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CAV – PAS
(Connected and Autonomous Vehicles - Priority At Signals)
Feasibility Study

SG transport innovation

WHITE WILLOW TRANSPORT INTELLIGENCE

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Issue and Revision History

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Glossary

CAM	Cooperative Awareness Message
CAV	Connected and Autonomous Vehicles
C-ITS	Cooperative ITS
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short Range Communications
ETSI	European Telecommunications Standards Institute
HGV	Heavy Goods Vehicle
ISO	International Standards Organisation
LEZ	Low Emission Zone
LHA	Local Highway Authority
LL	Living Lab
OTU	Outstation Transmission Unit
PT	Public Transport
SCOOT	Split Cycle Offset Optimisation Technique
SPaT/MAP	Signal Phase and Timing/Map
TRO	Traffic Regulation Order
UTC	Urban Traffic Control
UTMC	Urban Traffic Management and Control
VMS	Variable Message Sign

Contents

Note:
This document makes reference to the emerging ISO 19091 standard (Intelligent transport systems - Cooperative ITS - Using V2I and I2V communications for applications related to signalised intersections) and should be viewed as a developing standard.

1 Executive Summary

This study is aimed at understanding how Co-operative ITS (C-ITS) can offer new policy opportunities to UK Local Highway Authorities (LHAs) and how to deploy them into UK practice. The specific focus for this study is the use of changing traffic signal settings to give priority to freight vehicles, so reducing congestion and emissions to the benefit of all users. This is a possible first step towards wider support by LHAs for Connected and Autonomous Vehicles (CAVs), so is an important guide for the innovation path and use of new policy tools.

We investigated the feasibility of adopting the emerging C-ITS technology required to provide priority to selected vehicles in the urban environment. We firstly identify the institutional and technical implications to LHAs as well as providing an understanding of implementation from key industry players. We also explore the role of emerging standards and the potential impact upon the traffic management systems and services currently used by UK LHAs. We also explored the implication on the freight industry of being granted priority and what it would need to do to take up any opportunities, leading to an examination of the current business case for deployment.

We have maintained a dialogue with cities such as Birmingham and key actors involved in this emerging technology to ensure we provide an informed and balanced view. Whilst the study identifies some potential benefits, we are concerned with the practical implications of delivering C-ITS on street in the UK and in particular the impact on cities and LHAs this will bring. These are:

- The potential lack of interoperability between suppliers of C-ITS systems, partly because of the way the UK traffic signal control market and architecture differ from those of other countries who were involved in setting the standards now being promoted for C-ITS. This could mean extra costs to UK LHAs and remove current benefits from an open approach to equipment supply.
- A level of bureaucracy implied on an LHA in managing access and compliance, as well as resource impact in detailed mapping of junctions where priority is required; and
- A need for either new on board units for freight vehicles, or adoption by them of smartphone based solutions, both of which will impact speed of adoption.

Combining the above means there is **no clear business case** for freight priority using C-ITS, as the costs and effort are likely to outweigh the as **yet unproven benefits for stakeholders**. The path to adoption is currently complex and therefore **not likely to be a priority for smaller LHAs**. The study makes recommendations that DfT could adopt to lessen the impact and risk to LHAs in this area and help innovation adoption, with lessons learned for any next-step pilot. Key actions are:

- Discuss with developers of C-ITS hardware how current levels of supplier interoperability of roadside equipment could be maintained in the UK to avoid additional costs for LHAs
- Become more involved in standards development for C-ITS, so that UK interests are protected by including experts able to understand the implications on UK LHAs
- Look at potential a "lighter weight" deployment opportunity and perhaps a hybrid of existing loop based detection and a new link to the vehicle along with Signal Phase and Timing rather than standards based priority

- Promote the possibilities of C-ITS innovations to telematics suppliers
- Undertake an “on road” pilot to demonstrate real world benefits to LHAs for whom C-ITS currently has little attraction and remove some of the above unknowns. Key areas for this should be interoperability with existing equipment, measuring a real benefits driven business case and showing a road map for UK LHAs in C-ITS. The objective here is to kick start activity with LHAs that will lead to the provision of evidence and clear benefits of C-ITS to LHAs for them to follow. This is particularly important in identifying how C-ITS aligns to transport policy delivery and understanding the LHA business case for C-ITS.

2. Project Objectives

Connected vehicles can identify themselves to traffic systems in new cost-effective and policy driven traffic management tools through Co-operative Intelligent Transport Systems (C-ITS). For example, the OPTICITIES project has identified a clear need to provide better flow for specific vehicles handling Just-In-Time deliveries to major industrial premises in Birmingham. By addressing this specific business need, other opportunities emerge with wider relevance and application, for example access to retail centres for overnight re-stocking while simultaneously reducing HGV stops and noise at junctions on roads into cities.

This study therefore looks at the technical, operational and policy feasibility of connecting vehicles with traffic systems to grant priority and the impacts on UK Local Highway Authorities (LHAs). It examines how a UK LHA could enable this innovation, explore vehicle related aspects and outline further steps. It examines costs, benefits and risks. Without this, there are too many unanswered UK-specific questions to give confidence to either a local authority or freight operator to invest not just in freight priority, but more widely in C-ITS. Without a proven UK base of adoption, export opportunities will be limited too.

So the overall role of LHAs in supporting C-ITS is currently unclear and the way that the early adoption of such relatively straightforward innovations such as freight priority of existing vehicles will influence later adoption of more ambitious technologies.

3. Current Situation: Baseline - What actually is priority?

The ability to give priority to vehicles at traffic signals is not new. Priority is, traditionally, only given to buses, particularly on routes where buses stop frequently, for short periods and often fairly near junctions. The justification for bus priority is largely based on lessening impact on bus journey time (as their routing and scheduling cannot be changed in real time to avoid congestion) and this aids the punctuality of a bus service for passengers. However, this introduces pseudo-random factors which can cause problems for traffic management within Urban Traffic Control (UTC) centres. This is partly due to the communications solutions used for public transport (PT) priority that are now dated and slow.

However, as traffic demand and congestion increases, the need to manage the urban road network more efficiently for all road users presents new opportunities for granting priority. The questions now being asked are:

- What type of vehicles are granted priority?
- Which specific vehicles in this type are given priority?
- How is this delivered and when?
- What fundamentally is the difference between this problem and traditional PT priority?

