M6 Toll In-Vehicle Message Signs Project

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Executive Summary

This executive summary reviews the study on the implementation of the Virtual Variable Message Sign (VVMS) system for the M6 Toll, as a response to a recommendation made in the Midlands Motorway Hub Study. Initially, physical Variable Message Signs (VMS) were thoroughly explored, however, a feasibility study assessed that their implementation was deemed too expensive to install, maintain and operate, due to their size. VVMS are geospatial information hubs that provide real-time traffic alerts and instructions to moving cars. They can send messages everywhere on the road network without the requirement for physical infrastructure, and they can improve visibility and clarity compared to conventional roadside message signs. This work specifically focuses on an In-Vehicle Message Sign (IVMS) system. The VVMS makes use of networked digital infrastructure to enhance the effectiveness and efficiency of traffic management.

The following are the study's main recommendations and conclusions:

- The M6 Toll System provides an online solution that is adaptable, quick, and independent of actual sign positions. By increasing capacity, reducing congestion, enhancing travel times, and minimising pollution, it has the potential to have a positive influence on the road network in and around West Midlands and beyond. The scope of work for the VVMS system includes enabling technical and operational learning about cooperative ITS services as well as providing live service status displays and timely information to drivers approaching the M6 Toll.
- The VVMS system is made up of a number of different system components, such as an API for IVMS, a web interface for system managers, a journey time estimator, a message creation system, and a historical record database.
- To send VVMS content and position information, the VVMS system makes use of the Eco-AT DATEX-II IVI profile. With the help of this profile, IVI data can be transferred in a format compliant with the C-ITS standard. The transmission of in-vehicle information messages uses the C-ITS ETSI IVIM message standard. These communications are intended for the integration of car systems. As the positioning information is being sent as part of the standard, the device (phone, sat nav, vehicle) calculates when to show the message. This negates the requirement for feedback information on a customer's location, improving privacy, security for customers and GDPR compliance for authorities.
- The five steps that make up the end-to-end service for the M6 Toll system are:
    - data ingress
    - integration of the VVMS solution
    - data export
    - V2X communication services
    - distribution to end users.

  There are certain procedures and data flows for each stage. A microservices-based system architecture is needed to handle and analyse data in order to integrate the VVMS solution. For data handling and processing, the system makes use of Lambda functions, API Gateway, and microservices built on Amazon Web Services (AWS).
- The VVMS system uses a hybrid approach for journey time analysis and prediction that includes forecasts from outside sources based on floating vehicle data as well as historical and real-time raw data from road side sensors. This guarantees precise and trustworthy journey time forecasts.
- The system underwent rigorous testing, including the Factory Acceptance Test (FAT) and the Site

Acceptance Test (SAT), to ensure its dependability, performance, and readiness for deployment. The trials aimed to assess the system's potential to influence driver behaviour and network outcomes, focusing on behaviour change and human-centred design principles.

- Key findings from the trial include:
  - The app's messaging was more relevant to longer and unfamiliar routes, while shorter and familiar journeys received fewer messages. Strategies are needed to engage drivers on these shorter routes.
  - Some messages were perceived as irrelevant or incorrect, leading to confusion and decreased app usage. Ensuring message accuracy is crucial to maintain user trust.
  - *Approximately one in three drivers changed their behaviour based on the messages received, indicating the potential impact of the In-Vehicle Message Sign (IVMS) app. Further improvements could increase this proportion.*
  - Drivers preferred messages that provided peace of mind, such as safety alerts, traffic flow information, and potential route changes. Messages relating to traffic lights, repetitive road signs, or driver faults were less desired.
  - Messages emphasizing time-saving or time loss had different effects on driver behaviour, with the prospect of losing time prompting more action.
  - The IVMS app was generally user-friendly, but improvements could be made, including automatic activation, integration with in-car systems, and better readability of the interface.
  - Customization options, journey planning features, and AI-powered enhancements were suggested to improve the app's appeal and functionality.
  - Views on data sharing for improving road conditions varied, with concerns raised about privacy, safety, and fairness.
- Overall, the technical assessment of the system has been positive, with staff recognizing its benefits for public information and its ability to adapt to different situations. Further refinements and enhancements are expected as the system is used more extensively in the coming months.
- A roadmap is proposed for the implementation and scaling up of a Virtual Variable Message Sign (VVMS) solution across the West Midlands and beyond, considering several crucial factors.

