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# Driven by information revisited

## Stepping up a gear

Andy Graham
White Willow Consulting

August 2023

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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# About the Author

**Andy Graham** is principal of White Willow Consulting, which he set up in 2005 specialising in connecting vehicles and infrastructure. Andy has worked widely with highway authorities, the Department for Transport, roadside-technology providers, vehicle makers and service providers on services such as driver information, smart parking, fleet management, connected traffic lights and eCall.

Andy is a leading contributor to the Transport Technology Forum's Connected Vehicle Group, and previously Chair of the ITS UK Connected Vehicles Forum. He managed the RAC Foundation's Connected London to Brighton pathfinder run in 2021, showcasing the world's oldest connected vehicles.

He is a Fellow of the Chartered Institution of Highways and Transportation, a Fellow of the Institution of Engineering and Technology, and a Trustee of the Rees Jeffreys Road Fund.

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- The peer review team for challenge and support.

# Disclaimer

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# List of Abbreviations

| | |
|---|---|
| ACEA | The European Automobile Manufacturers' Association |
| ADEPT | Association of Directors of Environment, Economy, Planning and Transport |
| BODS | Bus Open Data Service |
| CIHT | Chartered Institution of Highways & Transportation |
| CONVERT | COnnected Network VEhicles in Real-Time (for network and asset management operations) |
| COYC | City of York Council |
| DfT | Department for Transport |
| DTRO | Digital Traffic Regulation Order |
| ESG | environmental, social and governance |
| FORS | Fleet Operator Recognition Scheme |
| FVD | floating vehicle data |
| GLOSA | Green Light Optimal Speed Advisory |
| HGV | heavy goods vehicle |
| HMI | human–machine interface |
| HRS | Highway Resource Solutions |
| IHE | Institute of Highways Engineers |
| ITS UK | Intelligent Transport Society of the United Kingdom |
| IVS | In-Vehicle Signing |
| LCRIG | Local Council Roads Innovation Group |
| Lidar | light detection and ranging |
| MOVA | Microprocessor Optimised Vehicle Actuated |
| NAP/FTD | National Access Point (now called Find Transport Data) |
| NPP | National Parking Platform |
| PAYGI | pay-as-you-go insurance |
| RAC | Royal Automobile Club |

# Executive Summary

The RAC Foundation report "Driven by Information", published in September 2020, sought to establish all the elements needed to achieve the benefits offered by the flow of data from and to increasingly 'connected' vehicles, in practice and at scale. It did this by revealing gaps in service delivery and by proposing quick fixes to address them. The purpose of this update is to now look at how matters have moved on in nearly three years and, specifically, to focus on the issue of funding.

In this context, 'connected' vehicles means any type or age of vehicle or person that can generate, transmit and receive/process data. Connection can be with other road users and vehicles, with infrastructure, and with vehicle manufacturers, data providers, insurers and services like mapping and satnav companies, generally over existing cellular networks (e.g., via smartphone or in-vehicle equipment). Data generated by or about a vehicle might include road condition (e.g., from detecting poor grip), traffic conditions (from vehicle speed and location) and about driver behaviour (such as aggressive acceleration and rapid braking). Data transmitted into the vehicle is generally aimed at informing the road user's decisions (e.g., via satellite navigation, or 'satnav', services) and, in due course, is set to play a fundamental part in enabling highly automated systems.

## The four illustrative services

Recognising that a benefit only flows when something happens as a consequence of data being *used* (fundamentally, data only has value if someone, somewhere does something with it and has the resources to exploit it), the original report 'process-mapped' four illustrative services[1] that were then in development:

- In-Vehicle Signing (IVS), displaying road signs and warnings to the driver inside the vehicle,
- Green Light Optimal Speed Advisory (GLOSA), which tells drivers what speed to adopt to be able to pass through the next traffic lights on green,
- using vehicle-generated data to improve traffic light timings, and
- using vehicle-generated data to improve road maintenance planning.

Through detailed end-to-end mapping, the previous report revealed every stage and connection between generation of data and its ultimate use, thus revealing gaps and obstacles and where benefits might be achieved in the near-term through workarounds and limited deployments.

## What has happened?

Nearly three years on and, as might have been hoped, many of the technology gaps have been or are in the process of being filled. For example, real-world IVS pilots have demonstrated how a variety of messages can be generated and conveyed to road users

1 i.e., services that together were representative of the wider range of services in contemplation, not necessarily those nearest to the market or offering the greatest benefits.

(including cyclists). With support from the RAC Foundation, a pathfinder on the RM Sotheby's London to Brighton Run showed IVS working to inform the drivers of the world's oldest connected cars.

Apps are now publicly available – for example, from KL Systems – that combine satnav with IVS, so that openly published[2] roadside messages on variable message signs (VMS) appear on the same screen as the satnav display, so traffic and safety warnings can be provided to drivers between physical VMS locations. Previously separate services are being combined, as drivers do not want separate screens displaying information from different apps. This is a key step towards more user-focused design and away from purely tech-based solutions. Work has started on automatic real-time notification of roadworks to IVS (involving temporary carriageway restrictions, traffic lights, reduced speed limits, etc.) to improve the accuracy and timeliness of information, and at least one private-sector operator (Vodafone) has developed a platform that can host, collate and release data to IVS systems.

GLOSA has made progress too, with evidence of environmental and fuel-use benefits from National Highways' pathfinder project on motorway slip roads, and with Transport for Greater Manchester (TfGM) now openly publishing GLOSA data. GLOSA and IVS have been combined in a single user-friendly app.

There is also more evidence of data from vehicles giving benefits. INRIX has launched a service that measures traffic light delays using connected data rather than fixed monitoring equipment (such as traditional 'loops').Transport Scotland is trialling the use of data from vehicles measuring surface regularity and identifying potholes to feed into their maintenance decisions and initial results are positive. Companies like See.Sense now provide data that monitors the location of connected bicycles and the condition of cycle paths. Gaist provides data revealing locations with a record of aggressive braking by drivers matched to road geometry, as a lead indicator of possible road-safety risk that could be addressed through highway engineering (e.g., amending the road layout, implementing traffic management measures, etc.).

Looking beyond the four illustrative services from the previous report, other relevant developments include the mandatory fitment of eCall in new cars and vans since 2018. This has now penetrated far into the vehicle parc, creating an automated data link between the vehicle and emergency services. This could play a critical part in the swift identification of stopped vehicles (including location). Furthermore, at least one new app has been launched to aggregate multiple payment systems that drivers might encounter (e.g., for parking, tolls, Clean Air Zones, etc.), so that payment is dealt with through the registered user's account. The Bus Open Data Service (BODS) has also launched, to supply real-time and historic connected bus data on traffic speeds and route performance.

2 i.e., available as free to use data, e.g., National Highways' National Traffic Information Services VMS feed.

## What remains to be addressed?

This update revisits the services mapped in 2020 and also draws from the wider picture of services that have now trialled or are in development. Many of the gaps found in 2020 have been filled, albeit at a small scale and by short-term pilots – but the question remaining is how are we to sustain the services and build them at scale? The remaining key gaps to address this are:

i. **Strategic inertia**. The Department for Transport (DfT) produced its Connected Vehicle Data Research in 2020, which suggested the value of the services mentioned here and ways to scale them to national services, through large-scale user-facing demonstrations. However, developments are still stuck at small-scale pilots, not pathfinders and demonstrators at scale,

ii. Established and embedded practices, procedures, standards and contracts that constrain highway authorities from adopting and using **new digitalisation approaches**. For example, the UK currently prescribes what technology to use to collect data for roads and footways and then how to use it. Moving from an analogue world to a digital world means a new approach, to prescribe what to do but not define how data is collected. Currently, the processes and procedures for highways do not fully provide standard datasets. The most visible element here is Digital Traffic Regulation Orders (DTROs), without which a range of potentially valuable services to support better management of traffic and parking are not enabled and, looking ahead, could be storing up problems for automated driving systems,

iii. Datasets from highway authorities are **not being released in an open, timely or readily accessible way**. Their release may be held back by data owners not understanding their value for public benefit, hoping for greater commercial gain, or simply (as with DTROs) a need to digitise a traditionally analogue process,

iv. **A lack of awareness, skills and capability** in the roads arena to understand and engage with the new data-rich and increasingly connected world, and

v. The **absence of a business model** to justify commercial investment in service development and provision, or of a sufficiently compelling economic/social benefit to justify the public sector taking the lead.

The core issue that this update focuses on is funding – the challenge of matching who benefits with who pays? Services that improve road safety or reduce emissions deliver a societal benefit that is hard to recoup from a direct charge to drivers, in the same way road signs are not funded by the people relying on them. Hence, not all services have a clear, commercial revenue stream. That said, this does not necessarily mean 100% public funding is needed. Through discussions with stakeholders, notably enabled by the ITS UK Connected Vehicles Group, a more nuanced picture emerges of six ways that services – or elements of the process through which services – might be funded:

## Publicly funded

i. The public purse continues, as now, to fund '**pathfinder**' projects but potentially as larger scale demonstrators to highlight benefits. This will either prompt development of commercial services with private funders or show the case for sustained public investment in the establishment and sustained operation of a large-scale rollout,

ii. The public purse funds, **where only it can**, those building blocks needed for **enabling connected services to flourish**. Examples include meeting the costs of opening up public data (e.g., DTRO), scaling up the National Parking Platform (NPP) and rolling out the Find Transport Data service. This could include public support for training and skills. Although couched in terms of public funding, a key task falling to government (with resource consequences) is the development and application of regulations, as has been the case for BODS. Accessing eCall data is a further service only the public sector can fund and provide, and

iii. The **public purse funds the development and delivery of services and data**, such as GLOSA and IVS and other 'digital road services', to secure a public benefit that is free at the point of use. This should only be where there is no other business case, i.e., there is a market failure. This case will typically be a combination of better information to users resulting in reduced congestion, improved safety and reduced emissions. It could be a combination of national and local government action – for example, national government could purchase in-vehicle-derived datasets on behalf of and for use by local authorities (reducing both the costs and bureaucracy involved) so improving affordability via an economy of scale with one national contract for additional floating vehicle data (FVD) rather than more than 100 separate local contracts.

## Privately funded

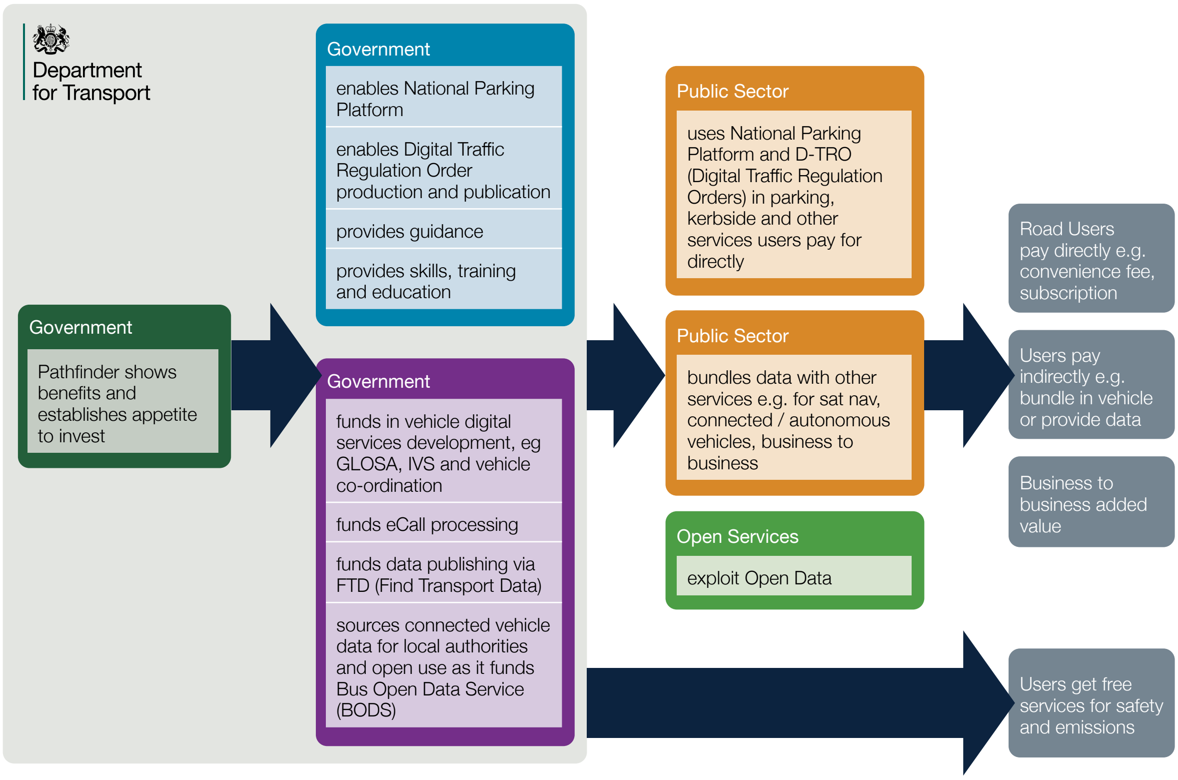
i. The private sector develops and funds **business-to-customer services**, where the road user pays directly for the service and benefits directly from it, e.g., some satnav and parking services. These services can only be deployed where sufficient basic data becomes available in the public domain and customers see enough benefit to want to pay. But even in these private services, government could provide building blocks for the creation of better, more accurate, private services that also achieve a public benefit (e.g., prioritising the publication of DTROs and the NPP, so that ultimately traffic and parking are managed more efficiently),

ii. The private sector develops and funds **business-to-business services**. Here, private industry develops commercial add-ons to public services – for example, by bundling several data sources and services together to make them more attractive, so that end users pay indirectly, e.g., via advertising or added services that users can buy. It can also be achieved by focusing on key niche customers, like logistics companies, who are willing to pay, provided they get a niche business benefit – so giving reduced costs of deliveries or vehicle operations, and

iii. Private industry or institutions fund **open data services** philanthropically, possibly as part of their environmental, social and governance (ESG) activities, e.g., to support improved road safety such as Vodafone's Safer Transport for Europe Platform (STEP), or because they gain a non-financial benefit, e.g., Google Maps providing a free-to-use satnav service in exchange for users' location data, which provides a building block for other services.

