Safe roads, reliable journeys, informed travellers

In vehicle traffic management – the trial

Summary report

Working on behalf of the Highways Agency

An executive agency of the Department for Transport

In vehicle traffic management – the trial: Summary report

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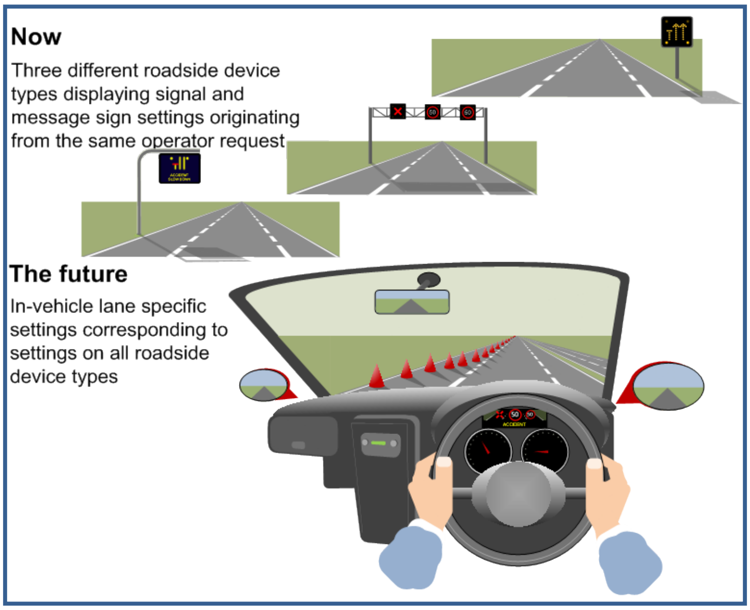
1 EXECUTIVE SUMMARY

The Highways Agency is one step closer to fulfilling the vision of providing traffic management information (variable sign and signal settings) direct to the motorist using in vehicle devices.

The in-vehicle traffic management (IVTM) prototype system trial has successfully demonstrated that it is possible to:

- Send traffic management information direct to an in-vehicle device in a timely manner
- Replicate traffic management information currently displayed using roadside devices
- Provide richer traffic management information content than is currently provided.



The platform for the trial was an IVTM prototype system that has the core components of a fully functioning traffic management system, including:

- A rules engine that generates primary and secondary signal settings, and the messages that support these, in response to operator signal setting requests
- An interactive map application (IMA) emulating the traffic management system used by regional control room operators
- An IVTM mobile application (for iPhone) for display of traffic management information
- A web publisher for distribution of IVTM traffic management information to the mobile device via the internet and mobile phone network.

In conclusion, the trial has successfully proved the concept. Indeed, the trial demonstrates that the IVTM methodology delivers significant advantages over the current HATMS (Highways Agency traffic management system) model in that:

- IVTM can generate a richer traffic management information set.
- Latency (interval between generation of IVTM data at the in-station and its display in-vehicle) is very low.
- Rules generating traffic management information are highly configurable allowing for rapid modelling and deployment.

The integration of the IVTM system into the HA's current traffic management system and system's scalability are two key considerations that must be addressed when responding to the DfT's *Action for Roads* mandate to roll out and develop this system further.

2 INTRODUCTION

This project is part of an innovative programme of work currently being undertaken by the Highways Agency to produce an in-vehicle traffic management system. The aim of this phase of the initiative is to demonstrate that timely, relevant and accurate traffic management information generated by an HA traffic management system can be displayed inside a vehicle by means of standard devices available to the public such as smartphones and 'satnavs'.

For the purposes of this initiative, traffic management information presented to the motorist by means of in-vehicle devices is that which relates to tactical information currently displayed on roadside infrastructure, such as gantries, cantilever and post-mounted devices. Specifically, this tactical information comprises signal settings representing speed and lane restrictions and the message settings that support these by providing additional information to the motorist.

