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Connected Roadworks in Derbyshire

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Background

Derbyshire, located in the centre of England, has an extremely varied topography, especially in the Peak District National Park. There are no cities in Derbyshire, with the largest town being Chesterfield. However, several important highway routes cross the County, including the M1, the A6 and A57.



Figure 1 – Location of Derbyshire – Sources :Encyclopaedia Brittanica and ImCity

In general, the eastern part of Derbyshire is urbanised with many settlements that used to serve heavy industry and mining. The Administrative County surrounds the City of Derby. In the west of the County, the countryside is extremely rural in nature with the Peak District National Park being mostly situated in the Derbyshire. Highway Links tend to be more numerous, with higher capacities in the east of the County (north/south) and in the south of the County (east/west), although the A57 along the Snake Pass connects the nearby cities of Sheffield and Manchester. The centre of the County has a limited number of rural routes that generally lie in steep river valleys, with capacity being constrained by steep gradients, low railway bridges, sharp bends and combinations of the foregoing.

Communities in Derbyshire are served by 18 bus companies, many of which have their services unduly disrupted when roadworks with temporary signals are present. The situation can be compounded as the rural areas have very few diversionary routes that can be taken by non bus traffic which would otherwise lower traffic difficulties when delays occur. Additionally, in the summer months, some 13 million people visit the Peak District National Park, and the associated traffic is unpredictable in its volume and patterns. Thus, the setting of timings of temporary traffic signals at roadworks can often sub-optimal to the prevailing conditions.

As an example of non optimum traffic signal timings at roadworks, the graphs below show journey times eastbound and westbound through a set of shuttle working traffic signals in the Peak District where it can be observed that traffic in one direction is generally disrupted far more in one direction than the other.

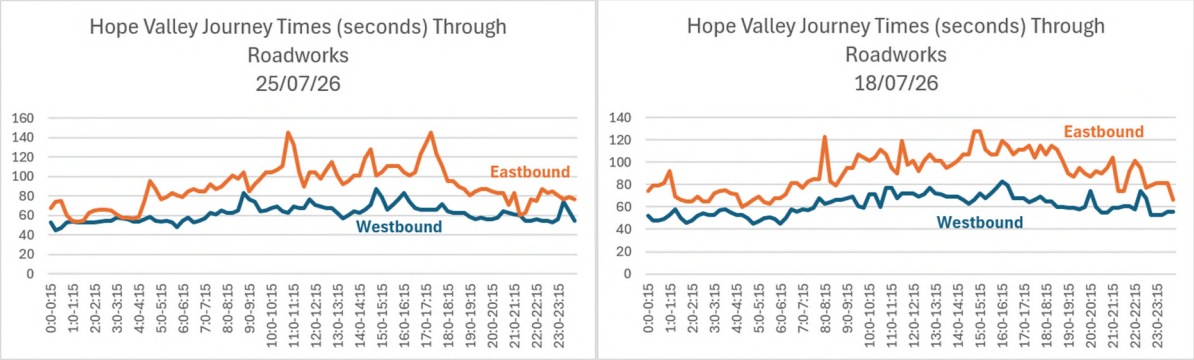


Figure 2 – Hope Valley Journey Time graphs – Source : PTMS Journey Time Monitoring Tool

The Pre-Emptive Traffic Management System (PTMS) is described later in this paper.

Bus Service Improvement Plan

In 2021, when preparing the Bus Service Improvement Plan (BSIP) proposals to attract funding from the Department for Transport (DfT), constant liaison was undertaken with the bus companies within and without the Enhanced Partnership (a forum for bus operators, the Council and other interested parties, senior managers from various bus companies). The Council's ITS and traffic signals specialists were constantly involved in such discussions and were instrumental in including various bus priority measures within the BSIP bid. Indeed, the Chair of the Enhanced

Partnership was someone with an international reputation in Intelligent Transport Systems (ITS) and the Programme Manager at the time was also an ITS specialist.



Figure 3 – Temporary Signals in Derbyshire (A6 near Buxton)

In parallel to the BSIP funding, the Council was already introducing a Common Database, provided by SWARCO (see later), a SCOOT based Urban Traffic Control (UTC) system provided by SWARCO and also a Pre-Emptive Traffic Management System – PTMS provided by AECOM. (also see later).

Within the discussions with the Enhanced Partnership when preparing the BSIP submission, there were strong representations to have a Work Package included within the BSIP proposals to mitigate delays for buses at roadworks. Ultimately, the specific element for “Connected Roadworks” was fully funded by the DfT in addition to the generous (and appropriate) settlement for other parts of the Council’s BSIP funding. Although not known for certain, it is suspected that as the BSIP proposals stated that the PTMS, UTC and Common Database (for convenience from hereon in will use name of the system “ImCity”) would be interconnected, this would be particularly attractive to the DfT. This is particularly the case as this interoperability would enable special traffic signal timings to be applied should a bus approaching a set of temporary traffic signals be delayed, or is predicted to be delayed.

As an aside, the Council is currently migrating to the use of SWARCO’s MyCity urban mobility platform. All the features developed for ImCity will be contained within MyCity, including the functionalities for the Connected Roadworks. Therefore, for the

purposes of this paper ImCity and MyCity are interchangeable terms, except when noted otherwise.

As with most, if not all Local Highway Authorities (LTAs), the majority of roadworks with temporary traffic signals, are installed and operated by the various Statutory Undertakers and therefore the LTAs do not have full control of the installation or operation of the signals. The permitting system is being investigated to assess what stipulations can be made to mandate the use of appropriate signals (with the UTMC interface), but as there are many instances of “emergency works” there will remain many occurrences of temporary traffic signals with suboptimal signal timings where the Council cannot easily influence the settings. Where the works are funded by the County Council, the stipulations for appropriate equipment are more easily established.

Prior to discussing the specifics of the interoperable systems, it is worth noting that the Council had already been adapting ImCity for a variety of purposes, and with the BSIP funding. The bus locations, in real time, are being fed into the systems, to allow schedule adherence and other metrics to be collated, but also to have the data available to allow actions to be taken should a bus be late running.

Using funding from the Council’s capital programme, the presence of roadworks, actual and planned is also included in ImCity. The graphic below is a screenshot of the same part of Derbyshire as the second image below. This does rather show that the Enhanced Partnership’s concerns are very much valid.