This blend is illustrated below in Figure 1.1. Direct payments may be app subscriptions or convenience fees (as already exists in parking). Indirect payment may be hidden in the purchase cost of a vehicle, navigation service subscription, advertising or in return for data from the user.

**Figure 1.1: The 'who pays?' model for connected services**




Source: Author's own

In a nutshell, the private sector can only be expected to step in where there is a clear market for a product. However, it cannot deliver advanced national parking or kerbside management services on a commercial basis unless government delivers DTROs and the NPP, and it is unlikely ever to deliver GLOSA or IVS because there is no evident prospect of there being adequate customer demand and a sufficient revenue stream.

Adopting this model of 'who pays for what?' would enable industry to both tool up and scale up, attracting external investment as both the business model and payment would be clear. It would also show where public funds are best placed, and make the most of work done to date.

Hence, this model shows that government does not have to pay for every connected service and it might not even have to pay that much. But in several cases, it almost certainly must pay to unblock data flow and support deployment at scale.

## Where now?

There is clearly scope for the development of further, purely commercial, services derived from ‘connecting’ vehicles, and for refining and improving those services already in operation.

But there is clearly far more scope to foster development of many more services to help achieve public policy outcomes on congestion, safety and environmental impacts if government nationally focuses urgently on five aspects:

i. Identifying those services where government is willing to pay in whole or in part for service delivery to achieve a public benefit, as the private sector sees no business case, and where those services should apply (e.g., on what type of junction is GLOSA best deployed?),
ii. Digitalising data by accelerating the delivery of the NPP, DTRO and Find Transport Data (previously the National Access Point), from which many valuable new services could flow, with dates by which highway authorities should be publishing data in these new forms,
iii. Generating more open data in readily accessible format (for example, GLOSA and IVS),
iv. Driving down the cost of data to local highway authorities through more centralised purchasing, and
v. Identifying those data feeds where public processing for a public client could deliver rapid benefits, most clearly by using the eCall system to its full potential.

Providing connectivity or data alone is still not enough. Services need to scale up and be sustainable for benefit to flow. Without such steps towards connectivity, there must be serious questions asked about not just connected services but also the safety and user experience of automated vehicles.

## To see the services in action

https://www.youtube.com/watch?v=ZBPos-hIqkU gives a good overview of the current art of the possible in connected services, from a Transport Technology Forum event at UTAC Millbrook in 2022.

https://www.youtube.com/watch?v=P57_eOL5yus shows a pathfinder of IVS on the RM Sotheby’s London to Brighton Run.

# 1. Introduction

There is increasing evidence (TTF, 2020: 13; USDOT, 2015; Grant, 2022; DfT, 2020a; Be-Mobile, 2023) of significant benefits to be gained in the safety, management, operation, maintenance and use of our roads from the growing extent to which vehicles are ‘connected’ through communications networks. As well as connecting vehicles to vehicles, this connectivity allows data to be harvested from the vehicle and information to be fed back to the driver (and, in time, to automated vehicles).

Data may be collected from a vehicle through many systems, e.g., by the vehicle manufacturer; through a fleet management system; by pay-as-you-go insurance (PAYGI) providers; and through smartphone apps such as satellite navigation (satnav) services. It can then be brought together by a data processor/aggregator, which can be a third party. The data collected can cover many aspects of the vehicle’s operation such as speed, acceleration and braking, even down to whether the windscreen wipers have been activated and seat belts fastened.

Perhaps the most widespread connected service already in use is guidance from various satnav services, but others are starting to become more common – for example, products displaying the location and availability of parking spaces (Appyway, 2022). Data from road operators could also be processed by these service providers into messages that they send to the road user directly, to help inform and influence their behaviour.

Work to explore the value arising from vehicle connectivity to and from highway authorities[3] has been carried out through limited pilots and trials. These have often been more focused on technical feasibility than the business case for wide-scale adoption of new services and data use – or, indeed, on other factors needed for them to work as an end-to-end service in the real world.

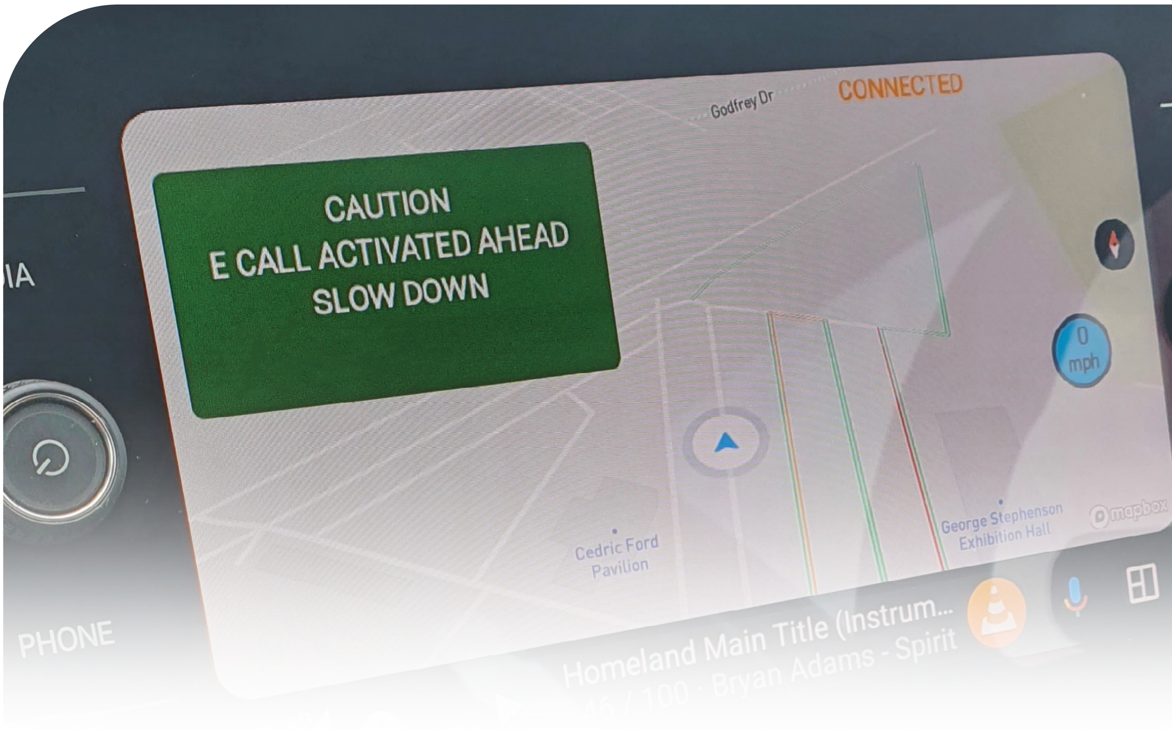
So, in September 2020, the RAC Foundation published research (RAC Foundation, 2020) looking in detail at four connected vehicle services, chosen to be ones that link road operators to vehicles (as this is more complex in organisational terms than vehicle-to-vehicle communications) and that together were representative of the wider range of services in contemplation or development (i.e., not necessarily those nearest to the market or offering the greatest benefits). By analysing the end-to-end process for each of these services, the research, first, identified the extent to which all the elements enabling end-to-end connectivity were already in place and, second, mapped where significant gaps emerged. The purpose was to identify and understand why these gaps existed and, more importantly, how they might be bridged.

Since that original report, many of the elements needed for securing 'quick wins' have been developed. This has been through publicly funded pilots, private innovation or a combination of the two, enabling real-world demonstrations of what was possible, if still short of wide-scale or nationwide application. Hence, the landscape of gaps is starting to change, with some becoming more important, and others – notably in technology – bridged by developments.

Hence, the aim of this update is to report on where gaps have been filled, with results emerging, and – importantly – how this learning influences future connected services. It looks at not just progress on the services chosen originally, but also where gaps remain and what needs to be done to bridge them.

3 The term 'highway authority' is used here to refer to any organisation responsible for the operation and/or maintenance of a UK public highway, of which there are over 130 in England alone, responsible for 96% of the road network by length.

# 2. Connecting Vehicles and Data




## 2.1 Updating the previous report

The previous report was a detailed analysis of the end-to-end steps and processes needed to enable four representative services to be deployed at scale, to secure the potential benefits for road users and highway authorities alike. The analysis focused on identifying 'breaks' in the connected chain of data generation, transmission and application to and from the vehicle. The concept of benefit from connecting road operators and vehicles might also be thought of as being akin to an electrical circuit – any one break means no end-to-end connection and consequently no flow of benefits.

Two of the representative services use data transmitted *from* the vehicle or user without their intervention. The other two involve the transmission of data *to* the driver (via the vehicle or a smartphone), to help inform and influence their behaviour.

The four were chosen for three reasons: because they were directly relevant to UK policies and challenges; because they could be used in all vehicles (not merely new cars); and because they had already been explored in the UK and were – at the time of the report – not far from deployment.

The services were:

- **In-Vehicle Signing (IVS)** – this entails a driver receiving messages (called 'virtual signs') from road operators warning of and/or explaining about road conditions ahead, e.g., congestion or roadworks, either repeating or augmenting the information carried on roadside signs. IVS was piloted on the A2/M2 project (DfT, 2020b) and is now starting to be provided by the private sector through apps downloadable to smart devices (TTF, 2022),
- **Green Light Optimum Speed Advice (GLOSA)** – this advises drivers what speed to travel at in order to pass through forthcoming traffic lights at green. This reduces unnecessary stops for vehicles, leading to fuel economy and emissions reduction (particularly important for the largest, heaviest vehicles, e.g., heavy goods vehicles (HGVs)), and has already been trialled technically (TfWM, 2018),
- **Use of vehicle data for better highway management and maintenance** – termed 'asset management'. There is evidence (DfT, 2020a) of the use of connected vehicle data to generate potentially large cashable (i.e. not purely economic) savings for highway authority budgets through the ability to streamline inspection regimes, spot issues more quickly and enable better-informed prioritisation of responses (e.g., in the deployment of winter maintenance vehicles in cold weather), and
- **Use of vehicle data to improve traffic light timings** – this involves tuning the design and operation of traffic lights to improve traffic flow. The previous report noted that many UK traffic lights no longer deliver the desired congestion reduction benefits they were intended to provide, owing to a failure to maintain sensors and not retuning traffic light operating algorithms as traffic levels and origin/destination patterns change over time (TTF, 2020).

A summary of the services is shown in Appendix A.

Having identified the breaks preventing service deployment, the report sought to find quick fixes that could bridge the gaps well enough to secure at least some of the available benefits, i.e., 'good enough' services for 'enough' vehicles, as well as the substantive solutions needed to support wide-scale delivery.

Hence, this update firstly focuses on the extent to which quick fixes have been identified and applied, and then goes on to look more generally at progress to date or in hand.

## 2.2 Beyond the original four services

In writing this update report it was timely to look beyond the original suite of services to draw in learning from projects that have subsequently been in development, including:

- eCall – mandatory since 2018 in newly type-approved cars and vans in the UK, now with more than 20% penetration (Vesos, 2023). This provides an automated connection to emergency services if sensors detect a serious incident (e.g., from the triggering of the vehicle's airbags). The system could be used more effectively to improve road safety (particularly on motorways), subject to tackling a set of ownership and institutional, rather than funding, issues and better awareness of its potential (National Highways, 2022a),

- The Bus Open Data Service (BODS) (Ito World, 2023) – a set of connected data collected at national scale where supporting issues (regulation, guidance and skills) have to some extent been addressed, but the bulk dataset has yet to be unlocked for analytical access,
- Integrated payment for parking, tolling and vehicle charging – where further development is awaiting delivery of the emerging National Parking Platform (NPP) (NPP, 2023), and
- Services for digital kerbside and roadworks management – enabling more efficient road use, facilitating easier deliveries, and generating improved data on roadworks for satnav services, where further development is awaiting regulations and Digital Traffic Regulation Orders (DTROs) (DfT, 2022).

