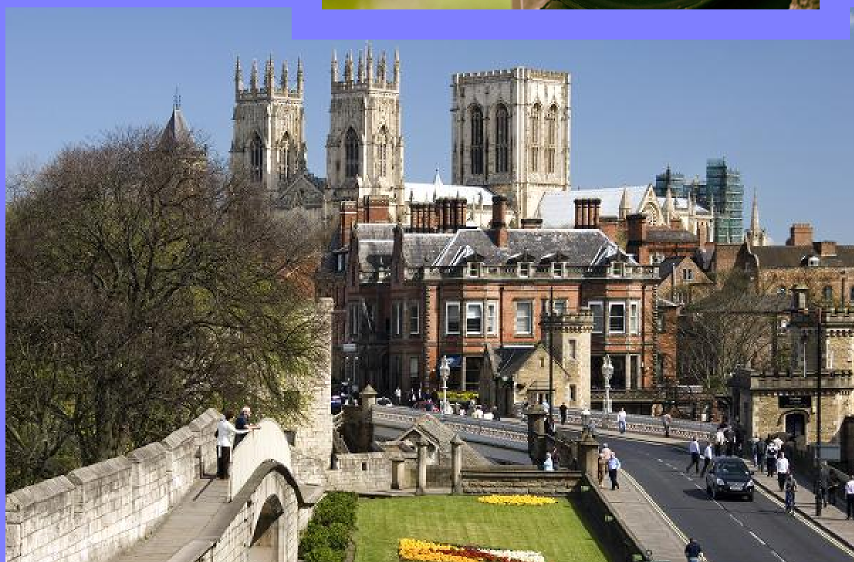
# Better signals using co-operative ITS data

*Transport Technology Research Innovation Grant*

(T-TRIG July 2016)



## Main Report

City of York Council
March 2017

CITY OF YORK COUNCIL

# Introduction

This report describes work undertaken from October to December 2016 by City of York Council focused on their local road network. The work was undertaken by COYC staff led by Darren Capes with their expert subcontractors White Willow Consulting, supported by Dynniq, IDT Ltd, IRC and INRIX as industrial advisors.

# Contents



# List of acronyms

C_ITS - Cooperative Intelligent Transport Systems

COYC - City of York Council

FVD - Floating Vehicle Data

ITS - Intelligent Transport Systems

MOVA - Micro-processor Optimised Vehicle Actuation

SCOOT - Split, Cycle and Offset Optimisation Technique

UTC - Urban Traffic Control

UTMC - Urban Traffic Management and Control

VA - Vehicle Actuation

V2I - Vehicle to Infrastructure [communications]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# Executive Summary

This project examines how data from vehicles can be used to improve traffic signal performance using "co-operative ITS". The focus is both the longer-term potential benefits and critically the early stages of adoption by UK Local Authorities in a step by step evolutionary approach.

The project considered the A59 corridor into the city centre, as this is typical not just of roads in York but many UK smaller cities and towns. Traffic visiting the business and tourist core of the City is constrained by its low capacity and it also has to support City of York Council's objectives of a reliable park and ride service, and supporting cycling and walking. It has 9 signal junctions on fixed time UTC with several mid-block crossings, and is part of York's UTMC investment. COYC seek to optimise timings of signals to achieve reliability and minimise delay for all travellers and the current system relies heavily on loop detection, which is costly to maintain, although new camera based detectors are in place. COYC want to know how to plan for future co-operative technologies, how these can help achieve new policy objectives and deliver more services with increasing pressure on resources.

Data from vehicles, either Floating Vehicle Data (FVD) provided by suppliers like INRIX or direct from vehicles, using technologies such as Vehicle to Infrastructure (V2I) linking using Dedicated Short Range Communications (DSRC) offers potential. But how a UK authority can start to adopt these is not yet clear. Firstly a literature review showed many use cases ranging from simple off-line auditing of signal plan performance, through improved fixed time plan selection, to fully integrated co-operative signal control using just data from vehicles . A TRL report for DfT showed that benefits from co-operative signalling could be over £100m across the UK, notably from better tuning of signals and also better temporary signal performance. This also highlighted that there could be significant benefits from off-line use of vehicle data to improve, for example, the choice of existing strategies or improving fixed time plans used in York and other cities worldwide before real time use is considered.

This search showed detailed algorithms that could be used for off-line plan building and the future aim of real time control, notably a US approach which uses individual vehicle data to reduce wasted green, and an approach from Dynniq in the Netherlands that uses processed journey time data with a control theory approach. Crucially, both work with low levels of sample size (below 1%) whereas many other approaches need higher penetration. The US approach uses individual vehicle data which is not normally available in real time from FVD, whereas the Dynniq approach uses processed data.

The project team then developed a wish list of future applications of vehicle data on the A59 corridor and developed an evolutionary approach to retain the existing signal controller and physical layout of the junctions, yet allow step by step adoption of both off-line and then real time data without excessive expense. The end point of the evolution would be a fully co-operative controller taking inputs from vehicles and other sources, and potentially supporting autonomous vehicles.  This approach was then tested by the industrial partners (INRIX, IRC, IDT and Dynniq) for practical deployment ability and to see what elements exist already in their products, and hence where gaps lie. This showed that many parts are already in place but the key functional gap is facilities for processing both FVD and DSRC data to derive new signal timings, including use of the above algorithms. This means there is a gap in the market for a solution for this processing which may be added to existing controllers or instations, or developed as a separate product. This could be seen as a low cost functional equivalent of the "set top box" used for digital TV handover, to allow existing signal controllers to use new inputs until such time that new controllers provide this off the shelf.

The key conclusions are that that probe and FVD data could both be used in a step by step evolution by a UK local authority to improve current performance, reduce reliance on physical detectors and to allow new policies and strategies for traffic control. The next steps would be to physically test some of the approaches to traffic control with real data from real vehicles to establish real benefits and costs of deployment, as well as integration of data with a UK traffic system. This would be of value to smaller UK authorities that cannot afford largescale replacement of their traffic control system estate but do have pressure to deliver more for less.