In this scenario, C-ITS can be used in a targeted manner to cover both buses and commercial vehicles to provide greater gains to vehicle fleets operating over more controlled or constrained geographical areas. This is because there is growing concern that if junctions have numerous vehicles demanding priority then UTC cannot cope with the demand[1]. This is particularly true in saturation flow conditions where bus priority actually makes congestion worse for all users. Based on the experience gained from bus priority by many LHAs and the potential benefits that C-ITS can deliver, the questions we should be addressing now are:

- Can we make the case for providing wider priority at signals to encompass freight vehicles and buses and, if so, how does this avoid the pseudo-random factors affecting PT priority?
- Technically how this is achieved (e.g. via messages from vehicle to roadside)? How do the emerging standards to support C-ITS deployment map into LHAs business needs?
- Institutionally how this is achieved (transport policy relating to priority allocation)? This will have to be based on the LHA policy and strategy requirements and each will have a different approach. However, the basic rule here is that this is on a right vehicle, right place and, right time approach with LHA policy determining the definition of "right".
- Operationally how is this achieved (when and under what conditions of congestion)? The level of network congestion is the key point in terms of operational efficiency. If a route or corridor is at saturation level then no priority can be given to any vehicle (PT or Freight) until traffic flow is re-established. This does indicate that priority measures or services can only be provided in off peak periods or in peak periods, up to a cut-off point.

Assuming the above questions are resolved, the rules for operation need to be carefully considered. For example:

- Are all vehicles given equal priority? In reality this almost certainly cannot be achieved
- In operational terms, what happens when there is conflict? This almost inevitably means that certain categories of vehicle get priority; possibly based on how green (in terms of emissions) the vehicle is or on its category e.g. HGV only at key access points or freight access gate(s) located at a strategic junction(s).

The potential of conflict between freight and PT is a key issue. In LHA policy terms PT to date always has a higher level of priority than freight (and there is a question of whether to give freight priority at all) therefore:

- Should this assumption now be challenged, particularly if the conflict is between a fully loaded HGV and a near-empty bus?
- Which has the greater value?
- Perhaps the priority is not specific to a junction but related to a consistent average journey time along a route or corridor?

There are other issues to be considered such as the impact on the other arms of a junction if a route or corridor is already prioritised. This could introduce an unintended element of traffic gating which could be an issue for LHA strategy development by causing potential dis-benefits to other road users in terms of accessibility and safety.

1 Traffic Signal Bus Priority: Is it time for a health check? Jackie Davies, Bristol City Council

4. Local Authority Policy and Strategy

4.1 Introduction

Cities currently restrain freight through measures such as Traffic Regulation Orders and recognise the potential traffic management benefits to be gained by moving to a more co-operative role. Freight priority at a junction, as with bus priority, can be linked to delivering journey time reliability along a corridor or linked to reducing emissions in air quality zones and areas outside them. Giving priority for both freight and buses could enable shared use of bus lanes at certain times (off peak, weekends). But before this can be done the business case for the city must be defined.

4.2 Priority at Signals

Cities are receptive to the idea of potentially providing priority at specific signal junctions to freight (e.g. on a strategic freight network) as well as buses. However, there are currently no solutions widely available. So to support wider adoption, there is a strong case for utilising existing on-street equipment and extending its functionality through add-on devices that allow vehicle classification and queue detection.

Additionally, it is possible that maximum benefit can be achieved by focusing priority measures on a specific site (such as the Jaguar Land Rover/DHL Automotive logistics operation in Birmingham). This approach can be acted upon locally to smooth journey times for freight and buses with minimal stop/start with the communications link possibly seen initially as one-way from vehicles to infrastructure. The deployment of priority measures in a constrained geographical area, with highly predictable vehicle movements (such as just in time deliveries) will enable accurate before, during and after monitoring of the effectiveness of the measures deployed, in terms of both cost and efficiency gains.

Cites are interested in data but they are not in a position to buy it, so getting data from messages sent by vehicles at no cost to the city is potentially an effective way forward. C-ITS may ultimately bring in additional data but it is entirely possible that a city will still need a level of infrastructure on street such as loop detectors, VMS signs etc.

4.3 The C-ITS market

C-ITS is a potentially global market. It is being influenced by projects supported by the EU and, to a lesser extent, those Member States where large scale demonstrations of C-ITS are currently planned or underway. However, the C-ITS market involves multiple stakeholders and cities and LHAs are not in a position to exercise significant control over the market, as their current primary role being to provide the test bed or "living lab" for implementation. There is potential for cities to have a small role in creating innovation in their local market through procurement practices.

But one way for authorities to influence the C-ITS market is to identify their unique roles i.e. tasks and information that only they have or do. This needs to be pragmatic, as an authority's offering might be quite small; based on a service that is already provided competitively such as:

- Traffic management including the vehicle priority assessed here
- Car Park management

- Street works
- Traffic Regulation Orders (on street restrictions etc.)

Many authorities realise that they are not the sole source of traffic data, be it volumes, speeds or journey times. Many others (such as Google, Apple, INRIX, mobile network operators etc.) generate and have access to this data. Whilst the equipment owned by the authority will continue to be used for operating existing systems, such as SCOOT, and for validating the third party data sources, it is possible that their data may not have a significant commercial value to others. There is an important point in striking a balance between the use and value of public and private data sources.

The IT communications structures used by the LHA also need to be considered in the market. Typically, this will focus on the link between the traffic control centre and the vehicle and the key questions are a) is this robust enough and b) is this beneficial for both the authority and the end user? The benefit for the authority could be related to providing a more intelligent approach to priority at signals for certain vehicles.

But there is a more fundamental question to answer: why should a city get involved with C-ITS anyway? Authorities that are aware of C-ITS are uncertain if C-ITS will actually help meet their objectives and, if it does, they do not know if the benefit justifies the investment. So a key question is:
"***will C-ITS enable a city to either reduce its costs of running and maintaining the road transport network or improve its efficiency by using C-ITS derived data in a cost neutral scenario?"***

Equally important is to understand where vehicle manufacturers and telematics suppliers interact with city network as, at the moment, they are typically more focused on customer requirements in terms of infotainment vehicle systems and fleet management services.

