HOW TECHNOLOGY CAN IMPROVE BUS RELIABILITY IN GREATER MANCHESTER

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1.   Introduction

This paper analyses how bus reliability can be improved by the granting of priority at traffic signals.

The congestion problem facing Greater Manchester, the risk it poses to sustainable economic growth and the role of buses in efficiently moving people around limited urban road-space will all be examined. The case for utilising technology, in the form of bus priority at traffic signals, and a description of how it works will then be presented. Finally, experiences of installing this technology and its future development will be reviewed.

One of the initial aims of this paper was to analyse the effectiveness of granting priority to buses at traffic signals, in improving reliability and punctuality, and the impact on other road users. However, there is already a substantial volume of literature covering this, which is considered. The focus, instead, is to examine the application of the technology within Greater Manchester and how it can play a role in sustaining the future growth of the conurbation.

2.   Congestion in Greater Manchester and the Future Role of Buses

Improved connectivity and accessibility facilitates economic growth, reducing the costs of moving both people and goods. The advantages of reduced congestion include; businesses being able to access larger markets and labour pools, more people being able to access improved employment opportunities, agglomeration benefits reducing costs and environmental benefits of improved air quality and reduced noise. However, as Greater Manchester expands the increased movement of people and goods can result in congestion that curtails future growth; as journeys become longer, more unreliable and more expensive. Continual improvements in connectivity and accessibility are therefore required if growth is to be sustained.

The current cost of congestion to the economy of Greater Manchester was estimated by Newby and Affleck (2015) in a report for Transport for Greater Manchester (TfGM). Using 2010 values of time (from the Department for Transport (DfT) WebTAG Data Book) and 2010 prices, modelling techniques put the total annual cost of highway congestion and delay at £1.3 billion.

This cost could rise further as the 'Greater Manchester Transport Strategy 2040: Consultation Draft' expects the demand placed on the transport network to increase as both the economy and population grow (TfGM, Greater Manchester Combined Authority [GMCA] & Greater Manchester Local Enterprise Partnership [GMLEP], 2016). This growth is expected to be particularly strong in and around the city centre, with up to 110,000 extra jobs and 50,000 homes expected by 2040, resulting

in an estimated 68,000 additional peak hour trips. Whilst the city centre is well-connected, it is thought measures will be required to ensure this growth is not jeopardised by congestion.

It is not considered feasible to cater for this increased travel demand by increasing the amount of road-space, especially in the city centre. There may be pinch-points that can be removed, but existing space must be used more effectively. It is for this reason that buses have a crucial role to play in enabling the efficient movement of people in and around Greater Manchester, especially within the centre and the radial routes that converge on it. Trains, trams, cycling and walking will also have important parts to play and thought must be given to land-use (how it can reduce the need to travel and ensure the travel which does take place is done in a sustainable manner). However, in terms of road-space buses offer a very efficient solution. Figure 1 (TfGM, GMCA and GMLEP, 2016, p.36) demonstrates this by illustrating the amount of space taken by one hundred people travelling via different modes.

Figure 1:   Illustration of road-space taken by one hundred people using different transport modes (Source: TfGM, GMCA and GMLEP, 2016).

The Draft Greater Manchester Spatial Framework (GMCA, 2016) sets out the approach to housing and employment land over the twenty year period to 2035 and its concerns mirror those of the 2040 Transport Strategy. It recognises that to improve accessibility enhanced transport infrastructure is required, that transport and land strategies need aligning and that growth will be curtailed if increasing numbers of trips, particularly into and around the city centre, leads to congestion. There is acknowledgement that an increasing proportion of trips must be undertaken by walking, cycling and public transport as (GMCA, 2016, p.63), "expanding highway capacity to meet an ever growing demand for car travel is not sustainable, or physically or financially practical."

There are also environmental and health costs associated with congestion. High traffic levels, standing traffic and stop-start flows all increase air pollution and greenhouse gas emissions. The Greater Manchester Low-Emission Strategy and Air Quality Action Plan (TfGM & GMCA, 2016) identifies these costs and the high proportion of emissions attributable to road transport. It identifies programmes and initiatives to reduce these emissions, which include changing travel behaviour and facilitating more journeys by public transport.

TfGM and GMCA (2106) note that growth in cities can be a sustainable option, as dense urban areas more readily support public transport networks and that short travel distances favour walking and cycling. However, they concede that this concentration of activity exposes more people to poor air quality. Ensuring that travel within Greater Manchester is facilitated as sustainably as possible is therefore critically important.