Implicit in this aim is that the trial will demonstrate that the same quality of traffic management is achievable through a future operational in-vehicle system that is achieved by the current HA traffic management system (HATMS).

3 CONTEXT

The Department for Transport (DfT) issued *Action for Roads, A network for the 21st century* in July 2013. This report sets out the growing challenges on the highway network and outlines measures to transform strategic roads in the future.

In the greener better network chapter, the embracing technology section includes a key paragraph that relates to the IVTM initiative (an extract is shown below).

The Highways Agency is developing new technology to provide traffic management information direct to vehicles, through standard mobile technology devices such as smartphones and satellite navigation devices. The project is looking to deliver a demonstrable system by 2014 and, if trials are successful, we will be looking to roll out and develop the system further to deliver a more comprehensive in-vehicle information service.

The DfT's *Action for Roads* provides a direct link to this project thereby emphasising the strategic importance of this initiative on the wider mobility agenda. As a result of this central government mandate the Highways Agency has adopted the balanced scorecard approach for this project. The wording is provided below:

By end of Q4 2014: Demonstrate whether the IVTM "system"

1. Messages can reach an in-vehicle device in a timely manner
2. Traffic management messages can be delivered directly to an in-vehicle device, replicating information on any roadside device
3. Will permit the opportunity to provide supplemental information to that which is on the roadside device.

4 TRIAL OBJECTIVES

The specific requirement of the IVTM trial project is to develop a prototype system that will convey traffic management information from a rules engine (described below) as an output on the screen of a smart phone and trial this system in order to achieve the following outcomes:

1. **Proof of concept**: Demonstrate that traffic management information generated by the rules engine (named SABRE – Stand Alone Business Rules Engine *for signal and message sequencing*) in response to operator input can be delivered to the vehicle; and

2. **Establish system limitations**: Establish limitations intrinsic to current mobile network service provision in order to inform future investment and design that will lead to a viable operational system for delivering traffic management information to the general motorist.

5 METHODOLOGY (HOW WE DID IT)

5.1 High level system architecture

The IVTM system comprises the following components:

1. SABRE : An in-station component comprising the rules engine application (REA) and interactive map application (IMA – emulating the HATMS WOIF);
2. Data Broker: An in-station component that forms a single communications interface. . for each of the other components that form the in-station
3. Web Publisher: In-station software that distributes signal settings from SABRE to the mobile device; and
4. IVTM App (mobile application): software that runs on the in-vehicle device and that receives and displays IVTM information;