# 1 Aims and Objectives

### 1.1 Project purpose, objectives and scope

There are over 25,000[1] traffic signal installations in the UK. They form an essential part of traffic management and control and are an important tool for transport policy. Every UK local authority (LA) has at least one installation. They vary from simple single junctions working on vehicle actuated (VA) signals, to city wide adaptive systems such as SCOOT in London. Ensuring signals perform well is an important part of the Traffic Management Duty of any authority.

Whilst to date, signal installations have used roadside infrastructure to detect vehicles and change signals, research has shown potential benefits of co-operatively using data from vehicles to do this. This could occur through having different data than current point based sensors (such as loops) can provide or by replacing sensors. Having this better picture could allow traffic management strategies to be used more effectively - to reduce delays, improve emissions, improve safety and potentially give priority to vehicles. It could also give authorities new tools to deploy policies by controlling traffic signals more effectively, whilst potentially saving maintenance costs of in road sensors. It is also a stepping stone to autonomous vehicles.

But no research has yet looked at the practical possibility of using this data in a UK context, on the likely real world benefits in a UK local authority network and on impacts on various UK traffic systems, such as SCOOT and MOVA. The work to date has largely been simulations of potential benefits - which are indeed encouraging- rather than assessing practical feasibility and measuring costs and benefits. A previous TTRIG[2] report on vehicle priority highlighted the gap between theory and practice in a similar area – priority at signals using connected vehicles.

Hence the objective of this work is to bring together a network operator - City of York Council, with real world traffic and transport policy problems with industry suppliers of both vehicle data and the equipment used to control signals (IDT, INRIX and Dynniq) and experts in traffic signal techniques(IRC). This report shows research into how real examples of junctions in York could be improved using data from vehicles, to match local policy aims and the implications on the roads authority, signal and data suppliers.

1 RAC Foundation

2 CAV-PAS – Connected and Autonomous vehicles – priority at signals SDTI – March 2016

This work aims to be a "paper prototype" for a later co-operative demonstration, using real vehicle data and real junctions.

In terms of scope, it is important to note that previous work has considered junctions in large cities, with high volumes of traffic and where authorities have large traffic control resources (people and funding). In contrast, we consider here a small city with limited resources and the pressure to do "more for less", of which there are many like York. We consider how the technology can be applied there, bringing learning applicable to many parts of the UK to bring co-operative solutions nationwide.

We will also consider data from both beacons that connect to the traffic signals directly (DSRC) and Floating Vehicle Data (FVD) via a service provider (INRIX). The scope is to consider the benefits and practicality of both approaches, especially at low penetration rates of beacon technologies, and on possible hybrids. We do not consider in depth the communications protocols to be used or messages sent from vehicles, instead we focus on how such data might be used to achieve policy objectives.

This is a desktop study, with the scope specifically designed to use T-TRIG funds to undertake research a Local Authority could not otherwise undertake, to inform future investment decisions. As later detailed, we have chosen the A59 corridor in York for the geographical scope of the project as it is representative of many urban arterials not just in York but across the UK.

# 2 How this addresses DfT's priorities

The project aim is to overcome the challenge UK Local Authorities face in deploying co-operative technology to improve traffic signals. UK authorities face both reducing resources and increasing policy demands. The need to address congestion, vehicle emissions and safety whilst supporting economic growth and prosperity presents a complex challenge. The benefits of even a small improvement are valuable, with congestion costing the UK around £10bn[3] per annum and emissions now becoming the dominant cause of transport related deaths.

3 INRIX data

Traffic signals are a key tool to benefit all types of road users but as systems age and authorities look to replace and expand them, emerging in-vehicle and Internet technologies have a crucial part to play in the next 5 years. However, DfT research[4] shows few authorities to be actively considering these. There is a danger that co-operation develops only in larger cities, out of alignment with the "one nation Britain" objective. The UK needs to understand how to exploit co-operative vehicles to avoid a patchwork of disconnected deployments that will confuse the market and motorist.

As local authorities consider investment in replacing ageing traffic control systems with new ones, it is essential that good guidance exists to inform decisions regarding what should be specified. This will maximise exploitation of new technology and help meet policy objectives. This research will therefore impact on the four DfT priorities and UK transport;

- Economic growth, by reducing congestion and improving journey times
- A one nation approach to co-operative vehicles
- Better journeys
- Ability to deploy new technology with limited resources

Specifically, this project allows COYC to explore new technology solutions to congestion and emission reduction, on behalf of other smaller UK authorities, and help remove barriers to introduction of co-operative systems. The outputs will help other LAs and UK industry but also help COYC in deploying its own policies. Hence the grant adds value by accelerating UK deployments, providing practical help to UK LAs. Competing this early stage of research would help COYC become a test bed for future pilots and demonstrations of small city approaches.

# 3 Criteria for Success

It is important to understand the criteria for success for the project, as they may be different from approaches elsewhere. COYC is committed to the use of new technology to deliver transport policy objectives and recognises the need to prepare for these both in traffic management and the vehicle fleet. This has to be balanced against ongoing pressure on resources and the need to make better use of assets, deliver innovation in the most cost effective way and limit ongoing revenue costs.

4 Atkins research for DfT on Local Authorities adoption of C-ITS

These aspirations and pressures are common to many local authorities and so developing real world strategies for traffic control in an environment of advanced vehicle sensing and connected vehicle operation would have widespread benefits.

A successful project would show how COYC can evolve from its current traffic control systems over time to embrace these opportunities, rather than have to change equipment in a "big bang" that smaller authorities may not be able to resource. A further measure of success would be to understand the potential benefits and implications on cost for an authority, and the likely timings of such change.

COYC's policies are not to actively encourage car use into the city but look at balanced use of the network for all road users. Hence a successful project does not simply focus on performance of traffic systems in terms of delay but also allowing allocation of road space to promote reliable public transport and park and ride journey times.