3.   The Impact of Congestion on Bus Operations

The above demonstrates the role buses have to play in combatting congestion and enabling sustainable growth. However, bus operations are particularly vulnerable to congestion as they have to run on fixed routes to pick up and drop off passengers. Any increase in journey times or reductions in punctuality and reliability will ally to make bus travel less attractive. This can lead to a spiral of decline, with a reduction in services further lessening their appeal. Congestion will also increase costs, as fuel use rises, and operators will need to run more buses to maintain frequencies. Once increased costs are passed onto passengers the appeal of the bus will fall further still.

Begg (2016) has identified that over the last fifty years bus journey times, in congested urban conurbations, have increased by an average of just under one percent per year. He estimates this has reduced fare paying passenger journeys by between 48 and 70% and argues that if this trend continues buses will cease to be a viable mode of transport.

Elasticities of demand, produced by Begg (2016), predict that every 10% decrease in operating speeds leads to an 8% increase in operating costs. If these increased costs are passed onto passengers it is estimated that patronage will fall by 5.6% and that a 10% reduction in frequency will reduce patronage by 5%. If reduced frequencies and increased journey times are considered together, Begg estimates that a 10% decrease in speed reduces patronage by at least 10%. Therefore, if buses are to efficiently move people around congested urban areas it is imperative that operating speeds are improved.

4.   Bus Passengers

The latest bus passenger survey (Transport Focus, 2015) found that 16% of passengers in Greater Manchester were dissatisfied with punctuality, 7% with journey time and 15% with waiting time. There is much room for improvement and this will be crucial in making the bus a more appealing travel choice, particularly to non-users whose views are not taken account of in this survey.

Data provided by TfGM revealed that midpoint bus punctuality (percentage of observed buses departing intermediate timing points on-time (between 1:00 minute early and 5:59 minutes late)) averaged 77% between August 2014 and September 2016, i.e. almost one in four buses were late. Average bus regularity (whether at the journey mid-point frequent services had gaps of over twice the headway or ten minutes (whichever is larger)) was 95.1% over the same period. Correlation between these figures and patronage is difficult to prove, but improvements would make bus travel a more attractive option to both existing and potential passengers.

Whilst passenger numbers are not available for individual routes, the latest figures from the DfT (2016) estimate that aggregate patronage in Greater Manchester was 204.9 million in 2015/16. The figures have fluctuated, but this is the lowest level recorded since the present methodology was adopted in 2009/10 (when patronage was 220.4 million). It continues a trend across English metropolitan areas, outside London, which has seen combined patronage half since 1985/86.

The reasons for these patronage falls are numerous. However, if Greater Manchester wants to curb congestion and make efficient use of its road-space, to ensure its economy can grow sustainably, then they must be reversed.

5.   Devolution and the Bus Services Bill

The Greater Manchester Devolution Agreement was signed in November 2014 and will enable the transfer of power and responsibilities from central government. The agreement aims to drive economic growth and reform public services, on the premise that decisions made locally can better meet the needs and aspirations of those who live and work in Greater Manchester (TfGM, 2016a).

The Bus Services Bill, which is currently passing through parliament, is one aspect of the devolution agreement and will give Greater Manchester's elected mayor the option of franchising bus services. TfGM (2016a) believe that a franchised bus system can create a joined up and coordinated bus network, that is fully integrated with both rail and Metrolink, and a simpler and cheaper ticketing system. It is hoped that franchising will allow the bus to achieve its full potential, as the number of trips made on Greater Manchester's transport network grows alongside the economy and population.

There are benefits associated with bus franchising, but it will not improve bus services in isolation. If buses are slow and unreliable they will not attract passengers and franchising will not succeed. This is evidenced by recent experience in London, which operates a franchised bus network. Whilst London bus patronage has grown over the last thirty years this trend has reversed in recent months, due to rising congestion reducing bus reliability (Passenger Transport, 2016). In September 2016 year-to-date bus passenger numbers were 35.7 million (3.3%) below what had been forecast and this lead to revenues being £22.8m (3.2%) below budget. These figures highlight the financial risks and the danger that congestion poses to the viability of bus franchising.