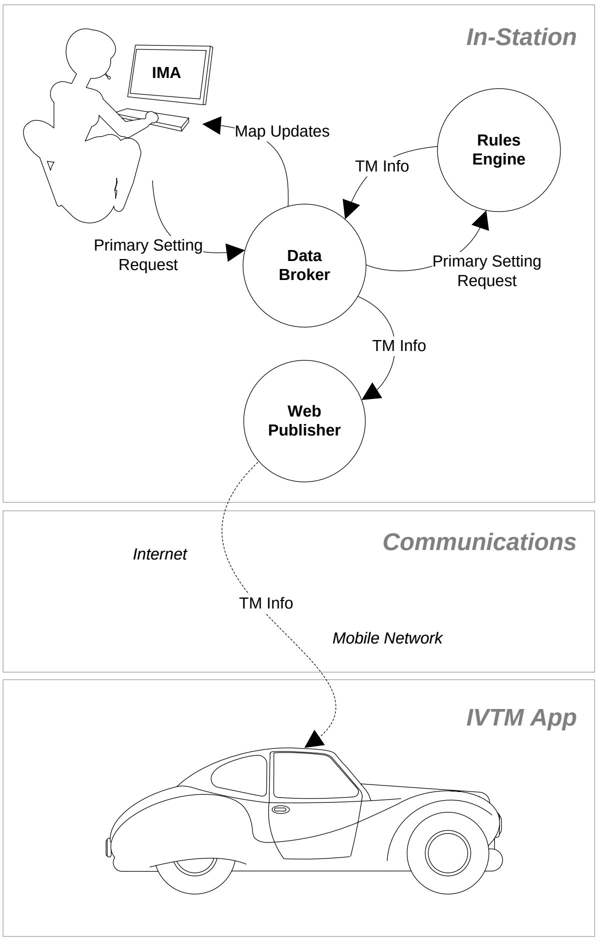


Figure 1 System architecture

5.2 Rules Engine

The SABRE rules engine is software that allows end users to specify the logic of the business rules (in this case signal and sign sequencing rules) and then to execute those rules in a runtime environment. This means that the logic of the rules is essentially separate from the software that executes them. The advantage of this is that rules can be developed and deployed very rapidly and without recourse to modifying software. Apart from the obvious benefits this offers in terms of cost saving and rapid development, it also means that the particular requirements for adaptations to the rules for the in-vehicle scenario can be investigated easily.

NB**:** It should be noted that the HA do not currently possess a rules engine for signal sequencing and therefore it was beneficial to the project to deploy the SABRE engine for the purposes of the IVTM trial.

5.3 Location Referencing

Location referencing is the means by which the system enables the mobile device to determine which information, generated at the in-station control system, is appropriate to display given the location of the device in time and space.

A '*geogate'* approach to location referencing has been adopted (Figure 2). A geogate is the area described by a configurable radius centred on a point location on the road network. When a vehicle enters that area, it is said to have *entered the geogate*. A geogate is defined by its GPS coordinates (latitude and longitude) and its bearing[1]. A geogate can be associated with roadside *signal sites* (gantry or post/cantilever mounted). A signal site may have one or more geogates associated with it so that different messages can be displayed for vehicles travelling in different directions.

Geogates are used as by the IVTM App as follows: The GPS enabled mobile device on which the App is installed samples its location periodically and, when the mobile device is within a defined radius of any of the geogates, displays the signal settings for the corresponding signal site.

With respect to the IVTM trial area, for each signal site within the trial corridor (described in section 6 below), a geogate has been positioned 200m upstream. This is a configurable distance that can be refined as necessary. The geogate's location (in terms of latitude and longitude) and bearing (necessary to ensure messages are relevant to a vehicle's direction of travel) are held within the web publisher.