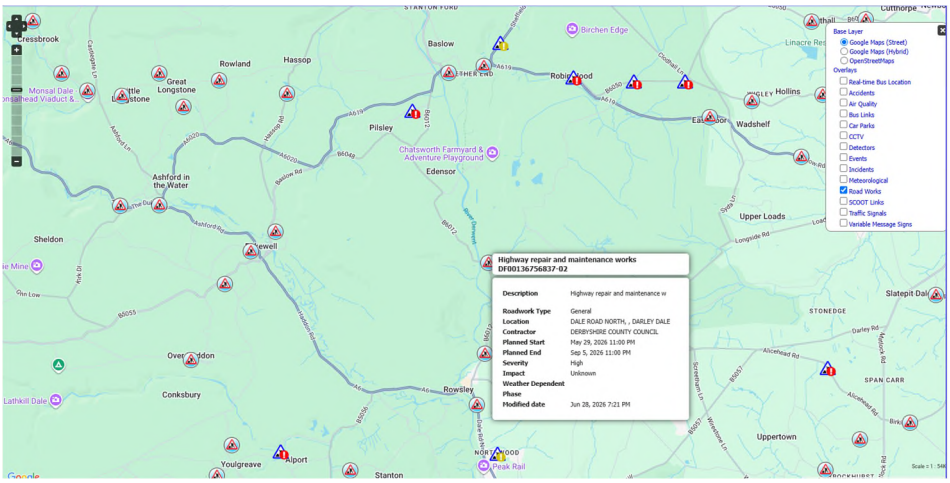


Figure 4 – Example of Roadworks in Derbyshire (25/7/26) from ImCity

The graphic below shows a screenshot from ImCity with the bus icons in dark blue. The graphic also illustrates the lack of diversionary routes in this part of Derbyshire. The updated graphics for bus locations in MyCity are shown in subsequent sections of this paper.

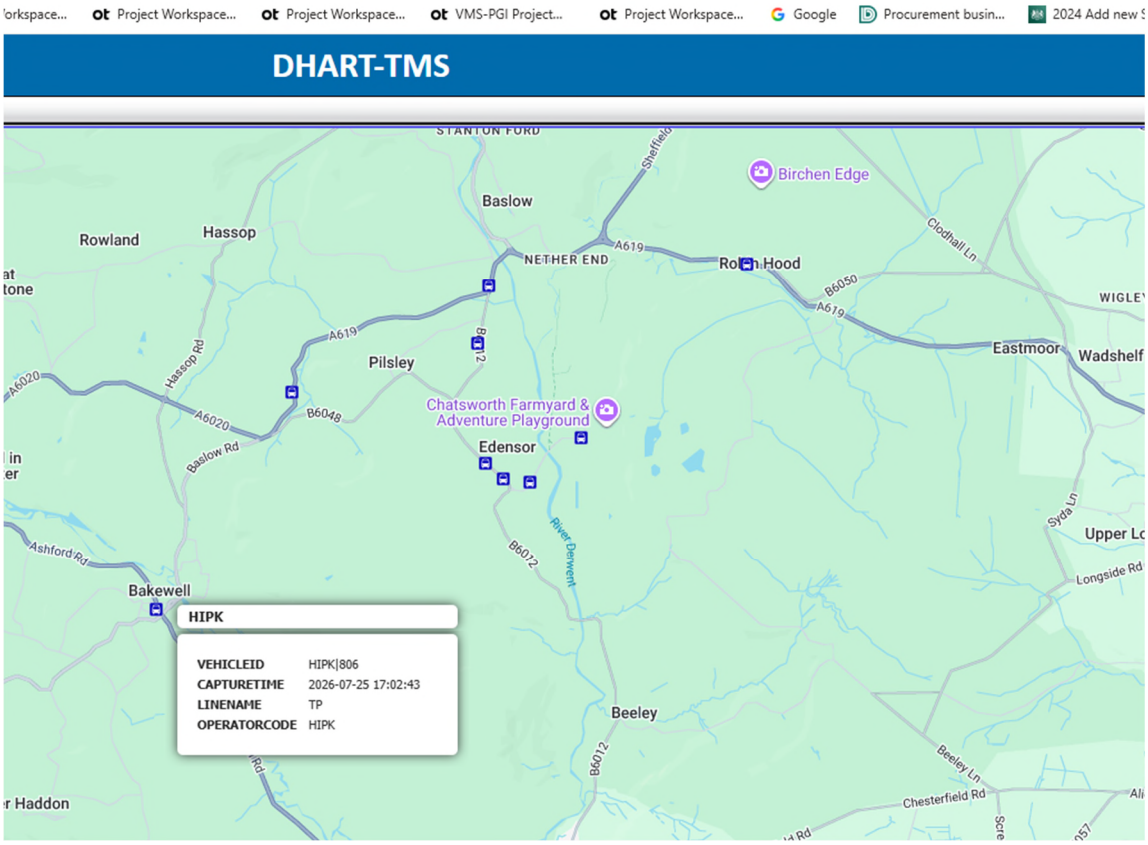


Figure 5 – Real Time Bus Locations in Derbyshire (Cropped Sample) from ImCity

Connected Roadworks Project

When submitting the BSIP proposals, the DfT only wished to have broad outlines of proposed measures, but they needed to be described in sufficient detail to allow the DfT's specialists to make an informed decision on the funding. Therefore, when submitting the BSIP proposal, as ImCity and also the PTMS, were still being developed and introduced, the precise functionality of the Connected Roadworks project had not been defined when funding was agreed. However, it was clear that significant adaptation of the systems would be necessary to allow the overall project to be a success.

A desktop exercise was undertaken to see if such initiatives had been trialled or applied elsewhere, but no instance could be found. It is known, however, that some temporary traffic signal manufacturers offer equipment that can adapt to changing traffic conditions, but the emphasis of the Connected Roadworks initiative was/is to assist buses by analysis of traffic conditions further away than the immediate approaches to the signals in question.

As the interconnection between PTMS and ImCity had already been proven and successfully tested, the development team did not have a standing start, but the specific passage of data required for the Connected Roadworks had not been developed within or without other BSIP work. Also, other back office systems such as gaining real time data on bus locations and timekeeping was not available. In this respect, due to the location latency from BODS (Bus Open Data Service) it was decided to use direct connections from the Electronic Ticket Machines (ETMs) on buses, collated on behalf of various LTAs in the East Midlands by NavIQuate (formally Trapeze). NavIQuate with their product Novus Realtime, delivers accurate, live passenger information at stops, online and in vehicles. By combining schedule and vehicle data, it keeps passengers informed about arrivals, disruptions and service changes as they happen. This dependency meant that the Connected Roadworks work package could not commence as early as initially planned, but nevertheless, Task Orders were issued by the Council to SWARCO and AECOM to commence collaborative adaptations of appropriate systems.