6.   Bus Priority

Bus priority measures allow buses to either bypass congestion or give them advantages that will mitigate its impacts. There are a range of possible measures and individually they provide only small improvements to journey times, punctuality and regularity. However, whole route treatments are more effective, as they combine improvements to produce solutions that are greater than the sum of their parts, and this approach has been adopted in Greater Manchester when developing Quality Bus Corridors (Greater Manchester Passenger Transport Executive, n.d.). An example is the ongoing Bus Priority Package, which is making substantial investments in key bus routes. It includes the Leigh Guided Busway, a 4.5 mile long bus only route, which has attracted high numbers of passengers since opening in April 2016.

Bearing the concept of whole route treatments in mind, the subsequent sections will analyse the use of technology in granting priority to buses at traffic signals.

7.   Why Grant Buses Priority at Traffic Signals?

In 2008 a series of reports were compiled for the Greater Manchester Transportation Unit (GMTU) analysing bus journey times along various routes. They compared journey times in the morning, evening and off-peak periods and estimated delays at traffic signals. Bus stop dwell-times were also assessed.

The 192 route, which runs along the A6 from Hazel Grove to Manchester, is one of the busiest and most frequent routes in Greater Manchester. Its report (Collins, 2008) estimated that in the morning peak 28% of the inbound journey time (towards Manchester) was spent at signals, with a figure of 17% in the off-peak. The outbound journey experienced delays of 30% in the evening peak and 19% in the off-peak. The reports for other routes also showed delays at traffic signals and demonstrate the scope for improvements in bus journey time, punctuality and regularity if their passage through signals is expedited.

There are a wide range of system architectures, technologies and strategies that can be adopted to provide priority to buses at traffic signals. Gardner, D'Souza, Hounsell, Shrestha and Bretherton (2009) reviewed many of these. They found that the benefits can vary as a result of factors such as the architecture used, the level of priority given to buses and traffic characteristics. However, the benefits provided to passengers and operators meant that systems typically paid for themselves within three to six months, with delay savings ranging from three to ten seconds per bus per junction. Providing priority to buses at traffic signals can therefore achieve substantial benefits and pay for itself within a relatively short time frame.

Incidentally, the GMTU reports also highlighted that a large proportion of journey time is spent dropping off and picking up passengers (dwell-time), with a figure of 24% in the am peak on the inbound 192 route (Collins, 2008). Whilst buses have to make frequent stops, increased use of smartcards and contactless payments to reduce (or eliminate) cash payments would minimise dwell-times. If smart payments were used in combination with priority at traffic signals then substantial improvements could be made to the speed and reliability of journeys.

8.   Signal-Based Bus Priority in Greater Manchester

In 2011 TfGM carried out a review of the options available to allow priority for buses at traffic signals. This review was to ensure all technical options had been considered, preferred options were proven and deliverable, proposed functionality was clearly described, to identify implications for stakeholders and to check the implications for interworking with tram priority.

Desk research was carried out to understand the bus priority process and the range of solutions available. Interviews were held with representatives from sixteen cities/regions to understand deployed solutions and lessons learnt. Finally, analysis was undertaken of the findings to inform the planning and design of the proposed system for Greater Manchester.

There were a wide range of system architectures available. Some solutions provided priority to all buses regardless of adherence to schedule, but could lead to buses running early and cause unnecessary disruption to other traffic flows. Others used on-bus technology and/or allowed individual traffic signal controllers to grant local priority, but these are expensive to install and operate as they require extra equipment on buses and at signals.

The review led to proposals to grant priority to late running buses at SCOOT (Split Cycle Offset Optimisation Technique) controlled traffic signals, a system that does not require extra equipment to be deployed. Its implementation is discussed in the following chapters.

9.   How Bus Priority at Traffic Signals Works

9.1   SCOOT

SCOOT is an adaptive urban traffic control (UTC) system that automatically responds to traffic fluctuations and co-ordinates timings of nearby signals, reducing delays and improving traffic flow (DfT, 1999). It utilises inductive loops, within the carriageway, that detect vehicles crossing over them. The flow data from these loops is used by the SCOOT software to adjust the **S**plit (proportion of green time given to a link within a cycle), **C**ycle (time for all signal stages to run) and **O**ffset (time within a cycle that a green signal appears, allowing linking between signals) for traffic signals within a region. It aims to keep the degree of saturation (ratio of demand to capacity) below 90% on all links. SCOOT offers advantages over normal fixed time control as it adapts to changes in traffic flows, therefore efficiently managing traffic and avoiding the need to update plans.

SCOOT is operating on approximately 800 of the 2,400 traffic signals within Greater Manchester.