Other developments have illuminated the future potential, notably the Netherlands' national data platform (Talking Traffic, 2020 and 2022; Be-Mobile, 2023) and domestically the lessons learnt from pathfinder projects such as Helm (National Highways, 2022b) on the benefits of connectivity, in this case through more efficient operation of HGVs.

## 2.3 Methodology

The update started with a bottom-up approach looking at the four existing services, by:

- Reviewing each service to establish the extent to which the benefits previously identified have been or are close to being delivered,
- Discussing progress with stakeholders, especially those who have developed pilots and trials, and
- Undertaking a literature review of newly published strategies, guidance, research and other reports, including those by the Transport Technology Forum (TTF, 2022), Digital Local Roads (TRL, 2022) and DfT (GOV.UK, 2023a, 2023b and 2023c).

There was then a 'top-down' analysis of core issues impacting connected services generally, by:

- Discussing the business-based barriers to adoption with the prospective suppliers,
- Debating the issues at a workshop by ITS UK's Connected Vehicle Group on 'who pays for connected services' (ITS UK, 2023), and
- Discussing the issues bilaterally with stakeholders in highway authorities and DfT.

Appendix A to this report sets out the original services and documents their impacts and benefits.

Appendix B looks in detail at the gaps originally found in the previous report and how they have changed, highlighting those that still remain.

## 2.4 Peer review

As in the previous report, the material and findings in this report have peer reviewed by the following experts:

### For IVS and GLOSA

- George Brown, KL Systems – an independent consultant with deep knowledge and significant experience in connected vehicles, who has been leading developments in IVS and GLOSA.
- Damian Horton, CEO of Eloy – a company leading the development of IVS and other in-vehicle services.
- Paul Rose, previously of Amey Consulting – led and managed real-world deployment of GLOSA in the Midlands, led and evaluated National Highways GLOSA deployment, and led deployment of IVS in Bristol and Oxford.

### For asset management

- Dr Jon Harrod Booth, Harrod Booth Consulting – an expert in both highway management systems and asset management, and vehicle-to-infrastructure data standards.
- Paula Claytonsmith, Local Council Roads Innovation Group (LCRIG) – bringing extensive experience in asset management innovation and local government policy support for the DfT's TTF.
- Brian Fitzpatrick, of Fitzpatrick Advisory – contributing extensive experience in asset management systems and use of new data sources in highway authority maintenance.
- John Cartledge, Gaist – bringing 30 years' experience in the application of geographic data in solutions, with the past six years focusing on data from connected vehicles.

### For better traffic light performance

- Dr Mark Pleydell, PTC Ltd – a widely respected designer, developer and maintainer of traffic systems, and leads the Traffic Open Products and Specifications (TOPAS) standards group.
- Dominic Paulo, INRIX – has 20 years' experience of both traffic data use and floating data provision, especially for UK local authorities.

# 3. Changes Since the Previous Report and Remaining Barriers

## 3.1 Key changes

More than two years on and, as might have been hoped, many of the technology gaps have been or are in the process of being filled.

### 3.1.1 IVS

**Key improvements**

Since the original report, much work has taken place to fill gaps through demonstrations and real-world pilots. Companies such as Eloy (Eloy, 2023), KL Systems (KL Systems, 2023) and Vodafone (Vodafone, 2022) now have apps for IVS across a variety of use cases and road types; for example:

- apps repeating openly published roadside sign messages now appear on the same screen as a satnav, shown in Figure 3.1, and
- apps showing "virtual" messages about congestion where there are no signs, shown in Figure 3.2.

This has helped fill gaps in how to connect to existing information and how to deliver it, although much work is still needed with real-world users on issues such as presentation. This is being explored in a pilot of IVS on the M6 (Hutton, 2023).

**Figure 3.1: Typical IVS deployment – repeating journey-time signs on satnav**


Source: KL Systems

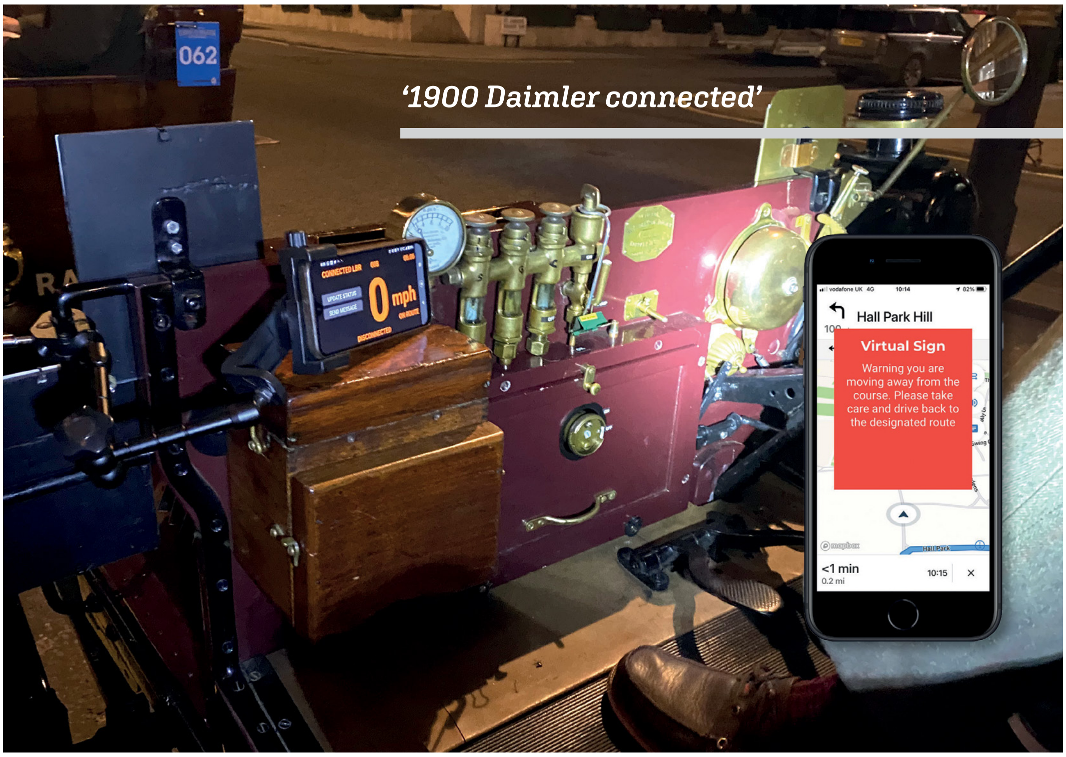
A DfT-funded project in Bristol and Oxfordshire helped understand, first, how to access highway authority information and, second, gaps in technical standards, showing IVS messages in cars and buses and on cycles (Amey, 2021).

The RAC Foundation (2021) supported a pathfinder of connected vehicles on the RM Sotheby's London to Brighton Run, which demonstrated IVS working to assist the drivers of the world's oldest connected cars, shown in Figure 3.3. This filled gaps in knowledge about IVS in all vehicles, not simply new ones, and how to synchronise fixed roadside information with IVS. It also showed the safety value of defining fixed satnav routes and raised awareness of connected vehicles.

**Figure 3.2: Virtual signs of congestion where no real-world signs exist**


Source: Eloy

**Figure 3.3: Connected 1900 Daimler with IVS and data collection**




Source: RAC Foundation

A new development is work by HRS and KL Systems (TTF, 2022) on automatic real-time notification of roadworks to IVS (involving temporary carriageway restrictions, reduced speed limits, etc.) to improve the accuracy and timeliness of information conveyed and to improve roadworker safety. Data is sent from roadside signs to the apps without being touched by human hand. This, allied to work by one.network in passing updated roadworks information to satnav companies, means better sources of information about roadworks, which is traditionally a poorly served area in terms of timely data (one.network, 2023).

The Rees Jeffreys Road Fund awarded its RJRF150 prize to Eloy as joint winners alongside Reed Mobility to develop IVS for single-track roads, to improve safety for all road users, as shown in Figure 3.4 (Rees Jeffreys Road Fund, 2022).

**Figure 3.4: Eloy's proposal for combining IVS warnings with satnav on single-track roads**


Source: Eloy

A TTF event at the UTAC Millbrook proving ground (TTF, 2022) showed many different data sources for IVS integrated into the single KL Systems app, including fixed and variable signing from HRS and SRL, eCall activation from Vesos, and emergency vehicle warning. This also showed the Eloy service above, as well as dynamic IVS from Vodafone/ Commsignia.

Vodafone (2022) also developed a platform called STEP that can host, collate and release data to IVS systems.

## Remaining issues

For IVS, a key question remains on how to access good-quality nationwide information content (above and beyond repeating existing signs and small-scale pilots), making it accessible and developing a full understanding of the driver experience of IVS. While IVS has made good progress in quick technology wins, there remain more fundamental gaps. In particular:

- Despite DfT now having a Data Strategy (GOV.UK, 2023a), there is still no strategic plan in place for scaling up IVS on a national basis – pilots have shown it can work technically but it needs to scale with a sustainable business model. There is an expectation, myth even , that transport can quickly move to 'naked roads' (Highways Magazine, 2019), but without IVS nationally this is simply not possible; and even with it, it is unlikely. The value of IVS is in filling in between fixed signs and backing them up in-vehicle. https://youtu.be/nnReka814AU shows an example of a sign repeated in-vehicle when the variable sign itself is not working, which is a hidden benefit of IVS,
- Mobile phone data coverage remains focused on towns and cities (buildings and built-up areas) not roads,
- There is still a lack of wide-scale data to make it worthwhile for a user to want IVS for anything beyond motorway travel, so the scalability gap identified in the previous report remains. There also remains a sustainability gap as electric vehicles and automated mobility are all sustainable businesses where it is clear how to fund and support innovation – because the user pays. But in IVS, additional funding is needed, as improving road safety is unlikely to be paid for by drivers directly, and
- There is a need for guidance and skills training in local authorities for collecting and sharing data.

### 3.1.2 GLOSA

## Key improvements

Since the previous report, a key project has been the National Highways / Transport for Greater Manchester (TfGM) Off-Slip GLOSA project, shown in Figure 3.5. This measured exhaust emissions and journey times in a project managed by Amey, supported by Ricardo and Eastpoint, at two slip roads off motorways in Oldham and Bury. One was an uphill slip road off the A627(M) and the other was downhill off the M66 (ITS UK, 2021a).

By not idling or not having to restart after stopping, the travel through a junction becomes much more efficient. Analysis of results show $CO_2$ emissions were reduced by up to 27% during the trial, with NOx emissions down by up to 17%. The most impressive results were for larger vehicles – for example, those delivering to regional distribution centres – as it was estimated that freight vehicles save on average 12.5p in fuel, at diesel prices then in place, by not stopping on a slip road. This suggests that significant financial, as well as environmental, benefits will add up from an at-scale rollout of GLOSA. The environmental benefits will be further increased when the reduction in tyre and brake dust due to braking is considered.

**Figure 3.5: National Highways Off-Slip app under test**


Photographs kindly provided by Amey Consulting – 2023

TRL (with permission of relevant traffic authorities) has now published data for Manchester as well as Bristol and Stoke (TRL, 2021). Using the same technology, GLOSA was applied in Manchester with multiple Urban Traffic Control (UTC) data sources and multiple apps in a demonstration of in-vehicle delivery, shown in Figure 3.6. Hence, previously separate services are starting to be combined, to avoid the need for separate apps. KL Systems has demonstrated how GLOSA and IVS can be combined on a single app, along with satnav (KL Systems, 2023). This is key, reflecting user-facing services designed around the customer, not technology. This was also demonstrated at the recent TTF event at UTAC (TTF, 2022) with GLOSA for temporary roadworks traffic lights.

**Figure 3.6: GLOSA integrated with navigation**


Source: KL Systems

## Remaining issues

Although there is now a larger feed of GLOSA data, proven benefits to both users and authorities, and the start of a customer-facing approach, GLOSA is yet to rollout at scale because there is no sustainable business to deploy it as there are currently no moves to create a national feed. Nevertheless, National Highways has an ambitious programme to look at how GLOSA can work with adaptive systems such as Microprocessor Optimised Vehicle Actuated (MOVA), which frequently change timings, so making prediction challenging (Bodenheimer et al., 2015).

Other challenges for GLOSA, as for its close partner IVS, are access to data and a business model sustaining services beyond pilots For GLOSA, as with IVS, there is an opportunity to exploit channels that already exist into the vehicle – for example, satnav, fleet management systems, Google Maps and apps such as Waze. Currently, there is little, if any, data feed from highway authorities to these suppliers (as for IVS), and often the view of such suppliers is that data from roads authorities is inaccurate, although services like those provided by one.network can improve the quality of satnav feeds (one.network, 2023). There is great value to be gained from connecting the chain here, but existing channels need to see a nationwide case.