Finally, as with many cities across the UK, York is faced with the need to accommodate significant additional development both in the housing and commercial sectors over the next few years. This will place additional stress on existing transport systems, that due to the constrained nature of the city, are unlikely to be able to expand accordingly to meet this need. There is a challenge therefore in ensuring the technologies the City uses on the highway are able to release the necessary capacity to accommodate this growth.

# 4 The concept

### *4.1 Current Traffic Systems and Sensors -Challenges to address for UK authorities*

It is useful to understand the current toolkit for signal junctions to understand how they may be improved using co-operative approaches. Most UK signal junctions that are not linked to others use Vehicle Actuated (VA) signals, where loops in the road detect a vehicle presence and then the signal controller changes signals to give that vehicle green (or extends a current green phase). A typical junction where appraoch speed is an operation consideration uses 3 loops in an 'XYZ' configuration per approach. At sites where speed is not an issue, it is common to provide a single 'stopline' loop and Microwave Vehicle Detector (MVD). Failure of these loops is common – over

50% of the COYC loops are damaged due to poor road surface or utilities. This leads to vehicles waiting unnecessarily for green signals, especially off peak. Different “plans” within the controller change the allocated green time to each approach by peak and off peak for example.

Where traffic conditions are heavier, Microprocessor Optimised Vehicle Actuated (MOVA) signals can be used to maximise capacity and minimise delay. These require more loops per approach but give significant delay benefits over VA. Indeed the use of MOVA on new all purpose trunk roads has mandated in DMRB and this standard has been adopted to some extent by local highway authorities for their networks.

Where signals interact with each other, Urban Traffic Control (UTC) is used to link the signals. This can use “fixed time plans” that are set up beforehand using software using historic traffic flows to define signal timings and offsets between signals. A central computer called “the instation”, often linked to an Urban Traffic Management and Control system (UTMC), manages these changes. Often a mix of strategies is used, with VA for off peak and FT for peak periods (as in York) and there are various means of choosing when to change (timetable, operator change). UTMC approaches allow a strategy selection which can be used, as in York, to change plans for example to cater for special events.

The next step is to “adapt” these fixed time plans by changing settings in real time. Many UK cities have invested in SCOOT to change the split, cycle and offset of signals in real time using data from loops and recently new types of sensors such as magnetometers. It is useful to recall these parameters;

***Split*** – the way green time is distributed between different approaches at one junction

***Cycle***- the time taken to “go around” each approach at a junction

***Offset*** – the time one signal will go green relative to its upstream neighbour – a good offset giving “green wave” and allowing progressions of platoons of traffic

These three concepts all impact on signal effectiveness – for example poor offsets result in vehicles “missing a green” if the time taken to drive between signals is not well tuned. Poor split times “waste green” that could be used by vehicles queuing on other approaches, and Webster and Cobbe[5] showed that delay at a junction is directly influenced by cycle time.

5 Webster, F.V. and Cobbe, B. M. (1966). Traffic Signals. Road Research Technical Paper No. 56. HMSO London UK

SCOOT requires all junctions it co-ordinates to work on the cycle time (or a multiple of it) and is not the only solution. SCOOT is not used in York for example as it does not apply well to the city's network. Other algorithms are becoming available and have been proven elsewhere.

Irrespective of how the signal timings are made though, they need;

- Up to date traffic data to set timings or plans. (often this is on turning movements, not just flow)
- Working sensors for real time operation and adaptive control
- Resource from the LA to calibrate and monitor maintenance resource, for example to recut damaged loops

Additionally, a change is now spreading across the UK in communications technologies used for signal control. The traditional "copper pair" communications on analogue telephone wires are being replaced by 'Internet Protocol' (IP) technologies using a wide range of media such as Wi-Fi, fibre-optic or broadband services. Although there are presently issues around technical constraints imposed by the TR2523 control standard, this will ultimately offer the opportunites to do much more with signal control, hugely increases the volume and complexity of data that can be sent to and received from signals and allows sites to be used as 'hubs' in wider data networks, (supporting infrastructure to vehicle communications for example). In York, this change is via City-wide private fibre-optic provision. This will lead to all traffic signals in the City either being directly connected to an ultra-broadband segregated fibre-optic network or linked to it via wireless bridges.

## *4.2 The Local Problem in York*

The A59 corridor forms the main arterial route into the city centre from the North West and links York with the A1 and Harrogate. It also forms the main route into the city for many settlements in the north west and so is important to ensuring residents of outlying communities have good access. The route also has a significant role in travel within the City and carries a park and ride service, numerous local and long distance bus routes.

The A59 also sees high cycle and pedestrian activity and is provided with designated facilities for them. The need to accommodate high usage by varied modes of transport within constrained physical limitations is why efficient effective urban traffic control is essential, both for travellers on the A59 corridor and for the city more widely.