The overall philosophy for the Connected Roadworks initiative is inherently quite simple.

> “IF there is a set of temporary traffic signals, AND, a bus approaching those signals is running late OR delays to that Link are actual OR predicted, a precalculated set of timings is to be introduced automatically, until such time as the bus has exited the signals OR, conditions are normal before the bus gets to the signals.”

The Boolean logic, with conditioning, is, of course, more precise, but subsequent sections of this paper will show this in detail.

There are important dependencies to the system in totality.

- Objective bus location data and the lateness of specific vehicles must be available in real time
- Objective real time conditions of the Links approaching the signals, or affecting a bus's journey to those signals must be accurate and available in time to influence the traffic signal timings
- The traffic signals in question must have remote communications and be included in the UTC system and ImCity databases.
- The adapted traffic signal timings must be such that the bus in question is offered priority without hugely adversely affecting "conflicting" approaches. This requires pre planning and data gathering

The degree to which these requirements are met by the project will be noted at the conclusion of this paper.

Pre-Emptive Traffic Management System (PTMS)

This is a system which was developed in Derbyshire with DfT funding, which, over time, has been applied to manage traffic on the complex road network of the County while reducing reliance on roadside infrastructure. Speed data is being continually measured and recorded continually for approximately 30,000 links. This is achieved through combining traffic data from a variety of sources, including real-time floating vehicle data and responding automatically to complex scenarios that would otherwise be difficult for a human operator to resolve.



Figure 6 – Network Operations Centre (2023) in Derbyshire County Council's Highways Hub (now Relocated) Showing Graphics Including the PTMS

The system generates interventions in response to changing traffic conditions in real time - these interventions include the provision of automated driver information delivered in-vehicle via mobile apps and to roadside variable message signs where available.

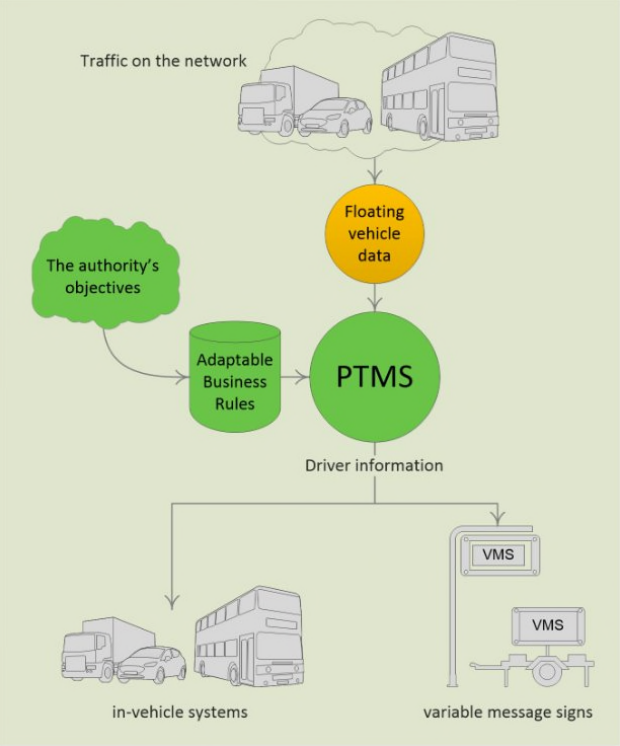


Figure 7 – Generalised Components of PTMS

In addition to management of traffic, the PTMS has been recently enhanced to provide a journey time calculation module to enable assessment of the impact of changes to traffic signal timings at junctions (this enhancement is the subject of a separate paper in the Symposium).

For a separate project funded by Defra, road-emissions data, an additional recent enhancement has been the creation of a traffic volume model that determines traffic density without reliance on physical count sites; this capability enables the monitoring and tracking of traffic volumes in real-time anywhere on the network. By combining the traffic volume model and a road emissions model, vehicle-borne emissions can be generated for the road network across the county. When development is complete, the PTMS will provide the capability to generate traffic management interventions in response to changing emissions levels and target quotas using a specific rule set.

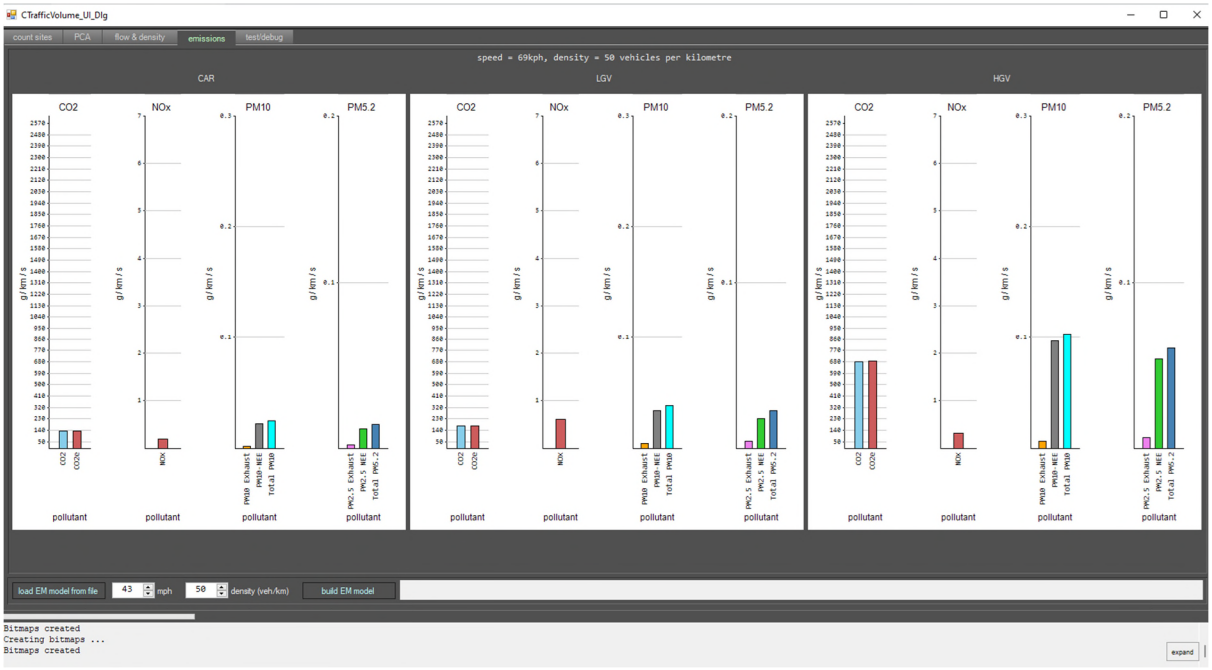


Figure 8 – The Emissions Module Providing Real-Time and Historic Reporting for all Key Road Vehicle Contaminants Attributed to Individual Vehicle Classifications

Emission outputs for each road are calculated in real-time for display on the main operator interface to highlight problem areas as shown in the image below.

