularity for the high frequency services).
- Maintains 'local' priority facilities (but under the control of SCOOT) and the potential for priority at isolated sites (unlike a centralised AVL/UTC interface).

5.1 Present bus priority architecture

The present bus priority architecture used in London is shown in figure 2.

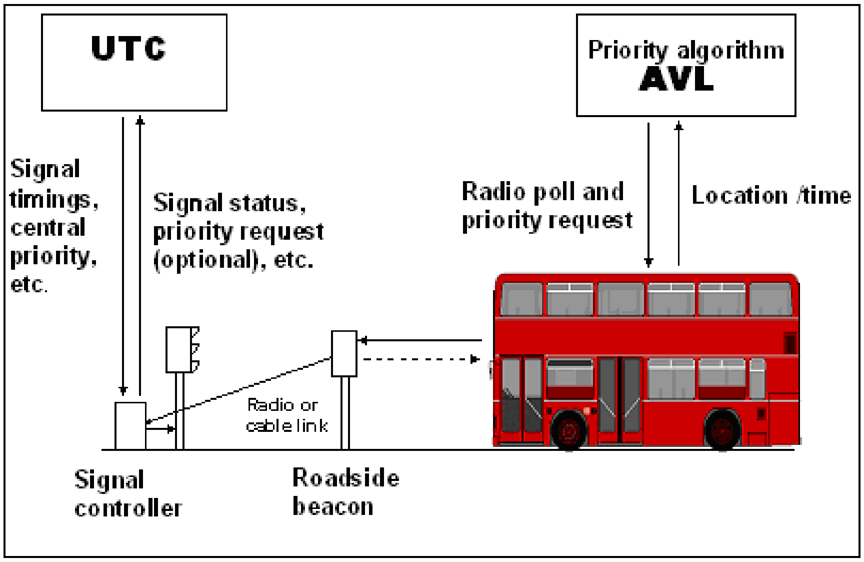


Figure 2. AVL based bus priority architecture in London

In this system, a bus updates its position with the help of roadside beacons placed at strategic locations supplemented by an odometer on each bus (Hounsell et al., 2000). The control centre communicates with the bus using Band III radio at every ~30 seconds to get its present location. The control centre then determines the priority level request (PLR) of the bus depending upon its lateness. The calculation of lateness is carried out for each bus at the priority calculation points (PCP) specified on the route. The priority level request (PLR) determined is then sent back to the bus at the next polling. The bus then transmits its priority request to the traffic controller when detected at the approach of each signal controlled junction. The decision to implement the requested priority is taken at the local or central level depending on the type of priority (extension/recall) required. A review of this present priority architecture based on the 3 key aspects of architecture discussed in Section 3 is given below.

Location of 'Intelligence'

The present system in London has 'intelligence' at the central level. This is possible because of the AVL system used for COUNTDOWN, and its capabilities to accommodate the bus priority functions. At present, the intelligence is used to determine the priority requirement of buses based on headway between two buses only (which can be achievable with local level intelligence also). However, with the 'intelligence' at the centre, there is much more potential for bus priority that has not been explored yet. This includes the implementation of dynamic priority described in Section 3.1.2.

Priority request

The system uses decentralised communications to request priority with priority requests from the bus to the traffic signal controller via the roadside beacon. Again, this method was preferred because:

- i) the communication process from the AVL centre to buses was already established and enabled bus priority requests to be communicated similarly;
- ii) the London system uses ‘precise’ bus location for priority relatively close to the junction because of high bus journey time variability (AVL beacons could then replace the transponder/bus detector system); and
- iii) no communications existed, nor were considered necessary between the AVL and UTC centres.

Priority decision

The traffic signals using the architecture described above are controlled under the SCOOT UTC system in London. Here the decision to implement priority is taken at both levels: central and local depending on the type of priority needed. The decision at both levels is an effective option as discussed earlier. Here, the implementation of local level control is used for extensions and central level for recalls. Even though the system is efficient, full implementation of local extensions has not been taken due to the modifications required in each signal controller to allow this.