9.2   Bus Priority in SCOOT

There is a facility within SCOOT to provide priority to late running buses. The configuration to be used in Greater Manchester makes use of Automatic Vehicle Location (AVL) technology that is installed within buses' Electronic Ticket Machine (ETM) systems. AVL uses GPS to allow operators to track buses, relative to their timetable, as they proceed along their route. It can therefore be used to identify when late running buses are approaching traffic signals. This system of granting differential priority, dependent on adherence to schedule, is particularly useful when improving punctuality and regularity of high frequency services that run at a given headway.

The report 'Bus Priority in SCOOT' (Bowen, 1997) gives an explanation of how the system works and is summarised below.

The position of a 'virtual loop' is decided upon, usually about 100m upstream of a stop-line if there are no obstructions that would hinder the progress of the bus (e.g. pedestrian crossings or bus stops). These virtual loops act as trigger points and when a late running bus passes through them priority is granted at the downstream set of lights. The advantage of using virtual loops is that they negate the need to install loops or detectors 'on street', providing substantial cost savings.

Dependent on the traffic signal stage that is running, the priority will take the form of either an extension of the current green time (to allow the bus to pass through the signals) or an early recall of the appropriate stage. There are various limitations on the priority that can be given, with maximum stage lengths and link saturation levels, to minimise the disruption to other traffic streams.

Without the bus priority facility installed SCOOT treats all vehicles equally and does not take account of the fact that buses can carry high numbers of people. Its installation minimises the time buses are delayed at signals, improving punctuality and regularity and reducing waiting times.

When this system was installed at SCOOT controlled traffic signals in London Gardner et al. (2009) found that there was considerable variation in the benefits to buses. At junctions with a low degree of saturation delays to buses could be reduced by 50%, whereas this reduction fell to 5/10% at junctions with high degrees of saturation. Typical reductions of delay of around three to five seconds per bus per junction were achieved, with the delay to general traffic dependent on the degree of saturation. It was found that the delay caused to general traffic was greater when providing priority by recalls than when using extensions. Granting recalls to buses on side roads was found to be particularly disruptive.

10.   Installation of Bus Priority at Traffic Signals

10.1   IT Requirements

The first trial, in Greater Manchester, is to take place using buses along the 192 route. SCOOT relies on the bus operators' ETMs communicating with the TfGM UTC system in a timely manner, requiring a direct connection between the two organisations' computer networks to allow buses to submit requests for traffic signal priority. This has been a lengthy process as both organisations have had to take precautions to maintain cyber security and ensure systems cannot be hacked and data accessed. Legal data sharing agreements and security protocols have had to be put in place, but these have now been agreed and a connection between the TfGM and bus operator's IT networks has been established.

10.2   Calculation of Cruise Speeds

When AVL detection is used an average bus cruise speed, on each link, must be entered into the system (Siemens, n.d.). This allows SCOOT to calculate the journey time from the virtual loop to the stop-line. If the link is on green SCOOT can calculate whether the bus can make use of it, the size of any necessary extension or whether a recall is required (if a maximum extension will not give the bus enough time to cross the stop-line). A recall may also be required if the link is currently on red and will still be on red when the bus arrives at the stop-line.

The first stage of calculating cruise speeds was to establish the positions of the virtual loops. GIS mapping software, Mapinfo, was used to overlay details of all the traffic signals, bus routes and bus stops in Greater Manchester. This allowed all SCOOT controlled traffic signals that have bus routes running through them to be identified. Provisional positions of virtual loops were then established, using the criteria that they should be approximately 100m upstream of stop-lines. If there were any features that would hamper the progress of buses, such as stops or pedestrian crossings, then the virtual loops were moved downstream of them. The rule of thumb used was that the journey time, from virtual loop to stop-line, should be between six and thirteen seconds. Any longer and the variability in journey time would affect the efficient operation of the signals. Any less and the signal would have inadequate time to grant priority. A 'Bus Cruise Time Uncertainty Value' can be entered into SCOOT, to maximise the chances of buses that are travelling slower than expected passing the stop-line during an extension. However, this grants more green time than necessary when buses travel at the expected speed and increases disruption to other traffic streams.

The GIS software also allowed grid references to be established for each of the virtual loops. These grid references will be used by the AVL software to detect when buses have passed the virtual loops.

Once that the provisional positions of the virtual loops had been identified a series of site visits were conducted, the first task of which was to assess the suitability of the loop positions and to move them if necessary. The second task was to record bus journey times from the loops to the stop-lines.