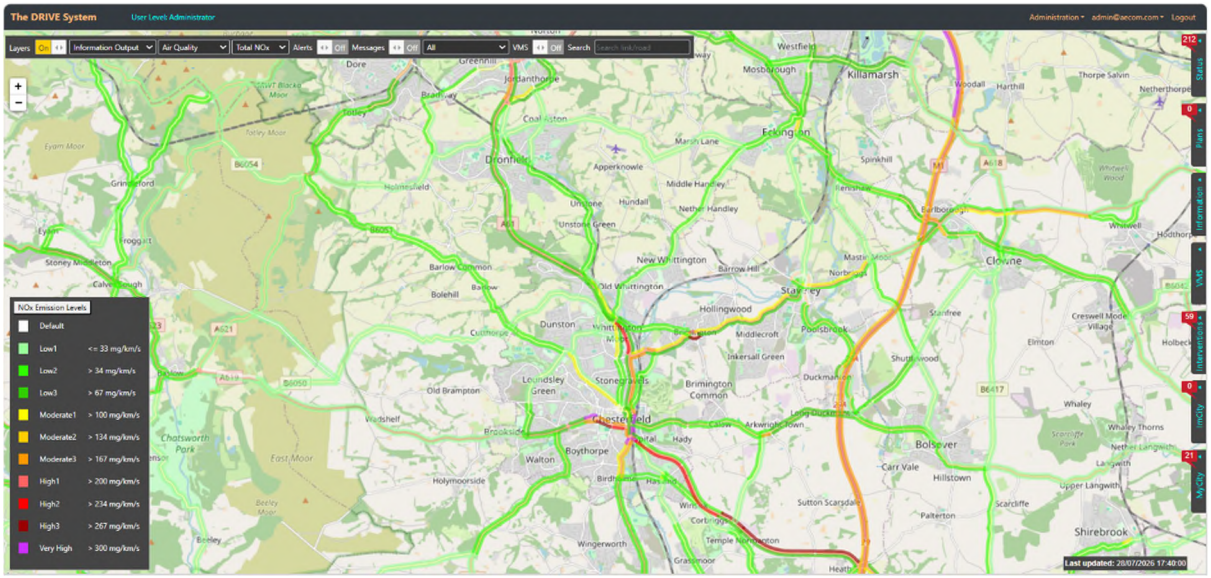


Figure 9 – The Upgraded PTMS Showing Predicted Emission Levels (Defra Grant Enabled)

PTMS and Connected Roadworks

The focus of the project described in this paper is to enable a reduction in delays to buses due to temporary roadworks. To achieve this, the PTMS was modified to

enable traffic speed predictions to set thresholds for setting amended traffic signal timing strategies to reduce congestion when that congestion is predicted to delay buses on that route.

Through the application of machine learning, a prediction algorithm was created to forecast traffic conditions a short time into the future. The system is currently operating with a 30-minute future prediction window.

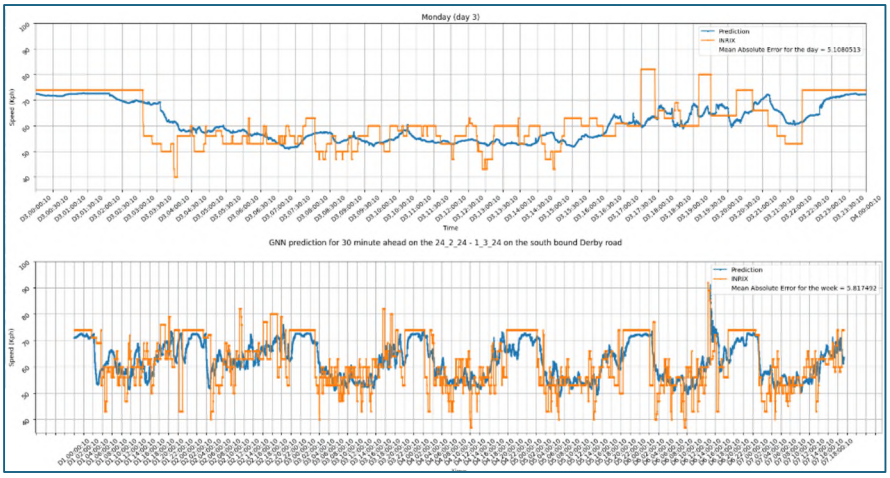


Figure 10 – Traffic Speed Predictions 30 Minutes into the Future (Orange Line Actual Speed and Blue Lines Predicted Speed Made 30 Minutes Prior)

Derbyshire has approximately 300 bus routes operating across the County. As a primary objective of the traffic signal enhancements was to reduce bus delays, it was essential to incorporate and regularly update bus route information within the system. This enables the locations and directions of active bus routes to be considered when generating alerts, ensuring that responses to predicted traffic conditions are relevant to services most likely to experience delays.

Retrieval of bus route data is linked to routes generated from Bus Open Data Service (BODS) contained within MyCity. The Bus route data is then mapped onto an independent network model to ensure future interoperability and compatibility with the PTMS operation and road network model from which alerts are generated.