In the pilots, user tests have focused on 'captive' users, such as employees of the highway authority or suppliers (Cowen et al., 2018), but the tests are now moving more to 'friendly' users – business drivers of fleets such as delivery HGVs (Hutton, 2021) and, in the M6 pilot, regular road users (Hutton, 2023). The final step will be with open 'public' users.

Similarly to IVS, a plan for the rollout of GLOSA is now needed to promote confidence in deployment, training and awareness. GLOSA will not work well at every junction, at every time of day – whereas IVS is likely to have nationwide value. Hence, a plan is needed for which junctions will be connected and when GLOSA will be used.

### 3.1.3 Data use in traffic light control

## Key improvements

Since the last report, INRIX has developed and commercially deployed a concept called 'signal analytics' (INRIX, 2023), which explores the use of individual vehicle data to historically monitor traffic light performance. The company explored this through a DfT-funded project (GOV.UK, 2020), working with 11 UK local authorities to develop a service that would help to identify which traffic lights are performing badly, aiding the prioritisation of maintenance resources.

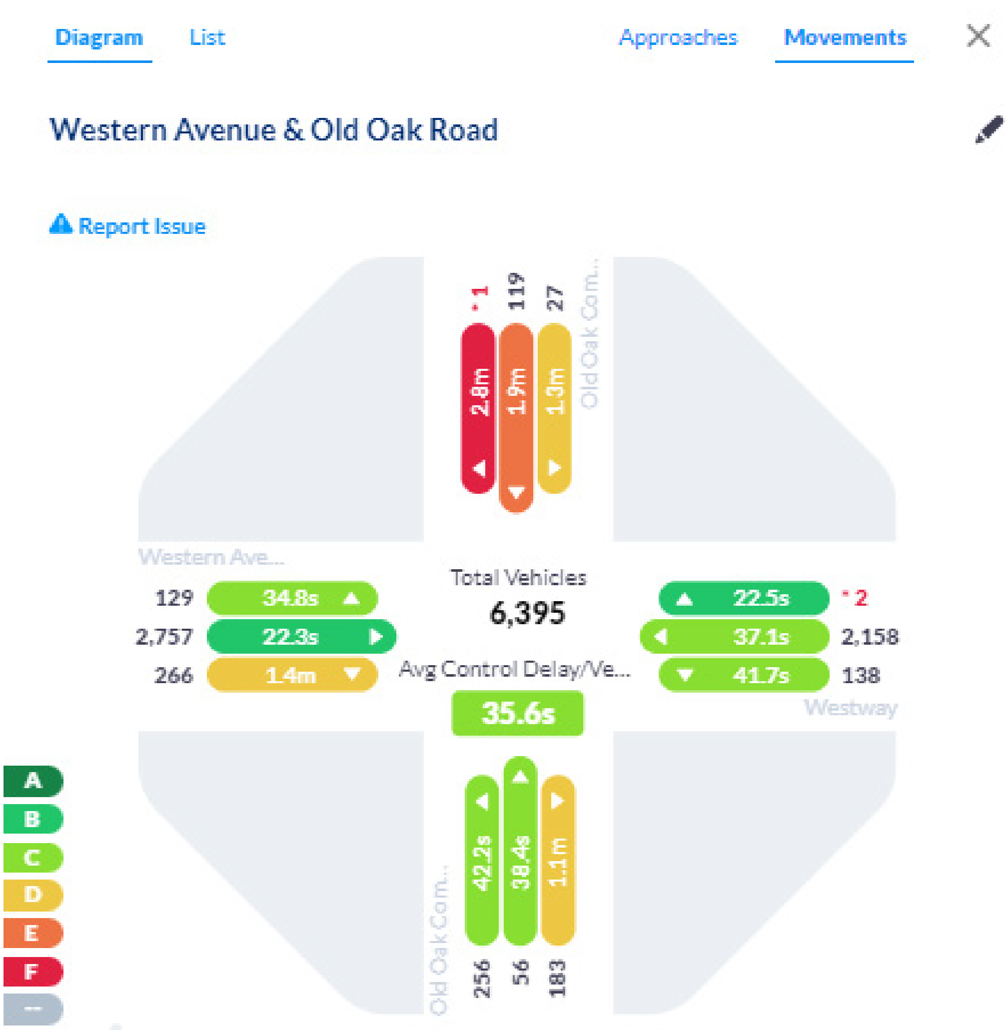
Figure 3.7 shows how a delay at a junction can be measured remotely using FVD, while Figure 3.8 shows how this data can be used to measure vehicles passing through a junction (shown in green) and delays for those stopped (shown in red). Tomtom has launched a similar service (Tomtom, 2022).

DfT has also funded £15 million of maintenance for traffic lights to improve performance ready for connectivity, and the delay data will be used to measure the benefits of investment, again showing the virtuous circle of data being used to evidence benefits of investment in connected services (TTF, 2023)

Traditionally, FVD has been a commercially derived data source, but more recently BODS is a DfT-funded source of vehicle location data for every local bus service in England, in a standard format and from a single access point. BODS is not simply about data but also the regulations, guidance and funding required for connected data use, so it is an example of how such services can be deployed.

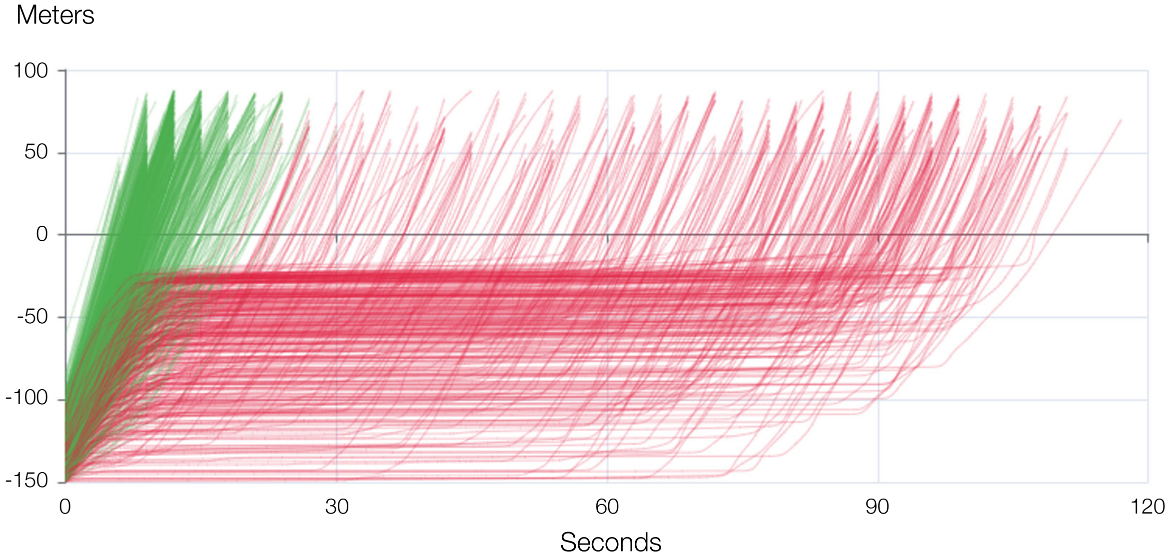
The data was not designed for traffic light priority at junctions, as it is not granular enough for traditional approaches (locations being updated every 5–30 seconds) (Ito World, 2023). However, this could be updated more frequently, and new techniques could be incorporated to use the existing data. BODS has more than 18,000 buses nationwide and shows the potential for a single national feed of FVD.

**Figure 3.7: INRIX uses connected vehicle data to analyse traffic light performance**




Source: INRIX

**Figure 3.8: Connected vehicle data used to show paths of vehicles either passing at green (green) or stopping (red)**




Source: INRIX

## Remaining issues

The value of FVD in historic analysis of junction performance is now clear. However, use of real-time data in control systems has yet to extend beyond limited pilots. This is due to difficulty in interfacing old traffic control systems based on loops with new data, although the new Fusion project has been designed to allow this (Yunex Traffic, 2023).

### 3.1.4 Data use in winter and asset maintenance

## Key improvements

Since the previous report, much work has been done on using new data sources directly from vehicles and cameras/smartphones on board them. Companies such as Nira Dynamics have taken data direct from Volkswagen/Audi group vehicles processed by on-board technology to produce international-standard data on road roughness and winter traction for the UK (Safecote, 2023). Nira Dynamics is using this data for winter maintenance planning and to monitor where traction is poor in real time, as shown in Figure 3.9. Other companies like INRIX, Mobileye, AISIN and RoadBotics, Vaisala, and RoadAI have similar datasets, importantly including See.Sense (British Cycling, 2023) for data captured from cycles.

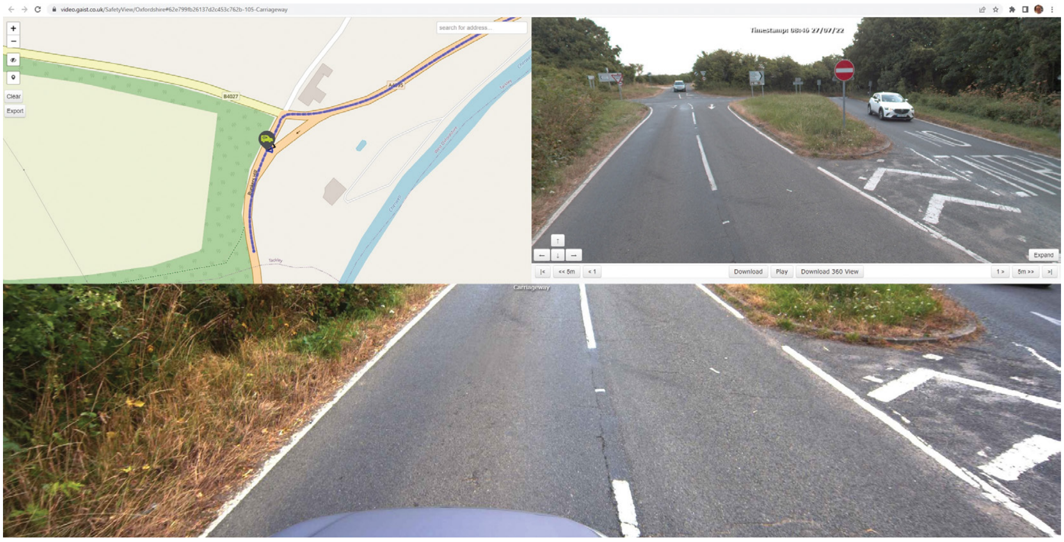
Gaist (2023) provides data revealing locations with a record of aggressive braking by drivers matched to road geometry, as a lead indicator of a possible road-safety risk warranting a look at highway engineering (e.g., road layout and the case for traffic management measures), as shown in Figure 3.10. Importantly, work is also underway in the asset management industry to make practical use of such data as well as images from phones and cameras mounted in vehicles, with services from Vaisala (Vaisala, 2023) and others – for example, now in use by UK local authorities.

Further integration of in-vehicle data with other uses is also becoming clear – the same sorts of data direct from the vehicle can also identify, for example, unexpected braking events, near misses and steering angle changes. When combined with other data such as road geometry, unexpected rapid braking can identify 'near-miss' locations, which may see a collision in the future (Aisin, 2023).

**Figure 3.9: NIRA Dynamics Road roughness data for the UK, sourced from VW Group vehicles**


Source: NIRA Dynamics

**Figure 3.10: Gaist combines vehicle rapid braking with road geometry to identify near misses**



Source: Gaiste

## Remaining issues

Vehicle technology and the data it provides are becoming mature, but for many authorities, the business process maturity and skills required to exploit the opportunity are not. The data has a range of potential uses (TRL, 2022). The potential benefits of digitalisation are not often clear across the various siloes in highway authorities – data about road condition can be useful to not just asset managers and winter maintainers but road safety teams too (Gaist, 2023). Using new data is often the responsibility of different departments in highway authorities and government to other connected vehicle and data projects, so siloes persist and develop.

So, the gaps remain about how to use these new data sources, alongside existing data, to improve asset management. Many of those interviewed for this project said the biggest block to cash savings from innovation in asset management, and hence decarbonisation and better services for drivers, was the way the UK currently prescribes what technology to use to collect data for roads and footways and then how to use it.

Moving from an analogue world to a digital world means a new approach to prescribe what to do, to help authorities in practice, but not to define how data is collected. Hence, DfT has started following the 2019 Transport Select Committee findings (UK Parliament, 2019; DfT, 2021) to review road condition data on new standards for highways road condition. Once enabled, this could allow future data collection to be drawn from more suppliers without prescribed technology, while allowing for a national statistical dataset to be reported by government. This would be a further key gap filled, because currently the processes and procedures for highways maintenance stifle the use of non-conforming datasets.