Journey times were not recorded for buses making standing starts, when the lights turned from red to green, as the free-flow journey time is required to calculate cruise speeds. If buses do make standing starts, as the lights turn to green, provided the minimum stage length is long enough they will cross the stop-line without the need for any priority. The only occasions journey times were recorded from standing starts were when the virtual loop was immediately downstream of a bus stop. It was assumed that all buses would have to use these stops and that these worst case journey times would ensure all buses crossed the stop-lines during extensions.

Guidance recommends that journey times be recorded for ten vehicles. However, this was not practical, given that buses can be infrequent and that some will approach the signals whilst they are on red. As there were around 800 links to record journey times for, it was not feasible to record times for ten buses on each. Approximate journey times were all that was required, they will be checked at the next stage of validation, so it was decided to record times for just three buses or HGVs on each link. Whilst waiting for buses or HGVs to pass, journey times were also recorded for ten cars, as it was thought that an average ratio of bus journey time to car journey time could be calculated and used for links where it was not practical to gather times for buses (e.g. if a bus only ran once an hour).

Using an average cruise speed, for all links, was considered. The drawback would be that it would not take account of factors such as gradient, road width, road conditions etc. However, the appropriateness of using an average value, as a starting point, could be tested during the next stage of validation.

Following the site visits, the distances from virtual loops to stop-lines were measured from AutoCAD drawings. All the raw data was then input into a spreadsheet, which calculated the average link journey times and cruise speeds. The cruise speeds were then input into the SCOOT model. If the position of the virtual loop had been moved, following the site visit, then its position was amended in Mapinfo, to establish its new grid reference, and the details sent to Vix Technology (the manufacturers of the ETMs).

10.3   Test Runs

To confirm that the bus operator and TfGM UTC systems are communicating with other, several test runs have been carried out along the 192 route. Out of service buses have been driven along the route, with the ETMs programmed to think they were running late. TfGM staff have been on-board these buses monitoring the TfGM UTC system. SCOOT bus priority was switched off, but the UTC system should still have seen the ETMs sending requests for priority. Unfortunately, the UTC system has to date not seen any of the priority requests sent to it. Engineers from Vix and Siemens (who supply the TfGM UTC system) are investigating and another test run is planned for the new year, when all involved parties will be present (TfGM, Vix, Siemens and the bus operator).

This episode highlights the difficulties in getting different organisations, with different IT systems, to work together efficiently on a complex technical project. Each party is taking part in the project voluntarily, with differing views of the benefits. Problems have occurred as a result of TfGM project management staff not having direct control of the bus operator's contractors, with the number of different partners creating delays when resolving difficult technical problems. This may be an area where bus franchising can improve things, with TfGM (backed by the GMCA and elected mayor) able to lead the project and push for solutions to the legal and technical difficulties that have hampered it.

10.4   Final Validation

Once the communication issues have been overcome, the next stage will be to permit late running buses to be granted priority. This will allow examination of how the facility works and how effective it is at decreasing delays at junctions. Live analysis will be conducted as buses travel through the signals, with the TfGM UTC system logging everything for post-trial analysis.

If the calculated cruise speed is either too slow or too fast then it can be adjusted following this analysis. If buses are getting to the stop-line quicker than the SCOOT model has calculated then the cruise speed can be increased or if the lights are turning to red before buses have reached the stop-line then it can be decreased. It can also be decided if journey time variability necessitates a 'Bus Cruise Time Uncertainty Value' to be input into the SCOOT model.

Data from SCOOT, bus operator AVL systems and TfGM Bluetooth journey time sensors will be used to analyse disruption to general traffic, when bus priority is granted, in comparison to benefits received by buses and their passengers.

Analysis will be carried out to assess bus delay, not just at individual junctions, but along the whole route. Comparisons can then be drawn with delays before the systems installation and the effect on punctuality and regularity. This will allow a judgement to be made as to the effectiveness of the system and the role it has to play in improving bus services and helping to ensure the efficient movement of people around Greater Manchester.

Lesson learnt from the installation of bus priority along the A6 can be utilised as the system is installed across the conurbation.

11.   Future Development of Bus Priority at Traffic Signals Technology

There are many ways that the bus priority at traffic signals technology could be developed in the future, including;

- Differential priority could be applied dependent on the lateness of a bus. Slightly late buses could be limited to less disruptive extensions, with recalls restricted to buses that are severely delayed.

