Driven by information

Securing the benefits from connected vehicles

Andy Graham
White Willow Consulting

September 2020

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RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

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About the Author

Andy Graham is principal of White Willow Consulting, a company he set up in 2005 specialising in connecting vehicles and infrastructure, after being the Director of AECOM's Intelligent Transport Business. 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 signals and eCall. He led the deployment of the Radio Data System -Traffic Management Channel satellite navigation services in the UK.

Andy is a leading contributor to the Transport Technology Forum, and Chair of the ITS-UK Connected Vehicles Forum. He also leads the working group on the deployment of Green Light Optimised Speed Advice in the UK.

He is a Fellow of the Chartered Institution of Highways and Transportation, a member of the Institution of Engineering and Technology's Transport Policy Panel and a Trustee of the Rees Jeffreys Road Fund.

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Disclaimer

Contents

List of Abbreviations vi

Foreword vii

Executive Summary viii

1 Introduction 1

2 Methodology 3

2.1 Introduction 3

2.2 The services 4

2.3 Exploring the gaps 4

3 Service 1: IVS 7

3.1 The opportunity 7

3.2 What IVS looks like to the driver 8

3.3 The outcomes 8

3.4 The current status 9

3.5 What needs to happen 11

3.5.1 The basic premise 11

3.5.2 Gaps for the highway authority 13

3.5.3 Gaps in the data 16

3.5.4 Gaps in the vehicle 19

3.5.5 Other gaps 20

3.6 A way forward 21

4 Service 2: GLOSA 23

4.1 The opportunity 23

4.2 What GLOSA looks like to the driver 24

4.3 The outcomes 25

4.4 The current status 27

4.5 What needs to happen 28

4.5.1 The basic premise 28
4.5.2 Gaps for the highway authority 30
4.5.3 Gaps in the data 31
4.5.4 Gaps in the vehicle 33
4.5.5 Other gaps 33
4.6 A way forward 34
5 Service 3: Asset Management 36
5.1 The opportunity 36
5.2 What asset management looks like to the driver 37
5.3 The outcomes 38
5.4 The current status 38
5.5 What needs to happen 40
5.5.1 The basic premise 40
5.5.2 Gaps for the highway authority 42
5.5.3 Gaps in the data 43
5.5.4 Gaps in asset management use 46
5.5.5 Other gaps 47
5.6 A way forward 47
6 Service 4: Improving Traffic Light Timings 49
6.1 The opportunity 49
6.2 What improving traffic light timings looks like to the driver 51
6.3 The outcomes 51
6.4 The current status 51
6.5 What needs to happen 54
6.5.1 The basic premise 54
6.5.2 Gaps for the highway authority 56
6.5.3 Gaps in the data 57
6.5.4 Gaps in the use of the data 59
6.5.5 Other gaps 60

6.6 A way forward 60

7 Conclusions and Implications 62

7.1 Conclusions and common features 62

7.2 What does the driver see? 63

7.3 The workarounds 66

7.4 Key actions 67

Appendix 1: Detailed Swim Lane Diagram for IVS 72

Appendix 2: Detailed Swim Lane Diagram for GLOSA 74

Appendix 3: Detailed Swim Lane Diagram for Improving Roads Maintenance (Asset Management) 76

Appendix 4: Detailed Swim Lane Diagram for Improving Traffic 78

Appendix 5: Service-Specific Gaps and Calls to Action 80

References 83

Figures list

Figure 3.1: IVS in tests – the VMS wording repeated on the vehicle's existing head unit via mobile communications 9

Figure 3.2: Queue warning from Google Maps 10

Figure 3.3: Adding signs into the vehicle – the basic premise 12

Figure 3.4: Workaround for IVS and actions required 22

Figure 4.1: Technology test app used for GLOSA 25

Figure 4.2: Advising drivers on green times – the basic premise 29

Figure 4.3: Workaround for GLOSA at niche sites for niche users and actions required 35

Figure 5.1: Road defect data from PAYGI devices 37

Figure 5.2: Making roads better using vehicle data – the basic premise 41

Figure 5.3: Workaround for better road asset management and actions required 48

Figure 6.1: INRIX FVD used to monitor traffic light performance (A59 into York) 53

Figure 6.2: Making traffic lights better – the basic premise 55

Figure 6.3: Workaround for better traffic light performance and actions required 61

Tables list

Table 7.1: Comparison of benefits and actions for new services by driver activity 64

Table 7.2: Comparison of benefits and actions for existing services 65

Table 7.3: Calls to action to fill gaps shared across many services 67

Table A5.1: IVS – specific gaps and calls to action 80

Table A5.2: GLOSA – specific gaps and calls to action 80

Table A5.3: Road asset management – specific gaps and calls to action 81

Table A5.4: Improving traffic lights – specific gaps and calls to action 82

List of Abbreviations

ADEPT	Association of Directors of Environment, Economy, Planning and Transport
CONVERT	COnnected Network VEhicles in Real Time (for network and asset management operations)
CROCS	Controller to Roadside Open C-ITS Standard
DfT	Department for Transport
FHRG	Future Highways Research Group
FORS	Fleet Operator Recognition Scheme
FVD	floating vehicle data
GLOSA	Green Light Optimal Speed Advisory
HGV	heavy goods vehicle
HMI	human–machine interface
IVS	In-Vehicle Signage
LCRIG	Local Council Roads Innovation Group
lidar	light detection and ranging
MOVA	Microprocessor Optimised Vehicle Actuation
NAP	National Access Point
PAYGI	pay-as-you-go insurance
SCOOT	Split Cycle Offset Optimisation Technique
SPaT	Signal Phase and Timing
TOPAS	Traffic Open Products and Specifications
TRO	Traffic Regulation Order
TTF	Transport Technology Forum
VMS	Variable message signing

Foreword

The modern motor car is sometimes described as being akin to a mobile phone on wheels, such is its ability to receive and transmit information.

Probably the most familiar and widely recognised benefit that connectivity has brought is satnav, which has gone from being a luxury to commonplace.

But what other benefits might connectivity enable? In-vehicle telematics systems and apps on smartphones in vehicles of all ages and types generate data about a wide range of things, from the speed at which the vehicle is moving and its location, through to capture of images from dashcams or smartphones and through to the acceleration of the vehicle.

If that data was accessible to others then the location and speed could detect queues at traffic lights to improve their timing plans, while processed images of the road and data on acceleration up-and-down could reveal the condition of the road surface and inform the highway authority's maintenance and repair plans.

This same connectivity could be used to inform drivers of the best speed to drive at to go through the next set of traffic lights at green, and also add extra warnings and information into their vehicles, ranging from parking availability to telling drivers of hazards where there are no gantry signs available.

So much for the potential, but what about the practicalities? Behind the small screen of a satellite navigation service sits a whole chain of processes. These harvest and combine data from various sources, apply that data accurately to a map, locate the vehicle, calculate the optimum route either in the vehicle or centrally and update this as hold-ups develop along the way. Connectivity simply means that the vehicle can receive the traffic or route information and can transmit data about its location – a vital part, but just one element of that entire data chain.

Realising the potential of connectivity requires a detailed understanding of the full data chain needed to support each service, in particular to identify where the action sits to exploit the data and, importantly, to spot any links missing in the connections. That is why we commissioned this report to gain a better understanding not so much of the specific services it describes, but of the things that would have to become true in order for those services to be fully realised and for benefits to flow to drivers and road operators.

As we suspected, the report does identify gaps, but also goes on to recommend actions for addressing them. We hope it will be a useful contribution to bringing forward new services that will make the management, maintenance and use of our roads safer and more efficient.

Steve Gooding

Director, RAC Foundation

Executive Summary

In amongst all the excitement about the possibilities of autonomous and highly automated road vehicles, the benefits to be gained from connected vehicles – whether automated or not – have tended to be overshadowed. Yet connectivity is already here on a large and rapidly increasing scale so, in principle, the benefits should be closer to delivery than those from autonomous driving.

Connected vehicles are those with the capability to generate, transmit and receive data. The connection can be with other vehicles, with the highway infrastructure, or both, but can also be with the vehicle manufacturer, with data providers and with service providers (such as satnav companies).

Data generated by the vehicle can include information about road condition (for example, from cameras detecting potholes), traffic conditions (from monitoring a vehicle's speed and location), and the information about the vehicle itself (such as engine idling). Data transmitted into the vehicle can inform a driver's decisions and, in due course, will play a fundamental part in highly automated systems.

Through connectivity there is emerging evidence to suggest that significant benefits could potentially be gained when it comes to the safety, management, operation and maintenance of roads, and similarly to the traffic that runs on them.

However, the generation and exchange of data alone is not enough to secure this value – the benefits only flow when something *happens* as a consequence of the data being used. Fundamentally, data only starts to have value if there is someone, somewhere, who chooses to do something with it, or do something because of what it reveals, and has the resources necessary to exploit it.

While research to date has tended to focus on the technical aspects of connectivity, the purpose of this report is to establish all the elements that would need to be in place to achieve the benefits of connectivity in practice and, ideally, at scale; to reveal the gaps and issues that need to be addressed; and to generate ideas for potential fixes.

To do this, the author has drawn process maps for four illustrative services, detailing the end-to-end chain from data generation through to resulting action:

- In-Vehicle Signage (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 pass through the next set of traffic lights on green;
- using vehicle data to improve road maintenance; and
- using vehicle data to improve traffic light timings.

Three headline findings emerge from the analysis:

- there are often gaps and obstacles in the end-to-end chain from data generation to action being taken for new services;
- where new services augment existing applications of technology, such as traffic lights, that base technology may need investment to bring it up to standard – for example, where the effectiveness of automated traffic control systems is compromised by inadequately maintained in-road sensors; and
- neither the benefits of the services nor the costs involved in achieving them are yet sufficiently clear and compelling to prompt the actions needed to realise them by the various parties involved.

The gaps and obstacles identified are not uniform across the four illustrative services. They do not lend themselves to a single 'silver bullet' solution – instead, they tend to involve multiple players rather than having a single owner, and mostly they are not technology-based, but arise from organisational, institutional and human issues. Examples of this include a lack of training or awareness, procurement challenges and, for driver-facing services, the extent to which drivers choose to respond to the information supplied – for example, GLOSA only works if the human driver actually adopts the speed advice shown. There is also a risk of allowing the best to become the enemy of the good, for example by pursuing universal IVS rather than focusing on those vehicles where it is already a practical option and in places where it has most value. Early services need simply to be 'good enough' to make 'enough roads' better.

The driver experience is a key feature, often overlooked. Services where the driver must take direct action (for example to download, use and then trust an app for providing GLOSA) have more gaps than those where data from the vehicle is used by the highway authority. Hence the services where data is harvested automatically and anonymously (e.g. better traffic light timings and better asset management) have fewer gaps to fill.

The good news is that there appear to be use cases where benefits could be achieved near-term through targeted applications working on the back of existing systems, and using current cellular communications; for example:

- delivering IVS on motorways to provide additional information to drivers on stretches of road between fixed signs and gantries, through working with satnav service providers;
- deploying GLOSA on a temporary basis for busy heavy goods vehicle routes – for example, to major construction sites (already the subject of a trial at Hinckley Point power station);
- using data from dashcams and pay-as-you-go insurance to inform many types of highway asset management decisions; and
- using existing Floating Vehicle Data to improve traffic light timings.

The report concludes with recommendations for the various bodies involved, namely:

The **Department for Transport** (DfT) should:

- develop a connected vehicle data strategy, to provide a clear plan of what services to deploy, when and why – as well as enabling a business case for investment to be developed by highway authorities, data providers and the traffic industry (now underway);
- tackle the difficulty experienced by individual local highway authorities in procuring data commercially, by running a central national procurement and hosting a subscription hub for data supply;
- provide funds for further developing skills and capability in sustained use of connected vehicle data by highway authorities, not just capital funding for equipment or research; and
- proactively lead on evaluating the real-world benefits from use of data from connected vehicles so as to build and sustain a national business case, as without better evidence there will be no business case for rolling out investment at scale.

Together with local and national highway authorities, DfT also has a role in working with OFCOM to plug the gaps in reliable, high-quality data feeds and mobile communications needed to support GLOSA and IVS for roadworks and hazard warning.

Highway authorities should explore to what extent, and at what pace, they could transition from simply using existing fixed sensors and time-based surveys to augmenting these with real-time data collected from vehicles, in order to generate a more comprehensive and timely data set. Together with **maintenance service providers** they should review the procurement of maintenance services to reward innovation by suppliers, in particular developing new, more flexible levels of service using data from vehicles.

Data providers should engage with their potential customers to identify and fill gaps in the granularity and coverage of their data, to maximise its value and uptake.

The **traffic systems and asset management industries** should engage both with highway authorities and the automotive sector to establish how best to introduce new data feeds into existing or planned systems and processes.

In-vehicle service providers and the automotive industry should continue to develop improvements in the design of the driver interface to reduce the safety risk from driver distraction, dashboard clutter and information overload, to ensure drivers gain swift and convenient access to the information they need to know.

OFCOM should work with Mobile Network Operators, engaging with DfT and others to identify and tackle gaps in data coverage across the highway network, moving away from a 'building-based' view of network adequacy to one focused on the level of coverage customers experience as they move around.

Industry, academia, and government should work together to fill the skills gap – to educate and train staff in the use of new data across current silos, and ensure that cyber security is addressed.

Everyone involved in the connected vehicles chain should do more to understand what makes for a good, trusted user experience. This is vital, as driver uptake of and active response to connected services such as GLOSA is key to achieving many of the benefits.

Addressing these actions would complete the connected data chain not just for one service, or even the four services considered in this report, but would also facilitate wider use of connected data, and thereby start to generate momentum in the development and deployment of more sophisticated, and ever more useful, connected vehicle services.

Neither the existence of connectivity nor the generation of data are, of themselves, enough.

1. Introduction

There is mounting evidence (TTF, 2018a :6, 2020 :13; USDOT, 2015) of significant benefits to be gained in the safety, management, operation, maintenance and use of our local and national road networks from the increasing extent to which vehicles are 'connected' by communications networks. As well as connecting vehicles to other vehicles, this allows both data to be harvested from the vehicle and information to be fed back to the driver (and, in time, to automated systems controlling the vehicle).

Data from a vehicle may be collected from many sources: the vehicle manufacturer, a fleet management system, pay-as-you-go insurance (PAYGI) providers, or smartphone apps such as satellite navigation (satnav) services. It can all then be processed by a data provider. The data collected can cover many aspects of the vehicle's operation including speed, acceleration and braking, even down to details such as whether and when the windscreen wipers have been activated.

Perhaps the most widespread connected vehicle service already transmitted to drivers is guidance from various satnav services, but other services are starting to become more common – for example, the displaying of the location and availability of parking spaces. Looking ahead, more data from road operators could also be processed by these service providers into messages that are sent to the road user directly, to help inform and change their behaviour.

The work so far to explore the value arising from vehicle connectivity to and from highway authorities[1] has been carried out by means of limited pilots, demonstrations and trials. These have often been more focused on technical feasibility than on the business case for wide-scale adoption of new services and data use – or, indeed, on their real-world practicability.

This report documents the findings of research into the practicability of a representative set of four connected vehicle services, deliberately chosen to be ones that link road operators to vehicles since this is more complex in organisational terms than vehicle-to-vehicle communications. By analysing the end-to-end process, it sets out to identify how far such end-to-end connectivity was already in place, where significant gaps emerged in the end-to-end chain of connectivity and, as far as was possible, propose how those gaps could be filled. By undertaking a detailed analysis of this 'connected chain', as set out in appendices 1-4, many gaps were found, often relating to the enthusiasm and capability (or lack thereof) of organisations to make use of the data.

Understanding these gaps, and more importantly how to bridge them, enabled identification of:

- Interim workaround actions leading to rapid benefits – often, the gaps related to relatively small areas where the activity has no clear owner who if identified could make benefits easier to deliver.
- Longer-term changes to exploit the opportunity – for example changes to contracts for road maintenance services to use connected vehicle data.
- Gaps that are common to many areas, so that filling them gives rise to multiple benefits.
- Softer improvements – for example in skills and education.

Some gaps arise because different engineering disciplines make different assumptions about what other actors in the chain can deliver (traffic engineers differing from automotive engineers, for example). Some gaps are the consequence of the natural inertia in the roads sector, whereas others exist because the business case for action is under developed or not widely understood.

The aim of this report is to explore these gaps – and, more importantly, how they could best be filled and by whom – in the hope that this will greatly assist in delivering the potential beneficial outcomes in congestion, emissions, safety and road user experience, as well as cost savings.

1 The term 'highway authority' refers to any organisation responsible for the operation and/or maintenance of a UK highway including strategic roads– of which there are over 130 in the UK.

2. Methodology

2.1 Introduction

This report documents a detailed analysis of the end-to-end processes that should be put in place to enable new services using vehicle connectivity to be deployed at scale. This scaling would help secure the potential benefits for road users and highway authorities alike. The analysis has focused on identifying the gaps that should be fixed which are currently breaking the connected chain to and from the vehicle to the highway authority. The concept of gaining benefit from connecting road operators and vehicles can also be thought of in terms of an electrical circuit – any one break means no end-to-end connection is made, and consequently that no benefit flows.

To find these gaps, this the report looks at four illustrative services. Two of these services use data gathered from the vehicle or user without their intervention and then sent to the highway authority. The other two involve the sending of data from the highway authority to a vehicle or smartphone, in order to help change driver behaviour. The vastly different role of the driver in the success of the second pair of services is key here, as will become clear.

These four services were chosen for three reasons: because they are of direct relevance to UK policies and challenges; because they can be used in all vehicles (not merely new ones); and because they have been explored in pilots in the UK, and are thus not far from being deployed.

2.2 The services

These services are:

- **IVS.** This entails a driver receiving messages (called 'virtual signs') from road operators warning of and explaining about, for example, congestion and roadworks at extra locations on the road, in addition to where current signs are located. IVS was piloted in the A2/M2 project (DfT, 2020) and the private sector is starting to provide it to a limited extent – by means of, for example, some satnav services. This report explores *what needs to happen* if the potential safety, driver experience and cost-reduction benefits that it could deliver are to be realised.
- **GLOSA** systems to advise 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. To date, this has been limited in the UK largely to technology trials such as the A45 (Transport for West Midlands, 2018). The report explores *what needs to happen* for it to become a scaled-up user-centred service.
- **Use of vehicle data for better management and maintenance** of the roads themselves – termed 'asset management'. There is evidence (TTF, 2018b :21) of use of connected vehicle data to generate potentially large savings from budgets to spend on other things, (rather than economic savings such as journey time that cannot be monetised), but these savings are yet to emerge at scale. The report explores *what needs to happen* to unlock these savings.
- **Use of vehicle data for better traffic light timings**. This explores how data from vehicles could be used to improve the way traffic control systems involving traffic lights are designed, maintained and operated to improve traffic flow. It reflects that many UK traffic lights do not now deliver the congestion reduction benefits they did when installed, owing to a lack of resources for maintaining sensors and retuning operating algorithms (TTF, 2020). It explores *what needs to happen* to make traffic light systems work more efficiently.

2.3 Exploring the gaps

This document explores the gaps in the connected chain in detail, as an end-to-end process view summarised in the text and then in more detail as 'swim lane' process diagrams[2] in the appendices.