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1.1. Introduction

1.2. Background and Context

In partnership with the Department for Transport (DfT), Midlands Connect delivered a Midlands Motorway Hub Study in 2018, which outlined a number of key recommendations one of which was in relation to Variable Message Signs (VMS) on the M6 Toll whose route is shown in Figure 1.
Initially, physical VMS were thoroughly explored. Indeed, previous studies assessed the feasibility to enable comparative journey time information, through variable message signs (VMS) on the approach to a number of relevant junctions, promoting a better use of the M6Toll motorway in those cases where this route actually represents a better alternative to the M6. These assessments included potential VMS provision that was translated into specific locations in accordance with the relevant National Highways (England) standards for roads and motorways and, subsequently, a multidisciplinary analysis to determine the specific design requirements of each VMS location carried out by Technology, Highways, Geotechnical and Environment disciplines. Based on the outcomes, their implementation was deemed too expensive to install, maintain and operate, due to their size. As a result, the decision was made to opt for virtual signage, offering a more flexible, cost-effective alternative.
Indeed, this project seeks to address this recommendation with an alternative approach by utilising connected digital infrastructure to enable the implementation of a Virtual Variable Message sign system (VVMS).
This M6 Toll System offers a virtual service that is not reliant on physical sign locations, is more flexible and responsive to network conditions and thus could impact the outcomes stated. These important system characteristics enable a better/more efficient use of infrastructure (i.e. the M6 Toll and surrounding road networks) and, therefore, generate a wider positive impact on roads in and around Birmingham by freeing up capacity, increasing safety, improving travel time, reducing congestion and pollution.
The service provides information to drivers using messages delivered in-vehicle and for this, throughout this report, it is also simply called In-Vehicle Message Sign (IVMS) system. These messages target specific decision-making points across the network, providing better information on network conditions, including relating to the M6 toll where appropriate. These messages are created following a process to capture real time information from national and regional data sources followed by analytical processes and executions of protocols and algorithms that create information packets (messages) that are approved and distributed to drivers by Transport for West Midlands (TfWM) and/or its partners.

Figure 1 - M6 Toll Route Map

1.3. Scope of work

The M6 Toll system is designed to offer an End-to-End service with the following functionality:

- Deliver live / timely information to drivers and/or vehicles approaching the M6 Toll from the North or South, to support driver decision making regarding which route to take to transit the Birmingham region (M6 vs M6 Toll).
- Utilise live traffic information from M6 and M6 Toll ensuring messaging to drivers is up-to-date, taking into account travel times, congestion and incidents on both routes
- Utilise standard-compliant Cooperative Intelligent Transport Systems (C-ITS) methods to provide dynamic messaging to select vehicles/drivers at appropriate locations.
- Provide a live display of service status, giving TfWM a means to view and monitor the service, as well as historical data for analysis of service impact.
- Enable technical and operational learnings about the use of new C-ITS services, based on Vehicle-to-Everything (V2X) technologies, in live traffic environments.
- Developed in a way that should enable easy adaptation for different use cases.

The purpose of the project is to provide the following system entities:

- An API for IVMS that allows downstream operators to distribute information on current journey conditions. This includes the relevance and awareness zones for the messages to support C-ITS services.
- A web interface that allows TfWM system administrators to visualise the relevance and awareness zones for messages and decide which messages should be published. The web interface also allows administrators to visualise the status of the road network.
- A journey time predictor predictor is created based on different data sources including the National Highways (England) vehicle flow information (National Traffic Information Service - NTIS) for selected routes and any existing systems.
- A message generation system that populates message templates with journey estimates and provides them as publication candidates to the web front end.
- A historical record database of the messages published corresponding with vehicle flow data from the road network. This supports further analysis on the effectiveness of IVMS solutions.
- The final system includes five main stages: data ingress, the VVMS solution integration, data export, V2X communication services and V2X end user delivery (Figure 2).