Connected data remains difficult to integrate, and there has been less work done about the business processes that need to sit behind the receipt of connected vehicle data and how best to integrate or aggregate such data and to make it useable (TRL, 2022). Many local highway authorities use different proprietary platforms and approaches, and there is no single way yet to pull all this information together onto a single integrated platform across different departments.

## 3.2 Other projects and lessons learnt from them

In the eCall system, access to the data is stifled by a lack of clear data ownership, institutional issues and a lack of awareness of the service (ITS UK, 2021b; Hutton, 2020). A recent demonstration (TTF, 2022) showed how eCall data could be harvested from a collision and used to both warn drivers and navigate a fire appliance to the scene.

Find Transport Data (previously the NAP) (NAP, 2019) and the NPP are initiatives designed to make access to data easier for end users, with the NPP offering a foundation for many services that need payment as well as parking costs and locations, so supporting a single app for payment across the nation (NPP, 2023). However, rollout at scale of these services has been slower than hoped.

The Helm final report on platooning highlights the benefits of connected HGVs in terms of fuel savings (National Highways, 2022b), even if platooning is not practical for UK roads.

Electric vehicles are ripe for good connected services – knowing the working status of charge points, whether they are occupied and how to reach them requires connectivity, and newer electric vehicles are already well equipped for data services. Hence, there is an opportunity to combine the benefits of electrification and connectivity to make a clear case for national services and improve the user experience.

## 3.3 Key remaining themes

In looking across the services and how they have evolved, together with further services like eCall, there are common themes, which are described below.

### 3.3.1 Strategic inertia

DfT produced its Connected Vehicle Data Research in 2020 (DfT, 2020a), which suggested the value of the services mentioned here and ways to scale them up, through large-scale user-facing demonstrations that mirrored successful work in the Netherlands (Be-Mobile, 2023). However, developments are still small-scale pilots. IVS could be a nationwide service, but it is unlikely GLOSA will have benefits everywhere – so a plan is needed for its targeted rollout via small-scale demonstrations to determine what type of junctions it works best at and how users want the information presented. The recent Data Strategy (GOV.UK, 2023b) still does not address the rollout of connected services.

Hence, the first common gap is a lack of momentum in moving from pilots to pathfinders and demonstrators at scale, and full national services.

DTRO and the NPP are examples of where new services enable other benefits from connectivity. In the DTRO case, it enables connected vehicle services such as Intelligent Speed Advice, better satnav services, improved logistics and utility planning, and indeed the NPP itself. The NPP then enables payment by users for parking with a single app (NPP, 2023). Individual parking authorities could adopt this new approach as their current contracts end, rather than as a ‘big bang’ change. But to do this, they need to be aware of the NPP and its advantages, and not carry on with ‘business as usual’ when tendering for parking services (Parking News, 2022).

### 3.3.2 Digitalisation

The process of moving from ‘analogue’ roads to ‘digital’ ones is slow, as evidenced by the rollout of DTRO, the NPP and Find Transport Data, as well as access to eCall data. A recent report (TRL, 2022) highlighted the challenges to the digitalisation of local roads and echoes many of our previous findings.

Established and embedded practices, procedures, standards and contracts constrain highway authorities from adopting and using new approaches. For example, the UK currently prescribes what technology to use to collect data for roads and footways (CIHT, 2023) and then how to use it.

For many authorities, the business processes required to exploit connected data and services are not in place (TRL, 2022). Paper-based systems still dominate – for example, in TROs (Ames, 2022) – holding up deployment of smart kerbside management, and this raises a question about our readiness to support automated vehicles.

Moving from an analogue world to a digital world means a new approach, new skills, new business models and, if required, regulatory support as shown in the BODS service.

### 3.3.3 Access to data

Datasets from highway authorities are not released in an open, timely or readily accessible way. Their release may be held back by data owners not understanding their value for public benefit, hoping for greater commercial gain in due course, or simply by a delay to digitise a traditionally analogue process.

There is also an opportunity to exploit channels that already exist into the vehicle – for example, satnav, fleet management systems, Google Maps and apps such as Waze. However, currently there are few real-time data feeds from smaller highway authorities to these channels (TfL, 2016), and often the view is that data from roads authorities is inaccurate.

There is great value to be gained from connecting the chain here, but existing channels need to see a nation-wide case, e.g., for data to be included in IVS services. Importantly, the data needs to be timely, accurate, comprehensive, georeferenced and in a standard digital format. It needs to be provided on a large-scale, if not national, basis (for example, IVS needs to be for all roads, but GLOSA is only needed where there are benefits and policy alignment). Even if data does not cover the nation, it needs to be accessible from a single point (the Find Transport Data service should help here) (GOV.UK, 2023c).

Connected data remains difficult to integrate with existing data. Many local highway authorities use different platforms and approaches, but there are now platforms (e.g., Vodafone's STEP) (Vodafone, 2022) that are available to receive, curate and present data for highway authorities. Using such platforms will not only help reduce organisational boundary issues around data management, e.g., concerning carbon reduction, but also potentially maximise use of connected data to accelerate changes improving digital maturity. There is still a need to consider combining asset management and vehicle movement data in an authority as they may be provided by the same source.

### 3.3.4 Awareness of potential, skills and capability

There is a lack of awareness, skills and capability in the roads arena to see the potential and engage with the new data-rich and increasingly connected world. For example, few people in the road-safety and highways industry are aware of eCall, even though over 20% of UK cars and vans now have it (Vesos, 2023).

Studies (TRL, 2022; DfT, 2018) suggest that as well as a lack of training, there is a lack of skilled staff. Hence, there may be a role for highway authorities to become more intelligent clients around the use of data.

### 3.3.5 Who pays?

What remains in almost all the services examined is the key question of 'who pays'?

This is because of the absence of a business model to justify commercial investment in service development and provision, or of a sufficiently compelling economic/social benefit to justify the public sector taking the lead.

# 4. Who Pays and Why?


## 4.1 The revenue challenge

In electric and automated vehicles, there are sustainable business models as it is clear how to fund and support innovation – the user pays directly. But in services like IVS and GLOSA, additional funding is needed, as improving road safety is unlikely to be funded by drivers.

Drivers do not directly pay for physical road signs, traffic lights or safety warnings now and so will not do so going forward. However, they will often pay for services like connected parking where there is a clear benefit to them (e.g., not having to use coins) and for niche ‘extra services’ adding value to public data, or bundling separate services together to make them easier to use.

So, there needs to be additional funding in place to pay for:

- Pathfinder projects that show the feasibility of scaled-up services to reduce the risk of investment, then
- Enabling technology, institutions and governance needed to support large-scale services, and then

- “Public-good” services that drivers simply will not pay for or cannot pay for directly. Even if subscription-based services are offered in new vehicles and drivers want to buy them, it would take a long time for them to penetrate the mass market as the average age of a UK car is now over 8 years and growing (SMMT, 2022). Even with free mandated services, such as eCall, it has taken 5 years to get to over 20% penetration (Vesos, 2023).

## 4.2 The six ways to pay

### 4.2.1 Overall approach

By examining areas where only the public purse can fund services directly, where the public purse should not fund (as it creates competition to innovators and is not good value) and where services can be provided by other means, six answers to the question of ‘who pays and why’ emerged.

These are best thought of as three publicly funded services and three privately funded services, although the former enable many of the latter by providing either the data they need or evidence for investment.

### 4.2.2 Publicly funded services

1. **The public purse funds ‘pathfinder’ projects**, as now but at a larger scale, to show the benefits of the above to funders and to develop the governance needed for scale up. These projects are a temporary answer – pathfinders need to then move to another type of funding to deploy large-scale benefits and to help suppliers decide whether to invest. The outcomes would be evidence of the benefits and confidence in public or private investment.
*Examples of these are the NPP pilot, DTRO pilots, the A2/M2 project and Highway Authority-led pilots funded by DfT such as in Bristol and Oxfordshire via the TTF (Amey, 2021).*
2. **The public purse funds (where only it can) enabling technology and organisations** to support the building blocks needed for nationwide services. It needs to support guidance and, if need be, regulation to move from outdated analogue practices to digital roads operations. Outcomes would enable a variety of services, both publicly and privately funded.
*Examples of these are national DTRO publishing, providing nationally the NPP’s services and governance, wider access to eCall data for highway authorities, rolling out Find Transport Data, and funding training and skills development. BODS is already a good example of this, with supporting budget, legislation and training.*
3. **The public purse funds the development of ‘digital road services’** for highways authorities to use that the user will not otherwise buy directly.. The outcome would be free-to-use services that would not otherwise warrant direct payment. This includes the purchase by central government of connected vehicle data for highway authority use. This will help give users better information, and

thereby reduce congestion, improve safety and reduce emissions – hence, societal benefits.
*Examples are the technology and data to provide services such as GLOSA and IVS and other vehicle co-ordination, and the extended national purchase of FVD.*

### 4.2.3 Privately funded services

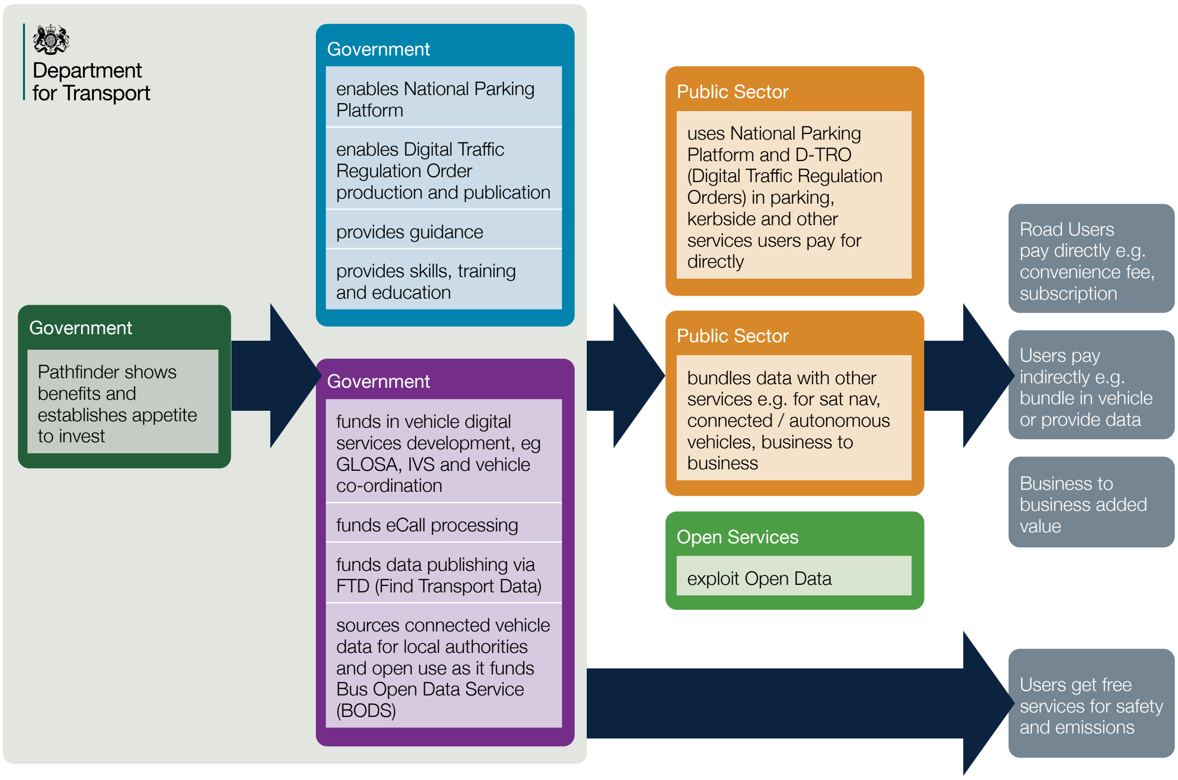
1. Niche services can be privately developed and funded, **where the road user pays directly for the service and benefits directly from it (business to consumer).** The outcome would be better user experiences for individuals and businesses, and public good (traffic and parking is managed more effectively). Even in these private services, government could provide building blocks for the creation of better, more accurate, private services that also achieve a public benefit (e.g., prioritising the rapid digitalisation of the TRO system and the NPP). The ask of government here is not to fund the service directly, but to prioritise the resources needed to deliver the rapid digitisation of the TRO system and the NPP that it relies on (which is part of the public-sector funding in the previous section).
*Examples include some satnav services paid for directly and parking, where there are already direct revenue-generating services in place, but where new opportunities exist for added services, e.g., parking pre-booking, minute-by-minute payment (Harrogate Borough Council, 2023), and the fusion of valet parking with future automated parking services*.
2. **Privately developed and funded –business-to-business services**. Private industry develops commercial add-ons to public services – for example, by bundling data and services together to make them attractive so that users pay indirectly, e.g., via advertising or added services they may buy. It can also be by focusing on a key business, like logistics, which is willing to pay, provided it gets a niche business benefit – so giving reduced costs of deliveries or vehicle operations (Stantec, 2021).
*Examples here are Grid Smarter Cities's virtual loading bay kerbside solution and Caura.com's single payment app (Caura, 2023), which is funded by insurance bought via the app rather than direct payment.*
3. Private industry or institutions fund certain **'open services' philanthropically**, or as part of environmental, social and governance (ESG) commitments to help road safety. These services will use the data enabled by the public sector to offer road-safety and other services. Again, this will enable better information – reducing congestion, improving safety and reducing emissions – and go beyond publicly funded services alone.
*Examples here are Google Maps – essentially free to use in exchange for location data – and Vodafone's STEP platform, along with the Data for Road Safety project (Acea,2020), which allows road authorities free access to safety data*.