It identifies the processes and actions, and gaps that are preventing connecting the complete chain:

- Between and within organisations in data flow and/or processing.
- In softer non-technical areas – for example driver uptake, trust, and confidence.
- In business case areas – for example the scale and coverage of data.

2 A swim lane is a type of flowchart that documents the steps or activities of a process flow (including, for this report, a separate 'lane' for each kind of gap), grouping these activities into rows that contain all of the activities in that lane's category, with arrows that indicate flow across lanes from one activity to the next.

- In knowledge, standards, and capability of staff.
- In commercial and stakeholder confidence; and/or
- In guidance from government.

These charts, and the gaps they reveal, were produced by:

- Reviewing each service as originally envisaged and seeing how well, or poorly as the case may be, developments that have emerged have conformed to the original plan.
- Holding discussions with stakeholders, especially those who have developed pilots and trials.
- Undertaking a review of published and work-in-progress research, especially that by the Transport Technology Forum (TTF) and its user groups, and by the Department for Transport (DfT).
- Referring to other roadmaps, such as the Zenzic roadmap (Zenzic, 2020) that explores developments for connected and automated mobility.

This work has been peer reviewed by the following experts in each illustrative service, whose comments and support for the report are gratefully acknowledged:

For IVS:

- George Brown, an independent consultant with a deep interest in connected vehicles, who led the development of an IVS Demonstrator for Transport Scotland while at Cubic.

For GLOSA:

- Jason Burrows of WSP, who has led GLOSA feasibility studies and deployments in the West Country, and who has been a leading contributor to the TTF GLOSA working group.
- Paul Rose of Amey Consulting, who has deployed GLOSA in the Midlands and is working on a Highways England GLOSA deployment.
- James Guilliatt from City of York Council, who has deployed connected vehicle data in a variety of trials and pilots. He is currently overseeing the development of publicly available GLOSA for deployment in York.

For asset management:

- George Lee, senior consultant at Blue Symmetry, a leading innovator in highway contracts and data collection and ex-chief executive officer of the Highways Term Maintenance Association.
- Dr Jon Harrod Booth, an expert in both highway management systems and asset management, and also vehicle-to-infrastructure data standards.
- Brian Fitzpatrick of Fitzpatrick Advisory Ltd, who has led research into the implications of connected vehicles on highway maintenance activities in local highway authorities.

For better traffic light performance:

- Dr Mark Pleydell, who leads the Traffic Open Products and Specifications (TOPAS) standards group and is a widely respected designer, developer, and maintainer of traffic systems.
- Dominic Paulo of INRIX, who has many years' experience of both traffic data use (with Mouchel and the Transport Research Laboratory) and floating data provision, especially for UK local authorities.

This work was also informed by discussions as part of DfT's Connected Vehicle Data Strategy undertaken by the Atkins/Jacobs Joint Venture.

3. Service 1: IVS

3.1 The opportunity

Since the start of motoring, information has been passed to drivers by fixed signs, and in recent times via variable message signs (VMS). Information sent directly to the driver inside their 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, being defined by the C-Roads project (C-Roads, 2017a: 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 warning 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.

3.2 What IVS looks like to the driver

IVS can give information to drivers in their vehicle 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 and through 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, and often an inability to capture settings from dynamic speed limits effectively).
- **Adding** to existing signs – for example by adding extra virtual signs at additional locations, or potentially adding further information along a route than one sign can safely show, subject to distraction.
- Potentially, 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. This is a very long-term potential gain, as the time taken to deploy services will depend in part on new vehicle sales, 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.

3.3 The outcomes

Successful deployment could result in:

- **Increased safety,** but only if trusted and credible hazard warnings can be given to drivers beyond those that can currently be conveyed through signs, 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 in safety 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;
  - display in the language of choice (important in tourist areas), and of information 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.
- 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 later as a separate case), so bringing about a **reduction in emissions.**

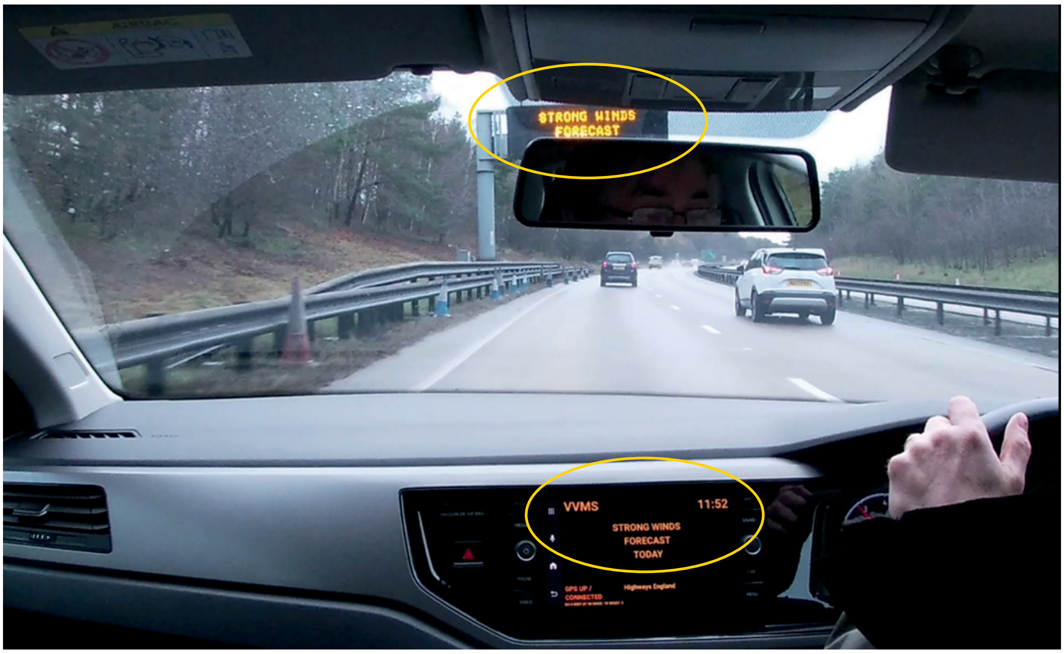
- **Reduced congestion** from reduced collisions and better awareness of road conditions.
- The ability to provide **more widely disseminated advice**, and more precise advice, about major national incidents such as terrorism, pandemic restrictions, bad weather and the like, rather than the current blanket messages.

3.4 The current status

IVS is not currently available as a public service in the UK. Various technical pilots of the technology to communicate with the vehicle have been carried out. These include the A2/M2 Project (DfT, 2020) and by Transport Scotland (Brown, 2019), repeating existing VMS, with limited user testing. It is, however, implemented in Germany in the C-Roads project (C-Roads Germany, 2017b) and in the Netherlands in the Talking Traffic project (Talking Traffic, 2020).

In Figure 3.1 is shown a demonstration of IVS which mirrors a VMS in a standard Volkswagen Polo using its existing ‘head unit’ – where navigation and information is displayed by connecting a smartphone to the car.

Figure 3.1: IVS in tests – the VMS wording repeated on the vehicle’s existing head unit via mobile communications

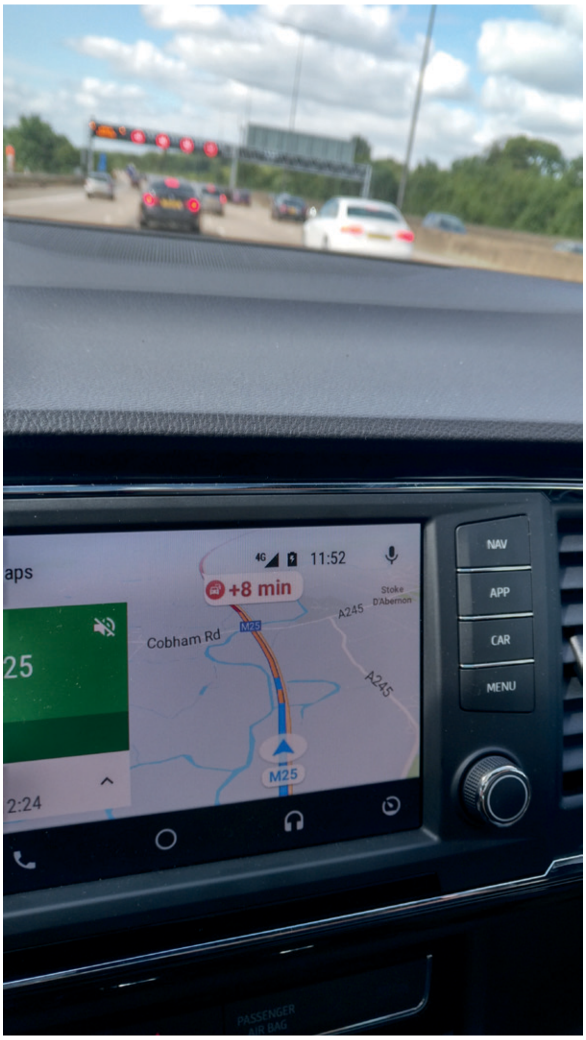


Source: Courtesy of George Brown

However, one form of partial IVS is already in place, in that the popular and widely used satnav and traffic information services Google Maps and Waze both provide warnings on the screen of vehicles equipped with linking software such as Android Auto or Apple CarPlay.

Additionally, satnav devices and apps can display information about queues (as defined by the satnav provider), using data sourced from their own subscribers' data or other data providers, as shown in Figure 3.2. Some can also show roadworks information, using such data sourced from road operators – as only they know when roadworks will start and whether they finish early, overrun, or simply do not occur as planned.

Figure 3.2: Queue warning from Google Maps



Source: Author's own

A key element of the IVS concept is therefore the **ability for a highway authority to communicate directly with driver**. This is so that they can give them information they want them to receive (for example hazard warnings), as opposed to a satnav provider generating messages themselves. Such apps and satnav devices are widely used already. This report therefore examines what would be required to combine the two approaches, so that highway authority information could use existing delivery channels.

3.5 What needs to happen

3.5.1 The basic premise

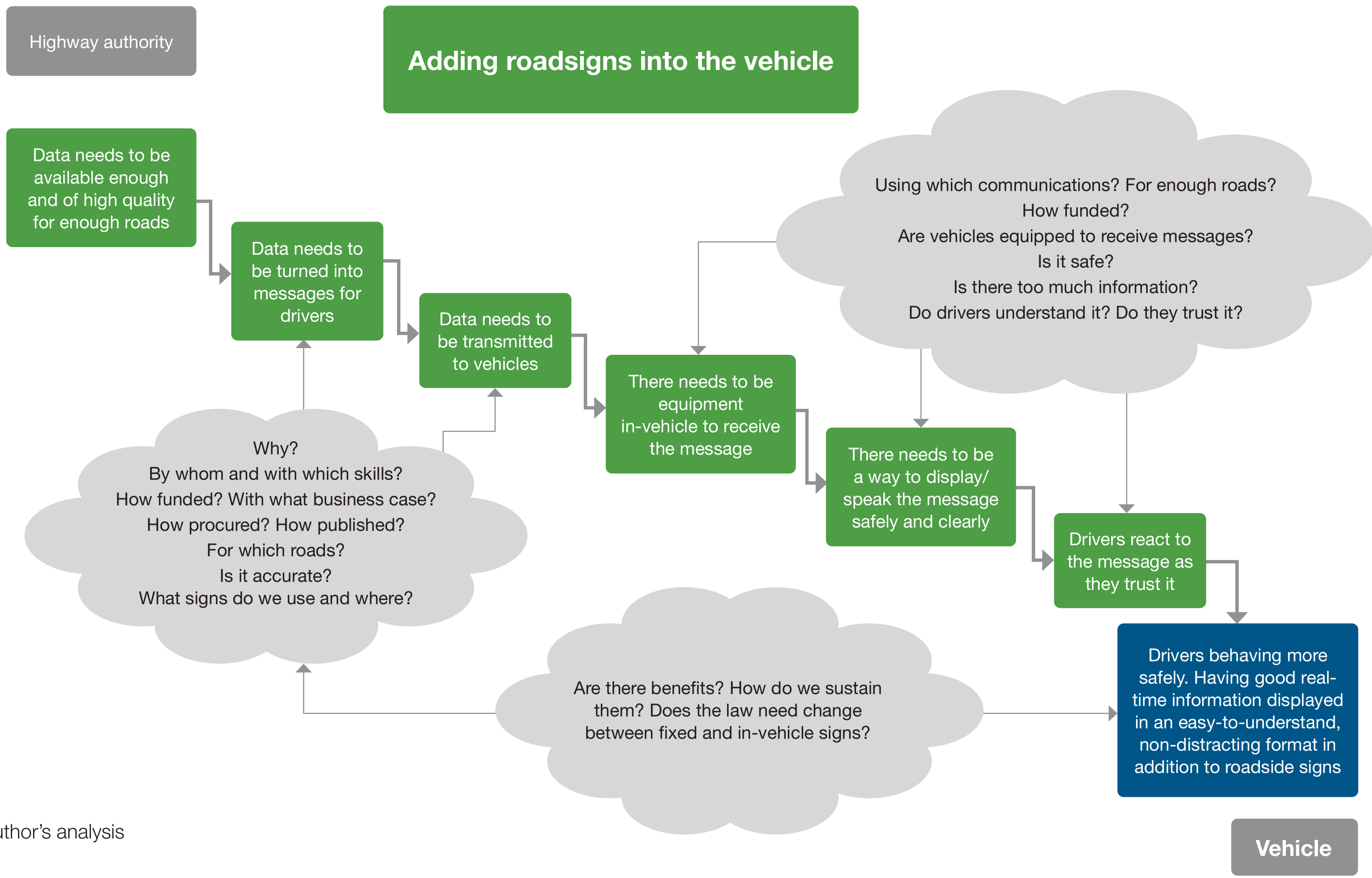
IVS is a connected chain that takes data from highway authority systems and presents it to the driver. For benefits to accrue in practice, all the steps shown in Figure 3.3 must happen. These steps are as follows:

- Data already in a highway authority system (if of good enough coverage and quality) is accessed.
- This data is processed into messages to be sent to drivers.
- These messages are transmitted into vehicles.
- Vehicles, or systems in them (such as a smartphone), receive these messages.
- The messages are displayed or spoken to the driver safely.
- Drivers can react to the messages if they trust them; and
- Outcomes are delivered: better driver experience, improved safety, and reduced cost of infrastructure.

Again, this highlights that neither data alone, nor communications, nor in-vehicle equipment is enough for IVS to deliver – the full connected chain must be in place. One disconnection in the 'wiring chart' will break the whole circuit.

The swim lane chart in Appendix 1 examines these basic steps in further detail and breaks them down into the gaps to be addressed. Discussion of these now follows, with actions (and/or the current state of play) shown in italics.

Figure 3.3: Adding signs into the vehicle – the basic premise



Source: Author's analysis

3.5.2 Gaps for the highway authority

The strategic gap

In the absence of a strategy nationally, or at least in England, sponsored by DfT, there is a risk of a disconnected patchwork of services leading to no clear business case for at-scale deployment, especially where funds are limited.

Drivers might have to change apps or services as they drive between UK cities. Conversely, a strategy that connects (a) new vehicles' technologies, (b) retrofittable technologies in older ones, and the (c) data sources from road operators all to each other could lead to services being able to develop at scale, with the associated benefits that this would bring.

This gap is now being addressed by DfT, which is exploring the value of the data and ways in which it can be exploited.

The funding gap

Without a change in the way IVS may well end up being funded, there is a risk of more pilots and demonstrations that cannot be carried forward into an at-scale business.

Pilots and demonstrations are typically funded from DfT's capital budgets via grants to local highway authorities. The commercial sector alone cannot deliver IVS, as much of the data required for generating real safety benefits (for example on roadworks and local hazards) must come from highway authorities. A change in the funding approach would thus enable at-scale deployment – especially as IVS might be replacing capital spend on new signs – in a way that would fund the access to and publication of data. It would also fill the various other technical and organisational gaps that are detailed below.

While Highways England may see a strong case for IVS, local highway authorities might not be considering IVS as a 'business as usual' service. This is due to a lack of revenue funds for current 'basic' services such as potholes and traffic light maintenance. The lack of a clear business case for connected vehicle data use is also holding back investment at scale. IVS should therefore ultimately be seen as a future day-to-day tool, like fixed signing, so as to move it away from a capital-funded research area.

There are plans for larger-scale citywide demonstrations of IVS to help inform the business case and demonstrate success, but additional funds would enable IVS to deploy across networks seamlessly at scale.

The skills gap

If a highway authority does not have people with the skills to understand the data it already has and ensure the quality of newly published data in the future, IVS will not be furnished with the data it requires to provide in-vehicle services which improve safety.

Accurate base data (for example fixed sign locations and fixed speed limits) and accurate and timely dynamic data that drivers will trust (such as dynamic speed limits and roadworks information) is fundamental. This is because users simply will not trust the information shown in the vehicle if it is out of date or located wrongly, or if it contradicts the fixed signing. There is little benefit in making a connected chain if the basic input data is poor.

One key part of the skills gap is in digitising transport data, as the basic data for IVS must be in a digital form. For example, digitised Traffic Regulation Orders (TROs) would define speed limit information directly and thus avoid the need to read signs with cameras. Currently, TROs are often paper documents. They define the legal basis for and location of speed limits, whereas cameras reading signs at the roadside do not have this legally compliant foundation, and are currently a workaround in the absence of the digital data.

TROs also define parking rules and regulations, and width and height limits, so there will be a need to have them digitised so that highly automated vehicles can navigate networks. Furthermore, they need to be able to change dynamically – to reflect temporary speed limits at roadworks, for example.

One of the challenges in digitising TROs is that the roadside estate (signs and yellow lines) does not always fully match the TRO legal definition. This can be for a variety of reasons – for example, the failure to update paper TROs as networks change, and as speed limit signs are sometimes put on existing poles in locations where the limit does not apply. Hence there is a back catalogue of TROs that might not tie up with the roadside information. A simple and effective solution here to work around the problem would be for highway authorities to use off-the-shelf technology to scan the network and make a digital twin of it, and then make the digital TROs derived from that twin match the physical layout found on the ground. This process can identify errors and inconsistencies in digital TROs, but requires a change in the legislative process for TROs (Boutcher-West, 2020).

Work has already started on disseminating updated roadworks information, for example to satnavs, but wider coverage would enable better deployment. This will also be essential for automated vehicles. It must also be delivered in a cyber-secure manner, another area where authorities tend to lack skills.

All of this requires skills and resource, not simply access to the data. While larger authorities may have these skills, many do not. Training and transfer of skills would assist this, but many authorities have limited resources.

DfT is already running research projects looking at unlocking data held in silos and in developing digital TROs (DfT, 2018), but the underlying skills problem should be addressed, possibly by means of getting authorities to share resources.

The procurement and support gap

Unless an authority can specify how to make their data widely available, and procure the technology to publish it, this data will remain unused in IVS services. Additionally, 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.

There are new procurement frameworks emerging, but one opportunity may be a national publishing service for all authorities, procured centrally.

The IVS coverage gap

Unless signs in vehicles do more than merely replicate existing signs (which might not currently be trusted by motorists anyway), the service will not be widely adopted, reducing benefits.

Simply repeating fixed signs and VMS is not in itself enough to create an attractive service that drivers will want to use, and which will lead them to change their behaviour in the connected chain. There must be added value from virtual signs that give much wider driver guidance at new locations and new roads, and which provide more information.