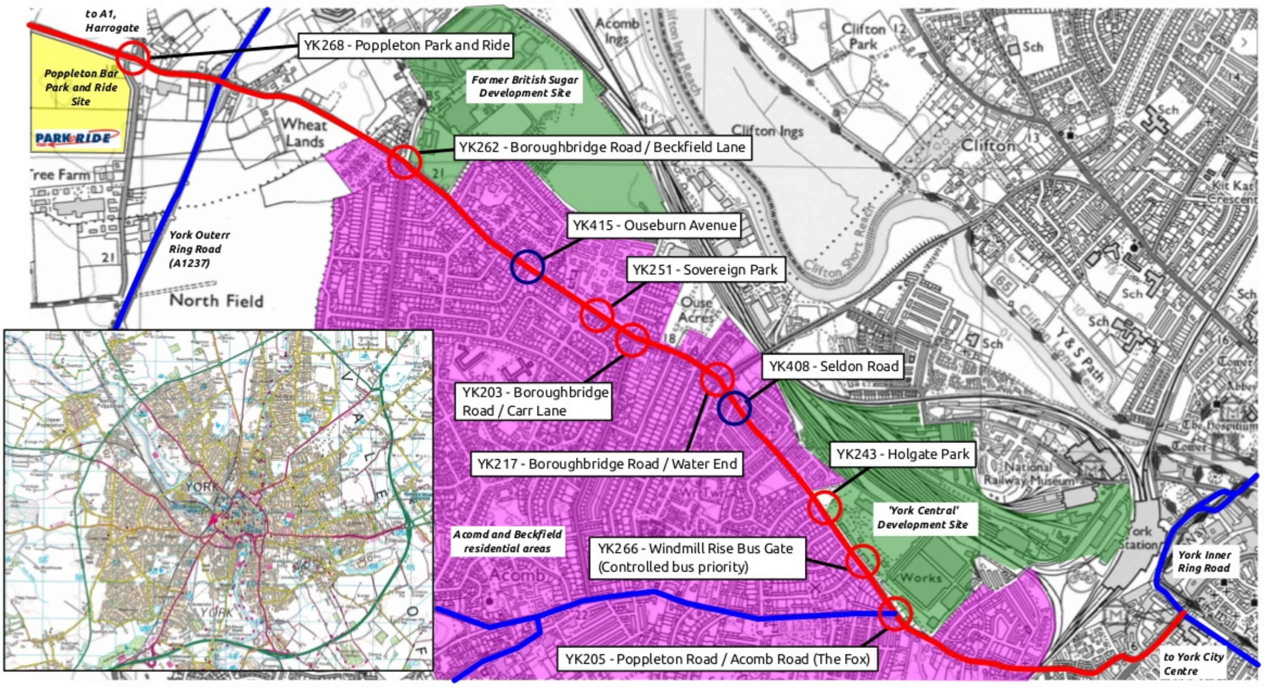


Figure 1: the A59 test corridor

The above map shows;

- The nature of the route as a main arterial route into the City from the outer to inner ring roads
- The park and ride site and controlled bus priority at the Windmill rise bus gate
- Large residential sites feeding the corridor
- Confluence of two corridors feeding the station area

Constraints on road development are;

- The built up nature of the corridor
- The need to encourage modal shift, and to ensure high quality pedestrian and cycling provision
- The need to adhere to the Council's hierarchy of road users when planning improvements

York's UTC system that manages this corridor is now coming to its end of life, so this is an opportunity to deploy new solutions, to give new tools to support new polices for better transport for all. COYC does not want to invest in an infrastructure system when data from vehicles is now emerging. Equally, it has invested in roadside equipment recently, and replacing this before the end of its life would be unacceptable use of limited resources. And it has limited resources for maintenance of sensors based systems that cause issues with delays to vehicles. The high-level problem to solve for York is therefore…

"How can COYC plan for future technologies in its UTC replacement to maximise opportunity and minimise resources".

COYC is currently engaged in a major capital investment in traffic signal replacement. The six year 'Traffic Signal Asset Renewal' programme will see around half of York's life expired signal installations replaced with new equipment. This presents an opportunity to provide new technologies and ensure the equipment deployed is future ready; This presents a specific problem for this study to address...

"How can COYC make best use of the existing signal equipment on the A59 using co-operative data?"

### *4.3 Potential solution*

It has long been seen that data from vehicles themselves could be used to augment or even replace the above data sources. This data is from "connected" vehicles - which can (in simple terms) tell traffic signals where they are and if they are queuing, to allow better co-operation between vehicles and infrastructure.

This connection can be done in a variety of ways;

- Through data from individual "probe" vehicles, that tell the signal system where they each are (using technologies described below); or
- Through data from a collection of vehicles processed together to inform for example on journey time or queue length. This we call "floating vehicle data" (FVD)

The first approach needs a direct connection to the traffic system, which could be via Vehicle to Infrastructure connections via DSRC/ ITS-G5 (a form of Wi-Fi) or by advanced cellular communications such as 5G. The key for this project is that apart from small scale trials, no technology exists in the market to support this and there is no user base installed in vehicles. Hence it is seen as a future technology.

FVD in contrast is widely available, from suppliers like INRIX, who use over 1 million probes in the UK to provide journey times for networks such as York, as shown below. Google and tomtom also provide services. The sources of data include in vehicle fleet management systems, sat nav, apps and mobile phone data. They are processed and aggregated by companies such as INRIX for journey times for sat navs and increasingly for local authorities' congestion reporting. This is typically reported on a per link basis rather than as raw individual vehicle locations, although raw data could be made available in principle (there has been little demand to date for raw data from authorities or sat nav customers) for historic use but currently not in real time. Such Systems typically use 2G, 3G or 4G existing communications.

One key question is to explore the potential between the low penetration of early probe data services and the more mature but often more processed FVD services. This is key, as penetration of in vehicle devices for V2I may rely more on the fitment of equipment to new vehicles than probe data will. The V2I deployment timescale is currently unknown so would be a risk to invest against for York.

To ensure the potential for use of FVD data, and not waste resources if York did not have sufficient coverage, an early INRIX data sample was used for the A59 to build a heat map of congested links by time.