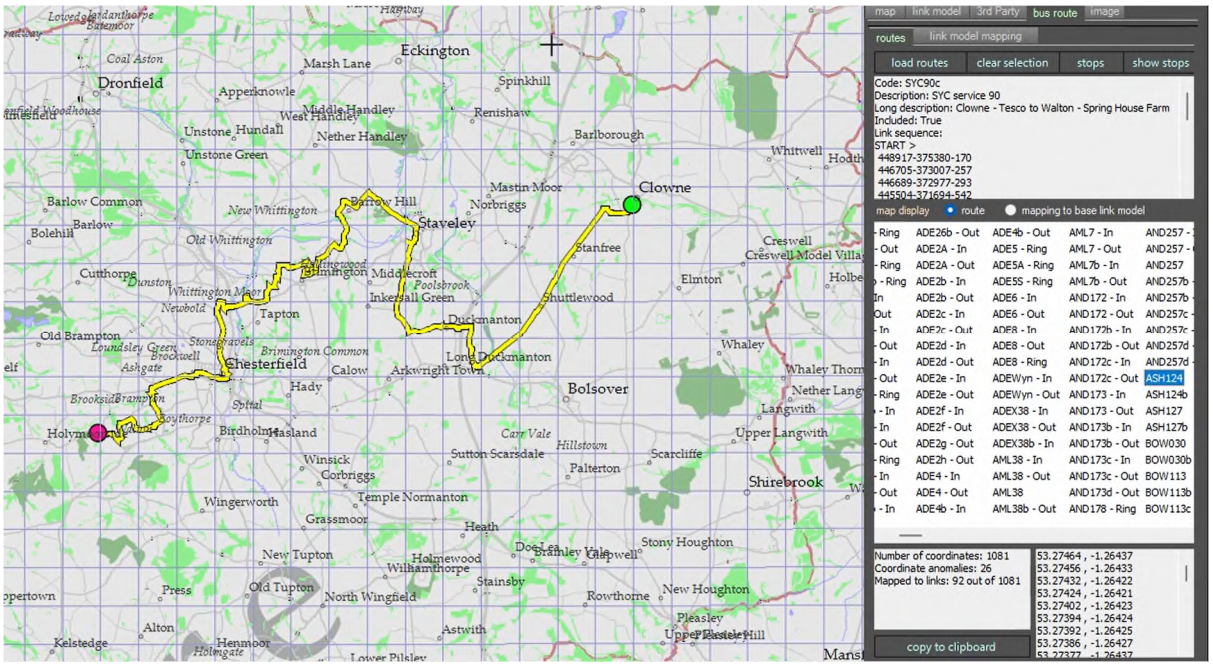


Figure 11 – Bus Route Mapping Incorporated into the PTMS (the Boxes on the Right-Hand Side Show the PTMS Network Model Link IDs

An API was created to enable data handling between the core systems and components. Predicted traffic state levels are generated by the PTMS and categorised from levels ranging from “free-flowing” to “congestion high”. These levels are used in an automated manner, when enabled, for both escalating and deescalating interventions requests to the MyCity Strategy Manager. Congestion levels use a rate of change calculation to determine the change in traffic conditions, so for example “Congestion building” would only be displayed during conditions when traffic levels are increasing rather than decreasing.

As predicted congestion events may affect one or more bus routes. The affected routes are identified via their System Code Number (SCN) and a start and end coordinate indicating direction of traffic affected.

Signal timing interventions are based on the congestion levels provided by the PTMS system. Deployment of those interventions is controlled by the MyCity Strategy Manager based on a numerical value assigned to the congestion level received from the PTMS and noted in the subsequent section of this paper.

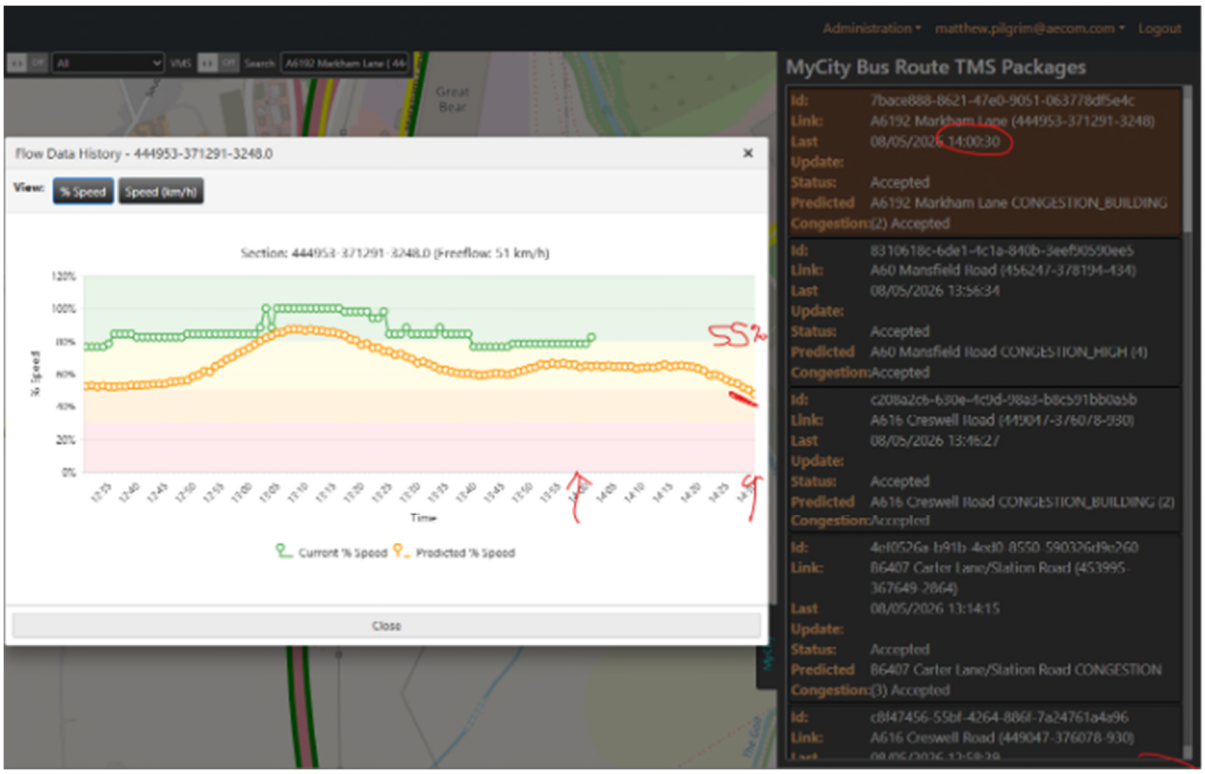


Figure 12 – Traffic Prediction Levels and Bus Route Signal Intervention Requests (Hand Drawn Arrows)

Initial testing of the system was carried out at Langwith Bridge as a close approximation of a temporary roadwork situation operating on a shuttle basis.



Figure 13 – An Approach to Langwith Bridge where Initial On-Road Trials Were Carried Out (source: Google Streetview)

Updates to the web-based user interface for the PTMS were required to provide visualisation of the predicted traffic speeds and a dialogue box to view requested interventions which would reduce delays to buses.