As an example, a dynamically created virtual sign alerting drivers to a hazard immediately ahead such as traffic at a standstill or an accident, or up-to-date roadworks information, could be have an effective impact on drivers. Virtual signs can also be quickly ‘installed’ where it would be impossible, or too costly, to install physical ones – in the case, for example, of informing drivers of unplanned roadworks well before they reach them.

The data to be shown as messages on these virtual signs should be published by a highway authority as described above, through digital TROs for speed limits, and through proactive capture, processing and publishing in the case of real-time information such as that relating to current roadworks.

For services to be seamless for the driver, this gap in coverage should be filled. While there should be some form of phased roll-out, drivers will soon expect every road to have IVS. Since they neither know nor care who operates the road, there should be a nationwide plan for deployment as part of the strategy mentioned earlier.

Research is required into the type and frequency of virtual signs, and how they might be displayed so as to attract maximum attention in a safe and customer-friendly way. These should be standard across different vehicles and other services, in the same way that road signs are standardised within countries.

3.5.3 Gaps in the data

The publishing gap

Unless there is one single, rapidly updated and secure national feed point for all IVS messages, there will be many different points of contact for service providers and vehicle makers. This will add cost and complexity, and potentially break the connected chain. This might mean gaps in services at best, or even no services at all.

Instead, sending data from authority traffic management systems to those that will publish them would allow seamless services across the nation, and a National Access Point (NAP) would promote those publishing the data for IVS, bringing it to the attention of bodies wanting to use it in their services. This requires better ways of accessing and exporting data from current authority systems (for both local and strategic roads). A UK NAP with a critical mass of information about the data available would support single points of contact for vehicle makers and service providers of existing services, but should also be backed up by actual exchange of the data to feed downstream parts of the chain.

Work is underway looking at the NAP (NAP, 2019) and in the Innovate UK-funded ConVEx project (ConVEx, 2020) at a platform for sharing data.

The communications standards gap

A critical gap is the absence of any agreed channel for communication to vehicles, which means uncertainty and lack of confidence in investment.

There are two technology options for connecting the chain:

- **Beacon-based** (called Intelligent Transport Systems (ITS) G5, or 'ITS-G5'), which requires roadside infrastructure and equipment to be installed in the vehicle on the production line. To date, in the mass-market, only the new Volkswagen Golf and a few other high-end cars will include such equipment as standard.
- **Cellular-based,** where existing mobile data communications, and evolutions of it, including 5G, can be used. For IVS, this does not require roadside infrastructure but instead is delivered as a service to cover the communication costs. This technology can also be deployed in older vehicles in the form of retrofit devices, notably smartphones.

The path to IVS as formally defined is uncertain regarding the receiving equipment in vehicles and deployment of roadside stations. This gap means that technology pilots have focused on communications into the vehicle, not how the messages are displayed.

It is important not to narrow the focus to new vehicles with new technology. The Society of Motor Manufacturers and Traders (SMMT, 2020) states that the mean age of a vehicle in the UK is eight years, and this average may become temporarily older in the wake of the coronavirus pandemic as new car sales take time to recover. Investment in roadside technology that can communicate only with newer vehicles will take a longer time to generate benefit than one that can be used by all vehicles. For safety benefits, road operators could address the least safe vehicles and drivers on the road, which also tend to be older vehicles with younger drivers. Local authorities may also have policy-based reservations about providing services only to new vehicles.

In addition, the cost for a UK local authority of installing roadside beacons is high, and with unclear business cases may even prove prohibitive. Transport for London, for example, has not installed beacons for the A2/M2 project (Cowen, Booth and Hardy, 2018) – instead, it used existing cellular communications. In contrast, given Highways England's smaller network and higher speeds, it may support a wider move to 'digital roads' using its fibre network on motorways and employing beacons for communications to vehicles.

In conclusion, a key action is that a channel (or a hybrid of both channels) is chosen, either by means of legislation or through market forces. While the debate continues, however, there are signs of progress:

- Vehicle makers are considering combining both beacon and cellular technologies in one hybrid device.
- Some vehicle makers are starting to fit beacon-based equipment (but, to date, no UK highway authority has decided to install beacons for anything other than test projects, and there is no policy at present for doing so).
- Much work has been done in the UK using existing cellular channels via smartphones to deliver IVS.

IVS is, at present, an additional feature with the role of supporting, but not replacing, traditional signing, both fixed and variable. Hence it is not safety-critical in the same way that roadside infrastructure such as lane-control signs is, and as some vehicle-to-vehicle services will be. This means that existing communication channels may be good enough for IVS in terms of coverage and rapidity of message delivery, until such a point that the services can be mandated and start to replace fixed infrastructure, when better communications will be needed.

> *Work has already shown that existing cellular data communications are generally suitable for IVS, even on remote roads (Brown, 2019).*

The communications coverage gap

Coverage currently varies from existing cellular data services to a few test sites equipped with ITS-G5. Even with an agreed channel, however, coverage should be as geographically complete as possible in order to provide the data into the vehicle and so complete the connection. Without reasonably complete coverage, drivers would not be able to see the messages sent by highway authorities, as they could not be picked up in their vehicles. Again, the connected chain would be broken.

Mobile data coverage of roads is still not geographically complete, as shown by previous reports (RAC Foundation, 2018), but it is improving. As shown in Scotland's IVS pilot (Brown, 2019), this may be already good enough for adding value. Rolling out beacon or advanced cellular services may give better performance that is required for future later safety services, but this will be a significant task and come at a significant cost. Existing cellular technology also has the advantage that it can be used in older vehicles via smartphones.

> *There is little to be lost by exploiting existing cellular channels in the short term.*

The installation gap

Unless vehicles have appropriate devices or software inside them, there is no way to receive IVS messages and connect the chain. Data and communications alone are not sufficient. Currently, limited IVS without highway authority input is available via satnav services on mobile devices, but highway authority data is required to make the most of IVS for safety.

As shown earlier, there must be sufficiently fast access to data, together with enough added value from IVS, to warrant vehicle makers supporting IVS installed in-vehicle. Additionally, service providers need to see a case for using it in existing equipment / retrofittable devices and for users to choose to turn it on.

IVS, especially as delivered through beacon-based communications, is seen as a service for new vehicles owing to the technology focus and potential for factory fitted equipment. However, this emphasis on new vehicles, taken with diminishing car sales (even before COVID-19), means slow penetration into the UK fleet. This could be avoided or reduced by using apps and cellular communications to bring IVS into vehicles of all ages.

There then arises, however, the question as to whether drivers want to use IVS in any case, even if it is available. The data must be used in such a way as to make it attractive, by either an in-vehicle factory fit or app. Data on its own is, once again, not enough.

With the undecided communications standards as described above, and little high-quality data being made available, few vehicle makers or service providers are considering using data from highway authorities in IVS. In contrast, Google and other service providers generate warnings within satnavs using, for example, their own datasets on queues. There is already (Elgin, 2020a, b) some success in capturing accurate and timely roadworks data from authorities for distribution to satnav suppliers, and this model could expand to cover the entire country and provide seamless services.

> *Authorities should focus on rolling out existing information to suppliers who already have customers for their information. This then creates a critical mass for expanding services: as many new vehicles use smartphone apps rather than an in-built satnav, this will enable penetration into new vehicles also.*

3.5.4 Gaps in the vehicle

The human–machine interface (HMI) gap

If drivers are distracted by IVS and other in-vehicle systems, the safety benefits may be reduced or even negated. To fill the gap about how to present IVS safely, more work should be carried out exploring HMI solutions to balance safety benefit against distraction.

Recent work by the Transport Research Laboratory (Ramnath et al., 2020), supported by the Rees Jeffreys Road Fund and IAM RoadSmart, showed concerns about the distraction of apps often used in-vehicle.

> *Research is required on how to minimise the distraction of drivers while still giving them a good customer experience, perhaps using vehicle maker expertise and HMI principles from aviation, where voice is often used as a primary way of alerting pilots. Equally, the traffic radio industry has much experience of how to package traffic news for most interest – and hence attention – in a minimum time, which may be helpful*.

The filtering gap

If drivers cannot tailor the level of information they choose, with a mandatory safety-warning-message-only level, they will probably turn IVS off to avoid it flooding them with unwanted messages. Messages should therefore have a priority for display attached to them, to retain driver interest.

Currently, VMS is used for safety messages such as 'queue ahead', real-time information such as journey times, advance warnings such as predicted disruption, and campaign messages. Simply repeating all these in the vehicle may mean drivers turn IVS off. One advantage of IVS is that messages purely of interest to HGVs (for example height limits) or other specific vehicles can be targeted at those users alone. This requires more testing to work in practice.

> *Research should include filtering of messages in the HMI to target users for best impact.*

The trust and education gap

If drivers do not trust the information that they receive, especially when it is not backed by roadside signs, and/or are not able to understand what action to take and then take it, then benefits will be lost and the connected chain broken.

Currently, there are varied levels of trust in roadside VMS, but good use of fixed signs. Timely, accurate, well-presented, and filtered information will form part of the solution, but, equally, drivers must be educated about how to use this new information. For example, users need to know whether speed limits are mandatory or advisory if shown inside a vehicle. What if the in-vehicle and roadside information disagree?

An example of the education gap is the deployment of eCall (an in-vehicle system to send data to emergency services for example on the location of a vehicle after an air bag is deployed in a collision). In the UK this has not been supported by driver education, meaning that potential benefits have not yet been fully delivered (Hutton, 2020a).

Service providers, vehicle makers and highway authorities must all learn the lessons from early satnav and recent eCall deployment about the value of educating users as to how to use new in-vehicle technology.

3.5.5 Other gaps

The evaluation gap

Unless highway authorities and service providers know that IVS messages are received and acted on to give benefit, and this benefit is measured, there is no clear business case for completing the connected chain. Few IVS projects determine whether drivers have actually changed behaviour, so there must be better evaluation of user benefits using feedback from real drivers. This would help complete the connected chain of benefits.

This is especially important for the purpose of feeding back into the business case for IVS deployment, and as part of continuous service improvement to retain driver uptake.

Work deploying IVS (and indeed GLOSA, as shown in Chapter 4) should move from technical and limited user testing to public-facing tests with rigorous HMI, and user-behaviour tests with users in the mass-market.

The sustainability gap

Unless highway authorities have the resources to sustain the new technology by means of maintenance and training, the benefits will be lost in the longer-term, as the chain will not stay connected.

The legislation gap

Unless legislation is changed, there can be no move to 'naked roads' – i.e. without physical signs. Legislation could shift IVS from an advice-based to a mandatory service, but this would need associated proof of receipt of the message and hence a different form of communication.

To remove fixed and variable signing (or more likely simply cease to install any new signs) would require a new approach, as IVS must in that case become mandatory. This is also important for highly automated vehicles. It will then be required to prove beyond reasonable doubt that the driver received the message, which implies an increase in the complexity of the system. Again, the data alone is not enough.

Research should explore how to move from an advisory to mandatory use of IVS in the future.

3.6 A way forward

The choice of a future communications channel is a key enabler for deploying IVS as usually considered, but for services provided by existing satnav providers (for example), the communications channel gap is already filled and the chain can be more easily connected.

The communications debate is unlikely to be solved any time soon, but there is an opportunity to exploit channels that already exist – for example, satnav and apps such as Waze, along with dedicated apps as used in Talking Traffic in the Netherlands (Talking Traffic, 2020). Currently there is little if any data feed from roads authorities to these suppliers other than for roadworks, and often the view of the suppliers is that data from roads authorities is inaccurate and not therefore worth accessing anyway. Recent work in the UK from Elgin has meant that accurate roadworks information is now available at a critical mass from a single point for onward publication.

This could be exploited quickly in three areas, if the following were to happen:

- There is a single point of access for high-quality data from enough road operators, in the case of data for which road operators are the only source (notably roadworks and variable speed limits, but also some bad weather data, and data on parking, temporary restrictions and so on). The ConVEx project in the Midlands shows promise here.
- Work is done to explore how to deliver this to the driver safely via existing devices such as smartphones linked to in-vehicle head units, or by voice, through integration with satnav, parking and other road-related apps.
- The service, and data that support it, are thoroughly consumer tested to gain trust from the user.

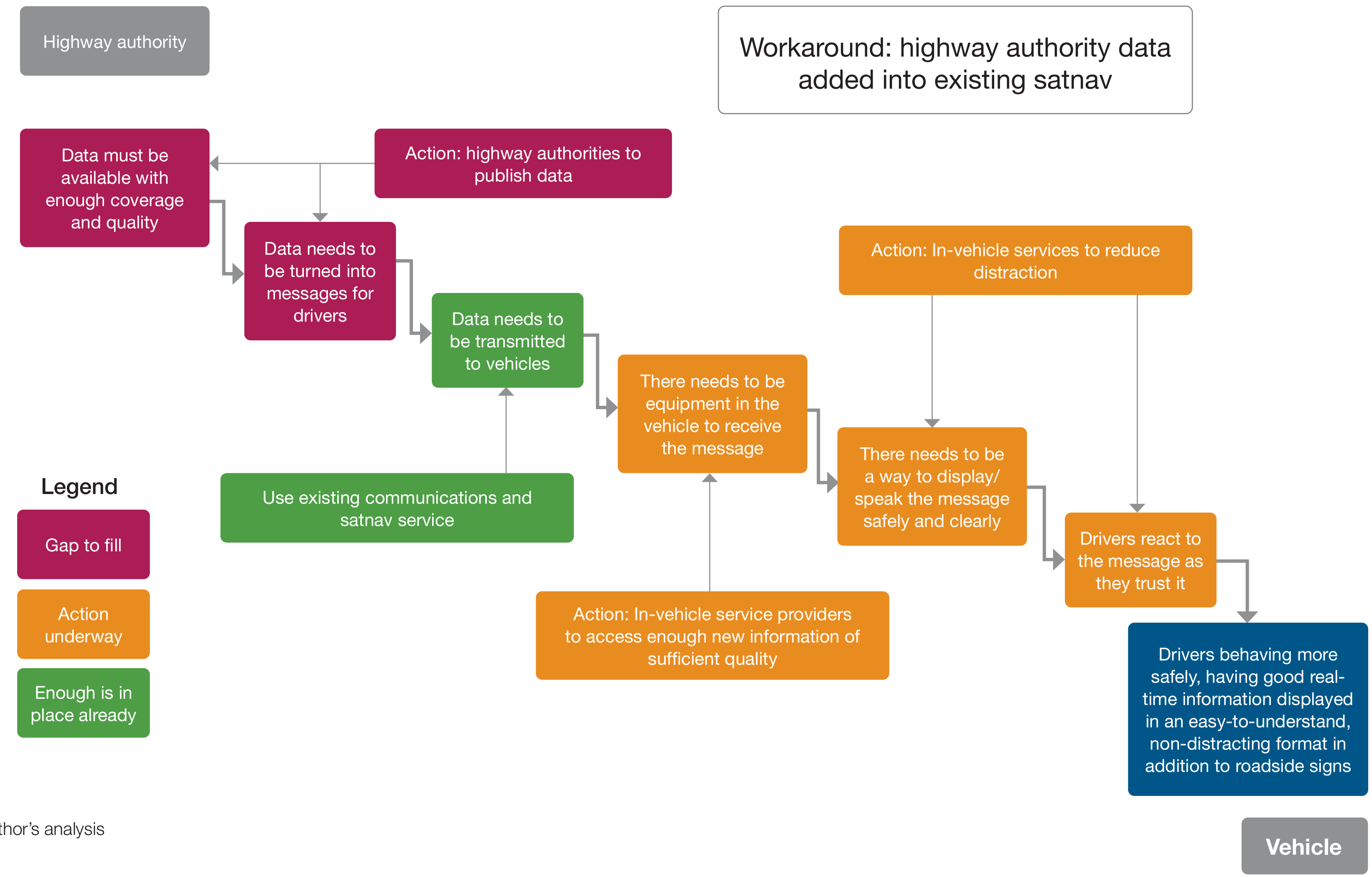
Making this the start of a UK-wide IVS system could deliver, in particular, safety-related outcomes for both older and new vehicles, and could form a part of a minimum set of services for future expansion. There is a danger in IVS that looking for technological perfection delays services which are currently already good enough to yield benefits, and which can also be used to accelerate future deployments.

One key aspect would be data coverage – it may well be that strategic roads (some being considered for expressway upgrades) across the UK might be enough to start a workaround service. For these roads, however, the service should do more than simply provide repeats of messages on existing signs. There is a particular opportunity here for Highways England to reinforce 'Red X' lane-closure signalling on its all-lane running[3] stretches, and also on their all-purpose roads which currently have no VMS but a far higher accident rate than motorways.

This approach is shown in Figure 3.4.

3 All-lane running is where the full width of the road is usable with emergency refuge areas alongside, and applies to smart motorways.

Figure 3.4: Workaround for IVS and actions required



Source: Author's analysis

4. Service 2: GLOSA

4.1 The opportunity

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

Pilots such as the A45 (Transport for West Midlands, 2018) show 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 tailpipe 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 of the concept have been developed, for example for cyclists in the USA (University of Oregon, 2019), and GLOSA is being explored for heavy vehicles exiting motorway slip roads in the UK (Highways England, 2019), as well as for HGV access to construction sites.

GLOSA would 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 a 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.

4.2 What GLOSA looks like to the driver

GLOSA can give information to drivers by either:

- **Showing what speed to drive at**, or indicating a need to slow down or increase speed in another way, to match green timings. This cannot exceed the speed limit of the road. Various interfaces have been used to show drivers what action to take, including the use of 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 cut-off is reducing junction throughput because of increased reaction times once lights turn green.

It can do this via a standalone app, an app linked to the vehicle's dashboard head unit, or the dashboard itself, as shown in Figure 4.1. At www.youtube.com/watch?v=yxTXnckRWLk can be found a video of its use on the A45 in Birmingham.

GLOSA resembles IVS in the previous chapter, in that data can come only from a highway authority system, and it must then be communicated into the vehicle and be accepted, and then trusted by the driver 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 is treated as a separate case in this report. This is 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 to traffic lights only). However, many of the issues, as for all this report, are similar. As shown later, combining IVS and GLOSA is a customer-friendly opportunity and one that could also provide an integrated data feed to the vehicle, thus reducing costs.

Figure 4.1: Technology test app used for GLOSA

Source: TfWM

4.3 The outcomes

The outcomes from successful GLOSA deployment could be:

- Reduced 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 more effectively with knowledge of when traffic lights will go green.
- Potentially a further **increase in capacity** as traffic lights in a series are optimised to work in tandem with GLOSA (so that platoons of vehicles are set up to pass through series of lights together).
- **A better customer experience** from better-informed road users, especially cyclists.
- Support for the roll-out of **highly automated vehicles** with a better customer experience.

There are, however, various barriers that need to be overcome in seeking these outcomes 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 (particularly in the case of HGVs that are turning). Near to the lights they 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 light. If IVS is included with GLOSA, research should explore how to hand over between the two services.
- A solution must be found enabling **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 it, and want to adopt the technology 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. This is unlike other countries in which GLOSA is deployed, where the timings are fixed, and thus more predictable but less effective at reducing congestion. Adaptive traffic light timings vary in predictability, being more predictable as congestion increases and less so as it decreases. In many cases, especially in the peak, this timing adaptation may be small enough not to matter, and work is already underway to explore how to deploy GLOSA with the Microprocessor Optimised Vehicle Actuation (MOVA) system, which is highly dynamic, thus affecting predictability of green timings.
- A way of **overcoming GPS accuracy limitations** must be found, particularly in the urban environment and where traffic light sites have more than one ingress/egress lane, and are served by multiple and conflicting phases. Incorrect GPS positioning can result in incorrect advice and potentially hazardous manoeuvres.
- **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, they 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 actually stationary does not engender trust. It follows that GLOSA should be explained to drivers, in order to manage expectations and avoid a negative reputation.
- **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.