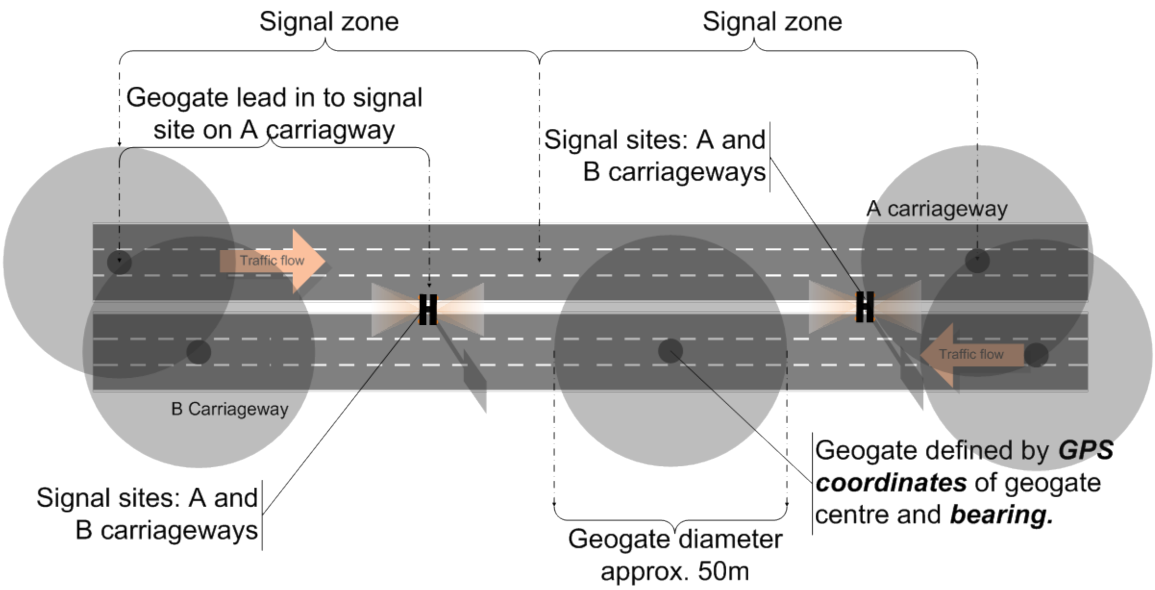


Figure 2 Geogate location referencing

5.4 Derived Test Strategy

In view of the above objectives, three categories of tests have been derived. These are:

1. Accuracy tests: Tests that will verify that the information received in a vehicle is complete and correct relative to the data being published at the in-station.
2. Relevancy tests: Tests that will verify that the in-vehicle device displays traffic management information pertaining to the location through which the vehicle is currently travelling and in and the direction in which it is travelling.

[1] 'Bearing' defines the *direction of travel* along the carriageway on which the relevant signal site is located.

3. Timeliness tests: Test that will quantify the latency involved from initial publication of traffic management information at the in-station to the time it is displayed on the in-vehicle device.

6 THE TRIAL

6.1 Location

The trial was undertaken on the M5 between junctions 20 (Clevedon) and junction 23 (Bridgwater). The trial area was selected on the basis that on this section of network there are currently only MS1 type devices mounted in the central reservation capable of displaying carriageway specific (as opposed to lane specific) signal settings. There are no associated message sign devices that support the signal settings displayed at these sites. Since the aim of this trial is to demonstrate that the prototype system can provide additional message sign support, this was considered an ideal location.

6.2 Equipment

The trial vehicle was equipped with cameras to record the in-vehicle device display as messages were received, a GPS sensor and a camera recording the carriageway view.

A GPS enabled iPhone was deployed as the in-vehicle device running the mobile application developed for the Trial (the IVTM App). The control office (housing in-station equipment) comprised a laptop with the IMA running, the SABRE software installed and a webcam recording operator commands (see schematic in Figure 3). This set-up enabled video footage to be compiled that enabled the scheme to be evaluated. Evaluation was possible by reviewing the concurrent footage of in-station activity with and mobile app displays. Figure 4 is a screen shot of the merged video footage.