Figure 2 - High-level End-to-End Service Overview for M6 Toll System

2. VVMS Service

2.1. VVMS Essential Data

VVMS are geospatial information points that deliver traffic alerts and guidance to vehicles as they move along a road segment in a certain direction. The following diagram (Figure 3) and the picture taken inside a car (Figure 4), show how a VVMS works.

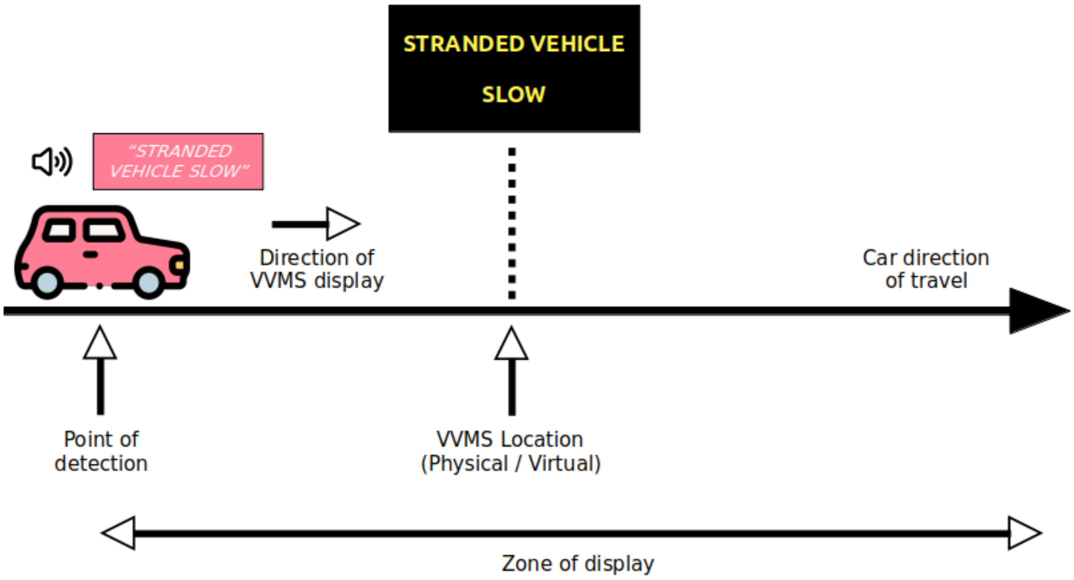

Figure 3 - VVMS operation

Figure 4 - VVMS in-vehicle – Android Auto test system

VVMS are referred to in European C-ITS projects such as C-ROADS [1] as IVIM[1] (In-Vehicle Information Messages) . Using communications and display equipment designed for that purpose, the provided information is meant to be received, displayed, and spoken to drivers inside the car.
The existing provision of alerts and guidance to drivers on roadside message signs by traffic authorities can be replicated or improved using VVMS.
VVMS can be delivered everywhere on the road network because there is no longer a need for physical infrastructure. The introduction of this innovation brings about a revolutionary level of freedom in terms of placement, liberating it from the constraints of rigid infrastructure. This flexibility fundamentally alters the paradigm through which we perceive and utilize this service, significantly transforming the mindset of road users.
They can be promptly created, enabling a hazard warning to be transmitted in-vehicle at any site throughout the road network, potentially even in places and on roads where physical signage has never been provided for and never will be. When not needed, they can also be instantly removed.
VVMS can also improve message boards at intersections by:

- Increasing the likelihood that the driver will notice the message; frequently, roadside VMS might be blocked by other vehicles or are difficult to see in adverse weather or direct sunlight.
- Displaying the message more clearly and for a longer period of time.
- Speak the message to the driver to reinforce the visible warning provided.

They offer a way to instantly inform drivers of dangers on the road ahead by connecting traffic authorities and drivers in-vehicle (e.g., Figure 5).