4.4 The current status

GLOSA is generally well defined by international standards for the data going into connected vehicles, in the form of SPaT (Signal Phase and Timing) data about traffic light timing, and MAP files[4]. There are also standards such as CROCS, the Controller to Roadside Open C-ITS Standard, funded by DfT, which govern how these messages are transferred to and from traffic light controllers and to and from vehicles (IDT, 2017).

GLOSA is not currently available as a public service in the UK, but various technical pilots have been carried out. These include the A2/M2 project in London and Kent, the Birmingham A45 pilot, and the Compass 4D project (Newcastle University, 2015). There has been much simulation of the impact of GLOSA in the Midlands and York (NIC, 2018), for example, as well as new projects now exploring HGV GLOSA in Somerset, and in Manchester, undertaken by Highways England.

GLOSA is available abroad as an at-scale service, notably in the USA, where the predominance of fixed-timing traffic lights makes the challenge of predicting future timings much easier (Etherington, 2016); in Germany (Audi Media Center, 2019); and in the Netherlands, through the Talking Traffic Project as described earlier. Several UK authorities such as City of York Council are now procuring GLOSA systems, but there is yet to be widespread take-up, for reasons explored below.

Various methods of accessing this critical input – the dynamically changing timing data – have been developed, ranging from openly disseminating it from the central system as done in Birmingham, using other cellular-based services as shown in the A2/M2 project, through to sniffing the IT network for messages that pass from traffic lights. Integrated proprietary GLOSA software, including the apps for drivers, has also been trialled. However, to avoid lock-in to single suppliers, which would discourage widespread use, the data must be published openly whatever the solution.

In the pilots, user tests have focused on 'captive' users, such as employees of the highway authority, but they are now moving more to 'friendly' users – business drivers of fleets such as HGVs. The final step will be 'public' users, but there is not yet the confidence for a wide-scale public roll-out.

4 MAP is a standard for encoding a junction and its lanes topologically – see www.collaborative-team.eu/downloads/get/SWARCO%20standardisation%20activities%20in%20cooperative%20systems.pdf

4.5 What needs to happen

4.5.1 The basic premise

The basic connected chain of GLOSA and the steps required to deliver are as follows:

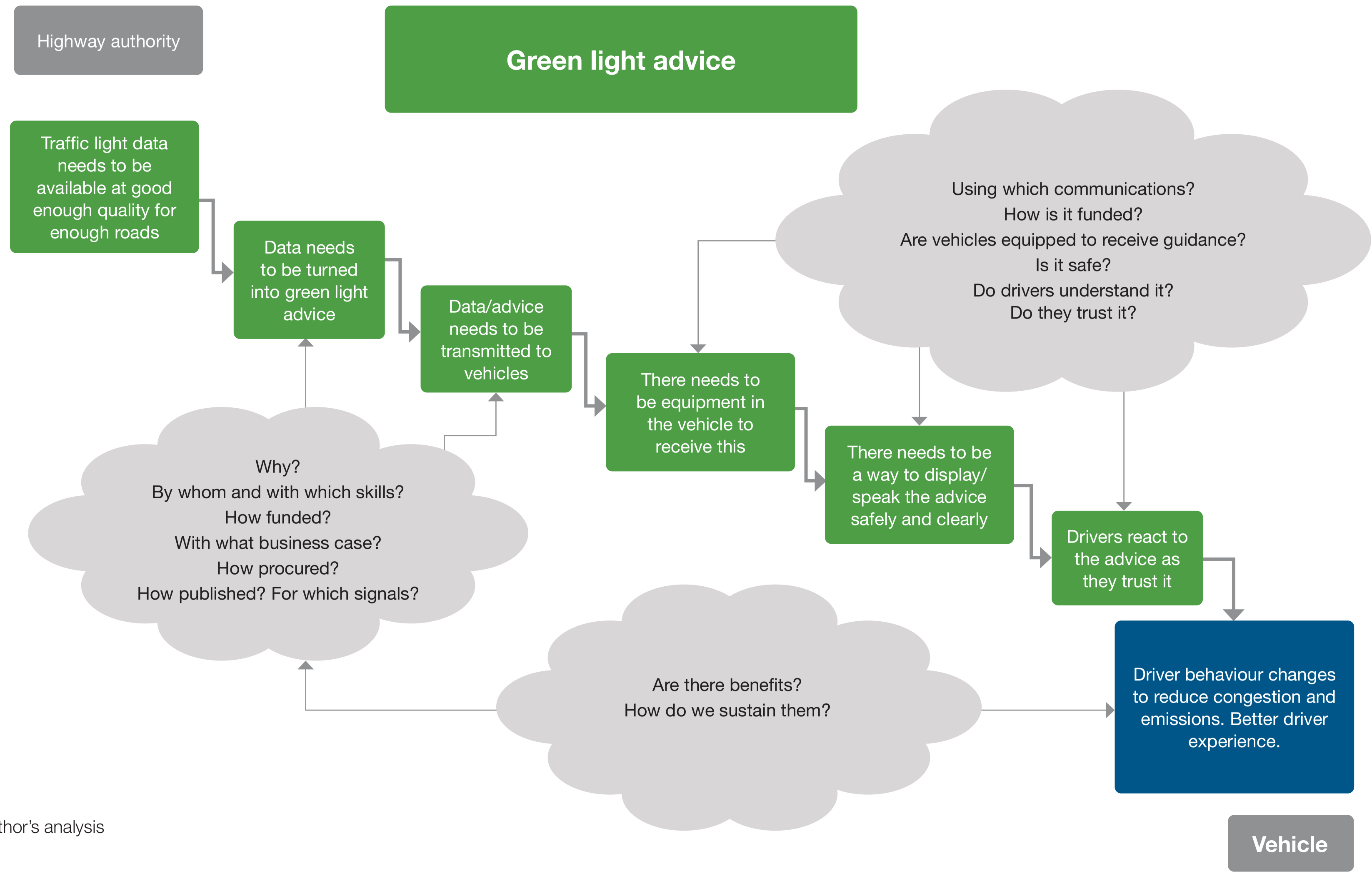
- Access and publish traffic light timing and junction geometric data of sufficiently good quality, for enough roads, for a viable service; using the SPaT and MAP messages (defined as international standards), turn this into accurate green light predictions.
- Send these predictions into vehicles at the right time and in the right place.
- Receive timely predictions in the vehicle.
- Display/speak the advice safely and clearly.
- See drivers reacting to the message and changing their behaviour, leading to the hope for benefit.

The swim lane chart in Appendix 2 examines these steps in much more detail, adding in the non-technical softer feasibility and business case aspects as well as evaluation, to show the full GLOSA approach. It breaks them down into the gaps, and identifies the 'things that need to happen' to fill those gaps.

The basic flow for GLOSA from highway authority to vehicle/driver is shown in Figure 4.2, highlighting again that obtaining a successful outcome is not simply a case of accessing the data or providing in-vehicle devices: there must be a complete connected chain.

These gaps are now discussed in turn, with actions to address them that are already underway shown in italics.

Figure 4.2: Advising drivers on green times – the basic premise



Source: Author's analysis

4.5.2 Gaps for the highway authority

The strategic gap, the funding gap, the skills gap and the procurement /support gap

These gaps are the same as for IVS discussed previously in subsection 3.5.2.

The SPaT and MAP gap

A specific gap results from the fact that unless an authority has the skills to enable it to access and securely publish traffic light data in the SPaT and MAP formats required for GLOSA, the connected chain is broken. This might be achieved by procuring extra systems/consultancy or by mining its own current data better.

Accurate base data, (such as traffic lights locations and lane geometry) and accurate and timely dynamic traffic light data is needed for GLOSA. In particular, unless there are better ways of accessing the dynamic traffic light timing data, the service cannot be deployed widely because linking to traffic lights is often the most difficult part of the connected chain for GLOSA. Older traffic light systems, often used in the UK, do not make publishing this data easy. If resources were dedicated to updating older systems, this would not only support GLOSA but also deliver other benefits (improved traffic light performance owing to the greater reliability of new equipment, and reduced maintenance costs). Some systems can publish traffic light data, while in others, as discussed, it is locked away. Knowing how to access the timing data is a key gap to fill.

Unless this data is accessible and published, at-scale services will not deploy nationally. This data handling must be carried out in a cyber-secure manner, another area in which authorities lack skills. While larger authorities may already have these skills, many smaller ones do not. Training and transfer of skills would assist this, but, as already mentioned, many authorities' resources are limited.

The only scalable solution is to provide data to the device inside the vehicle (for example a smartphone with an app), so that it can calculate the necessary vehicle approach speed itself. An agreed standard for the exchange of data is a fundamental requirement for enabling wide coverage – the CROCS standard (see section 4.4) is being used. There is a role here for government in updating mandatory standards for traffic light equipment to support the easier export of data.

Additionally, the benefits case for GLOSA is not yet clear. At peak times, traffic lights are of necessity biased to favour heavier flows and reduce queues anyway, so the only time GLOSA might be of real benefit is in the off-peak period when there is less queuing. There may well be niche areas of benefits, for example in the case of heavy vehicles off-peak, and integration with IVS is a clear opportunity here. This lack of a wider business case means that highway authorities may be reluctant to invest in publishing their data.

Generating the MAP files that literally map every junction in GLOSA is a further new skill that should be cultivated within local authorities more widely, rather than just provided commercially as is currently the case. MAP files hold geospatial data at a great level of detail – individual lane, stop line, pedestrian crossing route – which, generally, does not exist. Without this, large-scale roll-out will be a challenge.

Other data, such as TROs as for IVS, is needed but does not always exist in digital format. Even if TROs are becoming available digitally, they are not necessarily under the control of the same department or people as traffic light data.

DfT has research projects which are looking into unlocking data, but the underlying skills problem requires new thinking – authorities sharing resources might be a way forward. MAP file production could perhaps be procured centrally by DfT for UK highway authorities.

4.5.3 Gaps in the data

The GLOSA coverage gap

Unless there is enough traffic light data for GLOSA, the service will need to be launched and marketed only as a niche one – for example, for HGV routes into cities, distribution centres or major construction sites.

Simply providing GLOSA data on a few corridors in a few cities is not enough to connect the chain nationally. At-scale deployment and capture of the traffic light data is needed for a national service.

For such a national service, there must be a method for sending data to vehicles that is implemented consistently across the country, meaning that, for example, users do not need to change apps when moving between cities, and seamless services can be delivered to users.

DfT is considering a national business case and specification for GLOSA.

The publishing gap

Without a rapidly updated national feed point for SPaT data which sends data from authority systems to those that will provide GLOSA – service providers and vehicle makers, for example – there will not be complete coverage, and reduced customer uptake will result.

This feed point would allow seamless services, and a NAP would connect those publishing data with those wanting to use it for GLOSA. Use of the standard SPaT and MAP messages that underpin GLOSA is essential here. This relies on better ways of exporting data from highway authority systems. A UK NAP with a critical mass of information would support single points of contact for vehicle makers and service providers.

Work to fill this gap is underway looking at the NAP, and also in the Innovate UK (IUK)-funded ConVEx project.

The communications standards gap

There is no agreed channel for communicating to vehicles for GLOSA, which leads to lack of confidence in investment in connecting the chain.

A key barrier to GLOSA adoption so far has been the lack of an agreed channel into the vehicle, as with IVS. However, existing cellular communications are good enough for GLOSA, using software inside the vehicle to convert SPaT and MAP messages into speed advice.

As with IVS, GLOSA is, at the moment, an additional feature intended to support, rather than replace, existing technology – in this case, traditional traffic lights. Hence it is not safety-critical in the way that some vehicle-to-vehicle services are. This means that existing cellular communications may well be good enough in terms of coverage and speed for GLOSA. There are also practical ways of working around any data speed problems from cellular communications, as in any case drivers should not be looking at the app as the lights are turning green.

Work has shown that existing cellular data communications are good enough.

The communications coverage gap

Even if cellular communications are chosen, there still must be enough geographic coverage and system capacity to support GLOSA services, in a timely way, to give a good quality service that users will adopt.

For traffic lights in towns, where there are the best benefits, this currently is not an issue but for more rural areas, for example motorway junctions, inadequate coverage may be a problem.

As GLOSA is a data service, cellular coverage is often good enough, but there are still areas of coverage where GLOSA may not work well – mobile network operators and OFCOM need work together to infill these. 5G alone is not the answer, as it will initially be focused only on cities and has shorter range than the 4G signal currently in wide use.

The installation gap

Without vehicles with devices fitted to receive GLOSA data, the connected chain will be broken. There must therefore be sufficiently fast access to GLOSA data, and enough added value for customers, to make it worthwhile for vehicle makers and service providers to produce software or apps to show GLOSA, and for users to then in turn choose to turn them on.

GLOSA as an app for existing vehicles alone is not enough – vehicle makers also need to supply it in-vehicle at manufacture, as for example in the USA with Audi, to sustain its uptake and improve the customer experience. Vehicle makers need to see all the previous gaps filled in the connected chain, and a customer desire for the service – and ways to make GLOSA delivery of as high a quality as that seen in other aspects of the vehicle. GLOSA could also be integrated into freight vehicles' in-cab equipment to reduce driver information overload from adding even more services – there is an opportunity here to work with key industry providers.

In-vehicle GPS accuracy would need to support granular (lane-specific) GLOSA, as standard smartphones cannot yet always provide this level of accuracy.

GLOSA could also be useful for cyclists, but little work has been done to tailor it for UK cycle use.

Various technology projects have explored GLOSA in new vehicles, but few have integrated it widely enough to obtain customer feedback on its use on real roads. At-scale public-facing demonstrations are needed.

4.5.4 Gaps in the vehicle

The HMI gap

As with IVS, the benefits of GLOSA are in danger of being eroded by safety concerns relating to driver distraction, and the risk of users not liking how it is presented and thus choosing not to use it. There are specific concerns about distraction of drivers from GLOSA as they are approaching traffic lights so more work is needed on exploring HMI solutions to balance safety benefits against distractions such as voice.

Several pilot projects in the UK are now deploying public-facing GLOSA apps, but work is needed to collate the findings across them all.

The trust and education gap

As with IVS, unless drivers trust the GLOSA advice they receive, and understand what action to take, and then actually take it, benefits will be lost as the connected chain is broken. To date, few projects have explored real drivers' feedback (rather than that of selected test drivers).

Drivers need to be educated about what GLOSA can and cannot do – it will have little impact in the heaviest traffic conditions, for example. Additionally, further research is needed to explore how many drivers change their behaviour, even if they do trust the advice that they are given.

4.5.5 Other gaps

The evaluation gap

Unless highway authorities and service providers know that GLOSA is and acted on to give benefit, and this benefit is measured, there is no clear business case for completing the connected chain.

As with IVS, few GLOSA projects determine whether drivers have actually changed behaviour – there should be better end-to-end cost–benefit valuation to help the business case using feedback from real drivers to complete the connected chain.

Funding bodies need to incorporate exploring feedback from real drivers into their research budgets.

The sustainability gap

Highway authorities need resources to sustain the new technology through maintenance and training and thus keep the chain connected.

4.6 A way forward

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 the suppliers is that data from roads authorities is inaccurate. There is great value to be gained from connecting the chain here.

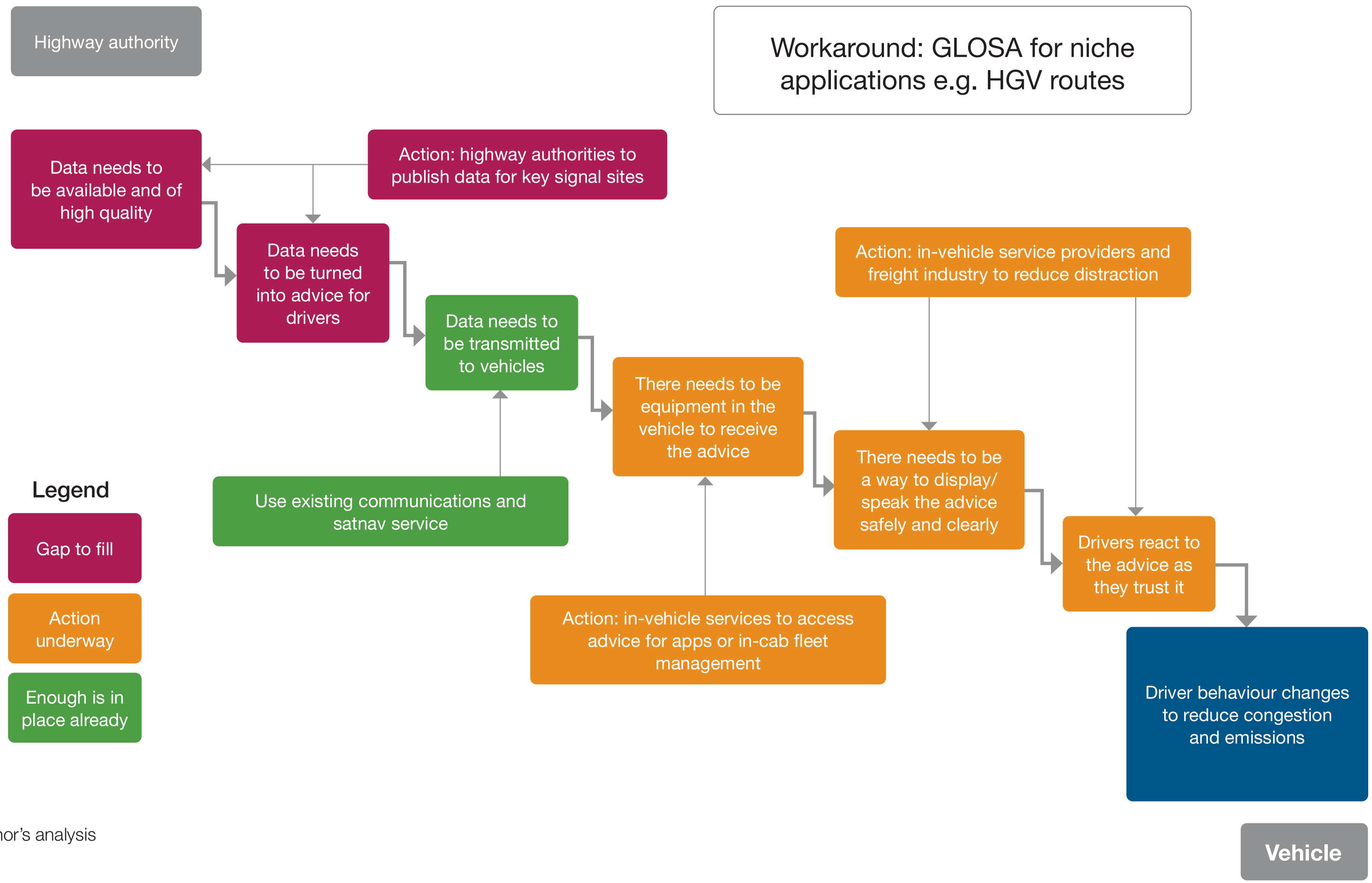
Elgin's work means accurate roadworks information is now available from a single point for onward use. Adding GLOSA to this approach would make a critical mass of data available which could exploit these existing channels and assist highway authorities to share more data with service providers.