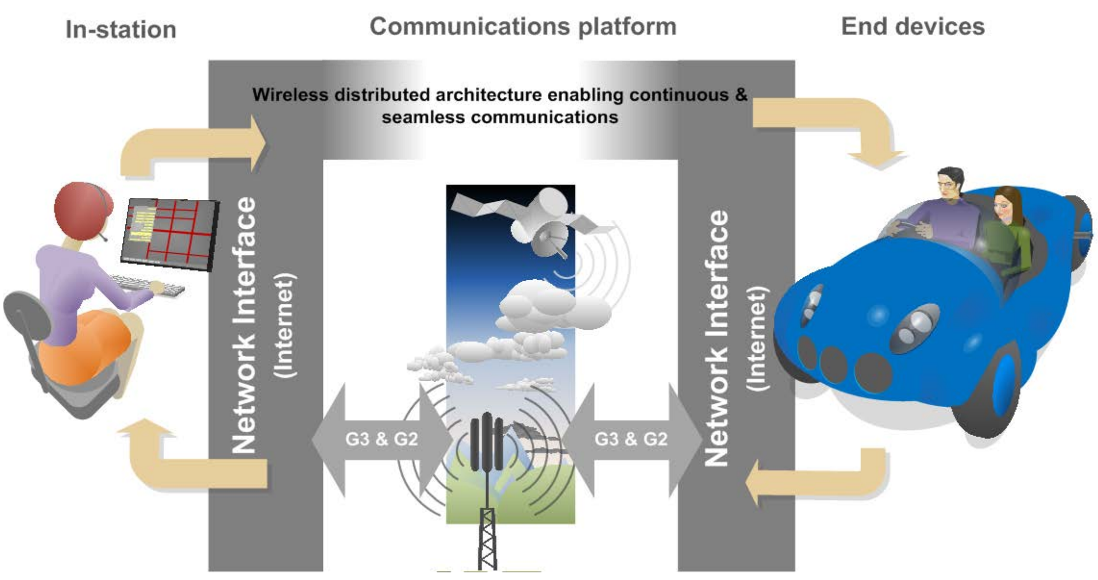


Figure 3 IVTM system

6.3 Trial procedure

A series of tests were derived to test for accuracy, relevancy and timeliness of data. In general the tests required the operator to propose and implement signal changes on the IMA. All primary and secondary signal settings generated by the SABRE rules engine, hosted on a cloud server, were then communicated to the iPhone via a standard commercial 3G/4G mobile phone network.

The image in Figure 4 below provides evidence from one of the tests. The top left inset in the image shows the IMA and the operator's desired speed setting of 30mph with an implementation reason of ANIMALS IN ROAD. This setting is displayed on the iPhone (bottom left inset) in advance of the MS1 signal site in the central reserve.