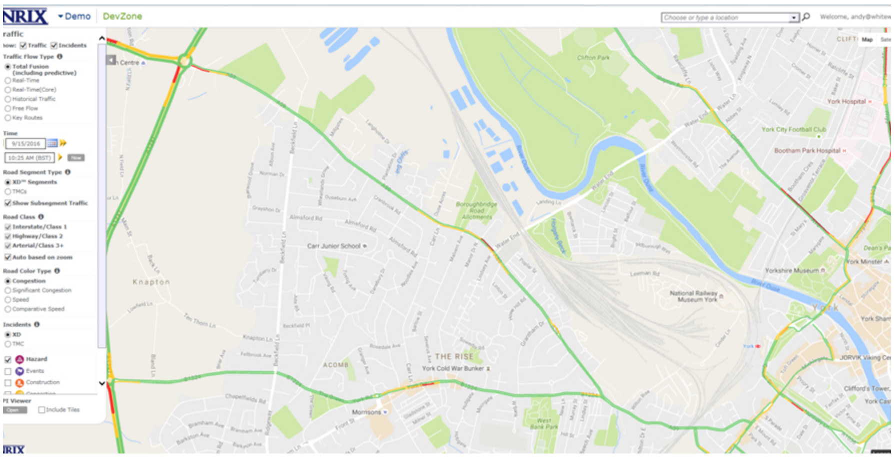


Figure 2: Inrix data from the A59 Corridor

This data showed good correlation with COYC's observed traffic and also showed that it is possible to see when congested link "spills over" into an upstream link (often due to exit blocking). Connected vehicle data can vary by aggregation (from individual to all equipped vehicles on a link, and in time), Timeliness/latency, Information generated (e.g. speed related, positioning,

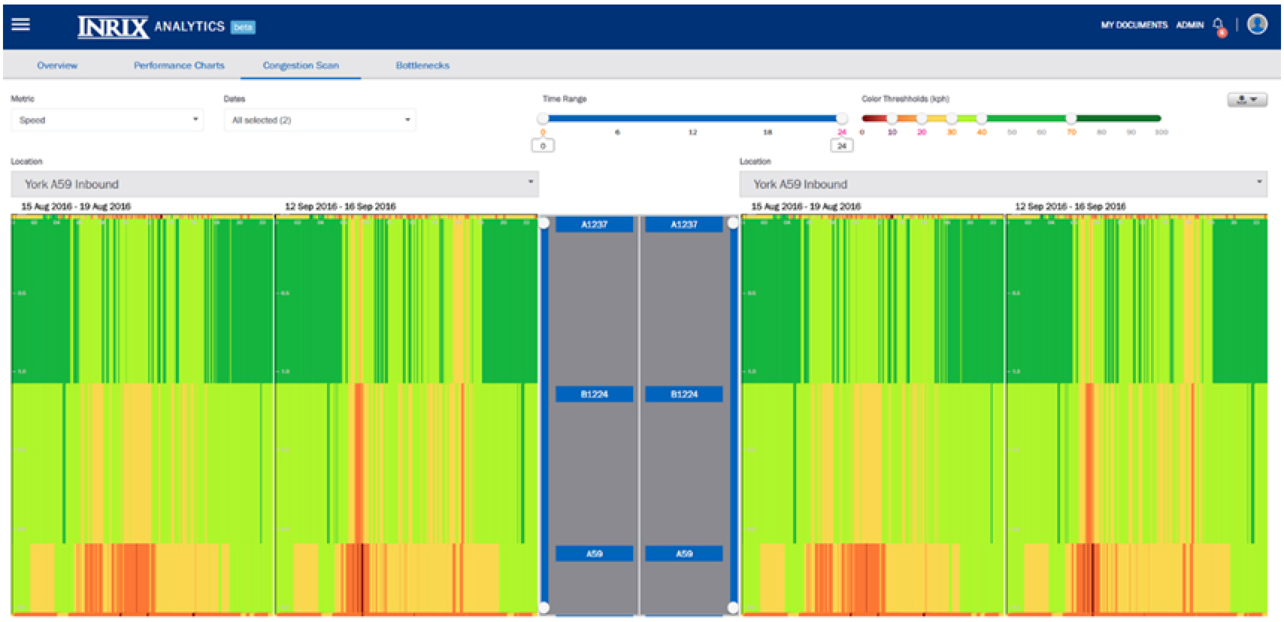


Figure 3: congestion map of A59

turning counts/intention), communications approach and availability

The table in appendix 3 looks at the data sets above plus Bluetooth measurement for availability

### *4.4 The project methodology*

After defining the problem to be solved and initial checking of the data available, the project then:

a) Captured the state of the art on signals and vehicle data through discussions with INRIX and Dynniq's global experts, allied to a short review of latest literature.

b) Identified different approaches that could help a UK local highway authority deliver policy benefits using co-operative vehicles and mapped which types of data would be needed, as well as benefits over existing sensors. This will bring in INRIX and Dynniq connected vehicle experience.

c) Identified the impacts on current controller design to understand what needs to be done to make standard UK traffic equipment. This includes beacon and probe data approaches

d) examined junctions on the A59 corridor in York where new technology might give benefits and identify other policy implications. These sites are representative of many junctions in small UK cities/ large towns.

e) Worked with IDT, INRIX and DYNNIQ to assess how such junctions would be equipped and likely benefits against policy, and also new areas such as SPAT (Signal Phase and Timing)

f) Produce concepts for on-site deployment and looked at what exists to support these in the UK, ready for a subsequent stage of research, by identifying the gaps needed to move in a step by step evolution.

This approach married established data from sensors, off the shelf data from probe vehicles and new data from beacon based systems to solve existing real world problems.

# 5. Project Outcomes.

### *5.1.1 The State of the Art*

The first section of the project looks at the state of the art in improving signal performance using co-operative approaches. Because of the specialist nature of the work, this literature search was deliberately focussed on this area rather than the wider benefits of co-operative ITS. The detailed review and discussion of relevant literature is included in Appendix 1 to this report

### 5.1.2 Summary of implications

The state of the art review shows that:

- There could be early benefits from using FVD data off-line to determine historical signal performance, exit blocking and poor offsets, without any changes to real time infrastructure. Probe or FVD data could be used to quantify problems at existing signals
- There may then be further benefits for tuning plans and signal parameters, again off-line
- Fully replacing detection with FVD or probe data is not as useful as a data fusion approach- therefore replicating loops that are broken or out of use, or adding extra “virtual loops” may be a better first step than replacing loops with low penetration probe data
- There are several approaches to real time use of data – ranging from use of FVD data in control theory based algorithms (Dynniq) to use of individual FVD or probe data to optimise offsets (Purdue).
- For the UK, there may also be benefits in using the UTMC approach with probe data to decide when to change strategy, e.g. from VA to fixed time to SCOOT, based on dynamic conditions such as exit blocking. This could augment the SAPS / APS solutions currently offered by Dynniq and Siemems