This could be exploited quickly if the following happen to connect the chain:

- There is a single point of access for high-quality SPaT and MAP data **from enough road operators,** as road operators are the only reliable source of traffic light data. This may in the first instance be for freight routes, where the business case may be clearer as a first niche, subject to local policies.
- Work is done to explore how to deliver this data to the driver safely via existing devices such as smartphones linked to head units, in-cab fleet management units or by voice, through integration with satnav, parking and other road-related apps**.** **In-vehicle service suppliers, the freight industry, and bodies such as the Fleet Operator Recognition Scheme (FORS) are best placed to do this.**
- The safety work undertaken provides for **GPS positioning inaccuracy** by combining clear advice for multiple lanes, and the driver then **follows appropriate advice** for the lane in question.
- The service and data that support it is **thoroughly consumer tested to gain trust from the user.**
- **Existing mobile communications** are used for data transmission.

This is shown in Figure 4.3.

Figure 4.3: Workaround for GLOSA at niche sites for niche users and actions required



Source: Author's analysis

5. Service 3: Asset Management

5.1 The opportunity

The physical highway assets – such as bridges and other structures, the road and footway pavement itself, signs, road markings, white lines 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, 2018b :21), meaning that even a small saving through the active use of better data in the connected chain would be a useful cashable benefit.

The condition of the roads is a key issue for authorities and drivers alike. However, the longer-term management of their condition is increasingly the focus for highway authorities, often driven by funding models. Drivers' concerns, on the other hand, are for the most part focused on immediate road condition (and typically on potholes in particular).

Traditionally, roads assets have been surveyed periodically using specialised equipment and/or staff, to develop a time-based picture of their condition, in order to then identify needs for maintenance and to plan future interventions. Data from these regular surveys is used in asset management systems to plan works and track the status of the asset, and to support modelling of deterioration.

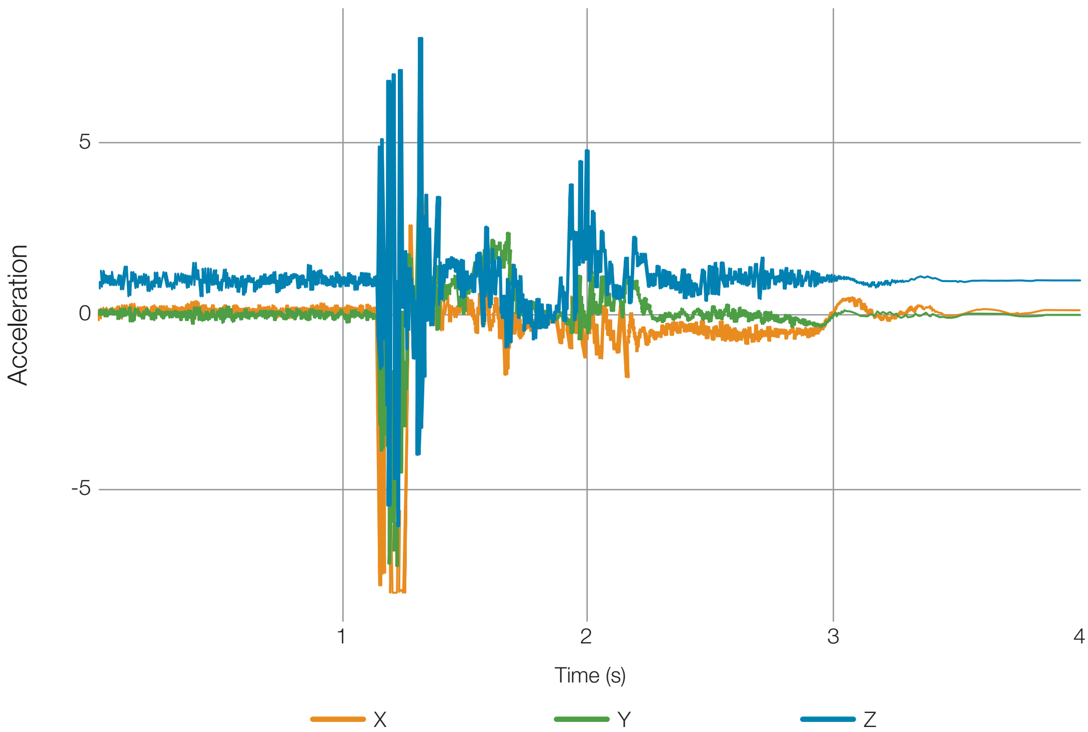
There is increasing interest in the use of vehicle data to help understand both current highway condition and the nature of longer-term deterioration, whether driven by road usage or external environmental impacts, such as extreme weather events. Consequently, various projects have started to explore use of data from vehicles as an adjunct to these surveys, or even to replace them potentially.

The take-up of digitisation through connected data and intelligence could potentially drive productivity improvements, and bring about improvements in the condition of the network and assets, but only if the existing systemic contractual and cultural problems which 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 costs down and productivity up in this field, using the power of connected vehicle data.

5.2 What asset management looks like to the driver

In contrast to the situation with GLOSA and IVS, drivers do not need to do anything when it comes to asset management. Data can be harvested without their intervention from vehicles in a way similar to that in which data can be used to improve traffic lights as described in Chapter 6. Figure 5.1 shows the green data spike in up/down movement from a PAYGI device made on crossing a road defect like a pothole.

Figure 5.1: Road defect data from PAYGI devices



Source: Pay as you go insurance provider.
Note: The blue spike shows up-and-down vehicle accelerations resulting from a road defect.

5.3 The outcomes

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 vehicles or drivers, or via smartphones.
- **Reducing the delay in existing surveys** – with surveys often up to a year apart, vehicle data might reduce the time between observation and intervention. 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).
- **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 plan better network changes, thereby reducing congestion, pollution and even the impact upon roads assets themselves (so reducing maintenance).

The final benefit here 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 to provide longer-term improvement of overall network and individual asset condition. 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.

5.4 The current status

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 several suppliers such as Vaisala (Vaisala, 2020), for signs and pothole surveys, but is also being used, for example, to detect impacts on assets of construction traffic. The number of potential suppliers is growing (Hutton, 2020b).
- **Accelerometer data from insurance devices**, used to detect road defects in Birmingham in the Enhanced Continuous Asset Monitoring Solution project (TTF, 2020).

- **Data from Jaguar Land Rover vehicles' suspension** used to detect road defects in Coventry (JLR, 2015).
- **Data from the fleet management systems in freight and service vehicles**, used to examine weight profiles of goods vehicles, turning movements etc., and changes in-road geometry.
- **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 highway authority 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).

Some work has been undertaken as part of the Association of Directors of Environment, Economy, Planning and Transport (ADEPT) series of Smart Places projects (ADEPT, 2019).

The driving forces for adopting this new data include:

- Reduced cost of data capture.
- More frequent updates of data – a shift from often yearly when done by surveys to almost real time.
- Larger data coverage (expansion of the number of data points).
- Providing continuous data, linked with analysis, to identify degradation and rapid change.
- Giving secondary evidence, complementing, and targeting professional surveys.
- Creating more opportunities for targeted/early interventions.

The landscape of developing new data sources, and the potential for high cash savings from using that data, therefore suggests that larger-scale adoption ought by now to be emerging. Unfortunately, though, asset management has been the Cinderella of the connected and automated vehicle world, because it is:

- Not a service in the European Commission's 'year 1 and year 1.5' Co-Operative ITS services.
- Not as attractive a media story as the self-driving automated car.
- Of little interest to vehicle makers, as it offers no immediate benefit to their customers.
- Often the responsibility of different departments in highway authorities and government from the mainstream connected vehicle and data projects.
- Difficult to integrate, as many local highway authorities use different proprietary platforms and approaches, and there is no single way as yet to pull all of this information together onto a single integrated platform across different departments.

Also, in some cases new technology sensors have been repurposed from other original designs for asset management by suppliers, perhaps without full knowledge of the data chain. Artificial intelligence and big data approaches have also been applied by new players entering the industry, but sometimes without a rounded understanding of the needs of customers. This has led to some expectations of the new technology remaining unmet.

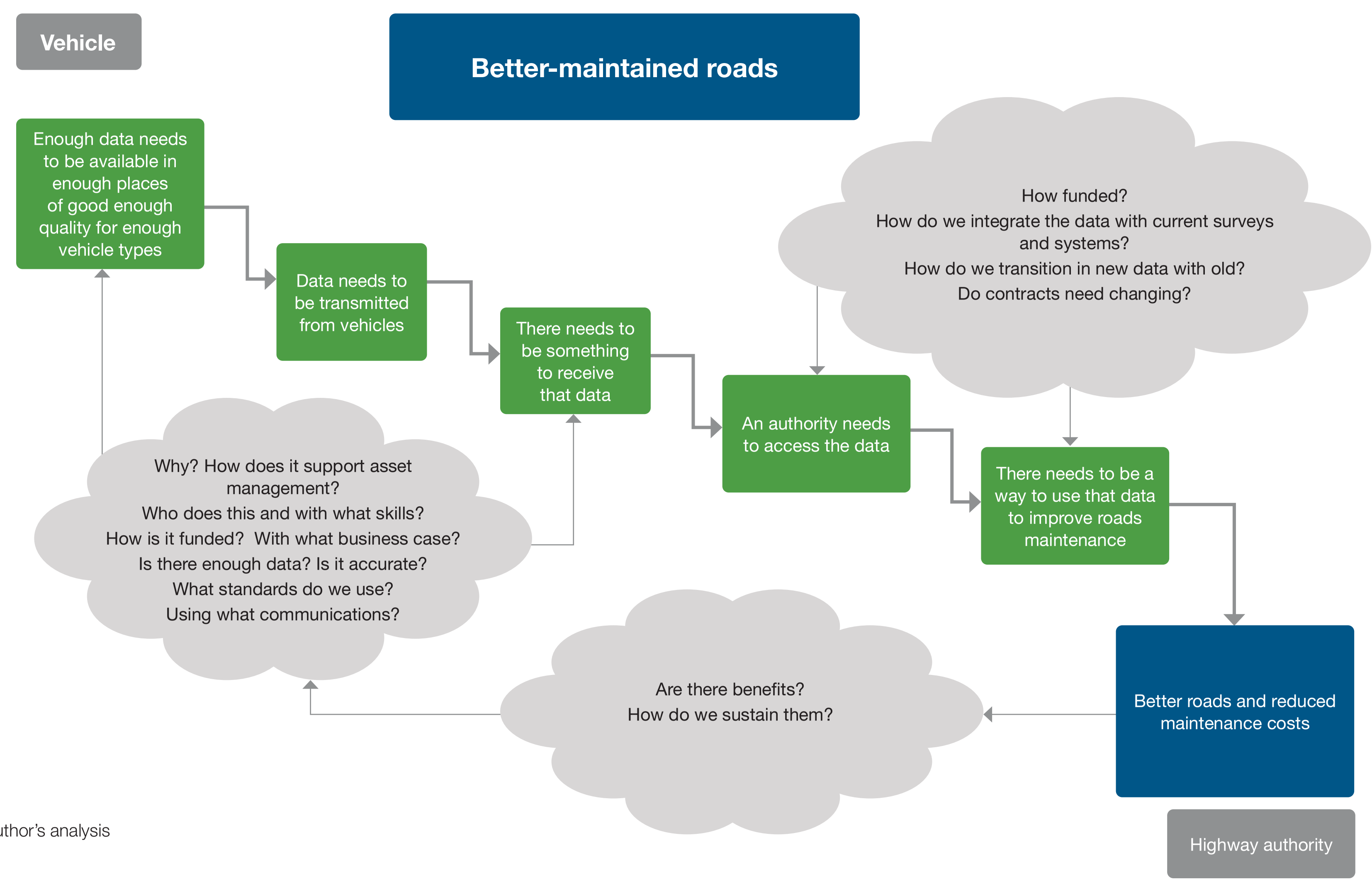
However, even if the factors above were not the case, many other factors have contributed to this inertia, as is now examined.

5.5 What needs to happen

5.5.1 The basic premise

The connected chain from the vehicle to the highway authority in the process of improving the road asset is shown in Figure 5.2.

Figure 5.2: Making roads better using vehicle data – the basic premise



Source: Author's analysis

The basic connected data chain consists of:

- Collecting enough data from enough vehicles at sufficiently good quality for enough roads.
- Transmitting it from those vehicles.
- Somebody or something receiving that data.
- A highway authority wanting/needing to access that data.
- This data being used by the authority to improve highway maintenance in their day-to-day work.

The swim lane chart in Appendix 3 examines these steps in much more detail, adding softer feasibility and business case aspects as well as evaluation, to show the full lifecycle. It breaks them down into the elements that are needed, and identifies ‘things that need to happen’ where there are gaps to fill.

These gaps are now discussed in turn, with actions to address them that are already underway shown in italics.

5.5.2 Gaps for the highway authority

The strategic gap and the funding gap

As is the case with other services, a UK-wide plan and strategy would avoid uncoordinated activity and maximise value for money.

This is already being developed by DfT.

The benchmarking gap

Without an agreed methodology for measuring asset performance which allows comparison against achievable levels, many different solutions and approaches could develop, increasing costs and reducing uptake.

There are already many ways for measuring asset performance across different authorities, so adding connected vehicle datasets could make this worse.

The connected chain should combine existing and connected vehicle datasets to make best use of what is there already. This could involve a move to fully risk-based data-driven asset management.

The understanding gap

Unless there is a better understanding of how connected vehicle data could be used to support asset management, traditional approaches will remain the only chosen option, thus reducing benefits from connecting the chain.

Asset management and traffic teams often work separately within highway authorities, and there is a lack of understanding of the potential for connected vehicle data to support asset management. There is also currently little real evidence of at-scale benefits. As a result of consistent under-resourcing, many authorities have become purely reactive and have lost the capacity for strategic innovation in asset management – and, therefore, the ability to do anything other than 'make do and mend'. This is potentially a genuinely lost opportunity for change.

Achievement of this goal could be assisted by sharing information between the TTF, the Highways Sector Council and the Local Council Roads Innovation Group (LCRIG), and by further evaluation and promotion of benefits from the connected chain.

The skills gap

Without a better understanding of how to combine datasets from vehicles with existing surveys to push forward improvement, the chain will not be connected and existing datasets will prevail.

An authority must have access to the skills needed to specify and procure data (unless it is collected centrally). Highway authority staff will need to learn about new technology and business cases for asset management. Authorities need also to understand the potential range of data that may become available and its possible sources.

Future output information should be in the same format as that which is used now, because highway authorities will still need to use existing data and platforms. Using new data combined with old sources and added skills should, however, help to catalyse a change and engender a refreshed appetite, once the data becomes trusted to generate 'what if?' and 'can I?' questions.

Highways sector best-practice groups such as the Highways Sector Council, LCRIG and the Future Highways Research Group (FHRG) should promote this within highway authorities. This would help understand the data relating to new technology and its potential to expand/support effective and improved asset management. Training is needed from industry as well. New providers also need to understand current requirements, and to build in further compatibility with current solutions and the adoption of new data by current equipment.

5.5.3 Gaps in the data

The data gap

Unless the volume of data by time and coverage is increased, the best possible business case and best possible advantage over current tools may not emerge to complete the connected chain.

Data service providers and vehicle makers will need to see a business case. Retrofit devices can be used if vehicle makers are not able to provide data. This is probably a sensible workaround, as the data can be contained and managed locally in the first instance.

The standards gap

Unlike the situation with GLOSA and IVS, when it comes to asset management there is no standard for data *from* the vehicle, only *to* it. Without such as standard there will be many different interpretations of the road condition, and no standard method for comparison – reducing the value of the connected chain.

There should therefore be **a standard for data emerging from vehicles' on-board sensors to include asset management.** SENSORIS (2020) is a group of organisations that sets standards for technical requirements of data gathered by vehicle sensors. It has created an industry specification that should be reviewed more widely by the asset management industry, especially in terms ensuring it includes data for asset management.

Further research is needed into what data can be extracted, and how this can be related to traditional asset management data and asset management systems. The results might be important given the proliferation of smartphone apps aiming to present accurate road condition information.

The 'not just cars' gap

Unless data is available for more than cars and freight vehicles alone, the full maintenance benefits may not be gained, and new forms of travel might be disadvantaged as a result of a data chain that is not fully connected. Maintenance of cycle lanes and routes would not benefit from the connected chain.

Solutions are needed for cycleways and footpaths as well as roads, or from cycle head cameras, and other devices. Devon County Council has already started to use data from Strava (a fitness-tracking and social media app designed for runners and cyclists) (Clark, 2020) to identify well-used cycle routes in order to prioritise maintenance.

This is an ideal area for innovation and ideas reflecting the emerging post-COVID-19 changes in transport. DfT should include, as part of its strategy, non-car data, especially from vulnerable road users and public transport vehicles, and seed-fund new developments.

The provenance gap

Unless new sources of data retain or exceed the level of provenance and confidence inherent in current data, highway authorities will not change their systems and processes to use new data, reducing cost savings from the connected chain. Data from vehicles must be of good quality, timely, resilient, secure and reliable. It should also be easily available to users.

Data from commercial suppliers needs to be easy to procure at a national level, and data from both roadside and vehicle sources must be mutually compatible and of suitable accuracy and granularity.

The business model gap

Without a business model, data providers will not generate sustainable revenues. They are therefore likely not to make the data available – or may make it available, but at too high a cost, so the connected chain will not be complete.

Procurement may need to move to a service-based model or national approach, and economies of scale need to be developed.

The communications coverage gap

Without confidence in the coverage of the communications channel from the vehicle, practitioners might not have confidence in new data sources. They might therefore choose not to use them, leaving the data chain incomplete.

Unlike GLOSA and IVS, only cellular communications can currently support asset management data from vehicles. 4G so-called 'notspots' (where there is no (4G) signal) may need addressing, or as an alternative data could be stored in the vehicle. Highway authority communications networks may need to be enhanced to cope with the volume of data, especially image data.

The installation gap

Unless enough vehicles have appropriate devices fitted for collecting asset management data, there will not be enough coverage or quantity of data to complement current survey approaches and connect the chain.

Currently, data is available via dashcam, smartphone and PAYGI devices but there must also be enough added value to warrant vehicle makers also fitting devices, or using software to access existing devices in vehicles.

More vehicle makers and data providers need to be aware of the opportunity to provide asset management data, but there also needs to be enough uptake on the part of customers.

The business case gap

Without a clear business case, suppliers of asset management systems will not invest in the adoption of connected data to allow more features, and the benefits from connecting the chain will be lost.

At the moment, only a few asset management system suppliers are able to ingest data from vehicles into survey systems, as there is no standard feed of data and no customer pull.

A standardised licensing agreement would be helpful to clarify the permitted uses of the data, what data, what coverage, quality and so on. Bulk (national) purchase could also be cost-effective.

5.5.4 Gaps in asset management use

The knowledge gap

Unless highway authority staff learn how to securely integrate, operate and maintain newly upgraded systems using connected vehicle data, the data will not in practice be used and the chain will be left incomplete.

Even if systems are upgraded, authority staff will need training in how to use them and how to maximise the value from new datasets.

Training is needed for highway authority staff, once the systems and processes are defined.