### 4.2.4 How do users pay?

In the above, from the user's perspective, there is a blended mix of free-to-use services, those directly paid for by either consumers or businesses, or ones they indirectly pay for. This mix is shown in Figure 4.1.

Direct payments may be subscriptions – for example, in new vehicles or convenience fees, as already exists with parking. Indirect payment may be hidden in the cost of the vehicle, advertising, insurance or other service, or a navigation / fleet management service, or in return for data from the user.

**Figure 4.1: The 'who pays' model for connected services**




Source: Author's own

## 4.3 Using DTROs as an example

DTROs have long been seen as a way to use connected vehicle data and unlock barriers to autonomy. They are digital versions of paper legal documents that authorities need to produce to enforce:

- Parking restrictions – they define where and when a driver can park,
- Height, weight and speed, and
- Road closures due to roadworks, street parties, filming, etc.

Work has been underway for some time to develop a standard UK digital model of TROs and many suppliers already have services in place that can develop TROs capturing all the necessary information in a digital form (Ames, 2022).

Further work is now underway on an 'alpha' project to prototype the technical architecture for a service for publishing DTROs. This should lead to an enabling service with access for services that need to use DTROs, notably the NPP that needs to know where people can park and how much they need to pay, and satnav companies that need to know about road restrictions and closures.

Unlocking the DTRO data would then enable:

- Open services, making TROs available to all users (for example, one.network (2022) has an open publishing platform it used for the late Queen Elizabeth's Platinum Jubilee and recent Coronation street parties),
- Business-to-business services and their benefits, such as Grid Smarter Cities's virtual parking bays (Stantec, 2021) and better fleet management,
- Publicly funded services, such as the NPP, that enable further public and private services,
- Private business-to-customer direct payment services, such as enhanced parking services, and
- Private indirect payment and business-to-business services, like better satnavs with knowledge of road closures, and 'all-in-one payment' services.

## 4.4 Why innovation funding is not enough

Government has set up funding to support innovation in connected and automated vehicles (GOV.UK, 2022a), but this does not address the 'who pays' question – it merely delays it until the innovation funding runs out. Nevertheless until an ultimate customer and revenue stream can be proven, innovation funding usefully brings concepts nearer to market. However, it is not the answer to the ultimate business model. In addition:

- Much of the technology in this report is no longer in the innovation stage and so does not qualify for funding,
- Recent Innovation competitions have required a mandatory element of autonomy (GOV.UK, 2022b), which many suppliers and local authorities are not able to support – the focus is still very much on self-driving vehicles rather than on support for all users by connectivity, and
- The scale of funding is often small.

Hence, what is needed to make the most of innovation funding is:

- A clear vision of who will pay for what type of service, and
- Funding for further pathfinders to deploy new services and test them at scale.

# 5. Where Next?

This update report shows that the key issue now emerging is 'who pays' for connected services. The answer is reliant on all stakeholders seeing the value of connected services, but a blocker for this is that the UK still has small-scale pilots rather than the at-scale evidence needed for publicly or privately funded services to emerge.

There is clearly scope for the development of further, purely commercial, services derived from 'connecting' vehicles, and for refining and improving those services already in operation. But there is clearly far more scope to foster development of many more services to help achieve public policy outcomes on congestion, safety and environmental impacts if government nationally focuses urgently on five things:

- Identifying those services where government is willing to pay in whole or in part for service delivery to achieve a public benefit and where those services should apply. This is where the private sector sees no business case and there is no need for nation-wide deployment(e.g., work is needed on where GLOSA is best deployed?). Government does not have to pay for every connected service, and it might not even have to pay that much, but in several cases, it almost certainly must pay to unblock data flow and support deployment at scale,

- Digitalising data, in particular by accelerating the delivery of the NPP, DTRO and Find Transport Data, from which many valuable new services could flow. Government needs to set timescales for when local authorities will provide the data needed for connected – and later, automated – services,
- Generating more open data in a readily accessible format that many services can use (for example, DTROs and data messages for GLOSA),
- Driving down the cost of data supplied to highway authorities through centralised purchasing, and
- Identifying the data feeds where public processing for a public client could deliver rapid benefits, with a clear example being use of the eCall system to its full potential.

Specific actions that would help the above are:

- Building on the recent ADEPT Live Labs £30 million competition model (ADEPT, 2022) on local decarbonisation of roads to include connected vehicle demonstration projects at scale. The lack of funding for connected vehicles contrasts with £42 million of funding for automated vehicle projects from DfT (GOV.UK, 2023d), and
- Guidance and investment to improve skills and capability in roads authorities, as was done for BODS and Active Travel (GOV.UK, 2023e), to make the most of data becoming available across the country.

Addressing these actions would help enable much wider use of connected data to make roads better, especially in terms of safety and emissions, while saving cash on maintenance and fuel. It would generate further momentum in the development and deployment of more services that are valuable and sophisticated, alongside being a foundation for automation.

Providing connectivity or data alone is still not enough. Services need to scale up and be sustainable. Without such steps towards connectivity, there must be serious questions asked about not just connected services, but also the safety and user experience of automated vehicles.

# Appendix A: More About the Services and their Benefits

Further detail on the benefits is given in the original report (RAC, 2020).

## A1: IVS

### The opportunity

Since the start of motoring, information has been passed to drivers by fixed signs and via variable message signs (VMS). Information sent directly inside the vehicle has in the past been limited to radio reports, more recently including satnav services. IVS now offers the potential to give more accurate, timely and relevant information, defined by the C-Roads project (2017: 27) as:

> "IVS is an information service to inform drivers on actual, static, or dynamic (virtual) road signs via in-car systems. The road signs can be mandatory or advisory."

This report uses a wider definition of IVS to include roadworks warnings and hazard notification. This is because drivers are unlikely to see a difference between what is technically defined as a road sign and a roadworks sign, since both are conveying information immediately relevant to a particular stretch of road; and because these services are already available through some satnavs.

### What IVS looks like to the road user

IVS can give information to drivers in their vehicle or to cyclists by:

- **Reinforcing** all types of signs' messages by repeating them inside the vehicle. This is already done for speed limit signs for many vehicles, through embedded screens, satnav systems and smartphone apps. Speed limits are already captured by using a camera to read a roadside sign in real time or by camera surveys to generate a database of signs, although both have drawbacks (missing/obscured signs, for example),
- **Adding** to existing signs – by adding extra virtual signs at additional locations, potentially adding more information than one sign can safely show (subject to distraction), or repeating the message when the sign is not working or missing, and
- In theory, well into the future, **replacing fixed and variable roadside signs** with data sent to the vehicle, which is then displayed for human drivers, and enhancing information for automated vehicles – so called "naked roads" (Highways Magazine, 2019). This is a very long-term potential gain, as the time taken to deploy services will depend in part on new vehicle sales, which have fallen recently (SMMT, 2022), in part on drivers adopting various forms of retrofittable devices (including satnav displays on dashboard-mounted smartphones) and because drivers may still wish to 'triangulate' different sources of information. There is also a key question of being able to prove the vehicle received the information digitally, in the same way that a physical safety sign, for example, can be shown to be in place at the roadside.

## Benefits

Successful deployment could result in:

- **Increased safety**, but only if trusted and credible hazard warnings can be given beyond those that are currently conveyed through fixed or variable signs (when they are working and visible), and on roads that are not currently fully equipped with roadside technology, such as over-lane gantry signs. Examples include approaches to roadworks, accidents, stopped vehicles and unexpected queues. This increase could come from:
  - increased awareness of messages, by permanently displaying information in the vehicle while it is valid, avoiding obscuration problems associated with fixed signs;
  - displaying information in the language of choice (important in tourist areas) and that which is relevant only to a particular vehicle type, such as HGVs, to reduce distraction for all other users for whom it is not relevant; and
  - earlier warnings of problems than fixed signs at current spacings can give,
- **A better customer experience** for better-informed drivers – receiving, for example, information not simply about congestion, but also about its cause and likely duration,
- **Reduced infrastructure installation and maintenance costs**, on the pathway to 'naked roads' – roads which have no fixed infrastructure – but also avoiding installation and maintenance costs for roads currently poorly equipped with technology, e.g., all-purpose trunk roads,
- Through using IVS technology, the ability to advise drivers what speed to travel to match a green traffic light phase (the GLOSA service is looked at as a separate case although it is now integrated into IVS), so bringing about a **reduction in emissions**,
- **Reduced congestion** from reduced collisions and better awareness of road conditions, and
- The ability to provide **more widely disseminated advice**, and more precise advice, about major national incidents such as terrorism, pandemic restrictions, bad weather and the like, rather than the current blanket messages.

## A2: GLOSA

## The opportunity

In simple terms, GLOSA advises drivers about the traffic lights they are about to approach, offering information about the best speed to drive at to pass through the lights at green and how many seconds remain until the red lights that they may be stopped at turn green.

Previous pilots such as on the A45 (TfWM, 2018) showed that, in off-peak periods at least, this can reduce unnecessary stopping by vehicles by up to 14% and improve journey times by up to 7%. This reduces not only exhaust emissions but also pollution from brake dust, tyre wear, asphalt damage and noise. It also improves fuel economy and gives the driver a smoother ride. Variations have been developed – for example, for cyclists in the USA (University of Oregon, 2019) and for HGV access to construction sites.

GLOSA will be important for automated vehicles, as otherwise such a vehicle would have to assume every traffic light might turn red imminently and sense its change via camera. GLOSA would therefore deliver a better driver experience. It could also help extend the range of electric vehicles by reducing the number of times they have to stop and start again, which wastes battery life.

## What GLOSA looks like to the road user

GLOSA can give information to drivers and cyclists by either:

- **Showing what speed to drive at**, or indicating a need to slow down or speed up to match green timings. This cannot exceed the road's speed limit. Various interfaces have been used to show drivers what action to take, including sound rather than visual displays; or
- **Giving a countdown display** showing when lights that are currently red will turn green. This can help improve reaction times for vehicles with automatic engine cut-off, as there is anecdotal evidence that this is reducing junction throughput because of increased reaction times once lights turn green.

GLOSA can do this via standalone app, an app linked to the vehicle's dashboard head unit, or the dashboard itself. GLOSA is being tested with cycles as well as cars and HGVs (C-MobILE, 2023).

GLOSA resembles IVS in that data can come only from a highway authority system. Then, it must be communicated into the vehicle and accepted, and it must be trusted by the driver if it is to have any impact. Once again, data on its own is not enough – there must be a connected chain.

Both IVS and GLOSA have humans at the end of this chain, who must do something for the service to deliver benefits (download and use an app, and then react to its advice). GLOSA was originally treated as a separate case in the previous report because access to the data (continuously harvested from traffic lights) and its presentation to the driver are more complex than for IVS. Additionally, the scope for its deployment is different (as IVS applies to all roads everywhere, but GLOSA applies to traffic lights only). However, many of the issues, as for all this report, are similar and a key improvement since the previous report has been the integration of GLOSA, IVS and satnav into a single app.

## Benefits

The outcomes from successful GLOSA deployment could be:

- Reduced number of stops of vehicles, with **reduced emissions**; this could be of value as another tool in air quality management and could aid the greening of transport,
- Improvements in **journey times**,

- Reduced **fuel use**, particularly in the case of HGVs, where an unnecessary stop can add to vehicle operating costs for high-volume routes (for example, to construction sites),
- Potentially, increased **safety** as drivers would know not to speed up to pass a green light, and as priority could be given to certain vehicles by a modified form of GLOSA,
- Potentially, **a small increase in intersection capacity** at individual junctions as drivers can prepare to move in a more timely manner with knowledge of when traffic lights will turn green,
- Potentially, a further **increase in capacity** as traffic lights in a series are optimised to work in tandem with GLOSA (so that platoons are set up to pass through series of lights together),
- **A better customer experience** for better-informed road users, especially cyclists, and
- Support for the rollout of **highly automated vehicles** with a better customer experience.