5.2 Discussion

The first implementation of bus priority at UTC signals in London, using bus transponders and inductive loop detection technologies proved effective and reliable, subject to the usual problems with inductive loops when road works occur. The substitution of this technology with roadside beacons, a component of the AVL system proved to be more cost effective and reliable in most cases. Providing equal priority to all detected buses has achieved significant delay savings for buses. However, the key performance criterion for bus services in London is regularity or punctuality, and ‘differential’ priority has therefore been an important facility. This has required substantially greater system complexity; for example a very high proportion of buses have to be detected to ensure correct headway data, and robust communications and data transfer is required between the AVL centre and buses. Whilst showing potential, the system has not yet been fully operational for a sustained period providing the desired level of performance. Currently a new AVL system is being procured for London, probably based on GPS for locating buses, which should provide new opportunities for bus priority..

6. Summary and Conclusions

Bus priority is becoming increasingly important in cities to help maintain an efficient public transport service against the threat of congestion. Where roadspace permits, priority can be provided effectively by providing segregated lanes/roadways for buses. In addition, priority can be provided effectively at traffic signals, most recently with the support of advanced technologies such as Automatic Vehicle Location (AVL). Benefits can be substantial. For example, field trials in the PRISCILLA project (PRISCILLA, 2002b) in a number of European cities showed increases of 5% – 16% in bus travels speeds and improvements in punctuality of 5% - 20%. However, published results of system performance and reliability are still relatively scarce, so this paper has had to focus on a review and categorisation of bus priority architectures being used.

This review of the main aspects of bus priority architectures (location of intelligence, method of priority request and the location of priority control) has detailed the options available with their relative advantages and disadvantages. The review showed that there can be numerous architectures possible for bus priority at traffic signals. A general categorisation of current bus priority systems used across Europe illustrated that the architectures used differ from place to place. A more detailed case study of the London architecture highlighted the influence of the exiting systems on the implementation of bus priority.

Based on this review and discussion, it can be concluded that the appropriateness of AVL-based bus priority architecture is likely to depend on various factors such as:

- Legacy traffic control systems (e.g. UTC, VA, etc.)
- Any existing infrastructures (e.g. detection, communication, etc.)
- Bus operational method (headway/timetable, scale of bus operation)
- Integration with other applications (e.g. RTPI, Fleet management, etc.)

Based on these factors, a requirements specification needs to be developed in each case of procurement to select the best-suited bus priority architecture for a particular situation. The basic requirement should specify the accuracy of an AVL system, priority determination method, communications architecture, detection method and priority implementation method. Such specifications should also incorporate a thorough acceptance testing procedure to check the fulfilment of the requirement. In this continuously developing field of bus priority systems, expertise is needed to incorporate the recent developments. Finally, the growing trend of bus priority implementation is a welcome sign that authorities are striving to make bus journeys more attractive, to encourage their use as part of a sustainable transport system.

7. Definitions of symbols

AVL (Automatic Vehicle Location) - A system that makes continuous monitoring of vehicle locations.

GPS (Global Positioning System) – Satellite based location system which allows determining the user location with the help of a receiver anywhere in the world.

ICPP (In Controller Priority Processor) – A component inside a bus that determines the priority requirement of a bus based on predefined criteria using bus locations available from the AVL system.

OBPP (On Board Priority Processor) – A component inside a bus that determines the priority requirement of a bus based on predefined criteria using bus locations available from the AVL system.

PCP (Priority Calculation Point) – A reference location where the PLR of a bus is calculated.

PLR (Priority Request Level) – Level of priority need of a bus determined on the basis of its lateness (adherence to the timetable or the scheduled headway).

RTPI (Real Time Passenger Information) – Provision of up to date bus arrival information at bus stops in real time.

UTC (Urban Traffic Control) – Coordinated traffic control system which takes account of a number of junctions in a network while optimising the cycle time e.g. SCOOT.

VA (Vehicle Actuation) – Isolated traffic control system where signal timing changes with the detection of vehicles on the approaches.

VD (Virtual Detectors) – Coordinates of the bus detection locations programmed on a bus computer so that the bus can register its presence once it reaches there.

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