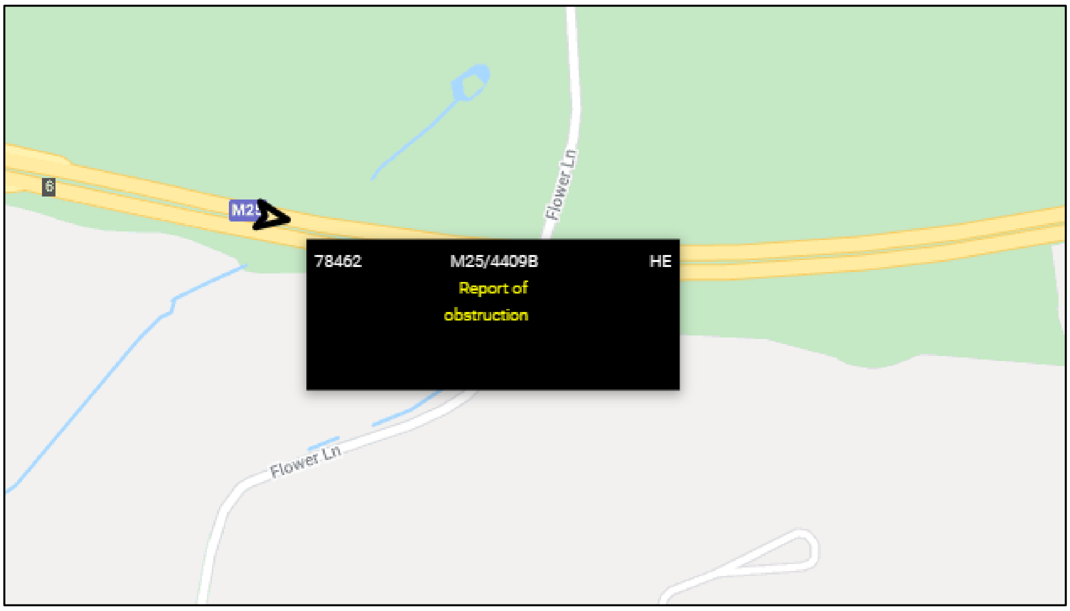

Figure 5 - An Urgent Hazard Alert displayed on National Highways VMS on the M25

VVMS are not the same as roadside message signs, despite the fact that they serve a similar purpose, as an efficient channel into vehicles is required for VVMS to be useful. At the side of the road, there is a fixed, illuminated message sign. In contrast, audio-visual equipment is required in vehicles and, if installed, must be turned on and in use. While VVMS are elective, physical VMS are effectively required viewing. Indeed, the bare minimum system requires a device that can do text to speech and is set to monitor for messages similar to a mobile phone text message or email app.

[1] Note the nomenclature can vary. In-vehicle Information (IVI) and In-vehicle Information Messages (IVIM) is the name used for such technology in the C-ROADS project whereas, for this project, we use the In-Vehicle Message Sign (IVMS). However, IVIM is still used in this report when specific standards, which were defined in the European C-ITS project, are mentioned.

2.1.1. VVMS data requirements

The required data for VVMS is typically specified by the point in space where alerts and guidance are to be delivered, as well as the nature of that information. Simple and quick alerts of a hazard ahead on the road are essential in this situation, so an overview of the key data in line with the C-Roads project [1] [2] is provided below.

Owner

The identification of the traffic or local authority authorised to issue VVMS messages, which could be a dynamically generated virtual sign or a VVMS that replicates a real sign.

Identifier

A unique identifier for a VVMS is provided by a combination of the owner of a sign and an identifier that is specific to a given traffic authority.
National Highways, for instance, defines VMS as "M25/4090B" where M25 is the road, 4090 is a roadside identification, and A, B denotes the direction or position of the sign.

Location definition

The location defines where the sign is shown and it is characterised by two components, the geographic location of the sign (latitude, longitude) and its direction.
For a VVMS, the actual physical/geographical location of a sign that is being replicated is not significant as it is the location on the road that the message is targeted at which is important. The screen capture in Figure 6 below illustrates the principle, the physical sign is located at the side of the road and the virtual sign shown by the arrow is positioned adjacent to the sign in the centre of the carriageway, so forming a logical virtual information point in space.

Figure 6 - Geographical VVMS location example [source: KL Systems]

The second element of VVMS location is direction; in order to construct a virtual VMS, it is crucial to indicate the direction of travel that the VVMS is intending to sign for. One method to do this is to specify the direction of travel of a car approaching the VVMS as a bearing clockwise from North (0 to 359 degrees) for the direction the message is intended for. The direction of the arrow in the screen capture above indicates the sign's direction.