The transition gap

Without a way of combining existing survey data with new event-based vehicle data, highway authorities will continue with time-based processes and systems, and again the new data will not be used in practice, and so the chain will not be complete.

New solutions may be needed for asset management systems. If data is supplied continuously, this creates the opportunity for undertaking much earlier interventions (such as repairs), but research on the processes which will be used to achieve this is needed. Also, ways to integrate large-volume crowd-sourced data with appropriate levels of confidence need to be found, to augment existing asset management systems and well-developed strategies using these forms of data. The findings from the CONVERT project have already identified solutions, including:

- Technology to aggregate and display asset condition information, including real-time data from a range of disparate sources.
- The development of exception condition reporting from connected vehicles – to report only when something of interest is found (a roadside sign is missing) rather than all the data.
- The development of a better contractual and incentivisation mechanism for asset maintenance suppliers, to ‘nudge’ them into beginning their own adoption of digital methods and bring innovation into their operations and their material solutions, and to enter into partnership with the highway authority more effectively.

Good approaches for fitting and matching data will be required, and these need to be integrated into commercially available asset management systems software.

The contracts gap

Unless asset management service providers are motivated to complete the connected chain and use the data directly, they will continue with 'business as usual'.

Both highway authorities and maintenance contractors need to be challenged to produce better long-term outcomes from less resource. This is because the supply-side culture in highway maintenance is relatively low-tech, and the bulk of activities are paid for by the amount of resource spent carrying them out. Hence contracts are heavily influenced by cost and margin considerations. This means that innovation will not be easy to achieve unless the need for contractual, commercial and cultural change is recognised.

Highway authorities need to be encouraged, or even required, to share data across all agencies involved in the maintenance and operation of highways, including utility contractors. There are already examples of data-driven maintenance being used effectively across different authorities, but these need wider deployment.

> *Contracts and penalty/bonus mechanisms need to be changed to reward those connecting the chain.*

5.5.5 Other gaps

The evaluation gap and the sustainability gap

These gaps are the same in essence as for previous two services, centring on evaluation, feedback, maintenance and training.

5.6 A way forward

Clearly, the main actions necessary for exploiting the connected vehicle data chain are at the authority user end, but as is the case throughout this report, the whole data chain must be at the same level.

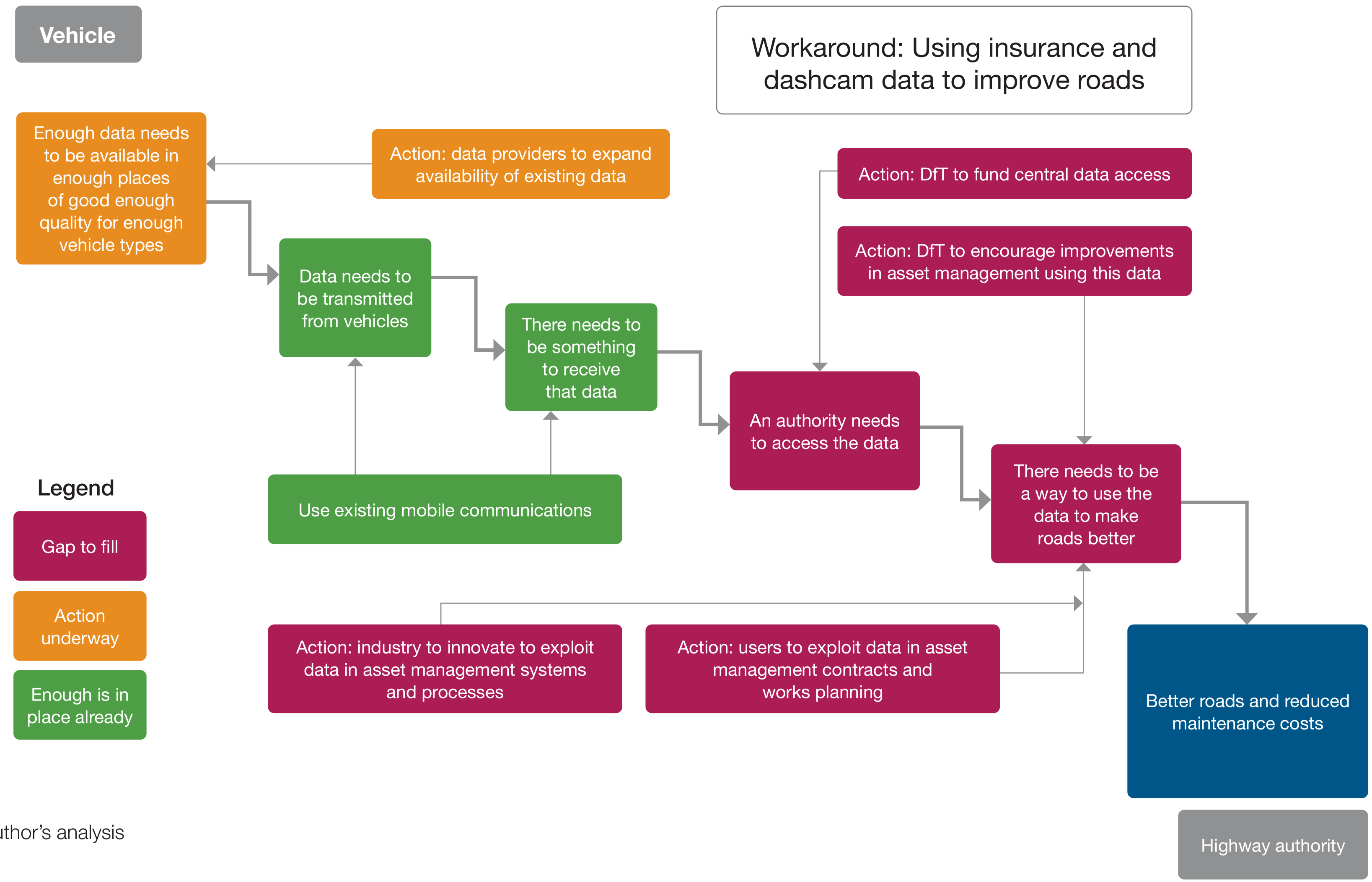
There is, however, a 'chicken and egg' situation here – data providers will not want to publish data without demand for it from users, but without data to test so as to build confidence, there will be no interest shown by asset management users.

Hence a way forward is for:

- The best use to be made of existing data sources from dashcams, apps and PAYGI devices.
- Use to made of existing mobile data communications to extract it from the vehicle.
- DfT to fund central access to this data for highway authorities and encourage improvements in its use.
- Industry to develop new back-office systems and processes to exploit the data, potentially within new contract approaches.

This workaround approach is shown in Figure 5.3.

Figure 5.3: Workaround for better road asset management and actions required



Source: Author's analysis

6. Service 4: Improving Traffic Light Timings

6.1 The opportunity

Traffic lights traditionally use physical sensors as inputs into control systems. These range from inductive loops in the road itself, through magnetometers and radars, to new CCTV image-processing tracking approaches. These are all roadside devices, needing to be installed and maintained.

These sensors are costly to maintain for authorities short of revenue funds. Work by the TTF showed that as many of half the sensors in a system may at any time not be working (TTF, 2020). 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 with these systems.

The TTF estimated that this could bring benefits of worth £400 million annually, from safeguarding the performance of existing tools and developing new ways to reduce congestion (TTF, 2018b :13).

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

Performance is often measured in terms of reduced delay, but this is not the only objective of traffic lights. Authorities may choose to favour walking and cycling (especially post-COVID-19), reduce emissions, favour key routes or vehicles, or throttle back sensitive routes – all through traffic light settings. Irrespective of the policy objective, the quality of sensor input when setting up traffic lights, monitoring, operating and maintaining them is key to delivering it.

As an alternative to roadside sensor data, or to augment it, Floating Vehicle Data (FVD) has been available from many sources for some time. In FVD, a device in the vehicle (such as a fleet management unit, a PAYGI device, a satnav or a smartphone running an app) collects data on GPS locations as often as 20 times per second and then sends this data by means of mobile data communications to a central point. The data is then processed for anonymity and data quality, and used for journey time monitoring, and determining origin and destination matrices. Data sourced from mobile phone operators can also be used for these use cases but it comes with less fidelity, albeit large 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 across networks. Until recently, it was not possible to access individual vehicle GPS traces, although this is now opening up. New forms of data, for example vehicle weight, are also becoming available in these feeds, as well as data from the vehicle itself like braking and other telemetry.

At the same time, work has progressed in the Co-operative Intelligent Transport Systems (C-ITS) arena in terms of data sent from vehicles to roadside infrastructure (beacons) from dedicated on-board units via the European Telecommunications Standards Institute standard for a 'Co-operative Awareness Message'. This locates a vehicle, again using GPS, but this time data is sent to the beacon, and then consolidated to a central service. This 'probe data' approach can be used to provide services such as GLOSA (examined previously) and for vehicle priority at traffic lights.

Both commercial and C-ITS data from vehicles offer authorities a way of going beyond the restoring of traffic lights back to the level of performance they were designed for, 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.

This fundamental difference between data types – that is, between vehicle-based data (irrespective of whether C-ITS or commercial) and that obtained by sensors – is a key barrier to adoption. This is because it requires re-engineering existing systems originally designed for sensor-based systems to exploit vehicle data. This is not the only barrier, and there are relatively quick-to-implement approaches already being tested, ones that exploit data that is available today.

6.2 What improving traffic light timings looks like to the driver

From the driver perspective, the evident difference would be improved traffic lights – for example less wasted green time and shorter queues or delays. 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 software and devices originally meant for 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 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.

6.3 The outcomes

Initial work has shown the following outcomes from connecting vehicles with traffic lights (Wood, Wall and Sanger, 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.

6.4 The current status

Several projects have already explored the use of FVD in traffic light control. The Eboracum project from City of York Council (CoYC, 2019) reduced congestion, to an extent perhaps equal to that expected from installing SCOOT, by changing traffic light timing plans when vehicle data suggests that journey times are increasing. The project identified the scale of benefits of using connected data for traffic lights, and then tested very simple strategies using FVD-derived journey times to change traffic light plans.

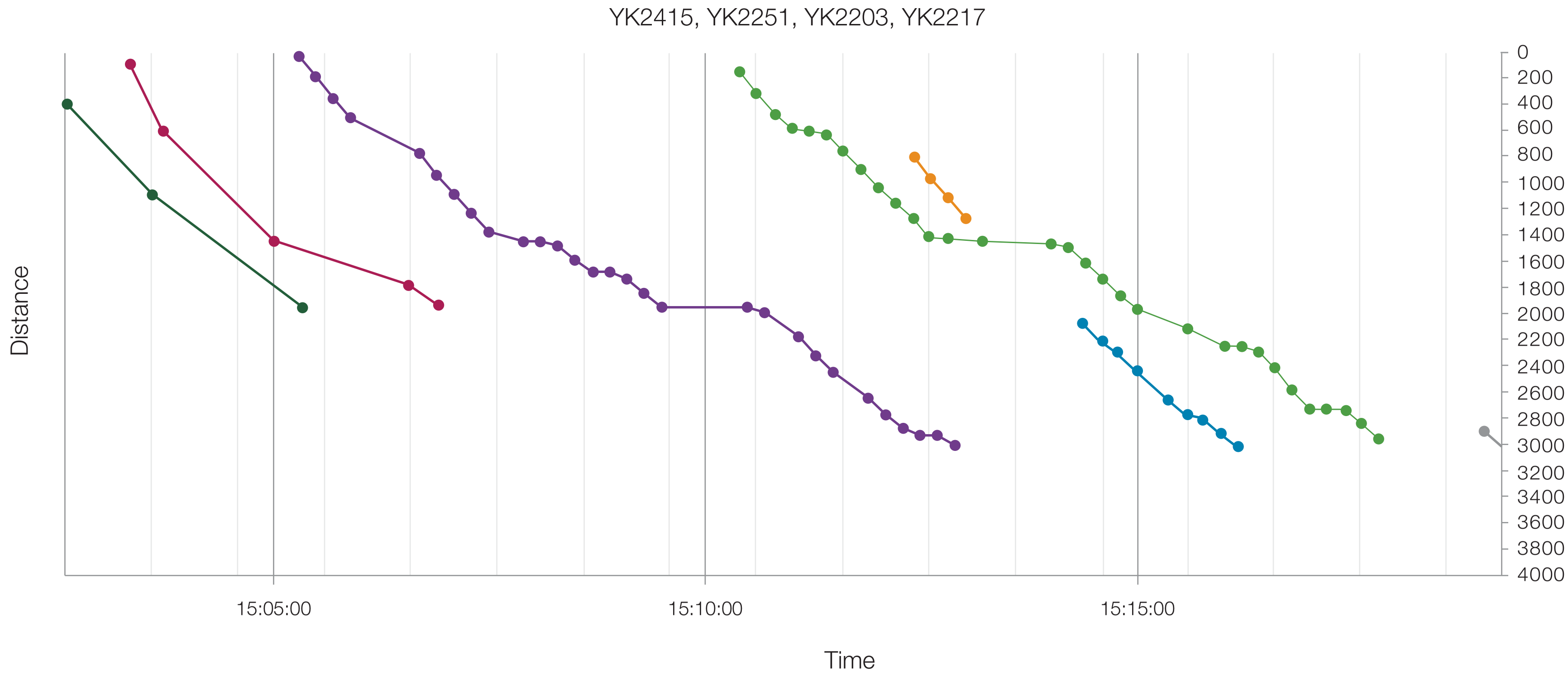
INRIX has developed a concept called 'signal paths', which explores the use of individual vehicle data to historically monitor traffic light performance. They are now exploring how to make this into a product through a DfT-funded project (GOV.UK, 2020). This tool would help to identify which traffic lights are performing badly, aiding in the prioritisation of maintenance resources.

Further research work in the USA and the Netherlands (Blokpoel & Turksma, 2014; Li, Day & Bullock, 2016) has shown the potential benefit of extending this to include the use of data for real-time control. By making use of the advantages of FVD, this has yielded promising results that go beyond those possible from merely making existing traffic lights work as they were designed to, using fixed sensors.

Figure 6.1 shows the progression in time (on the x-axis) of vehicles located using GPS and tracked on the A59 into York (with distance as y-axis). This was examined by INRIX as part of their DfT-funded Traffic Signal Adviser Service Project (DfT, 2019). The straighter the line, the better the progression of vehicles through the junction (as there is less slowing down and speeding up).

Where the line flattens out, this is due to a vehicle being stationary for some time at traffic lights. By adding multiple traces over several days of many vehicles, the performance of the traffic lights can be assessed and tuned, offline. This is the first step in using this sort of data in real time.

Figure 6.1: INRIX FVD used to monitor traffic light performance (A59 into York)



Source: INRIX Path Project

6.5 What needs to happen

6.5.1 The basic premise

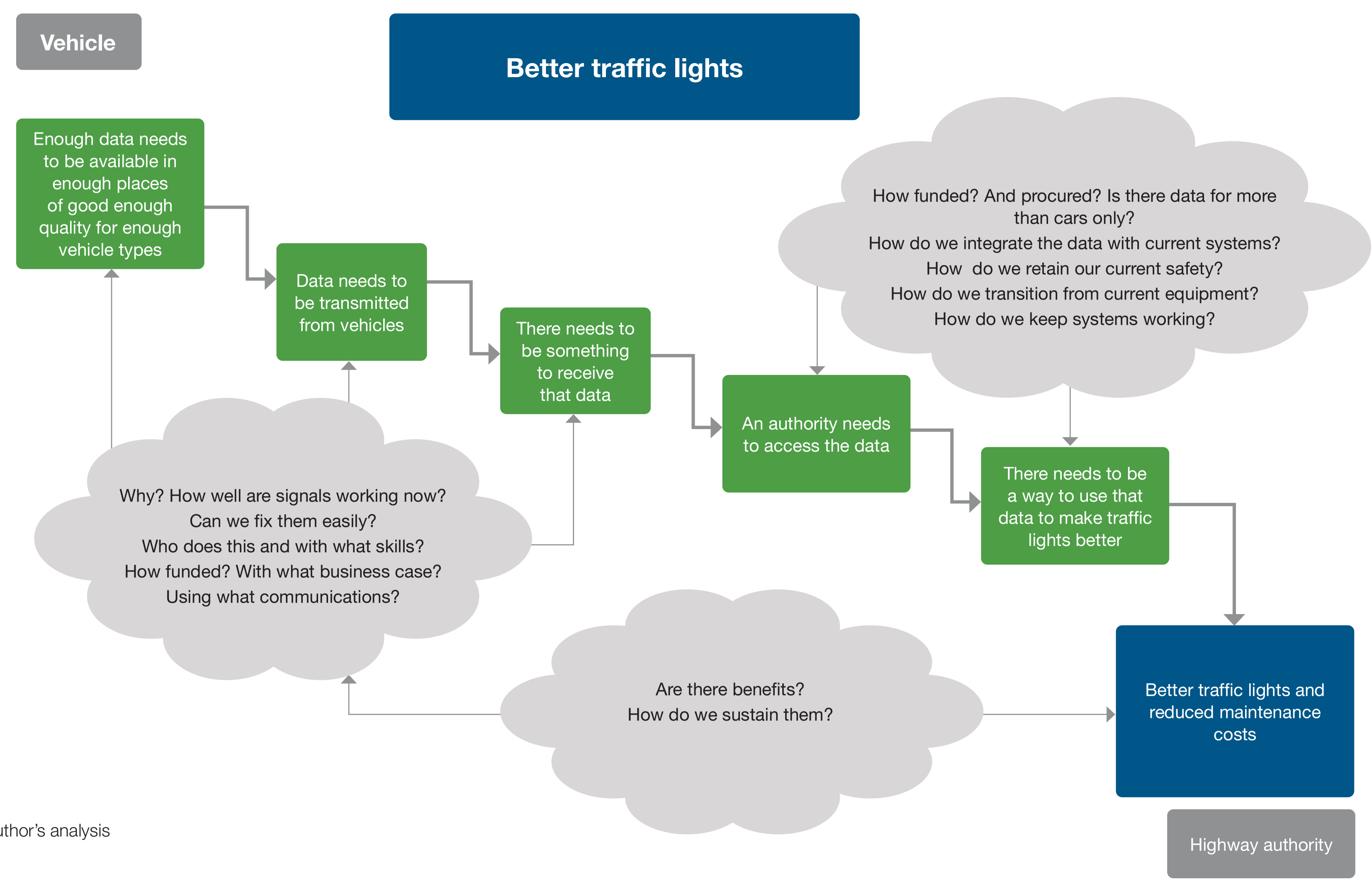
The basic data flow for the connected chain is shown in Figure 6.2, and consists of:

- Collecting enough data from enough vehicles at sufficiently good quality for enough roads.
- Transmitting it from those vehicles.
- Somebody or something receiving that data.
- A highway authority wanting/needing to access that data.
- This data being used by the authority to set traffic lights more optimally.

The 'swim lane chart' in Appendix 4 examines these in much more detail. As for previous services, it breaks them down into the elements that are needed, and identifies 'things that need to happen' where there are gaps to fill. These gaps are now discussed in turn, with actions to address them that are already underway shown in italics.

Because use of vehicle data can piggyback on other services like GLOSA, some of the same gaps occur as for previous services. These have been abbreviated where necessary.

Figure 6.2: Making traffic lights better – the basic premise



Source: Author's analysis

6.5.2 Gaps for the highway authority

The strategic gap

This gap is the same in essence as for the other services.