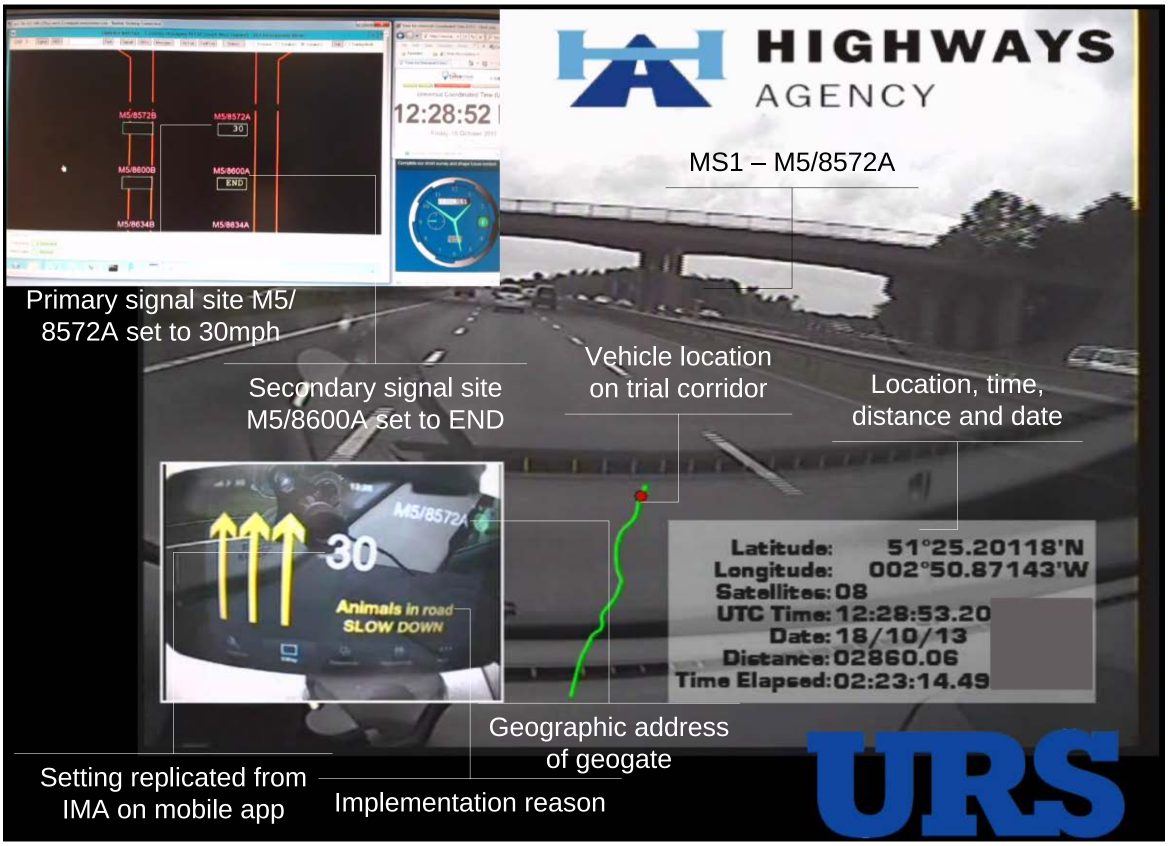


Figure 4 Merged video footage from the Trial

6.4 Results

Tests that were either pass or fail (e.g. test to confirm whether the iPhone displayed the right information at the right time) all passed and were verified by the trial witness. Tests that required an element of post processing were subsequently shown to also meet the stated requirements.

The tests included procedures to capture and identify the latency of the system. Over 200 latency tests were conducted and these demonstrated that latency was on average less than a second.

7 CONCLUSIONS

7.1 Limitations – mobile network service provision

The Trial highlighted limitations on *current* standard mobile network provision: It was observed and recorded that during congested conditions on the motorway, the data signal strength on the iPhone was diminished such that messages could not be received. A detailed analysis of this issue is not within the scope of this project however, a likely explanation is that the increased use of mobile phones to assess the cause of the congestion placed too great a demand on the radio base stations. Potential remedies for this are discussed below in section 8.1.

Mobile signal strength, too, is a potential limiting factor for the effectiveness of the system. However signal strength was not observed to cause problems during trial. That said, when signal strength is poor it is conceivable that messages may not be conveyed to the in vehicle device within requirements for latency. To mitigate this effect, traffic management data associated with a range of geogates within the vicinity of the in vehicle device are loaded onto the device at a time when the device is in an area of good signal. Traffic management information would still be displayed in 'black spots', but any subsequent automated changes or those made by an operator may not have been updated. A network survey of signal strength would therefore be required to fully comprehend this potential limitation and perhaps facilitate a dialogue with mobile communication providers to discuss how to improve coverage.

7.2 Latency (better than anticipated results)

Prior to the trial it was anticipated that latency, defined as the interval between generation of IVTM data at the in-station and its display in-vehicle, could be a limitation of the system in terms of the system's ability to perform to the standards for traffic management information timeliness. However, results from the trial surpassed our expectations. The observed latency based on a US $10 per month web hosting (Amazon AWS) service ensured that data was typically received in less than a second. This is within initial latency criteria[2] established in the initial feasibility study for IVTM.

This is thought to be significantly quicker than the current system (HATMS), which is hard-wired from the control system to the roadside devices, although a detailed study of HATMS performance would be required to accurately quantify this. It is worth noting that HATMS has built in latency to allow for fault reporting and other functionality specific to road side devices[3].

The criteria for latency could be significant in the future, when for example; autonomous vehicles are required to be integrated into the overarching control of the road operator's traffic management system. In that instance much more immediate and timely information would be required by the autonomous control system.

7.3 Summary

URS has successfully proved the IVTM concept by demonstrating that traffic management information generated by SABRE in response to operator input can be conveyed to a vehicle in accordance with the accuracy, relevancy and timeliness criteria outlined in section 5.4

[2] Latency Criteria were established at Phase 1 of the IVTM initiative (feasibility study) and were based on the distance travelled by vehicle moving at 60mph as a function of that distance as a percentage of a distance of 300m upstream of the point on the network where a restriction applies. As an initial approximation the 10% (representing 30m) was applied so latency criteria is based on the time it would take the vehicle to move that distance.