A further issue relates to the roadside infrastructure supply chain in terms of additional technology required to implement C-ITS. Public sector authorities are restricted in terms of both capital and revenue funding and physical resources. This is a situation that is unlikely to improve in the near future, so their concerns will inevitably be focused on the financial implications of C-ITS and the impact upon their current systems and service delivery.

The next sections address all these questions, by using Birmingham as a policy example.

4.4 Birmingham City Council: A city view of C-ITS

To understand how Local Authorities view C-ITS we have directly engaged with Birmingham City Council, the largest Local Authority in Europe and the UK's second city. Birmingham has the potential to provide an ideal test site as it has existing partnerships of multiple stakeholders and is ready to capitalise on the outputs of the OPTICITIES FP7 project (www.opticities.com). The city's existing ITS and UTMC implementations deliver traffic management, mobility interventions and results measurement. The dialogue with Birmingham refers only to C-ITS, as their current view is that autonomous vehicles are still a long way off implementation in sufficient scale for them to have any current concerns.

The "**Birmingham Connected"** White Paper sets out a long term transport policy that specifically addresses freight servicing and logistics and the role that technology can play. It recognises the potential of technology to influence physical, operational and behavioural changes on a network of strategic and local freight routes, to ensure vehicles stay on the most appropriate roads. On these key routes (e.g. links to the motorway network) priority could be provided to freight at certain junctions during off-peak periods. This 'smarter' approach aims to reduce delays from slowing down and speeding up (queuing delay) and is expected to benefit all road users. This approach also maps into the Combined Authority Key Route Network. The percentage of HGVs on key routes is high but not at London/TfL levels and is more typical of the UK as a whole.

The city has to manage the competing demands of road users, legislation and policy requirements such as the Traffic Management Act 2004, TROs, Low Emission Zones and movement restrictions. Working within this challenging environment, policy deliverers also need to balance services to users from both the public and private sectors. For example, freight priority is a vital tool in the policy toolkit but it must align with bus priority.

Freight vehicles can have a negative impact on air quality and this needs to be reduced. Low Emission Zones are key to the city and are a mandated requirement by central Government. This supports a key challenge faced by Government and the need to prioritise actions that impact upon poor air quality, through the use of innovative technology. This is also required by the EU Directive and establishing Green Travel Districts is designed as a counter measure.

Although there is acceptance of C-ITS at a high (policy development) level, there remains scope for improving its acceptance at the operational level, for example with control room staff.

To ensure the acceptance of C-ITS throughout a local authority the business case for C-ITS needs to clearly demonstrate the delivery of transport policy and strategies. There is a definite need to answer the "why C-ITS" question that is then followed by the who? what? when? where? and how? questions and to tackle negative perceptions about technology (i.e. it doesn't work) and to overcome gaps in understanding.

Once the policy case has been made, the next question is the role of the city in relation to the delivery and deployment of C-ITS. While the marketplace may be able to deliver commercial services (such as for infotainment and vehicle performance reporting), there will be little appetite from the market to deliver the low/no-revenue services that might be required for network management.

The city has statutory duties related to traffic signals and network management; and much of the physical infrastructure needed for C-ITS and is asking itself a simple question: what does the city have to do in CAV that the marketplace doesn't?

4.5 What is Birmingham's role in the C-ITS marketplace?

The city, like many others, needs the right vehicle on the right part of the network at the right time. Specifically, Birmingham needs to keep freight on designated routes appropriate for their use and has clearly set down road space allocation policy in support of this.

Delivering targeted priority information to freight drivers approaching at junctions is seen as a positive step but can, realistically, only be achieved on a limited number of junctions (perhaps 4-6) and under certain conditions based on the level of congestion. C-ITS measures targeted at specific road user(s) must have either a neutral, or beneficial, impact on other road users.

The current view in the city is that C-ITS solutions will be site-specific and that a wide scale "mass fit" approach will outweigh any benefits gained. At peak periods and other heavily congested times it is not possible to give priority measures to *any* vehicle as it will be counter-productive.

Keeping freight on designated route (and reducing the volume of freight traffic into key areas) leads to the development of 'green travel districts'. One measure towards achieving green travel districts is the use of local consolidation points for the last leg of the journey. Other measures, such as quiet delivery schemes where delivery times are scheduled outside peak hours, are particularly applicable to supermarkets which have regular, less time-critical deliveries.

A Freight Quality Partnership has been long established but in recent times this has lost momentum. The view is that this must be re-invigorated to ensure buy-in from freight operators and raise awareness of C-ITS related actions.

4.6 General Comments

During our discussions with cities and local authority representatives, we have asked what their expectations of DfT are in the take up of C-ITS. All have expressed the desire for DfT to provide guidance and advice in terms of understanding the financial, technical, operational and resource issues they face. To assist this process, some express their expectation for DfT to fund demonstration projects in cities who are willing to act as Living Labs for C-ITS experimentation. It was also expressed that funding of this type should not be competitive but distributed on an equitable and focused basis (i.e. on a particular aspect of C-ITS integration) and should be on the basis of smaller finance packages, perhaps spread over UTMC/ITS compliant cities, rather than a high cost demonstrator in a single city.

In terms of delivering transport policy and strategy benefits the following table summarises the potential benefit that CAV/C-ITS could provide:

Policy Requirement	C-ITS Impact	Technology
Reduce costs	Potential to reduce LHA costs by access to new data sources and the intelligent use of this data	Smart city approach, use of big data, connected vehicles and people.
Reduce journey time	Reduction in journey time on heavily congested roads may not be achievable but delivery of journey time reliability should be achievable on specific C-ITS enabled routes or corridors	Use of priority at signals can be an enabling factor in achieving journey time reliability – but only at key junctions and below high congestion levels. Data from CAVs can improve current signal performance over loop detectors in unsaturated conditions
Reduce traffic jams/congestion	C-ITS could have an impact on congestion reduction but only as one of a set number of strategic measures deployed.	Smoothing traffic flow by means of gap reduction and use of priority measures at appropriate times based on levels of congestion.
Reduce transport pollution & improve public health	Utilising C-ITS within a designated low emission zone could have a positive impact on improving air quality	Use of priority at signals can be an enabling factor within the scope of a LEZ, green transport district or air quality management area.
Improve road safety	Potential benefit to road safety by reducing unnecessary stop/start situations for certain vehicles, smooth flow of traffic reducing queueing and shock wave situations.	Proactive traffic management linked to intelligent use of data and ultimately connectivity to vehicles.
Improve service experience for the transport user	Positive impact for transport users linked to the delivery of mobility as a service	Smartphone apps/integration to in vehicle systems.
Improve dissemination of	Positive impact on RTI delivery;	Smartphone apps/integration to in

real time travel information	opportunity to get information directly to the driver that is location and time specific.	vehicle systems.