- Lessons could be learned from other cities. For example, Gardner et al. (2009) describe how in London local 'on-street' controllers have been programmed to allow them to grant extensions. This is expensive, but eliminates the three to five second transmission lag and allows extensions to be granted to buses that arrive in the last few seconds of green. It can be particularly useful in allowing priority on short links and where bus stops are located near stop-lines.

- Gardner et al. (2009) also describe how the problem of variable journey times, when granting extensions, can be eliminated by utilising cancel detectors to indicate that a bus has crossed the stop-line. As discussed earlier, using a 'Bus Cruise Time Uncertainty Value' can cause unnecessary disruption to other traffic streams. Using cancel detectors allows high uncertainty values to be set, to ensure buses make it across the stop-line, but allow extensions to be terminated as soon as they are no longer needed.

- Greater Manchester's Metrolink network has sections where trams travel on-street and pass through the same junctions as other traffic. Its passengers have the same concerns as those travelling on buses regarding journey times, punctuality and regularity. Indeed, the 'Metrolink Phase 3: Monitoring and Evaluation Early Findings Report' (TfGM, 2016b) found that patronage on new lines is significantly below that which was forecast and there are several reasons identified. These include longer than expected journey times, which could be reduced if delays at signalised junctions were minimised.

- Buses are granted priority at traffic signals due to the fact that they can carry large numbers of people. It is therefore logical to differ the level of priority granted dependent on the number of passengers on-board. For example, at highly saturated junctions disruptive recalls might only be granted to heavily loaded buses. This form of differential priority could also

help to manage conflicting demands for priority that could arise if two or more buses (or a bus and a tram) approach signals at the same time.

Further technology would need to be utilised to know how many people were on-board buses and trams, but this data could come from smart ticketing or from automatic counters that detect passengers boarding and alighting.

At junctions where air quality levels are a concern, it may be desirable to provide priority to highly polluting vehicles, such as HGVs, to ensure they are not idling at the junction longer than necessary.

- In the more distant future, the widespread use of autonomous vehicles could open up many more possibilities for ensuring the efficient movement of people and goods around the transport network. If journeys are pre-programmed into autonomous vehicles then SCOOT will have a much more accurate picture of when and where queues will occur. This provides an opportunity to utilise an advanced form of queue relocation. Autonomous vehicles, if it is calculated that they will impede the progress of a late running bus, could be deliberately held at lights upstream of a bus route. This would allow the late running bus to progress before the other vehicles can enter the road. It could also provide an alternative to bus lanes in locations where space is limited, such as constrained urban environments.

12.   Conclusions

If sustainable economic growth is to be achieved in Greater Manchester, accessibility must be improved and congestion minimised to facilitate the movement of people and goods. There is little scope for further car use, especially in and around the city centre, and bus use should be encouraged to utilise existing road-space efficiently. This should go alongside improvements in train, tram, cycling and walking networks and careful consideration of land-use planning.

Franchising is being considered as one way of improving bus services and a decision on whether to proceed with this will be made by Greater Manchester's elected mayor. Whilst franchising can create a joined up and coordinated bus network, with simpler and cheaper ticketing, it will not succeed in improving bus services and increasing patronage if buses are slow and unreliable. These problems will not only have a detrimental impact on the Greater Manchester economy, but will also pose a risk to the franchise operation if patronage and revenues are too low. A package of measures will therefore be required to improve journey times, punctuality and regularity. These will need to allow buses to either bypass congestion or give them advantages that will mitigate its impacts.

One such measure is to grant late running buses priority at SCOOT controlled traffic signals. There are clear advantages for buses in operating such a system that have been demonstrated in cities around the world. However, the role out of this technology in Greater Manchester has been beset by technical and legal delays. This highlights the difficulties of getting different organisations, with different IT systems, to work together efficiently on complex technical projects when there is no one organisation or vision guiding the project. This is an area where a franchised bus system, that is able to take a holistic approach, could more effectively manage the project.

Once that the project has been completed, along the A6 corridor, an assessment of its impact on bus services and other road users will be carried out. Lessons learnt will enable a smoother installation across the rest of the conurbation.

There are many ways this technology could be advanced in the future, to further increase accessibility and connectivity. These future uses range from different forms of priority for different circumstances to more effective and efficient use of the system. There is also scope for integrating the technology with the Metrolink tram system, smart ticketing and autonomous vehicles.

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