Since VVMS are intended to be utilised dynamically in real time by moving vehicles at high speeds, the precision of the stated location is crucial. An incorrect direction or position may prevent or delay the delivery of a message, or it may result in the message being delivered when the vehicle is travelling in a different direction.

Zone of display

To define trigger points for VVMS message delivery and updates, it is necessary to define a zone of display relative to the VMS location. This zone defines the road extents upstream and downstream of a VMS, either via a range of road length or by defining the geographic road section through a set of listed coordinates. Interfaces then know when and where a VVMS should be displayed. The receiving system is able to know when to display the message by completing some relatively trivial calculations to match the location and bearing.

Type/category of message

The type of message defines its nature and purpose. Messages are often categorised as follows:

- Urgent Hazard
- Traffic Management
- Future Information
- Traffic Information
- Campaign Message

Message definition

This is the information component of a VMS message, to be displayed in-vehicle to a driver. For physical VMS that is replicated in-vehicle, this message should follow the format displayed on a physical VMS.
The message could also be modified for effective auto speech generation. By removing abbreviations that were necessary to fit a message on a sign, or having data mapped to represent the complete value of an abbreviation, the in-vehicle system would be able to output the speech equivalent of ‘MINS’ as ‘minutes’, for example.
VVMS offers the ability to display longer messages than those displayed on physical signage, however, this practice should be avoided to prevent drivers from being distracted. Thus, following the message standards adopted for physical VMS is recommended[2].
Pictograms can also be potentially displayed in-vehicle; however, they should be accompanied by the appropriate text messaging and corresponding text-to-speech descriptions.
For VVMS, there is no purpose for a blank message. Messages should always contain a message body and useful information.

2.1.2. VVMS interface functional requirements

To ensure accuracy and efficient useability of a VVMS interface, the adoption of the following key functional requirements is recommended.

Latency

The time between a VMS being created, updated, or cleared, and the respective information being updated in authorities feed should be as minimal as possible. We recommend updated VMS messages be available to an in-vehicle system within 10 seconds of a message sign being set. This is an upper limit, and the ideal goal is to have these messages communicated within a second of being issued. There are two key drivers for achieving the recommended transmission times:

[2] Further studies will investigate optimising the VVMS messages for the screen and text to speech delivery

Many VMS messages are time critical. Messages are often used to inform drivers about an accident, or other urgent hazard, ahead – and thus should be displayed to the driver's in-vehicle system without delay. If a VVMS message is not updated swiftly, the information the driver may see in-vehicle may be different to the information displayed roadside. This could potentially cause confusion and lead to instructions being followed incorrectly. The latency of the system should be minimized to ensure such events do not occur. The downside to having this low latency could impact the cost of the system as it would require the app to poll the API at a high frequency and each request will be charged. This aspect of the service has not been investigated in this project.

Server Operation

An authority's VMS message server should provide both a pollable GET request- (for example) and a message subscription service. This allows for data requests to be issued and obtained when required, and with minimal delay.

2.2. VVMS Message Delivery

This is the European C-ITS/ C-ROADS message standard for in-vehicle information messages (IVIM). The CEN ISO technical specification TS 19321 "intelligent transport systems - Cooperative - ITS Dictionary of in-vehicle information (IVI) data structures" contains the core definition of the IVI data structures used in the C-ITS standards. Also, ETSI 10330 presents a description of the IVI message.

The C-ITS message set and related encoding and communications standards were created and specified with automotive application in mind. They connect to automobiles via specialised high-speed communications like ITS G5.

In this case, communications are defined in machine terms in ASN.1 definition files and use bit-level binary encoding called UPER (Unaligned Packed Encoding Rules). ASN.1 is a data description language that specifies a message schema; applications in both the car and as a component of external systems that utilize the messages compile and apply the ASN.1 definition. The messages are machine-readable, encoded, and geared toward the integration of automobile systems.

Although important and helpful in the context of C-ITS Car to Car and infrastructure to Car communication, the binary encoding via ASN.1 standard compiled code has various disadvantages for internet-based information publication and data export out of traffic authority systems.

Because these interfaces require a broader understanding of the ASN.1 encoding principles and frequently make use of specialised libraries to provide the necessary encodings, the barrier to use for these types of interfaces is higher in terms of the IT expertise and cost required to implement, use, and maintain them.