[3] HATMS has built in latency – see NMCS2 specifications

8 RECOMMENDATIONS (HOW TO GET TO END GOAL)

8.1 Developing an operational system

The Highways Agency is currently considering two options with respect to its role as a traffic management information data provider in the near future in-vehicle information system scenario. These are, broadly speaking:

1. **Data provider**: The Agency assumes the role of data provider to third party provides (e.g. 'sat nav' companies) who distribute traffic management information data to mobile devices by whatever means appropriate; and
2. **Service provider**: The Agency undertakes the data provider role described above but also assumes a wider remit and broadcasts traffic management information data using a dedicated but as yet unspecified transmission system direct to vehicles.

On either of these options, the prototype system developed for the IVTM Trial is flexible and can be developed quite readily into an operational system. The real issues are as to the nature of the larger TMS (traffic management system) that the operation of the IVTM system would integrate into, i.e.

- Will IVTM be required to integrate into the extant HATMS?
- Will it form a component of a new and as yet unspecified replacement for HATMS? or
- Will it first be deployed as a standalone system (e.g. as a small portable RCC for controlling mobile VMS or sections of the network that are not currently controlled by a TMS)?

8.1.1 *Integration into extant HATMS*

With respect to the first of these, it should be noted that the current system (HATMS) is characterised by a highly bespoke architecture that has evolved over many years. This is true (as the IVTM studies have shown) of both its various components (subsystems) and the intercommunications between them. This can be problematic for attempts to introduce components implementing radical new techniques (such as the Sabre) into the internal architecture. However, Sabre, and the IVTM subsystem of which it is part have been designed with well-defined interfaces to their discreet and logically grouped (as opposed to evolved and dispersed) functionality. On this approach, the suggested method is to modify the existing relevant subsystems so that they access the IVTM/Sabre functionality. For Sabre, this means accessing its highly configurable Sign and Signal Sequencing functionality. For the IVTM Subsystem this may mean access to its external Web interface.

The upshot of this approach is a gradual componentisation of HATMS that could preclude the need to replace it wholesale.

8.1.2 *Replacement of HATMS*

With respect to the possibility of integrating into or forming a component of a future replacement for HATMS, nothing further can be said at this stage until the form of that system is known. However, we consider that vital intelligence has been gained through the IVTM Trial and through the development of a radical Rules Engine (as opposed to hard coded algorithms) approach to implementing the Sign and Signal Sequencing Algorithms and anticipate that this intelligence would inform subsequent specification and design of the future system.

8.1.3 *Standalone system*

With respect to the third option for an operation system, aside from further testing and development for scalability the prototype IVTM system is a traffic management system and can be used to manage traffic. With increasing manufacture of vehicles with integrated in-vehicle mobile devices it is likely that within five years a significant proportion of new vehicles will be so equipped. The deployment of a small but versatile system such as IVTM could be a viable means of extending network management without the need to extend existing roadside infrastructure

8.2 Innovations and opportunities

The trial has demonstrated that the IVTM system is truly versatile and having seen it tested, has prompted numerous ideas for ways in which the IVTM system can be used as a tool to test and implement emerging technology and address smarter travel policy objectives. These include:

- **Improving vehicle throughput** – using floating vehicle data as a potential replacement for MIDAS to provide automatic congestion and incident monitoring. The IVTM system could also be used to manage priority lanes (such as bus or HOV) and provide 'blue-waves' for emergency vehicles where a chosen lane is dynamically managed to allow unobstructed progression through traffic
- **Enabling autonomous vehicles** – the IVTM system can facilitate autonomous vehicle systems integration into existing control regimes by being able to prioritise information from different sources and contexts. For example, prioritising an autonomous response such as the vehicle detecting a pedestrian, over other messages such as campaign, tactical or strategic
- **Modelling for scheme design** – as an interim measure, the rules engine could be adapted as a signalling and signing scheme designer by incorporating a graphical tool kit for the placement of signal and message sites.