5. Opportunities for Adopting Innovation

5.1 Technical Integration Requirements

There are several ways for a vehicle to request priority, ranging from current practice to emerging standards:

- As currently used in Birmingham, a vehicle being detected by an inductive loop as a long vehicle, e.g. a bus or HGV and then granted priority without checking the vehicle identity. Automatic Number Plate Reading could potentially be used to check against a list of vehicles (or even the vehicle class via DVLA) but this is operationally and politically a challenge. Nevertheless, this one-way priority works technically, is widely adopted and has understanding. There is no confirmation that priority has been granted to the vehicle typically, as the green phase will occur. This could be potentially added in a hybrid approach for example for Signal Phase and Timing (SPaT/MAP) messages or to confirm priority has been granted.
- Using "here I am" heartbeat messages sent by the vehicle from some form of on board unit that can identify the vehicle and its location. The traffic signal may then check the identity of the vehicle against a list and grant priority, or simply advise on the signal phase and timing (SPaT/MAP). Here the emphasis is on the traffic system to provide information where priority may or may not be the objective. With SPaT/MAP the vehicles benefits as they change behaviour to match the signals unchanged settings, or may benefit further if they have been granted priority
- Using a specific request for priority from the vehicle to the system. The system then manages the request and may grant priority in a two-way exchange. This use case has been envisaged in the standards development as a full two-way communication, as it is one subset of many other use cases where safety critical information is exchanged

We will focus on the second and, in particular, third option but it must be remembered that to make the most of existing infrastructure and vehicles, a hybrid approach might offer an easier path to deployment and showing benefits.

5.2 C-ITS Communications Standards

Almost every technical standards body in the world has published standards for C-ITS. In Europe the communications standards development activity has been led by the *European Telecommunications Standards Institute* (ETSI) with US work led by the *Society of Automotive Engineers* (SAE). Meanwhile, in Japan the ITS National Committee has largely adopted work undertaken by the International Standards Organisation (ISO). The result is a complex landscape of data messaging protocols that are capable of being transmitted at various frequencies via roadside infrastructure or over cellular networks. Despite the prevalence of 'standards', C-ITS practitioners (and nations) remain divided over how some of these standards should be used.

There are two elements to consider here in C-ITS communications:

- What message is sent between a vehicle and say a traffic signal (e.g. "here I am") which is determined by a "use case" (i.e. the problem to be solved)
- How it is sent (over what communications system, e.g. WiFi or cellular)

The debate over which communications are preferable for C-ITS applications generally fails to distinguish between the use cases.

The generic term for C-ITS communications between the roadside and a vehicle is DSRC (Dedicated Short Range Communications). The term "DSRC" is actually sufficiently generic to include infrared-based systems for tolling but they are generally not being adopted in C-ITS solutions so this document concentrates on radio-frequency DSRC. Standards for DSRC have been developed in various regions; the 5.9GHz band was allocated in Europe for tolling and in 2009 ETSI agreed on the "ITS-G5" communication standard, effectively a form of WiFi. In Japan a different standard but also at 5.8 GHz was adopted. Prior to that the USA had standardised at 5.9 GHz for several years.

5.3 ITS Stations

Communications are always between two or more entities so, in C-ITS terms, we need to consider what entities send messages to whom. ETSI defines four types of "ITS Station" ('ITS-S') as follows:

- **Vehicle ITS-S**: a vehicle ITS-S is implemented in-vehicle and provides ITS applications to vehicle users. The vehicle ITS-S is usually implemented as an On Board Unit (OBU) sub-system. The OBU is connected to in-vehicle systems e.g. vehicle electronics systems and exchanges information with other vehicle ITS-Ss, roadside ITS-Ss and the central ITS-S. We will call this for simplicity an OBU.

- **Roadside ITS-S**: a roadside ITS-S is implemented at the roadside and provides ITS applications to vehicle users or service operators. Usually, the roadside ITS-S is implemented as an RSU sub-system. The RSU comprises wireless or wired communication device and exchanges information with vehicle ITS-Ss or central ITS-S. According to the deployment strategy, a roadside ITS-S may connect with other roadside equipment e.g. traffic signal control equipment. For an LHA, this will be associated with a traffic controller for this use case.

- **Central ITS–S**: a central ITS-S is implemented at the back office or instation such as Traffic Management Centres etc. in order to provide services to vehicle users or to other service providers. For an LHA, this may be a SCOOT system for example or could be a separate platform. The implications of this are explored later.

- **Personal ITS-S**: a personal ITS-S is implemented at personal devices e.g. smartphones and provides ITS applications to users.

For a vehicle to communicate with the roadside (or Central ITS-S) it needs to use a wireless (i.e. radio) connection. This connection is likely to be either:

- Cellular (i.e. a 5G or LTE connection requiring a paid-for SIM card in the car transmitting via a mobile network operator) or
- DSRC such as ITS-5G as described above (i.e. a free of charge transmission to/from equipment in the vehicle over a short range to a wireless unit at the roadside).

There is considerable debate over whether cellular or DSRC solutions will prevail. There are strong arguments for and against each; meanwhile other practitioners advocate hybrid solutions.

5.4 C-ITS message types

The content of the messages transmitted between vehicles and the roadside depends on the purpose of the message – the use case and the problem to solve. C-ITS vehicles will periodically transmit CAM (co-operative awareness messages) to notify other ITS-S of their presence – the "here I am" message. Roadside ITS-S at junctions will transmit SPaT/MAP messages. A SPaT message describes the signal phase and timing of the signals at a junction. A MAP message contains the topology of a junction. The MAP message is sent in combination with a SPAT message and is essential for a vehicle to relate the signal phase and timing information of the traffic light to the lane topology. They will also transmit DENM (Decentralized Environmental Notification Messages) to alert road users of detected events such as congestion.