There are, however, various barriers that need to be overcome through the connected chain:

- The **information must be shown/spoken without distracting the driver** when they could be reacting to other in-vehicle warning systems. Near to the lights, the driver should be looking only at the physical traffic lights and other road users – to assist this, many implementations cease giving GLOSA advice as the vehicle nears the lights,
- A solution must be found to enable **predictions of the traffic light timings to be accessed** with enough accuracy and timeliness so that drivers receive such high-quality advice that they realise they can trust, and so they want to adopt the technology in the long term. GLOSA is a voluntary system, not a mandatory one, so drivers can simply turn it off or ignore it. An additional challenge is that in the UK, many traffic lights continuously adapt their timings to match the traffic. Adaptive traffic light timings vary in predictability, being more predictable as congestion increases and less so as it decreases. In many cases, especially during the peak, this timing adaptation may be small enough not to matter, and work has been underway for some time (Bodenheimer et al., 2015) to explore how to deploy GLOSA with the MOVA system, which is highly dynamic, thus affecting predictability of green timings,
- **Drivers neither know nor care who operates traffic lights**, neither do they know what system the lights are running on. For GLOSA to be widely adopted and trusted, drivers will expect all traffic lights across a corridor, city or even the UK to work in the same way. There must therefore be no visible seams across organisational boundaries requiring, for example, the user to change apps or devices. Drivers also should, if possible, know if GLOSA is not available for a given set of traffic lights, so they are not distracted by the lack of information,
- GLOSA clearly **works best when traffic lights are not highly congested** – telling drivers to travel at a certain speed to pass a green light when they are

stationary does not engender trust. It follows that GLOSA should be explained to drivers, in order to manage expectations and avoid a negative reputation, and to highlight that it does not apply well at all junctions, and

- **Third parties could be using timing data** published by highway authorities. This will require control to ensure that safety and accuracy standards are met in how it is displayed – for example, to control use in an app to avoid breaking the speed limit or other unwanted behaviour.

## A3: Asset management data

### The opportunity

Physical highway assets – such as bridges and other structures, the road and footway itself, signs, road markings, white lines, drainage, and surrounding features such as bollards, trees and lighting – are expensive to maintain. The UK spends around £10 billion annually on "highway asset management" (TTF, 2018: 21), meaning that even a small saving through active use of better data in the connected chain would be a useful cashable benefit.

In most authorities, roads are surveyed periodically using specialised and prescribed equipment, to develop a time-based 'historic' assessment of condition, which is then used to identify maintenance interventions in the future. Data from these regular surveys is used in asset management platforms to plan works and track the status of the asset, and to support modelling of deterioration. But the platforms for different assets and a range of other related activities exist in isolation from each other, and manual collation and validation is required to make information actionable.

The take-up of digitisation through connected data and intelligence could potentially drive productivity gains in highway authorities and bring about improvements in the condition of networks and assets, but only if the existing systemic technical, contractual and cultural problems that lead to current poor productivity are mitigated.

There is therefore a significant opportunity to recast the way the way in which networks are maintained, and to drive carbon used and costs down and productivity up in this field, using the power of connected vehicle data. This opportunity has been reflected in the recent ADEPT competition (ADEPT, 2022) to some extent, which focused on ways of working as much as technology.

### What asset management looks like to the road user

In contrast to the situation with GLOSA and IVS, drivers or other road users like cyclists do not need to do anything when it comes to asset management. Data can be harvested without their intervention.

### Benefits

Outcomes of better roads and lower maintenance costs could be achieved by:

- **Reducing the cost of existing surveys** – using new data sources and crowd-sourced data, such as that from drones, vehicles, drivers or smartphones,

- **Reducing the delay in existing surveys** – with surveys often up to a year apart, the use of connected vehicle data might reduce the time between observation and intervention, or allow better planning of repairs. In addition, it might provide a better understanding of asset performance over time, or in response to short-term events (e.g., weather extremes, the impact of traffic diversions resulting from other maintenance activities, use by HGVs and so on), and
- **Improving the ability to plan better maintenance** and, in the future, design better roads with many more and new types of data. Authorities might be able to use movement data to decarbonise operations and plan better network changes, thereby reducing congestion, pollution and even the impact upon road assets themselves (so reducing maintenance).

The final benefit is a key opportunity from connecting the chain. Better planning and integration of maintenance activity across the highway authority's operational portfolio could deliver savings by either reducing revenue costs or expanding planned/structured maintenance. It could also reduce congestion and hazards from roadworks.

Westminster City Council's 'Connected Network Vehicles in Real-Time' (for network and asset management operations) project (CONVERT, 2020) concluded that savings of 3–5% of scheme value were possible, amounting to a saving of between £300,000 and £700,000 annually. Across the UK, such a saving could be worth £100–£200 million annually.

Examples of the data already being made available include:

- **Light detection and ranging (lidar) / camera data from vehicle surveys**, used for investigating parking and road asset condition. The assessment of its potential to collect asset condition data, and to inform preliminary road or public realm scheme design, formed the basis of the CONVERT project. While lidar is currently a specialist tool, it will form an important part of the sensor suite for future connected (and later, automated) vehicles and so will become a mainstream device in new vehicles,
- **Dashcam/smartphone video image processing**, trialled in the Pothole-Spotter project (Pothole-Spotter, 2017). This is now already available using artificial intelligence processing of image data from suppliers such as Vaisala (Vaisala, 2020), for signs and pothole surveys, RoadBotics and Xais with EyeVi. Additionally, high-definition image-based technology is being used to deliver safety surveys by Gaist to several authorities,
- **Accelerometer data from insurance devices**, used to detect road defects in Birmingham in the Enhanced Continuous Asset Monitoring Solution project (TTF, 2020). It is also being collected by DfT through INRIX (GOV.UK, 2023f) for highway authority use,
- **Data from connected cycles** is now being used in many schemes to design and maintain cycle paths and monitor their safety (British Cycling,2023),
- **Data from fleet management systems in freight and service vehicles**, used to examine weight profiles of goods vehicles, turning movements, etc., and changes in road geometry, and

- **Smartphone apps** that measure, record and transmit road-surface condition through proxy measurement of the comfort of a journey (Davis, 2017).

Much of this data can already be derived from traditional survey vehicles and potentially now automatically from vehicles that travel the network regularly (for example, refuse collection vehicles). It can, however, also come from mass fleets, with suitable anonymised data – for example vehicle makers' data – or from insurance devices. There is further potential to harvest data from emerging low-cost factory-fit sensors in mass vehicle fleets (radar, lidar or image capture from dashcams) or retrofit sensors (which could be in another device such as a smartphone).

The driving forces for adopting this new data include:

- Reduced cost of data capture,
- More frequent updates of data – a shift from often yearly surveys to almost real time, if required,
- Larger data coverage (expansion of the number of data points),
- Blending different types of data points,
- Providing continuous data, linked with analysis, to identify degradation and rapid change, and
- Giving secondary evidence, complementing and targeting professional surveys when required.

## A4: Improving traffic light timings

## The opportunity

Traffic lights traditionally use physical sensors as inputs into control systems. These range from inductive loops in the road, through to magnetometers, radars and image processing. These sensors are generally costly to maintain. Work by the TTF (2020) showed that as many as half the sensors in a traffic light system may not be working at any time. This means reduced quality data input into adaptive systems such as Split Cycle Offset Optimisation Technique (SCOOT) and MOVA, with the result that traffic lights do not work as well as they did when installed. The TTF estimated that this could bring benefits worth £400 million annually, from safeguarding the performance of existing junctions and developing new ways to reduce congestion (TTF, 2018: 3).

Temporary traffic lights, used for roadworks, traditionally have just one sensor per approach and relatively crude control, although work to connect them to centralised systems has improved this. Nevertheless, temporary traffic lights can be a source of delay (COYC, 2016a and 2016b).

Performance is often measured in terms of reduced delay to vehicles, but this is not the only objective. Many authorities choose to favour walking and cycling (especially post-COVID-19), reduce emissions, favour key routes or vehicles, or throttle sensitive routes – all through traffic light settings. Irrespective of the policy objective, the quality of sensor input is key to delivering it.

As an alternative to roadside sensor data, or to augment it, FVD has been available for some time. In FVD, a device already fitted in many vehicles (such as a fleet management unit, a PAYGI device, a satnav, a smartphone running an app or a cycle red light with sensors embedded in it) collects data via GPS on locations as often as 20 times per second and then sends this by means of mobile communications to a central point. The data is then processed for anonymity and data quality, and used for journey-time monitoring. Data sourced from mobile phone operators can also be used with less granularity of vehicle type and location, but larger sample sizes. This data has long been supplied by commercial data providers such as INRIX, TomTom, Here and Google, who collate and combine various fleets' data to obtain journey times. Newer players are increasing competition and data coverage from more and more vehicle types and marques. This does not require consumers to go direct to vehicle makers – these service providers have filled a data access gap.

Data from vehicles offers a way of going beyond the restoration of traffic lights back to the level of performance they were designed for, by also adding new approaches to their control. At a simple level, this is because while roadside infrastructure can measure all vehicles at that point, FVD can measure a sample of equipped vehicles, from far upstream of a junction, all the way through it and on to the next one. Adding this earlier information on a vehicle trajectory allows the junction to be better prepared for the arriving traffic and so better optimised. The key for FVD traffic light use is to have individual vehicle paths rather than journey times.

This fundamental difference between these data types is a key barrier to adoption. This is because it requires re-engineering existing systems that were originally designed for sensor-based systems to exploit vehicle data in real time. This is not the only barrier and there are relatively quick-to-implement approaches already being tested, exploiting data that is available today.

However, data from FVD can also be used historically, to monitor traffic light and other control system performance without interfacing to control systems in real time. This formed the basis of a quick win identified in the earlier report and now delivered.

### What improving traffic light timings looks like to the road user

From the driver's or cyclist's perspective, the difference would be improved traffic lights – for example, less wasted green time and shorter queues. However, as the data to achieve this change is sent from the vehicle without the driver's intervention, this would not require any action on their part.

It could be that the data is collected from other services – an app for smart parking (a system in which sensors in each parking space detect whether it is free or occupied, enabling drivers to find a vacant spot to park in), GLOSA or IVS, or a fleet management unit also providing data for asset management. This ability to piggyback on other services is a key advantage of this data – drivers and fleet owners will install devices for other reasons, but the same data can be used in many ways.

## Benefits

Initial work has shown the following outcomes from connecting vehicles with traffic lights (Wood et al., 2005):

- Reduced congestion,
- More flexible traffic control, especially for temporary traffic lights,
- The ability to identify when traffic lights are not working in line with policy objectives (for example, side-road queues are excessive or a vehicle's progression through traffic lights is thwarted by unnecessary stops – rectifying this reduces emissions),
- The potential to reduce maintenance costs due to having fewer in-road sensors and reduce reliance on them as a single source of data,
- The ability to give priority to certain vehicle types (for example, buses and emergency vehicles), and
- Establishing more opportunities for targeted/early interventions.

# Appendix B: Gaps Found in the Previous Report and Updates Since Previous Report (red is a strategic gap, amber requires work, green is a gap now filled)