- There may well be large benefits from expanding improvements in temporary traffic signal control settings using probe data

A key finding in all these papers was that benefits are almost always determined by simulation rather than real world measurement. There are two implications here:

- The need for real world tests to prove the benefits; and
- The need for a second data set to measure benefits distinct from that data set used to determine the changes made

Other implications are that early uses of probe data could are likely to involve:

- Loop emulation ( needs large sample size)
- Changes of strategy or control system (eg UTMC Strategy selection)
- Changes of plan timings on or off-line

This implies an evolution keeping the current controller and road layout in place. If beacons are to be used, they would need to be sited to be able to communicate with vehicles at current loop locations to match control strategies initially (eg MOVA loops, VA loops, SCOOT entry loops). Also

- The sample size for loop emulation may not be achieved by DSRC beacon messages. These offer other potential benefits but needs a higher penetration.
- FVD data offers earlier applicability, as 10% of UK veh miles available and 3% of all vehicles are currently sampled from many suppliers and this will increase, and there is no need for infrastructure installation. However, granularity and processing of data for current sat nav use means individual vehicle data in real time may be a challenge. Purdue University has used an algorithm using individual INRIX data off-line however
- Junction delay minimisation approaches (Dynniq) can use processed data as looking at outcomes from timing change on point to point journey times. This is more applicable to SCOOT.

## *5.2 Customer needs*

An initial list of customer needs for potentially using this state of the art was then drawn up by COYC. These were:

- The ability to retain current traffic controllers for as long as possible. This means use of existing facilities to "adapt" a controller to using new inputs
- Use probe and FVD data for both strategic uses (via UTMC and the central computer) and tactical control of the junction (in real time)
- Be able to use (in the future) data provided from the cloud via an IP connection
- Cost effective deployment with minimal additional staff resources
- Require no physical changes to junction layouts
- Be able to support if possible park and ride and general bus reliability through the provision of selective vehicle priority
- Not require any assumptions of uptake of technology in vehicle dependent on third parties

This implies an evolution keeping the current controller and road layout in place at the start.

### *5.3.1 The Evolution wish list*

The above findings plus a workshop with COYC staff led to a "wish list" of evolutionary changes from the current UTC and VA based system to a future fully probe/ FVD co-compatible controller. Each of these is a potential stage in evolution that would depend for example on DSRC uptake, benefits being shown and costs of supply. This list is illustrated in table 1 overleaf.

This wish list was developed with a view to it's ultimate deployment on the eight junctions on the A59 Corridor, as shown in figure 1 on page 7. Although this study has been a desktop exercise, it has been undertaken with a view to future real world use. To achieve this, the development of the outcomes has been considered against the conditions found on the A59, which in turn tests the proposals suitability for wide-ranging deployment across the UK. This assumption is based on the nature of the A59, which aligns closely with many other primary radial routes into small to medium size cities.

Officers of COYC have been involved in the development of the proposals in order to ensure they demonstrated real world practicality and relevence.

Table 1: Desired potential evolution steps for co-operative signals

| Complexity | Customer Requirement from COYC | Strategic / tactical** | Outcome |
|---|---|---|---|
| Simple | Offline testing of current plans vs congestion using analysis of performance via FVD | Tactical | Better FT plans to reduce congestion / improve bus journey time |
| Simple | Offline decisions as to best strategy to use (e.g. SCOOT to MOVA, SCOOT to FT) | Strategic | Better choice of strategy tied to existing conditions |
| Simple | Online switching of strategy based on ITS- G5 or INRIX data (e.g. FT to VA) from instation | Strategic | Better control of progression into and out of peak periods |
| Complex | Emulating a loop (presence or SCOOT) from processed FVD or DSRC e.g. to replace VA loops for off peak | Tactical – as input to existing strategy e.g. VA | Less fixed loops to maintain |
| Complex | On-line changing of plans based on triggers from FVD | Strategic | Better choice of existing plans tied to traffic conditions |
| Complex | On-line changing of plans based on triggers from ITS-G5 data | Strategic | Better choice of existing plans tied to traffic conditions |
| Complex | Support CROCS Schema | Tactical | Support for SPaT |
| Complex | Use FVD data to change timings in temp traffic signals instead of / as well as presence detectors | Tactical | Better timings with impact on network understood |
| Complex | Process multiple inputs to change strategy | Strategic | Better signal timings across network |
| Very Complex | Process Dynniq and Perdue algorithms to improve plans or change stage in real time | Tactical | Better signal timings |
| Very Complex | Process multiple inputs to change tactics (e.g. stage, vehicle priority for bus based on occupancy | Tactical | Overall network efficiency and New policy tools |
| Extremely Complex | Full co-operative signal control with digital controller and digital inputs for both strategic and tactical control | Both<br><br>**(i.e. impacts many or single junction) | Overall network efficiency and New polices, reduced infrastructure etc. |

### *5.3.2 Evolution architecture*

This wish list, plus early discussions with industrial partners, showed various steps that in practice would support the evolution beyond off-line use of the data. The first figure shows the current York and UK signal architecture in terms of functions. It does not necessarily show the physical connections;