In general, it is not necessary to use the C-ITS ETSI IVI message, but if it is needed, local authority data can be converted to that downstream at a central facility processing data from numerous authorities where the necessary expertise is available, saving costs on supporting that at the local authority level.

The message set chosen must, however, be in line with and include the essential data needed by an IVIM, especially data for in-vehicle use including message categorization, zone of relevance, and zone of display using TS 19321 requirements.

3. End-To-End Service

The M6Toll system is divided into five primary phases: data ingress, integration of the VVMS solution, data export, V2X communication services, and distribution to end users. Figure 7 gives an overview of the different elements characterising each phase that will be described in the sections below. Figure 10 shows how data was handled within the project.

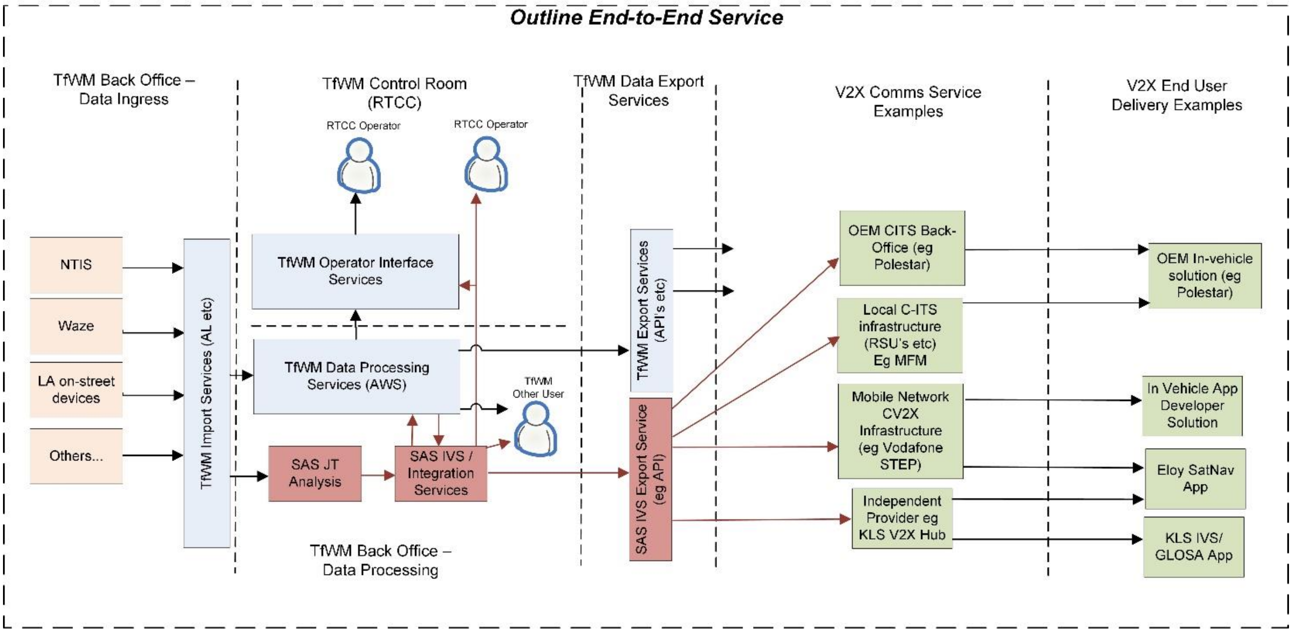

Figure 7 - Overview of End-to-End service

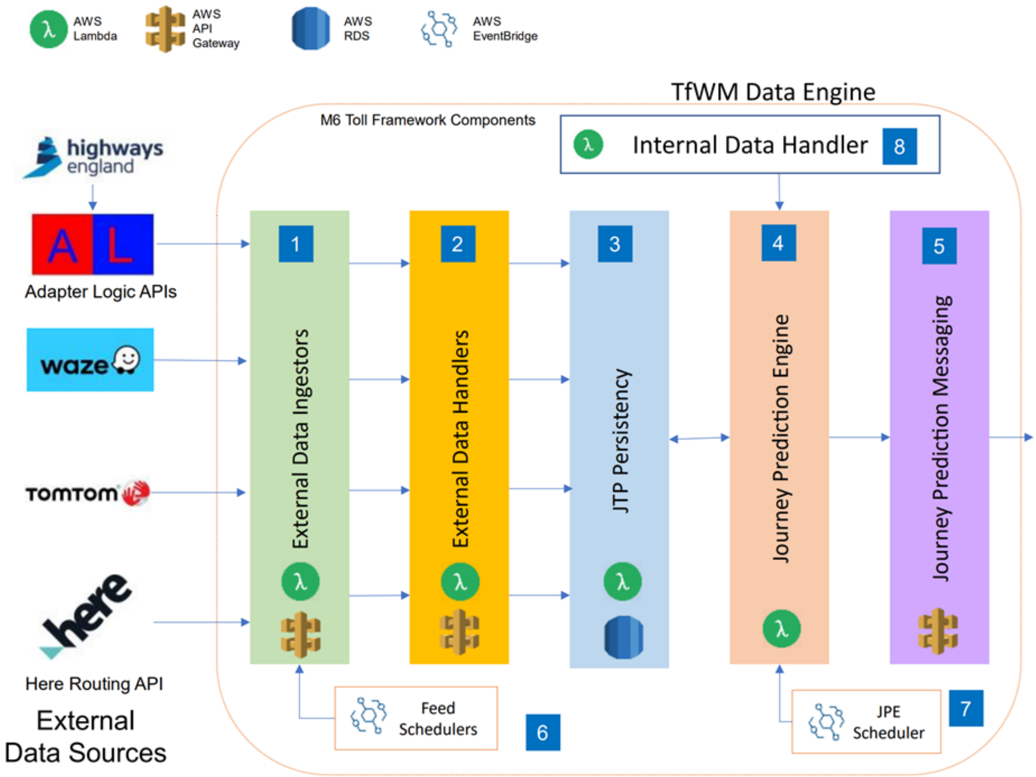

Figure 8 - TfWM data processing service

3.1. Integrating the VVMS Solution

3.1.1. Control Room (RTCC) and Operator Interface Services

The VVMS system allows operators in Regional Transport Coordination Centre (RTCC) to control the display of VVMS site messages based on a set of operator-configured rules. The rules in Table 1 have been implemented to support the agreed VVMS system use cases discussed during the project. However, additional rules could be added to the system beyond this project if required to support other use cases in the future.

Figure 9 – West Midlands Combined Authority RTCC

Rule Type	Description
Route Delay	If the predicted journey time for a given route is *greater* or *less* than *x* minutes. Then set a *VVMS Site message* to a given message template or raise an *Alert* to an RTCC operator (displayed on the alerts dashboard page).