The signals benchmarking gap

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 traffic light performance. Highway authorities need to know what needs fixing and how far to go.

However, this might be achieved with commercially available historic FVD before real-time control is considered. The policy balance between vehicle and personal mobility within an authority will inform the need for other datasets (for example, as well as vehicle datasets, also those relating to cyclists and pedestrians). There may need to be a combination of new roadside sensor technologies, such as image-processing, with connected vehicle data.

> *Agreed methodologies for measuring junction performance would allow comparison against achievable levels, and help in determining the minimum work (and minimum data) needed to regain and then exceed prior performance levels.*

The funding gap

This gap is the same in essence as for the other services.

The reliability gap

Unless basic traffic equipment is working reliably and 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.

Work by the TTF (TTF, 2020) revealed the pressures on UK local authority skills and resources resulting from the need to simply make the most of what is currently there in terms of traffic lights.

> *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 that efforts can be prioritised.*

The understanding gap

Without a better understanding of data availability and its information content on the part of owners of the traffic control equipment and data sources, there will be no demand for connecting the chain. Hence the data would remain unused and the benefits reduced.

This could be achieved by bodies such as the TTF. Education and enhancing understanding of new opportunities, and how to transition from what is there already, should draw on business case evidence and previously proven and emerging evidence of benefits.

> *To allow more sophisticated control approaches to connect the chain, systems need to be able to exploit the richness of vehicle data directly. Industry would need to continue to develop better control approaches, unify standards for commercial FVD and for newer sensor technologies, and test them to show their various merits when compared with traditional methods, to inform business cases for procurement.*
>
> *Control strategies need to be able to use this available (and potential) data to best effect.*

The skills gap

This gap is the same in essence as for the other services.

6.5.3 Gaps in the data

The data gap

As with other services, without more granular data by time, and more complete data by geographical coverage, the chain may not be fully connected.

> *Data service providers will need to be convinced of a business case. Retrofit devices can also be used if vehicle makers are not able to provide data. Industry should continue to harvest existing FVD, as use of C-ITS beacon-based approaches may be limited to only newer vehicles. For real-time control, however, the speed of delivery of the data to and from the vehicle becomes important. Again, without a clear business case for investment in speeding up data, this could become a barrier.*

The 'not just cars' gap

> *As with other services, connected data from cyclists will be important for improving traffic lights for all users in the connected chain too.*

The provenance gap

Unless data is of good quality, timely, resilient, secure and reliable, and is actually available to users, the chain will be not connected.

Data from commercial suppliers must be easy to procure at a national level.

The business model gap

Without a clear business model, current data providers will provide separate feeds to each highway authority, adding costs and complexity.

Currently, GPS data from vehicles is procured piecemeal by each highway authority. This represents a barrier to connecting the chain.

As with asset management, a single national contract for data from several suppliers would encourage take-up as it would ease procurement and reduce costs.

The communications standards gap

This gap is the same in essence as for the other services.

Additionally, unless data from both roadside and vehicle sources is mutually compatible to help new control strategies to be adopted with existing equipment, users will wait for the vehicle fleet to upgrade, delaying the benefits from connecting the chain. For offline use, existing mobile data is good enough.

Unless practitioners gain confidence in the future communications channel from the vehicle, they will not deploy new technology, so breaking the connected chain. The suitability of cellular approaches for delivering the timeliness needed for real-time control should be explored.

As with other cases, the choice of cellular or ITS-G5 communications would help in decision-making about roadside versus cellular investment. However, much can still be done with existing communications. In either case, data must be complete enough, and sent rapidly enough, for traffic light use. Alternatively, systems must have a tolerance built into them to accommodate shortcomings or delay in the data.

The communications coverage gap and the installation gap

These gaps are the same in essence as for the other services.

6.5.4 Gaps in the use of the data

The innovation gap and the business case gap

As with other services, 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.

Current traffic light equipment manufacturers and data providers need to find a business model that evidences better revenues from making the change than from continuing with the current situation.

> *Procurement may need to move to a service-based model in which entire end-to-end services, including connected vehicle data, are delivered – rather than piecemeal investment. This should assess the whole-life cost implications of bringing in innovation to replace legacy equipment that is hard to maintain.*

The signal safety gap

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.

> *Registration of services through bodies such as TOPAS would assist safeguarding.*

The learning gap

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.

> *Training is needed from industry. New providers also need to understand current requirements and build in compatibility with current solutions, and adoption of new algorithms by current equipment.*

The transition gap

Unless new sources can assist with easy transition from existing equipment, users will continue with existing systems and the benefits from the connected chain will be lost.

There are over 33,000 traffic light sites in the UK, and they cannot all be changed overnight. Authorities' investments need to be safeguarded by having a modular approach to adding additional data.

> *More work is needed on how to transition from existing systems.*

6.5.5 Other gaps

The evaluation gap and the sustainability gap

These gaps are the same in essence as for the other services.

6.6 A way forward

Because using vehicle data for improving traffic lights can piggyback on other services such as GLOSA, and the data is becoming more widely available, there is an opportunity to connect the chain, to:

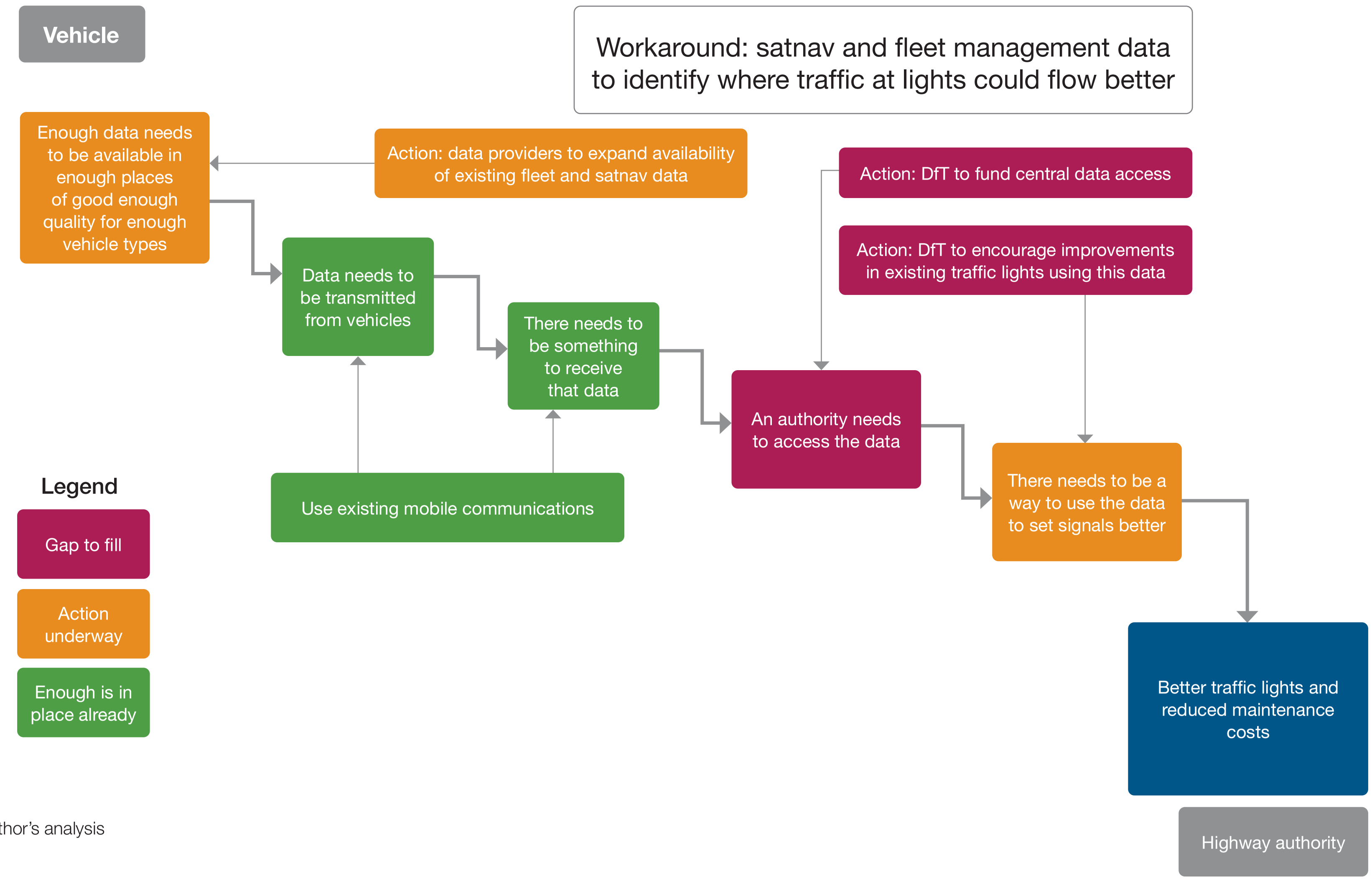
- Use data that already exists to help traffic lights improve, by identifying problems offline so that they can be fixed. This will help to combine evidence gathered both pre- and post- installation calibration, compare the design and actual performance of newly installed sites, and ensure that different authorities assess their asset by means of a unified approach.
- Subsequently, make a move to connected vehicle data and physical sensor hybrid systems. For this:
  - to encourage early uptake, new players with roadside sensors and connected vehicle data may need to simplify their offerings to be compatible with existing traffic systems;
  - this may combine the best advantages of different approaches – for example video processing can classify all vehicles at a point (e.g. to identify cyclists), but FVD can identify the movement of that vehicle before and after a single point;
  - data from buses, for example, might include lateness and occupancy statistics; and
  - as well as receiving GLOSA messages on the approach to traffic lights, HGVs could be given priority, especially late at night on motorway junctions.
- Then, ultimately, move to 'naked roads' – using just data from vehicles. Including GLOSA and IVS in this might enable the building of platoons of connected (and later automated) vehicles.

The diagram in Figure 6.3 shows a workaround to allow the first of these steps to occur to connect the chain. In this workaround:

- Some data providers need to further expand their services so that the granular data needed for traffic light control is more easily available.
- DfT should fund central access to this data and encourage authorities to adopt it, to identify where to make existing traffic lights better.

Work is underway already on tools to support this.

Figure 6.3: Workaround for better traffic light performance and actions required



Source: Author's analysis

7. Conclusions and Implications

7.1 Conclusions and common features

This report has found the gaps preventing at-scale deployment, demonstrated how they can be bridged, and shown the need for someone to see a reason to bridge them. It has also shown that:

- There is no single action capable of making any of the services happen. Actions are needed to fill gaps in many areas, although often these gaps and actions are the same across the services.
- Some gaps are common to all the services, and thus lead to common solutions including:
  - a national strategy and means of funding connected vehicle data use;
  - a clear business case for deployment for both the highway authority and suppliers;
  - a better understanding of the opportunity and skills needed for developing connected vehicle data;
  - improvements in data availability, granularity and coverage by vehicle type, and the need for devices or software to be installed in vehicles, and then used and trusted;

    - clarity about the communications to and from vehicles – although for most applications existing mobile data is good enough;
    - easy access and procurement of data from a single central point;
    - innovation to allow easy transition from existing systems and processes, and provision for training staff in how to use them; and
    - evaluating the impacts of early deployments and sustaining their use.
- Some gaps are specific to services, for example improving the safety of in-vehicle displays, and the need to modify road maintenance contracts to motivate industry to adopt the data.
- In many cases, services can integrate and piggyback on one another – for example, Green Light Optimal Speed Advisory (GLOSA) systems can work with In-Vehicle Signage (IVS) and provide data to set traffic lights better.
- There is no single owner for all the above actions – the data chain requires connection from the vehicle to or from the highway authority by more than one body.
- Most gaps are not technology based, but organisational, institutional, or arising from lack of training and awareness, or from procurement difficulties.
- Solutions could emerge using workarounds and making the most of existing deployments, notably cellular communications and the integration of services.

7.2 What does the driver see?

The driver experience is a key feature, and often a forgotten one. Services where the driver must take a direct action (for example, download, use and trust an app) have more links in connecting the chain than those in which data is harvested directly from the vehicle and then used by a highway authority.

Table 7.1 shows the four services, and the benefits for the road operator, the driver/vehicle operator, and the data provider / vehicle maker. It also shows the involvement of the driver where there is any. Green shows those areas where there is a clear benefit, whereas amber shows a less clear one. All the services have clear benefits for road operators, but the benefits for the driver or vehicle operator are less obvious, apart from softer factors such as better driver experience (although there is also evidence of a reduction in vehicle operating cost from GLOSA for commercial vehicles). This means an immediate risk to deployment – if drivers see little benefit, will they bother to adopt? These services are coloured red.

Hence those services – better traffic lights and better asset management – that need no action from the driver (because the data is harvested automatically and anonymously) are coloured blue and present less risk to deployment, as connecting the chain is easier. They can often piggyback on services like GLOSA if provided, but they do not depend on them.

Table 7.1: Comparison of benefits and actions for new services by driver activity

New service	Benefits for road operator	Benefits for driver/vehicle operator	Benefits for data provider / vehicle maker	Does driver need to do anything?
Better traffic lights	Reduced congestion and emissions / better alignment with new policies. Reduced maintenance costs. New ways to manage network. Support for automated vehicles.	Less queuing.	Revenue? The public good?	No, as data is harvested from vehicle / smartphones / pay-as-you-go insurance (PAYGI) devices. Could come from GLOSA and IVS if deployed together.
Better asset management	Cost savings for maintenance. Fewer claims for damage. Better planning of investment. Ability to receive more data from different sources.	Fewer road defects. Better ride quality. Fewer roadworks with congestion.	Revenue? The public good?	No, as data is harvested from vehicle / smartphones / PAYGI devices, or even a combined app including GLOSA, IVS and other services, for example smart parking, in which sensors in detect whether it is occupied, enabling drivers find a vacant spot.
In-Vehicle Signage (IVS)	Improved ability to warn drivers. Reduced costs of new equipment installation. Safety and congestion improved.	Safer journeys. Better journey experience.	Better journey experience leads to more revenue and better margin	Yes: driver must choose to buy/install service, turn it on and continue to act on it.
GLOSA	Reduced emissions of all types. Reduced road wear. Support for automated vehicles.	Reduced vehicle operating cost (especially for commercial vehicles). Smoother journeys. Better journey experience.	Better journey experience leads to more revenue and better margin	Yes: driver must choose to buy/install service, turn it on and continue to act on it.

Source: Author's Analysis

Note: Green – a clear benefit; amber – a benefit that is less clear; red – a risk of failure to deploy; blue – no action needed from driver

Table 7.2 shows a similar analysis, but of connected vehicle services – notably the eCall service and smarter parking – that have already deployed because the chain in their case is already complete. This makes for an interesting comparison with the illustrative services shown in Table 7.1.

Table 7.2: Comparison of benefits and actions for existing services

Deployed or emerging service	Benefits for road operator	Benefits for driver/vehicle operator	Benefits for data provider / vehicle maker	Does driver need to do anything?
eCall	Safety. Notification of incidents. More network intelligence.	Safety. Peace of mind. Lower insurance?	Safety. Increased sales. Ability to piggyback on other services.	No, as this is mandated by law; but effective use still needs more driver education.
Smart parking	Better space utilisation and longer stays. New ways to charge for parking. Reduced cost of collecting charges.	Better parking experience. Peace of mind re penalties and payment.	Revenue. Improved journey experience leading to more sales.	Yes: driver must download and use an app (but they may have to do this anyway to pay for parking with a less capable app).
Floating vehicle data	Managing congestion. Better planning of investment. Safety. Roadworks monitoring. Weather monitoring.	Better satnav routes.	Data sales revenue.	No, as data is collected anonymously and automatically.

Source: Author's analysis
Note: Green – a clear benefit; yellow – some action is required from the driver; blue – no action needed from driver

The eCall service is now providing voice connection to UK emergency services from vehicles type-approved since 2018. Prior to COVID-19, 5,000 calls per month were being received. Unfortunately, the rich connected data available from eCall has yet to be fully tapped into and explored for both historic and real-time use, despite several proposals for connecting the chain (Hutton, 2020a).

Smart parking (a system in which sensors in each parking space detect whether it is occupied, enabling drivers find a vacant spot) is becoming increasingly successful, as it offers clear benefits and a business case for connecting the whole chain. It does require drivers to download an app, but increasingly they would have to do this anyway, or at least use a phone to pay.

Floating vehicle data (FVD) is increasingly being used by roads authorities to augment or replace roads infrastructure for measuring journey times, and to provide movement data. Several data providers offer it as a service, often using the data from satnav devices, which is in turn improved by the probe data (see section 6.1) – there is a reason for drivers to fit these. No further action is required by the driver, and often data is sourced from fleet management, insurance and mobile phones as well.

There are therefore lessons here about what makes a successful connected service. There must be:

- Clear benefits to all users in connecting the chain, and thus a clear business case.
- As little driver action as possible outside what they would want to do anyway (for example for parking, or for navigation).

This means that not all services are equally easy to deploy, and highlights the fact that those involving the driver directly may need far more work to deploy quickly. The report now examines these workarounds.

7.3 The workarounds

The swim lane diagrams in the appendices examine the full engineering approach – to discover all the gaps in detail and find out how to fix them. This test was against providing the connected chain of services as originally envisaged, and across the network, and for all vehicles. This seeking of a 'perfect' solution has, to some extent, stifled lesser but more practical and easily implemented developments.

The report has, however, also shown workarounds, making the most of what is in place in niches that might yield the earliest benefits by focusing on 'good enough' services for 'enough' vehicles.

Examples are:

- **IVS for motorways**, to add additional information, especially in all-lane running sections of smart motorways, by working with satnav providers to lever off their penetration in existing vehicles.
- **GLOSA for heavily trafficked HGV routes**, for example to major construction sites and into cities, rather than citywide deployment (as is already happening to some extent) – this could be achieved via an app and provided alongside IVS, as much of the work is common to both.
- **Existing sources of data, such as dashcams and Pay As You Go Insurance (PAYGI), for asset management**, especially to maximise the efficient use of additional funds for pothole filling (implementation of this is now underway).
- **Existing FVD to identify those traffic lights where timings could be improved** – this would make the most of existing investment in traffic control, where the benefit has been lost through lack of resources; again, work is underway on this.

In all the above, mobile data communications are adequate for the connected chain, as none of the services should be safety-critical or replacing current technologies, but rather augmenting them. Work will be needed on branding, the human–machine interface, and education to ensure that users understand that these services for are for advice only, so that they do not regard them as replacing their driving responsibilities. Integrating these four services would offer a joined-up driver experience and new datasets – services could piggyback on one another well.

The question is therefore perhaps no longer just 'what needs to happen?' but also 'what needs to be made good enough?' to accelerate deployment.

7.4 Key actions

Appendices one to four detail all the actions needed for each of the four services, but below are actions shared by many of the services, often all of them. Filling these gaps would also deliver services that can piggyback on one another. Therefore, to maximise the benefit from connecting the chain, the calls to action shown in Table 7.3 would fill the gaps identified in this report and make services good enough at scale and at pace.