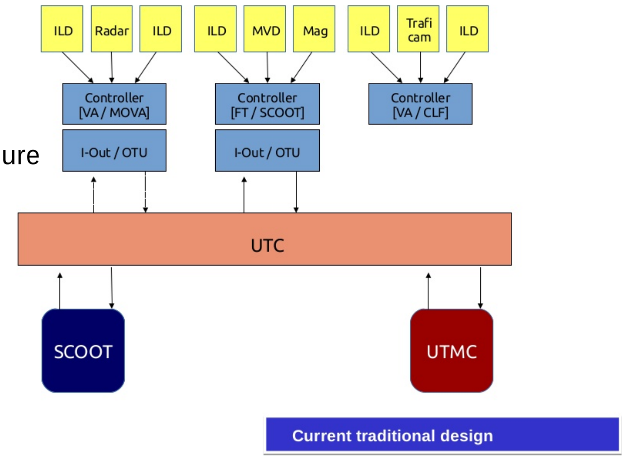


Figure 4 - As-is architecture

The next figure, (left), shows the new types of data becoming available;

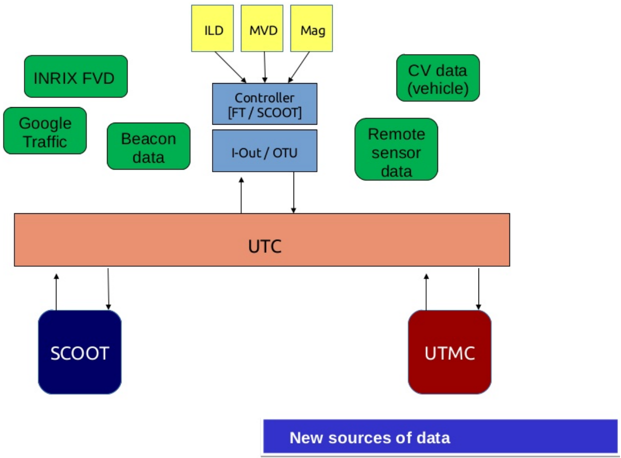


Figure 5 - New sources of data

This next figure, (right), shows that these will all be available via the internet / cloud;

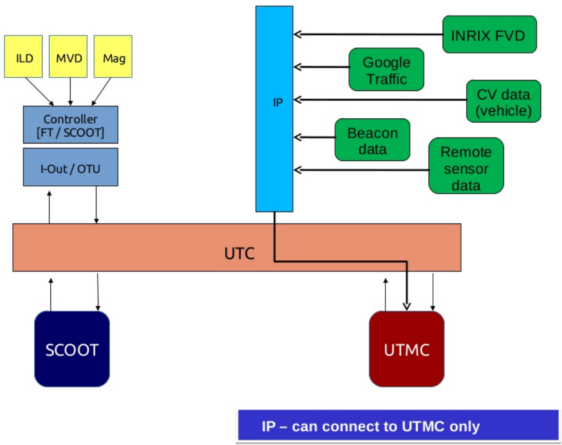


Figure 6 - Connecting new data sources

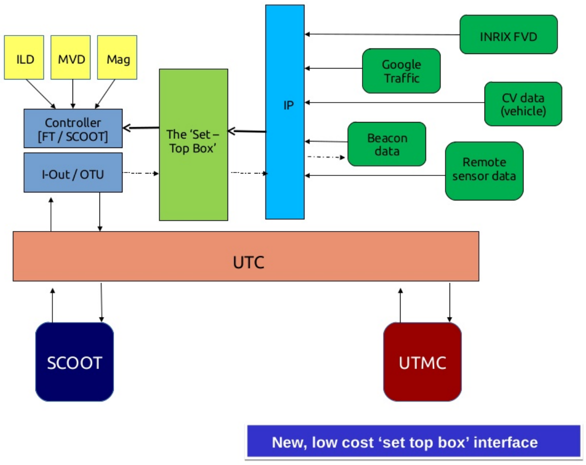


Figure 7 - The set-top box function

The figure to the left then introduces the functional component of a "set top box" that connects an existing traffic signal controller to the internet data sources. This is similar in concept top a digital TV set top box. The key is that it is a functional set of requirements not a single physical device

Ultimately, all the functions of the set top box will be integrated into a new controller, as shown below. The functions of the set top box can then be removed.

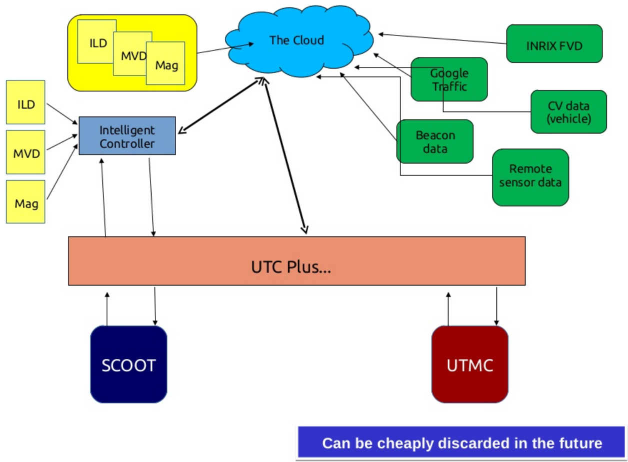


Figure 8 - The ultimate integrated controller

## 5.4 Elements already in place

A key question is which of the functions of the "set top box" are already supported by the market, by the current controller standard UG405 or via UTMC and where the gaps lie. Appendix 2 shows a detailed analysis with a summary opposite, where green indicates all items available, yellow that work is needed on some and red that there is no current support