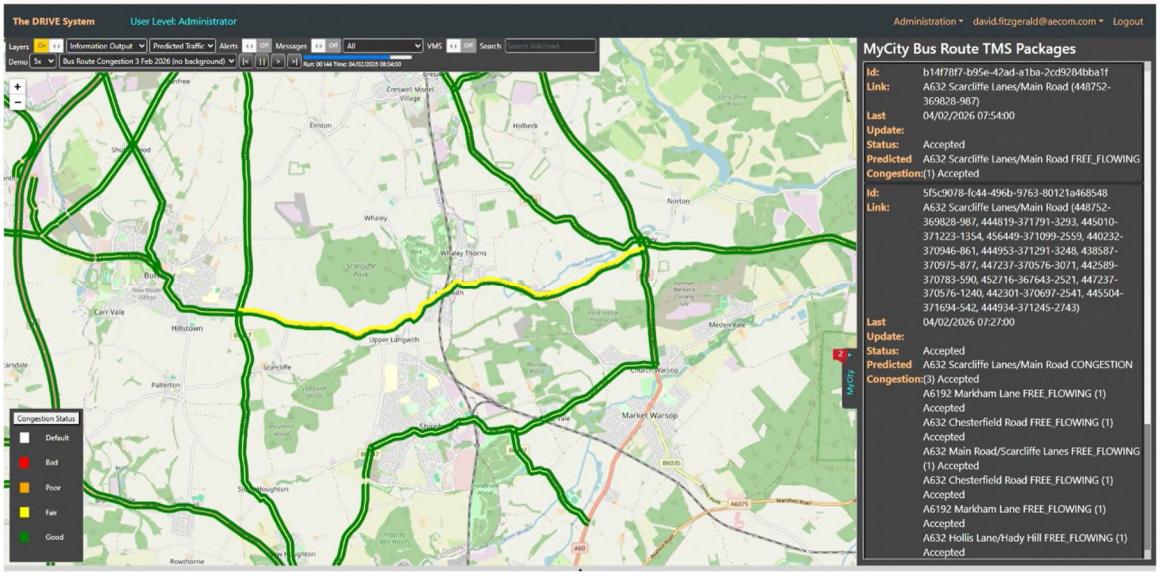


Figure 14 – System Testing at Langwith Bridge – User Interface Showing Traffic Building with the Bus Intervention Package Status on the Right

Common Database (ImCity)

ImCity is the Common Database which is being used by Derbyshire County Council to control traffic from varied inputs. With respect to the Connected Roadworks the decision was taken to move the BODS data feed to the MyCity Urban Mobility Platform, and create the new API connections to the AECOM PTMS system which feed directly into the MyCity system.

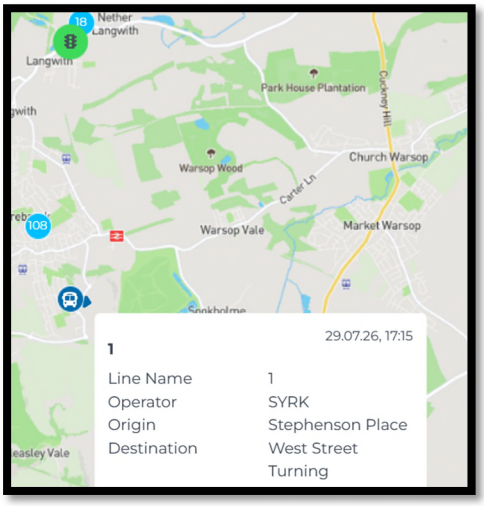


Figure 15 – Bus Location Data Directly Shown on the MyCity GUI (Graphical User Interface)

The first part of the API which was created was the output from MyCity into PTMS, sending the bus route data. The second part of the API, was the input (alerts) from PTMS into MyCity, this is where the control and automation part of the process can really take place. The MyCity Strategy Manager is used to input the predicted congestion level it receives from the PTMS, as a defined rule / trigger to make something else happen in the system / connected systems. More triggers such as pollution monitoring, journey time data and many more can be used in the Strategy Manager alongside the PTMS predicted congestion data, but for this paper the focus relates to the PTMS input for bus priority.

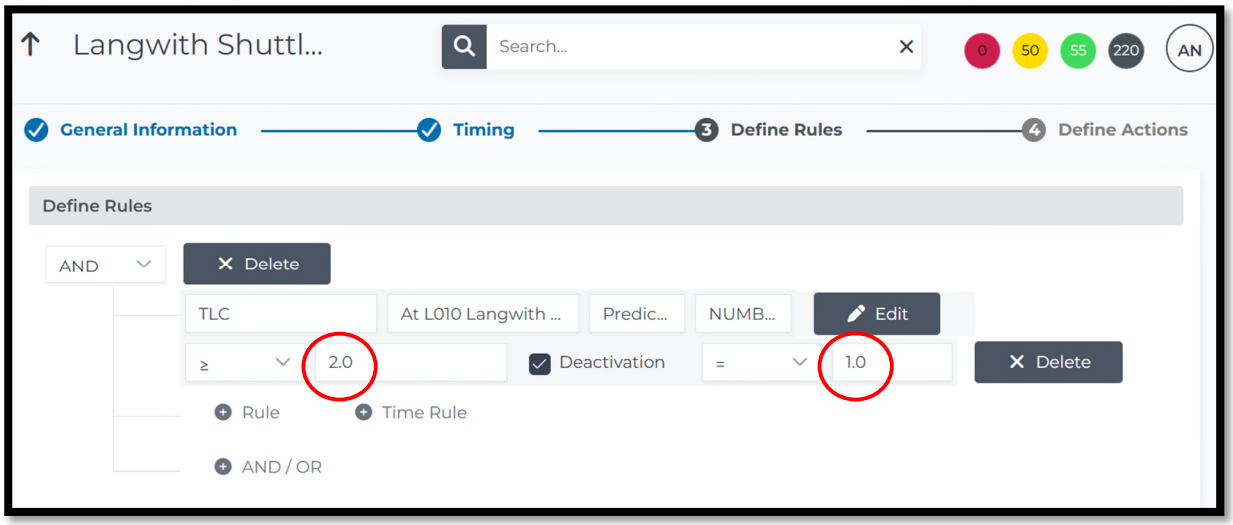


Figure 16 – Defining Rules on the MyCity Strategy Manager with Predicted Congestion Level Inputs from the PTMS (Circled)

Multiple strategies have been created on the project to show different functionality and how strategies can be given different priority levels, to show which direction of travel through the junction would be provided priority if two late running buses arrive together from opposite directions. From this point, the Westbound strategy is set with the direction of travel being from the West of the bridge through the junction to have a priority of 162, whereas the Eastbound strategy with the direction of travel being from the East of the bridge through the junction had a priority of 158. The strategy priorities on MyCity can range from 1 (lowest priority) up to 9999 (highest priority).