SPaT/MAP is perhaps the significant use case benefit of C-ITS to LHAs. The receipt of SPaT messages from a traffic signal controlled junction would enable vehicles to traverse the junction with minimal stop/start behaviour and can be used on existing junctions with all vehicles. Descriptions of each of these message types is shown in the tables below:

Name	**Cooperative Awareness Message (CAM)**
Description	"Here I am, going there". CAM messages are distributed within the ITS-G5 network and provide information of presence, positions as well as basic status of communicating to neighbouring ITS-Ss.
Generation	All ITS-S shall be able to generate, send and receive CAM messages as long as they participate in C-ITS networks
Media	ITS-G5
Communication	A CAM is broadcast to neighbouring ITS-Ss within the direct communication range. These messages are continuously being sent by all ITS-Stations between one and ten times a second depending on the situation detected by the sending ITS-Station, for example the frequency is increased when a vehicle is turning, braking or accelerating.

Name	**Decentralised Environmental Notification Message (DENM)**
Description	Decentralised Environmental Notification Messages (DENMs) are mainly used to alert road users with event messages, like roadwork warning, post-crash warning, icy road, emergency vehicle warning, electronic brake light etc. These messages are sent and received both by vehicles and road site units. Like CAM, the frequency that messages are sent may vary depending on the situation, but unlike CAM these messages are only sent when a certain situation, such as some kind of road hazard, has been detected by the ITS Station
Generation	The general processing procedure is as follows: • Upon detection of an event, the ITS-S immediately broadcasts a DENM to other ITS-Ss located inside a geographical area and which are concerned by the event. • The transmission of a DENM may be repeated with a certain frequency. • The DENM broadcasting may persist as long as the event is present.
Media	ITS G5
Communication	A DENM shall be disseminated to as many ITS-Ss as possible located within the relevance area.

Name	Signal Phase and Timing (SPaT)
Description	Current maneuver(s) permitted, remaining time for maneuver, next maneuver to be serviced, information, and pedestrian warning information.
Generation	Traffic signal controller or in the UK Outstation Transmission Unit (OTU)
Media	ITS-G5
Communication	A SPaT is broadcast to vehicles within the direct communication range. SPaT messages are not normally re-broadcast. SPaT data is used in two ways: (V2I) to extend the green phase if a vehicle is expected to enter the intersection within a pre-determined time (i.e. grant priority) and (I2V) to inform the vehicle whether and for how long the signal will be extended. An alternative implementation would be to provide the vehicle with speed advice to clear the intersection before the red signal. This is intended to provide either direct or indirect vehicle priority at intersections.

Name	MAP
Description	Intersection Geometry (MAP base), permitted manoeuvres, restrictions and user classes (e.g. bus only lanes)
Generation	Roadside equipment
Media	ITS G5
Communication	A MAP is broadcast to vehicles within the direct communication range

5.5 Communications between the instation and the vehicle

The debate over whether cellular or DSRC communications are preferable for C-ITS applications generally fails to distinguish between the use cases. Cellular networks have evolved from 2G to 5G with significant reductions in latency at each stage. Research projects have shown that car to car messages and warnings can be transported via the mobile network within 50-150 ms using Long Term Evolution (LTE).

ITS-G5 has been specifically developed for ad hoc broadcast communication between vehicles and the road side infrastructure. The specification is derived from the well-known WiFi specification (IEEE802.11) with adaptations especially for the vehicular environment, supporting high driving speeds and low latency requirements.

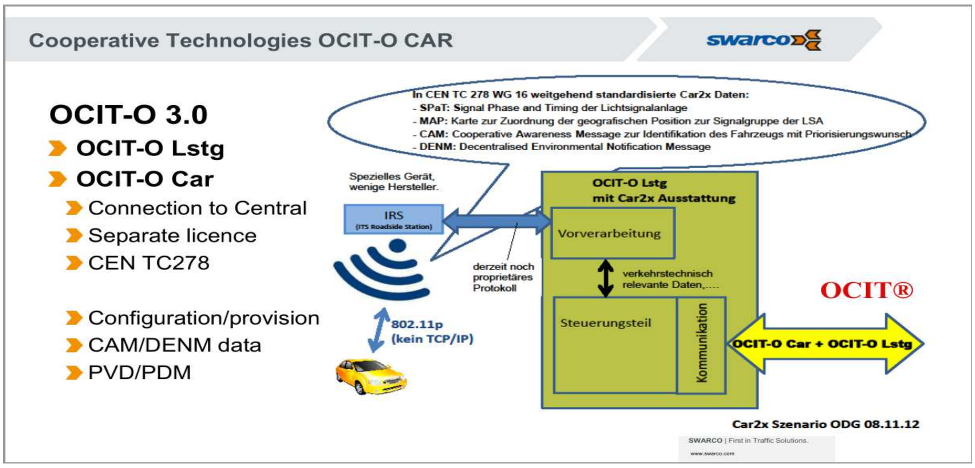
ITS-G5 is used to transmit the CAM, DENM, and SPaT/MAP messages described above. It has a transmit range of around 300 m and enables CAM and DENM to be forwarded further via multiple hops. It is designed to support time critical road safety applications where fast and reliable information exchange is necessary.

All leading European C-ITS projects have, to-date, used ITS-G5 which is based on the IEEE standard 802.11p. Much of this work has been led (or influenced by) the "Amsterdam Group" and the Car to Car Communications Consortium (C2CC)[2].

5.6 Roadside equipment impacts

*2 2www.**car**-2-**car**.org*

The architecture of a roadside unit which derives from the C2CC work is shown below. The blue box is the element that communicates with the vehicle, the green box the traffic controller.



From Swarco

One of the critical links is that between the traffic signal controller and the ITS-G5 wireless unit (shown by the large blue arrow above). In the diagram this link is marked "derzeit noch proprietäres Protokoll" or "currently a proprietary protocol" a situation which we understand was agreed by the participants in the Amsterdam Group.