Table 2 : Analysisi of functions and gaps

| Ref | Complexity | Requirement from COYC | Gap to fill |
|---|---|---|---|
| 1 | Simple | Offline testing of current plans vs congestion using analysis of performance | None |
| 2 | Simple | Offline decisions as to best strategy to use (eg SCOOT to MOVA, SCOOT to FT) | None |
| 3 | Simple | Online switching of strategy based on DSRC or INRIX data (eg FT to VA) from instation process that instructs controller | Needs to be developed for a tactical approach but strategic switching possible. This has strong market potential |
| 4 | Complex | Emulating a loop (presence or SCOOT LPU) from processed INRIX or DSRC eg to replace VA loops for off peak | Processing data to emulate loop may be a gap. Sample size for loop emulation may be the challenge (esp DSRC). FVD cannot be currently used |
| 5 | Complex | On-line changing of fixed time plans based on triggers from INRIX data | Taking an "alert" from INRIX and changing plan is a gap |
| 6 | Complex | On-line changing of plans based on triggers from DSRC data | Input route into UTC needs to be developed. Sample size an issue |
| 7 | Complex | Support CROCS Schema | Controller or device development to output CROCs |
| 8 | Complex | Use FVD data to change timings in temp traffic signals instead of / as well as presence detectors | Needs development |
| 9 | Complex | Process multiple inputs from cloud based services eg Dynniq emissions dashboard and detectors to change strategy | UTMC may provide already... but without UTMC; Input route into UTC needs to be developed |
| 10 | Very Complex | Process Dynniq and Perdue algorithms to change plans offline or change stage in real time | Gap in processing data and Input route into UTC needs to be developed |
| 11 | Very Complex | Process multiple inputs to change tactics (eg stage, vehicle priority for bus based on occupancy | Low latency input route into UTC needs to be developed |
| 12 | Extremely Complex | Full co-operative signal control with digital controller and digital inputs for both strategic and tactical control | The end destination |

Whilst the above table shows technical possibilities, any future work would need to assess the benefits and costs and hence priorities of deployment of COYC

### *5.5 Implications*

The above analysis shows that:

- For applications using historic data off-line there is no gap in development to fill
- Once historic data is used to change between fixed time plans or change strategies, work is required to take outputs from probe and FVD data sources and process them to trigger changes. This is a first gap the "set top box" needs to support
- Emulating a loop at the controller level also would require a similar process, but given the focus on small penetration of data it is not clear that this would work effectively, The same outcome (eg identify the presence of a vehicle) might be better done with DSRC data for example
- Temporary traffic signals do not use full capability controllers but using vehicle derived data to replace current detection is a clear possible benefit
- Some of the UTMC strategy selection tools may be improved by better functions provided in the set top box approach
- Supporting the Purdue and Dynniq algorithms for real time use (eg in SCOOT) would need development in the set top box. Real time use of the Purdue algorithm is not currently possible
- A new controller which supports FVD and DSRC inputs for strategic and tactical control would be a major development, but would be informed by the steps along the evolution highlighted above.

In terms of data supply, the annex also compares FVD with DSRC and Bluetooth as a standard way of capturing data. It concludes that FVD provides all the historic data needs and some of the real time, whereas a high penetration DSRC would add more real time (or FVD made available in real time as individual vehicles). Bluetooth offers a journey time alternative but could not be used for loop emulation. Hence no single data source provides both the availability, penetration and accuracy needed for all the above needs.

# 6. Practical applications of the concept to UK transport

### 6.1 Evolutionary Deployment path for a Local Authority

In conclusion, the above work shows several key stages in co-operative ITS for improving signals.

a) off-line data use, to improve existing signal settings
b) semi real time use, for example in strategy selection
c) real time use, for changing timings

Only step c) requires significant changes to signal equipment and large development by industry. There are gaps to fill in how vehicle derived data is used in delivering b) and c) to but the existing signal controller specification supports many approaches that use fixed time plans or changing between strategies. We have identified some potential for use of FVD and probe data in SCOOT but this requires different approaches and this is best left to SCOOT suppliers to consider.

Hence deployment should focus on quick wins from existing data, to make the most of the opportunity, and to learn lessons for how to adapt existing approaches to use connected vehicle data.

### 6.2 Cost benefit assessment

Value for money is obtained by:

- Avoiding the do-nothing situation of York staying with an aged UTC system and then having to invest in an infrastructure based system just as co-operative ITS techniques are proven. By being an early adopter because of this pressure to renew, COYC can avoid wasted investment in old technology. This is a key value consideration York cannot be seen to invest in obsolescent approaches, yet does not know what new approaches to invest in.
- The congestion savings shown in the appendix for the BCR impacting an average AADT across the scheme of 14,742 VPD (2015 figures, DfT database)
- Specific traffic management benefit for park and ride and other buses, to reduce traffic demand
- Improving modal shift and so according with York’s Road User Hierarchy
- Developing a knowledge base for use by other UK authorities and suppliers in using probe data

The objective of this project is to understand the potential for a C-ITS approach, so estimating a BCR needs to be undertaken with caution. However, this approach might be likened to the adoption of SCOOT over fixed time, where data from TfL suggests across 600 junctions, SCOOT is delivering an average 12.84% reduction in delays and 4.6% reduction in the number of times that vehicles have to stop. These gave an average saving of £90K in the first year and a 12:1 CBR.

York's average traffic flow and congestion is less than TfL. Calculations have been made, in the attached appendix to account for this that suggests a BCR range of around 4.0 to 1 to 9.9 to 1 could be achieved, but we emphasise this is an estimate. The appendix calculations have been independently validated by Neil Hoose FIHT, Visiting Professor and Associate Research Fellow, Centre for Transport Studies, Imperial College London, Director, Bittern Consulting Ltd

# 7. The next steps

## 7.1 User Consultation

Although this work has brought together thinking from an active local authority, several suppliers and signal experts, it needs testing with the wider LA and supplier community. Hence, we will present it via the Transport Technology Forum, ITS UK and via the partners' customers for further comment.

We will also share it with our international partners in the US and Netherlands whose support is gratefully acknowledged. This feedback will help all the partners understand the evolution of their products to support UK policy needs with this opportunity

## 7.2 Real world pilots

This work shows the ability to deploy some quick wins using existing products in York to validate these concepts and quantify benefits and costs. In addition, it also shows that with some development, especially in "instation" developments, new approaches to control could also be deployed. And with further investment, real time approaches using co-operative data might also be tested (eg Dynniq algorithm with INRIX FVD data)

All the above shows value in examining how a UK local authority can move down the evolution path we have defined in this report. For this reason, the team have applied for C-ITS funds from DfT to take this paper study and apply its findings on the A59.