Strategies can also be modified to use specific date and time ranges as trigger points into the strategies, so different priority strategies can run automatically and allow the different directions of travel to have priority at different times of the day. For the Connected Roadworks project, when MyCity receives a predicted congestion level from the PTMS, the pre-defined Strategy Manager will automatically apply the appropriate pre-defined fixed time plan at the traffic signals in question. This is shown in the strategy manager as a defined action, to make a command or action take place once the trigger thresholds have been met. This is the same for the times of the day / days of the week, as well as the Predicted Congestion trigger. For this project, when the Westbound strategy was the higher priority and the Predicted Congestion trigger has been met, the strategy will activate and send a command to the Derbyshire UTC system to Force a Plan command of fixed time Plan 76.

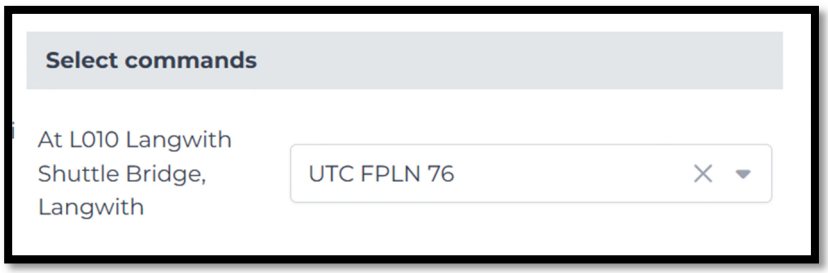


Figure 17 – Defined Action in the Strategy Manager to Force Fixed Time Plan 76

This means that the command has been sent to the Derbyshire UTC system, to change the controller plan from the current plan (or isolated state) which is being run, to run plan 76 instead.

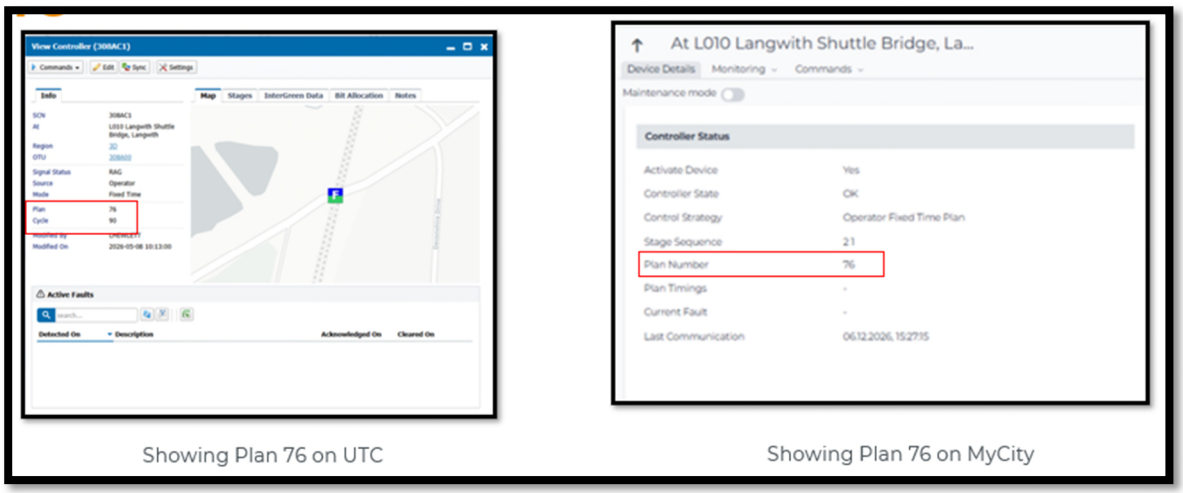


Figure 18 – The Fixed Time Plan Changes Visibility on both the Derbyshire UTC and MyCity Platforms

With the fixed time plan changes visible on both systems, this gives the users confidence in how the MyCity Strategy Manager works and shows the current controller status on both systems.

It should be noted that for the Langwith Bridge site which has been used for this trial, the operation of the traffic signals was monitored over a week and the timings were analysed with “biased” fixed time plans being derived from these records. The merits or otherwise are discussed in the “lessons learnt” section of this paper, but for the initial purposes of the project, the initial fixed time plans were judged to be robust as also confirmed by site observations.

AM Peak

Average

Stage 1		Stage 2	
Mean	17	Mean	20
Min	7	Min	7
Max	46	Max	48

14/04/2026

Stage 1		Stage 2	
Count	54	Count	53
Mean	19	Mean	21
Min	7	Min	7
Max	41	Max	43

15/04/2026

Stage 1		Stage 2	
Count	68	Count	67
Mean	18	Mean	21
Min	7	Min	7
Max	34	Max	33

AM Interpeak

Average

Stage 1		Stage 2	
Mean	13	Mean	16
Min	7	Min	7
Max	47	Max	64

14/04/2026

Stage 1		Stage 2	
Count	76	Count	77
Mean	12	Mean	16
Min	7	Min	7
Max	44	Max	64

15/04/2026

Stage 1		Stage 2	
Count	88	Count	90
Mean	13	Mean	15
Min	7	Min	7
Max	47	Max	31

PM Interpeak

Average

Stage 1		Stage 2	
Mean	15	Mean	18
Min	7	Min	7
Max	51	Max	71

14/04/2026

Stage 1		Stage 2	
Count	80	Count	78
Mean	14	Mean	18
Min	7	Min	7
Max	37	Max	44

15/04/2026

Stage 1		Stage 2	
Count	78	Count	79
Mean	14	Mean	18
Min	7	Min	7
Max	51	Max	48

Figure 19 – Example of Actual Timings at Langwith Bridge (April 2026)

Fixed Time Plan	Cycle Time	Stage 1*	Stage 2*
75	80	40	40
76	90	45	45

* Includes variable intergreens

Figure 20 – Fixed Time Settings for Bus Priority

The “However”

The successful Site Acceptance Test (SAT) of the end to end system took place in early July 2026. However, due to the relatively high costs and complex

arrangements to undertake the SAT on an actual set of temporary traffic signals, it was decided to apply the system to a set of permanent shuttle working signals at Langwith Bridge in the north east of Derbyshire referred to earlier in this paper. As any temporary set of traffic signals would need a compliant UTMC interface (UG405), and would need to be included in the UTC database, the principle of using permanent traffic signals was of equal relevance. The image below shows a bus moving away from the Langwith Bridge shuttle working signals