The lack of open protocols between these parts of the road side equipment potentially affects the uptake by UK LHAs of C-ITS. This is because in the UK, the Outstation Transmission Unit (OTU) (and/or traffic signal controller) and the wireless communications systems that currently link junctions together and allow central co-ordination can all be supplied by different manufacturers. This has allowed significant cost savings for UK Authorities though a "plug and play "approach. Other countries do not always follow this approach.

C-ITS deployment may therefore require the local highway authority owners to procure and install additional communications equipment specifically for C-ITS functions or even change their existing traffic controllers. There may be an opportunity minimise costs to LHAs by the adoption of a common protocol between traffic signal controller and ITS-G5 unit. This could also reduce barriers to adoption, encourage innovation in the UK supply chain and help the market grow more rapidly.

5.7 Communications between the instation and the roadside

To understand the potential impact of re-introducing proprietary protocols it is useful to consider the benefits to the UK from removing them via a DfT initiative called UTMC (Urban Traffic Management and Control). Prior to the adoption of the UTMC Technical Specification, exchange of data in UK urban traffic control systems used data communications protocols which were proprietary to the system supplier. UTMC facilitated migration to IP-based communications, specifically the UG405 protocol which is used for UTC/SCOOT. This led to considerable financial savings for LHAs as they were able to replace expensive, single-sourced analogue copper circuits with digital circuits. These circuits were not only cheaper but simultaneously supported other services such as the transmission of data for CCTV and driver information. Many UK LHAs achieved further financial savings by linking traffic signal controlled junctions with wireless networks and there are now over 6,000 junctions in the UK connected wirelessly at operating costs considerably lower than they would have been 20 years ago.

Most C-ITS communications activity has focused on the wireless links between the roadside ITS-S and the vehicle ITS-S. But central ITS-S will need to exchange data with roadside ITS-S. For example, it may be necessary to transmit a DENM message because of an incident elsewhere on the network. In the EU, DATEX II is an agreed communication protocol to communicate with traffic infrastructure such as VMSs and currently the scope of DATEX II is foreseen as “centre to centre” and does not extend to “centre to field” or vice-versa. As such at present it does not cover communications in the scope of this study and certainly not C-ITS communications from centre to OTU

The UK's UTMC Technical Specification does not currently have any provision for centre-roadside exchange of specific C-ITS content.

In the UK in the short term, SPaT/MAP messages will be generated by the roadside equipment located in the vicinity of a junction. Longer term, it is possible that SPaT/MAP data may be generated centrally. To support this in a UK context, Open (i.e. non-proprietary) protocols need to be agreed for the exchange of other C-ITS messages (e.g. DENM) between the central station and roadside equipment.

5.8 Data exchanged to request (and provide) priority

Assuming the above key implication can be addressed, the question still remains of what data needs to be exchanged between vehicle and roadside.

There are various use cases explored in developing standards for freight priority, the most relevant of which is in the developing ISO 19091 standard. We have reviewed this in detail bur cannot include its full content due to copyright.

In this standard, various message types exist for data from the vehicle for exchanging information which have attributes such as:

- Vehicle ID (which could be for example used to identify vehicle emissions class etc. to grant selective priority
- Vehicle class and type
- Vehicle location (which needs to be aligned to the junction location held in the vehicle)
- Request for priority for a given turn movement (from a pre-determined route e.g. from SatNav)

It is possible that other parameters might be used – for example from the OBD2 or CAN BUS of the vehicle its emissions performance or a “virtual MOT” might be checked (e.g. to grant priority to vehicles only with say all indicator lights working, to improve cycle safety). However, the basic granting of priority is centred on a vehicle identifying itself and a system checking if priority should be granted to it. In current bus priority, the presence of a bus in a bus lane, or use of a transponder that identifies the bus is the trigger – there is no need for central administration. Messages back to the vehicle then can advise it on the time for the next green signal phase and can confirm granting of priority as discussed earlier.

Looking at this standard for the priority use case implies:

1. Apparently many transactions for what is currently a simple detection of a vehicle, but which add precision and security to the granting of priority and a link back to the vehicle. This is indicative of the comms and automotive focus of the standards rather than the evolution of

current traffic management practice. However, the sheer complexity of messaging for what is not a safety critical application is indicative of the overhead of adopting C-ITS

2. An on board unit (OBU) capable of supporting the message set and communications required and that can identify the vehicle
3. Detailed mapping of the junction geometry at high level held on the vehicle so that the vehicle can report its proximity to the junction.
4. A traffic control device at the roadside or centrally able to make priority decisions and change traffic signal timings
5. Some rules and parameters set by the LHA centrally to manage conflicts and access. At a minimum this will be a list of valid vehicle IDs for priority. It may well be that all vehicles of a given type (e.g. bus) are given priority but it is not currently clear how to avoid the owner of a vehicle OBU fraudulently declaring itself as a bus. This needs more investigation
6. How does the OBU determine its eligibility for priority?

5.9 Implications for UK use

From the above there are several key implications for the UK of using the standard approach:

Limits on functions that can be realistically supported:

For an LHA, granting priority using the above standard approaches will require new equipment to communicate with vehicles, potential technology change to signal equipment, administration of lists of vehicles that can be grated priory and potentially mapping of new junctions to provide the level of data foreseen in the standards based approaches. It may therefore be that the fundamental question is: is it worth it?

Given that loop based priority is often used, the benefits of the extra work would have to be very clear. It may be that instead for formal standards based priority requests, simpler SPaT messages are “good enough” for example for improving freight running along arterials at night. A hybrid approach – of loop based detection plus a message back to the vehicle may be easier to deploy to show benefits in any pilot.

Implications of mapping.

The above approaches often require highly accurate mapping of junctions. Whilst this is becoming available for automotive use, this will require updates and maintenance, especially for example if using priority to grant access to an ever evolving construction site (for example HS2 in Birmingham). While it may be possible to automate the production of MAP data from traffic models, the full implications on an LHA of providing MAP data for a junction (as well as accurate geographical mapping) to support standards-based approaches are an unknown.

List management

LHAs would need to keep and maintain lists of vehicles or vehicle types able to be granted priority for both network management and security reasons. These may be simply lists of equipment serial numbers or more likely vehicle VRMs, but the effort in collecting the data and marinating it when vehicles are sold to new owners and so on may be high. A web based solution might be possible, using DVLA data to recognise appropriate vehicle types, but there are lessons from PT priority management to learn here as vehicles move around fleets and need to join lists. List management for London Congestion Charge and Dartford Charge is an overhead for vehicle operators too.