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Services will be only short lived and not sustained by an effective business model – **the sustainability gap.** | All | Provide resources to all points in the chain to sustain services – especially highway authorities. | Sustained benefits from sustained services. | None: The small-scale pilots have not yet shown a sustainable business model or business case yet – so who will pay? |
| There will be piecemeal developments and a disconnected patchwork of services. No national business case to encourage investment beyond pilots – **the strategic gap.** | DfT | Define a UK-wide connected vehicle data plan. | A clear plan of what services will develop, and how, when and why: this would help public and private investment in connecting the chain. | Very little: While DfT has published a Data Strategy and many successful small-scale pilots are now in place, there is no wider plan in place to connect or scale them, so this reduces confidence in investment. |
| Work will continue with only limited pilots and not move to full 'business-as-usual' use of connectivity – **the funding gap.** | DfT | Provide revenue funding for services and capital funding for pilots. | Services involving connected data can become mainstream, with benefits in sustainable congestion, safety, emissions and cost across the nation. | Very little: As above, an answer is needed for sustainability in business terms and a clear revenue stream. |
| Only poor-quality authority data is available and not in the correct format for use in connected services, as not enough skilled people are available. Connection to vehicles becomes a specialist niche and not part of 'business as usual' – **the skills gap.** | Highway authorities and DfT, Highways Sector Council, ADEPT (Association of Directors of Environment, Economy, Planning and Transport) | Provide training and national shared resources (for example, in data for GLOSA and DTROs). Encourage adoption of new data into authority use. Separate connected data from automated vehicles, needing different skills. | High-quality data to support new services becomes available. Users see connected vehicle data as 'part of the day job', not a bolt-on. Cashable benefits from adopting new data. | Limited: Work has started in some courses on new skills, e.g., from the Institute of Highway Engineers (IHE), but data and roads skills are a rare combination. |
| Data is still stuck in siloes because of lack of understanding of the opportunity. Continued reliance on fixed sensors. Cyber-security problems arise because of lack of understanding – **the understanding gap.** | Industry, academia, DfT, Highways Sector Council, ITS UK, LCRIG (Local Council Roads Innovation Group) | Explore new opportunities with data from vehicles to make roads better. Promote benefits of connection with vehicles. Educate staff in use of new data across current siloes. | A move from existing fixed sensors and time-based surveys, and transition to data from vehicles. New approaches are deployed and sustained, while ensuring cyber security is addressed. | Limited: Particularly with traffic lights where commercial products are now being used exploiting FVD. Progress with understanding of the role in improving asset management. Lack of understanding of eCall. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Data will remain unused in IVS services and unless an authority can maintain the levels of service reliability that is a prerequisite for trusted in-vehicle services, vehicle makers and service providers will simply not use the data anyway. Publishing data in an authority system requires services and/or systems to be procured. This is a new area for most authorities. If data is to be published, services must provide availability 24 hours a day, seven days a week, every day of the year, if it is to be of interest to automotive companies and service providers **– the procurement and support gap.** | Highway authorities and DfT, traffic management industry | There are new procurement frameworks emerging, but one opportunity may be a national publishing service for all authorities, procured centrally. | The data from highway authorities is of good enough quality and published reliably enough to feed downstream users. | Limited: Some authorities and TRL are now publishing data in a way that can be used by GLOSA and IVS, but there is a lack of guidance. Some data streams are available on frameworks, so procurement is easier. |
| Insufficient data is available from authorities on IVS or GLOSA to warrant launching widespread services. Drivers then just see a repeat of physical signs **– the IVS coverage gap and the GLOSA coverage gap.** | Highway authorities | Develop virtual signs where physical signs are not present. Focus GLOSA on sites with most benefit for users – for example, freight routes. | Widespread adoption of IVS and GLOSA where there is most benefit in terms of emissions and safety. | Limited: Wider use of GLOSA is now being planned, but some services have been rolled out as pilots not demonstrations. |
| There will be a disconnected patchwork of services and a missed opportunity, as there is not enough good-quality data coming from the vehicle – **the data gap.** | Data providers | Continually improve the granularity and coverage of connected vehicle data (underway). | Maximisation of the uptake of data to widen the benefits of the connected chain. | Good: Data quality (e.g., reporting frequency) and the number of suppliers has improved, and BODS data is available. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Data will be available from cars and freight alone, so does not support safety of cyclists or other vulnerable road users, or maintenance of cycling routes and footways – **the 'not just cars' gap.** | DfT, data providers | Work with providers of other datasets, e.g., cycling, to connect the data chain. Should be part of DfT's strategy. | Enabling maintenance of all assets, and allowing timing of traffic lights for cyclists as well as cars. Potential for GLOSA for cyclists. | Good: Companies such as See. Sense now have connected cycle data available, but it needs to be used to fill the gap fully. DfT has published a Data Strategy and Guidance for Local Authorities. |
| Feed points for all IVS and GLOSA data to vehicles are too numerous and too slowly updated – **the publishing gap.** | DfT | Access data and develop a central high-quality data feed (e.g., motorways and traffic lights for GLOSA). Work has started on Find Transport Data. | UK-wide coverage and speedy adoption by current service providers of authority data. | Good: KL Systems can receive data and provide a central source, as can Vodafone with the STEP service, but it needs raw data to sustain. |
| There is no agreed channel for communicating to vehicles, meaning that investment decisions are delayed – **the communications standards gap.** | DfT, automotive industry | Use good enough mobile communications for non-safety-critical services until 5G/ITS-G5 situation clarifies. | Services that benefit vehicles of all types and ages, not just new cars, to reduce congestion and improve safety. | Limited: 5G and ITS-G5 confusion still occurs; rollout of both limited by lack of new car deliveries. But work has shown that existing 4G and 5G are good enough for non-safety-critical services, so this is not a key issue in the short term. Few new vehicles have ITS-G5 equipment fitted. |
| 'Notspots' of coverage remain, reducing data availability – **the communications coverage gap.** | OFCOM and mobile network operators | Improve mobile data coverage where required – for example, to fill notspots to support rural IVS for safety. | Maximised use of what is available in the short term. | Limited: Mobile network operators may consider better road access if the business case can be made. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Not enough vehicles have appropriate devices, software or smartphone apps for collecting or receiving data, so coverage is patchy – **the installation gap.** | Data providers, service providers and automotive industry | Build on already high penetration of satnav, dashcam, insurance and fleet management devices, plus create apps to add additional information for display or simply to collect data. | High penetration of services for all road users and improved user experience. | Good: App-based IVS and GLOSA have been combined with satnav to deliver integrated services from existing devices and hence in all vehicles. Mainstream satnav suppliers are yet to adopt the data though. |
| Connected vehicle data is not used in practice, as current users do not have confidence in its source, quality or processing. Systems and processes thus remain unchanged – **the provenance gap.** | Data providers | Show how connected vehicles' data is compatible with or exceeds current sources in quality, accuracy and granularity. Work alongside existing data sources to demonstrate this – do not compete against them. | Connected vehicle data becomes a trusted tool for road maintenance and operations, reducing congestion and costs for the authority. | Good: New players in the market and improved existing sources mean more comfort in data use. |
| Not enough net revenues for data providers emerge to sustain costs of provision. Overly high costs of provision and too many points of contact for data use to sustain investment **– the business model gap.** | Data providers, support from DfT | Procurement should adopt a centralised service approach to gain economies of scale. New data providers need to fully understand the constraints of the highway market. | Data providers invest in providing new forms and bigger quantities of data. Data flows to authorities for onward use (for example, in road maintenance). | None: There is still a need for injection of funds. |
| There is no clear business case for using data, so suppliers of asset management or traffic systems do not invest in upgrading systems to use connected data – **the business case gap.** | Data and service providers, highway authorities | Procurement may need to change to a service-based model. Evaluation and promotion of benefits, especially cashable savings, is needed, along with customer 'pull'. | The connected chain is not just for data, but also for revenue to support its collection, so clear and measurable benefits arise from its use. | As above: There is still a lack of revenue. |
| Only new asset systems and traffic control devices can use connected data, requiring large investment in new equipment. No mixing of existing and new connected data – **the transition gap.** | Traffic and asset management industries | Develop ways to include new data in existing systems and processes without wholesale change. | A transition from what is there now to a mix of data without need for wholesale change. Gain benefits at existing sites. | Limited: Work is being performed on traffic control, but it is still required further in asset management. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Safety problems emerge in the vehicle and distraction also causes a poor user experience – **the human–machine interface (HMI) gap.** | Service providers, automotive industry, FORS (Fleet Operator Recognition Scheme), fleet management | Develop safe HMIs, combining GLOSA and IVS with traffic light improvement. | The adverse impact on safety from potential distraction is reduced, as is duplication by piggybacking on other services. | Limited: Work has focused on use of speech, and deconflicting IVS, GLOSA and satnav messages, but there is still much to do. |
| There will be poor-quality and incomplete services that drivers will not understand and thus simply not use or trust – **the trust and education gap.** | All | Make services (GLOSA, IVS) something that drivers really want to use. Educate drivers in how to use them and manage expectations. Research what drivers want from services. Evaluate what best triggers changes in behaviour. | Drivers understand the services, know how to use them and modify their behaviour; so, improved safety, emissions and congestion are delivered. | Limited: Still only technical studies rather than full user-experience work. |
| Connected data will not have a clear and sustainable business case as no outcome evidence is available – **the evaluation gap.** | All | Evaluate benefits from connected vehicles, as current work is often poor or poorly promoted. | A business case at both local and national level is built and sustained. | Limited: Good evaluation of GLOSA impacts in practice, but few other projects have the resources to do a full evaluation with users. |
| Too much information is displayed in-vehicle, so drivers ignore key messages or turn off IVS – **the filtering gap.** | Automotive industry and service providers | Research into how best to allow drivers to filter non-safety-critical messages and to target users for best impact. | Drivers take notice of messages. Improved driver experience. | Limited: KL Systems and Eloy are working on unifying, filtering and avoiding conflict with satnav. The area of research needed is what voice guidance to give and when. |
| No move to 'naked roads' as physical signs are still needed – **the legislation gap.** | UK government | Explore how to move from advisory to mandatory IVS. | Reduction in roadside infrastructure costs. | Limited: Work has focused on legislation for self-driving vehicles, but DfT recently completed a discovery project for the use of kerbside management. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Not enough high-quality data available for at-scale services – **the GLOSA data gap.** | Highway authorities and DfT, traffic control industry | Training in developing data and other new skills and services.<br><br>More open publishing of data from UTC systems.<br><br>Updating older traffic lights and systems to support GLOSA (and improve reliability). | Wide deployment of GLOSA, allowing reductions in emissions and a better driver experience. | Limited: TRL has developed open feeds for SCOOT from cities, but wider data feeds are still required. |
| Different mutually incompatible solutions and services emerge, as there is no agreed methodology for measuring asset performance – **the benchmarking gap.** | DfT, asset management industry, highway authorities | The connected chain should be able to combine existing and connected vehicle datasets to make best use of what is there already.<br><br>This could involve a move to fully risk-based data-driven asset management. | Wider adoption, at lower cost, of asset management data from vehicles, as there is a standardised way to report road quality. | DfT has started on new standards for road condition. |
| Disparate data sources and no standard way for sensors in vehicles to report road condition – **the standards gap.** | DfT, highway authorities, asset management and automotive industry | Include asset management needs in automotive projects such as SENSORIS. Carry out further research on what data can be extracted, and how this can be related to traditional asset management data and asset management systems. | Lower cost data collection and increased data volumes mean more scope for reducing asset management costs. | DfT has started on new standards for road condition. |
| Unless highway authority staff learn how to securely integrate, operate and maintain newly upgraded systems using connected vehicle data, the data will not be used in practice and the chain will be left incomplete – **the knowledge gap.** | Highway authorities, asset management industry | Develop skills and training to use the system and new processes. | New data sources lead to improved asset management and reduced costs. | Some progress via TTF and IHE courses, but most authorities are still unaware. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Unless asset management service providers are motivated to complete the connected chain and use the data directly, they will continue with 'business as usual' – **the contracts gap.** | DfT, highway authorities | Develop new contracts that reward innovation and outcomes rather than pay for resource spent.<br><br>Encourage/require data sharing. | The connected chain would be complete – there would be a business case for active use of new data by contractors. | Limited: Change remains slow due to contract cycles and formats. LCRIG is, however, working on a dynamic purchasing system for Innovation. |
| Unless there is a better understanding of how each traffic light network is already performing against policy outcomes, there will be no strong demand for connecting the chain to improve performance – **the benchmarking gap.** | Highway authorities, data providers | Institute agreed methodologies for measuring junction performance to allow comparison against achievable levels, and inform on what is the minimum work (and data) needed to regain prior performance levels.<br><br>Use commercial FVD as a first step in identifying what to fix (underway). | Better junction performance in line with local policy objectives (e.g., reduced congestion and/or emissions). Business case made for investment in improvement in junctions. | Good: INRIX and Tomtom have both announced services to measure junction and network performance. |
| Unless basic traffic equipment is working reliably at a basic minimum level of performance before any upgrades or use of new technology, there is little point in adding services such as GLOSA or using new data sources to tune its performance – **the reliability gap.** | DfT, highway authorities | This requires more resource budgets for authorities and less emphasis on capital spend. Providers of existing systems should be encouraged to measure and share the effects of sensor degradation on traffic light performance, so efforts can be prioritised. | Better junction performance in line with local policy objectives (e.g., reduced congestion and/or emissions). | Good: DfT has invested £15 million in junction performance improvements and connected vehicle data will be used to assess the benefits gained from this investment. |
| Unless systems using the data are modified to exploit its richness in various ways and industry providers can see a business case for doing so, connected vehicles' data will not be used to complete the chain – **the innovation gap.** | Traffic control industry, data providers | Current traffic light equipment manufacturers and data providers need to find a business model that demonstrates better revenues from the change than from the current position. | The data in the connected chain is fully exploited to deliver policy outcomes. | Limited: TfL's Fusion system replacing SCOOT can use FVD as well as existing sensors. |

| What will happen if gap not filled? | Owner of action | Action required in previous report | The outcome of action would be | Progress/change since previous report |
|---|---|---|---|---|
| Unless new real-time sources retain or exceed the level of safety inherent in testing and approval of physical sensors, there could be safety problems or at least a lack of confidence. Again, this could mean breaks in the connected chain – **the safety gap.** | Traffic control system suppliers, data suppliers, TOPAS | Registration of sources through standards bodies such as TOPAS. | The safety inherent in the UK traffic light system is retained. | Good: DfT has funded a project called Digital Controller Interface Specification to explore how to ensure safety of new services. |
| Unless highway authority staff can learn about operational models and new systems, and make business cases for their adoption, the connected chain will not be completed, as services will not be deployed – **the learning gap.** | Highway authorities | Training is needed from industry. New providers also need to understand current requirements, and build in compatibility with current solutions and the adoption of new algorithms by current equipment. | The connected chain would be complete as services will be deployed. | Limited: IHE, for example, now has a course that features connected vehicle data, and the TTF has a dedicated group for connected vehicles. DfT has issued guidance on opening up data. |

Source: Author's analysis, 2023

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