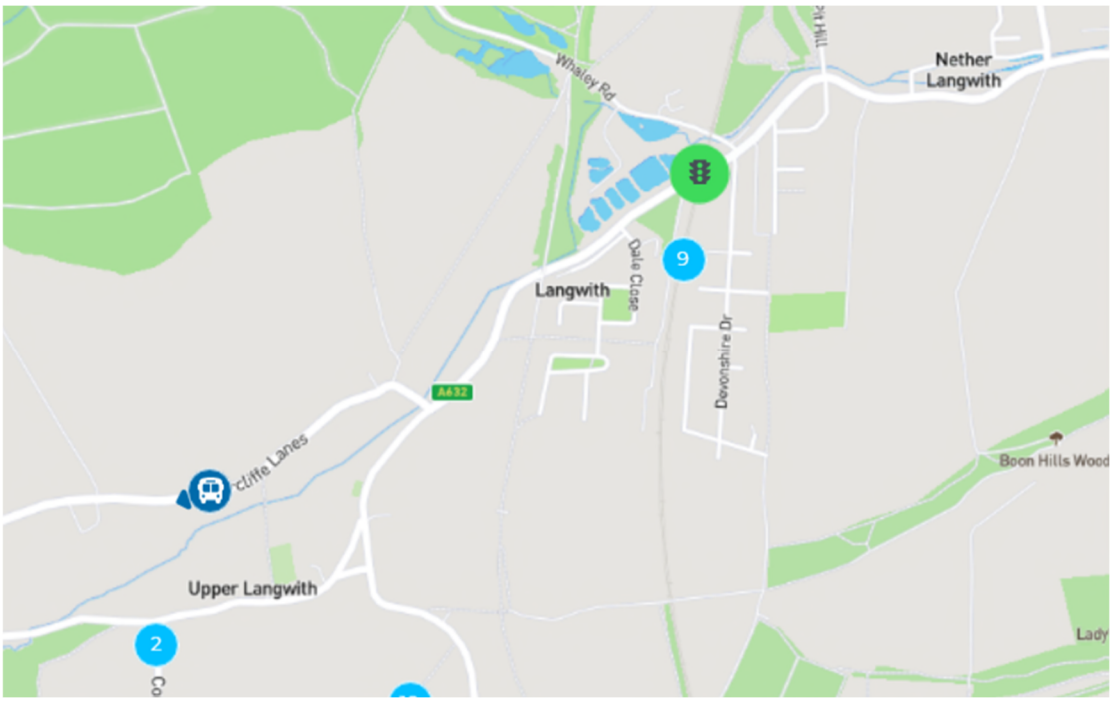


Image 21 – Bus Approaching the Langwith Bridge Shuttle Working Signals on MyCity

Next Steps

Although discussions of applying the technology to “real” sites where there are temporary traffic signals at roadworks have been taking place since 2022, until the technology was proven and ready, understandably, those responsible for defining how the signals would operate were nervous about applying the Connected Roadworks project until all the technology and functionality were proven to be successful. However, in all discussions, the merits of enacting this strategy have been met with universal enthusiasm, such that it is now expected that appropriate sites will be chosen for the inaugural application of the Connected Roadworks strategy in reality.

In the context of the above, it should be noted that there are several criteria that define where the strategy will be enacted, none of which are 100% fixed as only experience will tell where the Connected Roadworks will be appropriate. Nevertheless, initial discussions suggest that the following site “types” will be appropriate.

- The County Council, at least initially, must have complete control of the roadworks site so that the imposition of the Connected Roadworks strategy can be mandatory on the Contractor
- Good communications to/from the site via SIM card technology must be available. In some rural parts of Derbyshire, there are significant “not spots”
- The temporary signals must be in place for a suitable minimum period to justify time, effort and expense to implement the system
- Delays to buses are anticipated
- Unpredictable delays to general traffic are expected

It is acknowledged that if, for instance, predicted delays to buses are expected and that the duration of the roadworks is less than the initial threshold the effort of implementing the strategy would be worthwhile.

Answering the elements posed earlier in this paper –

- Objective bus location data is available in real time
- The real time conditions of links approaching traffic signals are available
- Remote communications can be provided by SIM card technology, albeit “not spots” are a significant consideration
- Careful assessments of normal traffic signal timings can be undertaken with the various tools available to the Council, but currently the setting of the signal timings requires the judgement of an experienced traffic signal engineer with good local knowledge rather than a completely scientific approach. Some may consider that this situation, however imperfect, is highly likely to be more successful than traffic signal settings made by non specialists

Lessons Learnt

The integration of systems, although complex, was entirely successful as was the enactment of the initially chosen strategy. The “institutional” elements of the work have not been as straight forward, not due to any reluctance by any party, but because this is not currently mainstream work for the specialist traffic management teams. Also, the main proponents of the initial work in the bus companies have left the industry or new personnel are now managing the bus operating companies so some of the “demand” for application of the system is less than it was.

After undertaking the SAT, it was assessed that a better means of applying special timings would be to extend the associated stage maxima of appropriate phases if the signals are on local VA mode.

To enable the strategy, the staff engaged in setting up the databases have to be experts in two or three specialist fields, and have time availability to set up the signals when required.

Probably the most important lesson is to gain the buy-in of the traffic management specialists into the process of the system development otherwise there must be some suspicion that this will “just” generate additional work and costs (to the Council) without necessarily benefiting traffic appreciably. It is necessary to have three of four actual instances of the technology being applied with a rigorous analysis of benefits and costs so that the value of applying the strategies is clear. Indeed, this is the next task for the eventual “Business as Usual” introduction of the strategy to suitable sites. For confidence, the initial sites are to have temporary traffic cameras installed so that live conditions can be monitored directly from the County’s Network Intelligence Centre, or remotely elsewhere.

On a very positive note, it is clear that the Connected Roadworks Strategy can be applied to permanent traffic signals, perhaps those with more than two stages.

Trials of actual temporary traffic signal operation and adaption with the Connected Roadworks system will be closely monitored and the results disseminated. This will

provide valuable data to fully assess the benefit : cost model for appropriate interventions.

Summary

The interconnected traffic technology behind the Connected Roadworks strategy in Derbyshire has been extremely successful, with continual tests and verification to make sure each step has delivered what was expected. Some of the developments of the prediction of delays have been based on Artificial Intelligence and Machine Learning of the characteristics of traffic conditions, which, with the particular technologies used is something that may not have been used to date elsewhere.

It is now vital to conduct trials at “real” sites to prove the worth of the interventions with objective data and an economic model for the time and effort involved in the application of the strategies. Confidence will require building with traffic management teams and as this occurs, it is expected that the Connected Roadworks system in Derbyshire will greatly assist the mitigation of disruptions for the benefit of buses, their passengers, and potentially, other road users.

Any opinions contained herein are not necessarily those of Derbyshire County Council.