On board unit costs.

Most UK commercial vehicles, especially those over 10 Tonnes are equipped already with some form of on board unit for fleet management. Many lighter vehicles have a smartphone based app or OBD2 based "dongle" (e.g. plumbers' vans) and increasingly this is offered as line fit (e.g. the Telogis solution is offered on the Ford Transit, Scania and Volvo also have line fit devices). Hence any OBU for granting priority using standards based approaches would need to be newly installed as most current devices could not be used. This means added costs for operators for an as yet unproven benefit.

There are telematics devices being developed that support the communications standards needed, such as ITS-G5, but these are nowhere near as numerous as the simple devices now used in the vast majority of applications for fleet management and smart phone based telematics.

6. Risk and Barriers to Implementation

6.1 LHAs

For LHAs, the roll out of C-ITS and hence CAV shown above raises potential barriers to implementation and associated risks. The institutional barriers are associated with the LHA roadside infrastructure and legacy equipment/systems. If C-ITS is the next level of technology for LHAs to adopt, this implies the need to develop a robust business case for them that identifies the benefit to them, the associated risks and the impact on their capital and revenue costs. This will impact on the wider adoption of CAVs which may have far bigger implications.

The barriers however, do not stop at the roadside. As shown above there is also impact on the back office systems and services, and the provision and maintenance of a data platform that supports, amongst other services, C-ITS and later full CAV roll out. There are also implications to traffic management systems currently in use and the impact on systems such as SCOOT and UTMC. This is particularly relevant in providing priority at signals, with the implication that CAV will need to interact in the UK with SCOOT and UTMC compliant systems to provide this level of functionality. The development of appropriate technical guidance and standards will play a critical role in this area.

For LHAs, the above issues inevitably lead to the question of who pays and why? Many LHAs struggle to maintain existing roadside infrastructure and traffic management systems particularly with regard to year on year maintenance costs. The potential cost implication for LHAs could be high. There is a further consideration in terms of having sufficiently skilled resource to manage and maintain C-ITS related systems and infrastructure. Many LHAs struggle with retaining in house expertise to manage and develop their existing ITS capabilities, many currently have to buy in expertise and CAV has the potential to further impact on LHA ITS resource and expertise.

CAV will inevitably impact upon communication systems currently used by LHAs to roadside infrastructure. This may have implications on the LHA capital and revenue budgets. How much of this is their responsibility and what benefit do they get in return for this cost?

The lack of open standards between key components of a C-ITS solution inhibits competition and may also act as a barrier to C-ITS uptake by LHAs. The risk of committing to a single-supplier solution is, once again, reminiscent of Betamax vs VHS.

6.2 Vehicle operators

For a commercial vehicle operator to take a vehicle off the road and install another OBU for vehicle priority (whether bus or HGV or van) or provide a smartphone (which is not acceptable for many HGV style operations) there needs to be a clear financial return. Saving a small time at a junction may not warrant this investment.

Without a clear financial justification, other potential ways to drive compliance will be:

- Compliance with local regulations for freight, but given the impacts on an LHA this seems unlikely to be a key priority
- Compliance with contractual regulations. Many customers, e.g. big supermarkets, require telematics devices for suppliers' vehicles, and some construction sites now require app based management systems. The extent to which a customer might demand vehicle priority is not clear however as the benefit to them will not be clear
- If vehicles and telematics devices provide the functionality anyway, due to global standards becoming available in products and services available in the UK. This is likely in the long term, but could be around 5 years away.

6.3 Telematics providers and vehicle manufacturers

The telematics industry now generally regards the on board unit as a commodity. The differentiation of services is currently in their management reporting and added value such as driver coaching. So adding costs for new communications and messaging standards like ITS G5 will add costs for services in a very commercial market. Without a strong business case for adding the feature it may not be included in developments going forward.

Vehicle makers will in time deploy the standards in their new vehicles, but this will take time (around 5 years) for significant deployment. In addition, it will then take time for this to filter through to the vehicle park.

Hence a smartphone deployed solution is likely for retrospective fitment, but this can pose operational difficulties for larger fleets.

Nevertheless, there is a potential innovation opportunity for a UK OBU designer for a retrofit telematics device that both supports the communications and messaging required for C-ITS but also that focuses on the basic customer needs from telematics. Currently such devices are specialised test and small volume devices, not mainstream deployment

6.4 Summary of Key Risks and Mitigation

The findings of this report may appear pessimistic but there is mitigation for many of the issues presented as shown below:

	Risk/ Issue	Mitigation
1	Lack of LHA CAV Business Case; potential impact on costs	Reduce costs by simpler approaches and show benefits in real world demonstrations

2	Lack of LHA Resource/Expertise to implement CAV	Shared resource and partnership. Minimise LHA inputs needed
3	Emerging CAV standards incompatible with LHA UTMC/SCOOT Systems requiring potential move away from current open UK approach	Influence standards deployment so that it understands UK architecture and benefits from an open market
4	Lack of LHA day to day resource to manage priority, map changing junctions, etc.	Make systems as automated as possible. Reduce reliance on mapping data if possible.
5	Costs of new OBU required mean little benefit for freight operators and little new fitment in vehicles	Use smartphone or ensure next generation OBUs support C-ITS
6	CITS not adopted for priority as shows little benefit over current status	Show benefits and reduce barriers to entry through demonstrations
7	CITS complexity means no adoption in UK	Consider "lightweight" standards or solutions

6.5 Summary of risks

This report shows there is a key risk that C-ITS freight priority might not be deployed in the UK as:

- Even for a city like Birmingham, the number of sites where it might offer benefit is constrained by local traffic conditions and polices
- It is currently a complex change to what could be a simpler infrastructure only approach and so might prove "too difficult" especially for smaller LHAs
- The benefits are currently unproven
- It might imply changes to the UK traffic controller approach that could remove current interoperability between manufacturers – a backward step LHAs are not likely to support
- It has high cost implications for the fright industry for what might be small financial benefits

This risk could be mitigated by a real world demonstration to address many of the unknowns and hence enable more interest and support. For example, a telematics provider supporting 802.11p in a mass market device at low cost would have a global advantage but may not be currently aware of the potential. Now is the time to develop and explore the value in such a device in an integrated test.