Table 7.3: Calls to action to fill gaps shared across many services

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
There will be piecemeal developments and a disconnected patchwork of services. No national business case to encourage investment beyond pilots – **the strategic gap**.	Department for Transport (DfT)	Define a UK-wide connected vehicle data strategy (already underway).	A clear plan of what services will develop, and how, when and why: this would help public and private investment in connecting the chain.
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.
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), FHRG (Future Highways Research Group)	Provide training for staff and national shared resources, for example in building MAP files for GLOSA and digital Traffic Regulation Orders. Encourage adoption of new data into authority use. Separate connected data from automated vehicles, needing different skills.	High-quality digitised data to support new services becomes available from highway authorities. Users see connected vehicle data as 'part of the day job', not a bolt-on. Cashable benefits to authorities from adopting new data.

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
Data is still stuck in silos 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 United Kingdom, LCRIG (Local Council Roads Innovation Group), FHRG	Explore new opportunities with data from vehicles to make roads better (already starting). Promote benefits of connection with vehicles (starting). Educate staff in use of new data across current silos.	A move from existing approaches of fixed sensors and time-based surveys, and transition to data from vehicles. New approaches to reduce congestion and cost are deployed and sustained, while ensuring that cyber security is addressed.
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.
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 emissions and safety.
There will be a disconnected patchwork of services and a missed opportunity to improve traffic lights and assets, as there is not enough 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.

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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 (underway).	Enabling maintenance of all assets, and allowing timing of traffic lights for cyclists as well as cars. Potential for GLOSA for cyclists.
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 a NAP (National Access Point) and in projects such as ConVEx.	UK-wide coverage and speedy adoption by current service providers of authority data.
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.
'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.
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.
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.

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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 roads maintenance.
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 for revenue to support its collection so clear measured benefits arise from its use.
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.
Safety problems emerge in the vehicle and distraction also causes a poor user experience – **the human–machine interface 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.
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, modify their behaviour, and so deliver improved safety, emissions and congestion.
Connected data will not have a clear 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.

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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.

Source: Author's analysis

Addressing each of these actions – 'things that need to happen' – would complete a workaround of the connected chain. It would generate enough momentum to give confidence in developing the more detailed and sophisticated versions of the service.

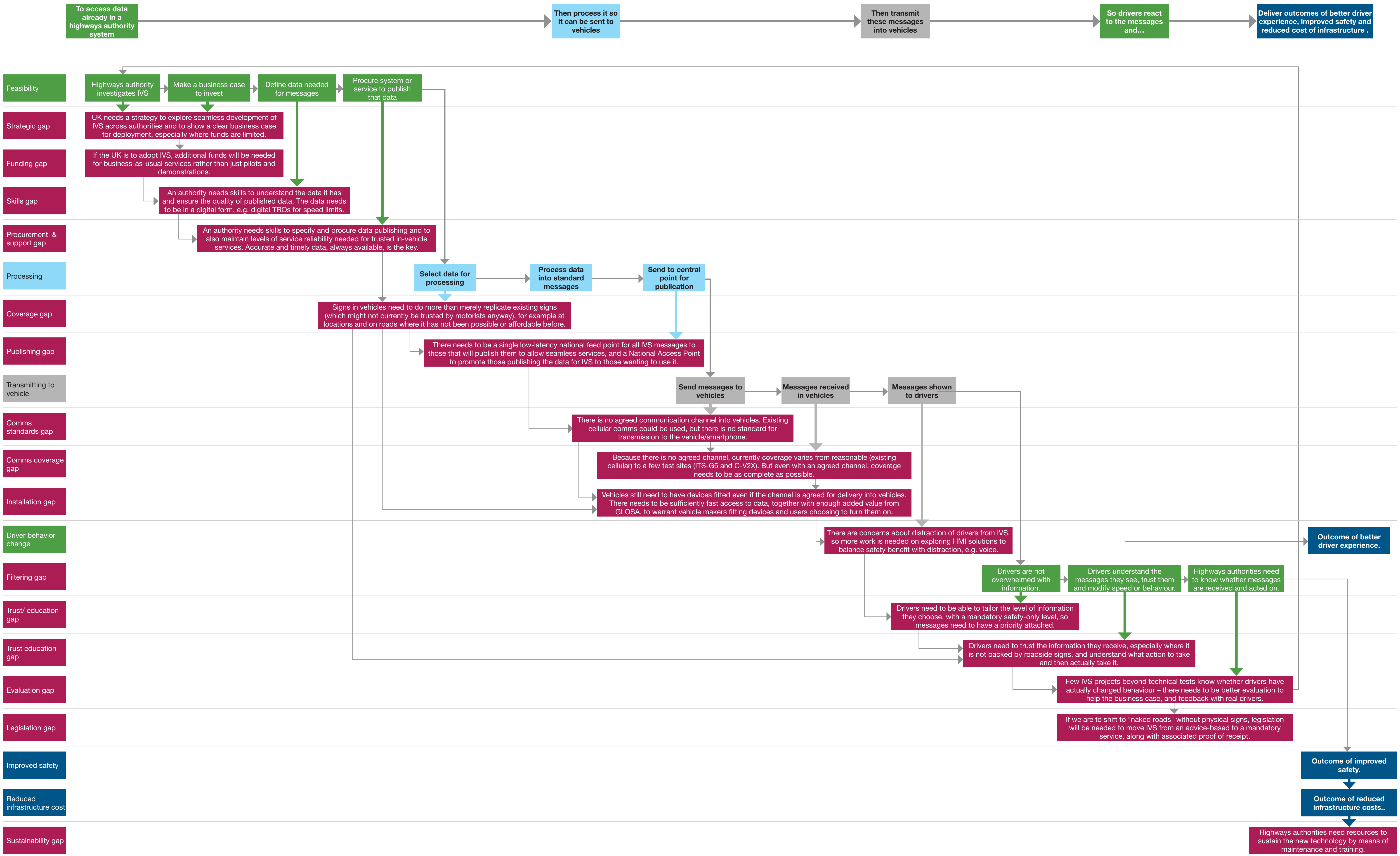
Addressing these would also make traffic lights work better and reduce stops at them through GLOSA, help make the roads themselves better for all road users, improve the road user experience, and potentially, through IVS, improve road safety.

The time is right for exploiting connected vehicles data, by connecting the chain at scale and providing services that are 'good enough'.

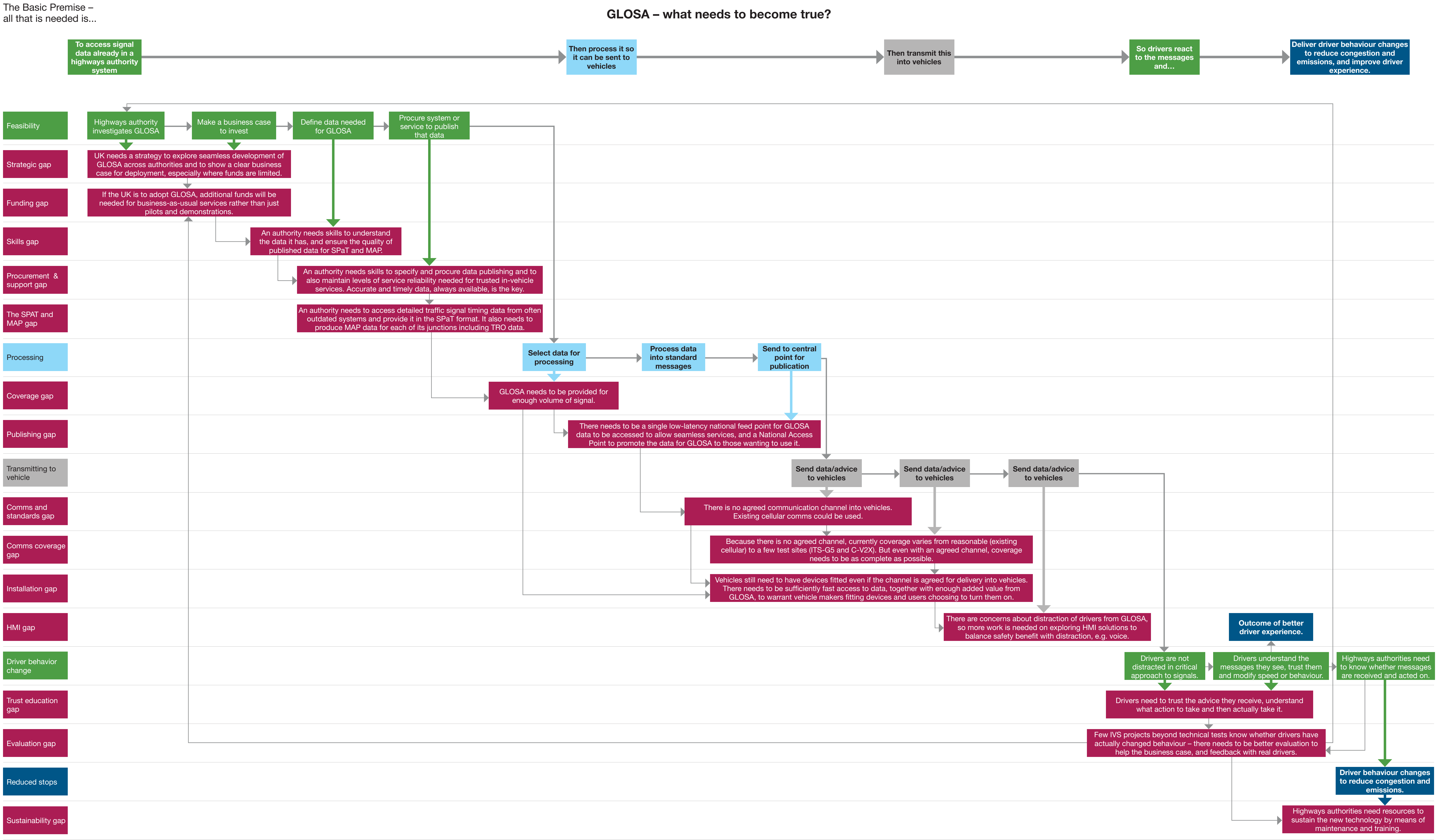
Appendix 1: Detailed Swim Lane Diagram for IVS

The Basic Premise –
all that is needed is...

In vehicle signage – what needs to become true?



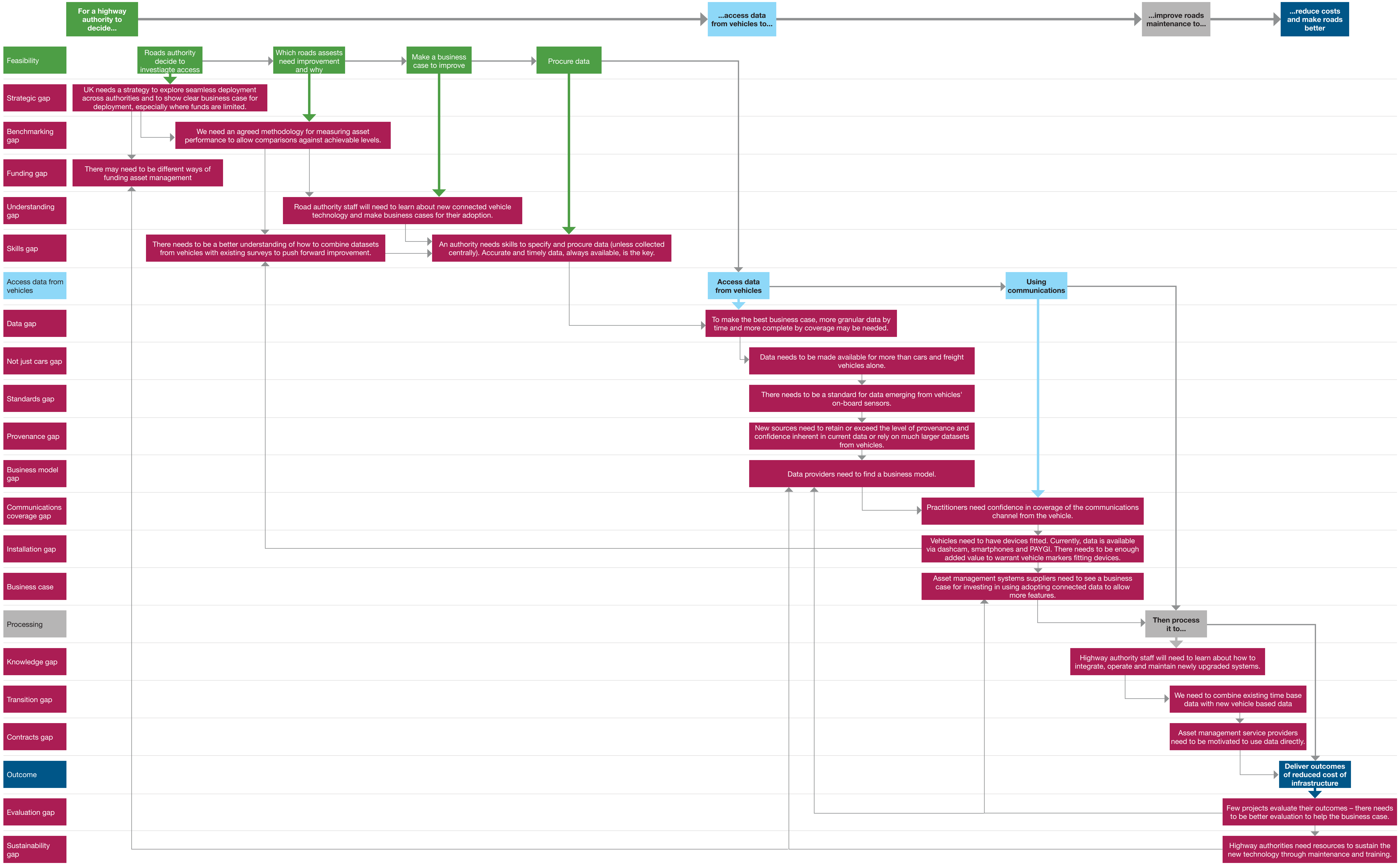
Appendix 2: Detailed Swim Lane Diagram for GLOSA



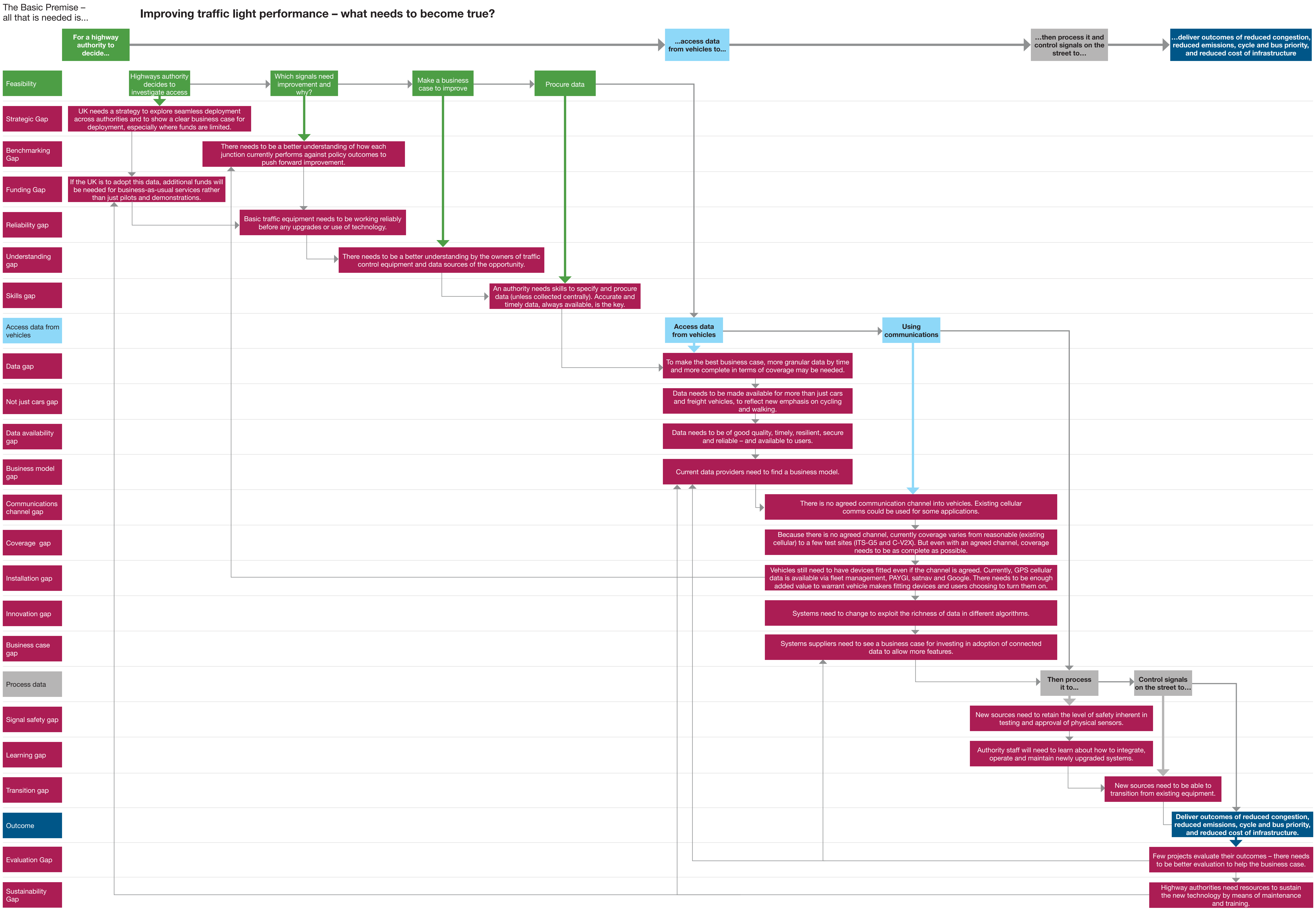
Appendix 3: Detailed Swim Lane Diagram for Improving Roads Maintenance (Asset Management)

The Basic Premise –
all that is needed is...

Improving roads maintenance – what needs to become true?



Appendix 4: Detailed Swim Lane Diagram for Improving Traffic Lights



Appendix 5: Service-Specific Gaps and Calls to Action

Table A5.1: IVS – specific gaps and calls to action

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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 target users for best impact.	Drivers take notice of messages. Improved driver experience.
No move to 'naked roads' as physical signs still needed – **the legislation gap**.	UK government	Explore how to move from advisory to mandatory IVS.	Reduction in roadside infrastructure costs.

Source: Author's Analysis

Table A5.2: GLOSA – specific gaps and calls to action

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
Not enough high-quality SPaT and MAP data available for at-scale services – **the SPaT and MAP gap**.	Highway authorities and DfT, traffic control industry.	Training in developing MAP data and other new skills and services. More open publishing of SPaT data from urban traffic control systems. 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.

Source: Author's Analysis

Table A5.3: Road asset management – specific gaps and calls to action

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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. This could involve a move to fully risk-based data-driven asset management.	Wider adoption, at less cost of, asset management data from vehicles as there is a standardised way to report road quality.
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.
Unless highway authority staff learn how to securely integrate, operate and maintain newly upgraded systems using connected vehicle data, the data will not in practice be used, 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.
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. Encourage/require data sharing.	The connected chain would be complete – there would be a business case for active use of new data by contractors.

Source: Author's Analysis

Table A5.4: Improving traffic lights – specific gaps and calls to action

What will happen if gap not filled?	Owner of action	Action required	Outcome of action
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 signals 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. Use commercial FVD as 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.
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).
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.
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 signal 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.
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 adoption of new algorithms by current equipment.	The connected chain would be complete as services will be deployed.

Source: Author's Analysis Author What will happen if gap will happen if gap not filled?

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RAC Foundation
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London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

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