7. Financial Implications: Business Case and Benefits

The above shows that there would be:

- Capital costs for an LHA in deploying C-ITS infrastructure. As shown above these may require changes to existing traffic controllers to support C-ITS
- Capital costs for a fleet in deploying new OBUS/ smartphones
- Revenue costs for both for communications (although these are likely to be small)
- Revenue cost for an LHA in mapping new junctions (or even providing data to map makers) and managing list of priority

The administration of priority might be outsourced or centralised but would still require managing list of vehicles, changes when they are sold, etc. The FORS scheme in London would be a useful model but whether smaller LHAs can support his sort of administration is not clear. Birmingham for example has tried to start a similar Freight Partnership based scheme but not gained traction. An LHA might also decide to withdraw priority to a non-complaint operator, or to all vehicles. It also has to decide the times and circumstances when priority is allowed.

The business case and benefits of C-ITS are affected by the relative immaturity of the market and the technology. This inevitably translates into unreliable cost/benefit calculations at present and we have found little current evidence of benefits, beyond those generated by simulation models. However, considerable resources are being deployed to meet this challenge, through projects such as CIMEC, but these have yet to arrive at a robust, repeatable conclusion. Our proposal of a "on road" pilot is to add to this in identifying potential benefits and operational costs that reflect the needs of the UK LHA marketplace for C-ITS. We conclude that C-ITS offerings may emerge with the potential to deliver conflicting benefits and costs but without clear business cases. The proposed "on road" pilot is designed to tackle this potential problem, by providing evidence based on a real world implementation of C-ITS.

Hence unless a strong policy led and benefits driven business case is clearly available for freight, an LHA may struggle to see a need to deploy C-ITS for freight priority. There may be wider lessons here for other more complex C-ITS and the adoption of CAV

8. Conclusions and Recommendations

8.1 Mitigating Risk

Currently there is a key risk to C-ITS deployment in that there is no clear UK business case nor knowledge of how to deploy standards-based approaches. Projects like Compass4D have shown the UK potential with specific use cases but there is now a need for a wider approach.

An on-street pilot of freight priority adopting a standards based approach would start to provide many of the answers needed to build a business case. However, far more useful would be a large city pilot of SPaT/MAP messages as:

- They impact all vehicles and have clearer benefits from reduced stops (e.g. emissions)
- They require less changes to traffic control infrastructure where the vehicles match the signals, not the other way round
- They could be implemented via an app in existing vehicles
- For Birmingham, as an example, there are far more sites likely to benefit than for bus priority
- Priority is being explored in the Compass4D project in Newcastle but with limited vehicles.

8.2 What steps needed to make a pilot on street?

The key steps required for an on street pilot are:

- Identify a test site which can demonstrate the benefits of deployment
- Determine the level of control an LHA requires
- Look at the type of vehicle to be included
- Determine which of the possible approaches to test (hybrid, Spat or full priority). Note they are not exclusive
- Identify the OBU features needed to support this (smartphone or new OBU)

- Identify road to vehicle communications needed to support these OBUs and changes to traffic controller and communications to support this
  - This is a key way to understand the risk to the UK of proprietary links between UK traffic control equipment and vehicle communications devices, and how to safeguard the UK's "plug and play" benefits
- Map out an operational plan for the LHA
  - Mapping (if required)
  - Technology changes
  - Day to day control
- Define measures of success and how they would be collected using the in vehicle units

8.3 Wider implications

Whilst the study identifies potential benefits and an on street pilot will mitigate risks, we are still concerned with the practical implications of delivering C-ITS on street and in particular the impact on cities and LHAs this will bring. These are:

- The potential lack of interoperability between suppliers of C-ITS systems, because of the way the UK traffic signal control architecture differs from those of other countries who were involved in setting the standards now being promoted for C-ITS
- A level of bureaucracy implied on an LHA in managing access and compliance, as well as resource impact in detailed mapping of junctions where priority is required; and
- A need for either new on board units for freight vehicles, or adoption by them of smartphone based solutions, both of which will impact speed of adoption

Combining the above means there is no clear business case for freight priority using C-ITS, as the costs and effort are likely to outweigh the as yet unproven benefits for stakeholders. The path to adoption is currently complex and not likely to be a priority for smaller LHAs. This may be a wider implication for the general adoption of C-ITS and hence CAVs. In contrast, SPaT/MAP offers wider and more visible benefits, is easier to deploy and makes the most of existing infrastructure. It is more valuable to undertake a SPaT/MAP pilot than priority as a step to C-ITS.

Undertaking a SPaT/MAP pilot will provide answers to questions that cannot currently be answered with accuracy that relate to technical, operational and financial issues. We have found some evidence of work undertaken by TfL in this area but this was only on a trial basis, hence the need to conduct a more robust demonstration through an on street pilot that builds on this initial work

8.4 Key Recommendations

DfT could adopt the following to lessen the impact and risk to LHAs in this area and help innovation adoption, with lessons learned for any next-step pilot.

No.	Recommendation
1	Discuss with developers of C-ITS hardware how current levels of supplier interoperability of roadside equipment could be maintained in the UK.
2	Become more involved in standards development for C-ITS, so that UK interests are protected. This needs to be through experts who understand the implications of EU wide decisions on current UK equipment. (for example, standards such as ISO19091 should allow for the possibility of a hybrid

	deployment but developers will want to know what features deployment of loops facilitate; how loop detection fits into the information flows to trigger the request for priority & send a 'simple' Spat message).
3	Look at potential a "lighter weight" deployment opportunity for priority and perhaps a hybrid of existing loop based detection and a new link to the vehicle.
4	Promote the possibilities of C-ITS to telematics suppliers
5	Undertake an on road pilot of SPaT/MAP to demonstrate real world benefits to LHAs for whom C-ITS currently has little attraction and remove some of the above unknowns. Whilst there are unknowns for LHAs many are willing to act as Living Labs actively participate in a on road pilot on a cost neutral basis in order to broaden their knowledge and understanding of C-ITS implementation.

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