Relative Delay	If the predicted journey time for a given route is *greater* or *less* than *x* minutes compared to that of another route. Then set a *VVMS Site message* to a given message template or raise an *Alert* to an RTCC operator (displayed on the alerts dashboard page). RTCC Operators are only able to create rules to compare routes within the same route group. The route group is an identity assigned to a route during route creation by System Administrators, in order to associate routes into a particular category or geographic region.

Table 1 - VVMS System – Rule Types

VVMS Management Web Dashboard

The VVMS system web dashboard layout has been developed to provide closer alignment with the existing Midlands Combined Authority RTCC Data Engine dashboard. Features provided by this dashboard include:

Item	Description
Dropdown Menu	Dropdown menu in the upper left corner to provide easy navigation to system functionality

Item	Description
Sidebar	A collapsible sidebar on the left-hand side provides the operator easy control over functionality such as VVMS site creation, and filtering information displayed on the map. This sidebar also provides a helper function to guide operators through certain system functions such as VVMS site creation.
Journey Time Status Bar	A Journey Time status bar is provided at the top of the dashboard to provide real-time updates on predicted journey times for routes configured within the VVMS system. The information displayed within this status bar is configurable.
System Entity Helper dialogues	A number of dialogues appear when an operator is carrying out system functions requiring a number of user input steps such as creating new message templates, creating VVMS site locations and new Journey Time prediction routes etc.

Table 2 - VVMS Dashboard Layout

Figure 10 and Figure 11 highlight the VVMS dashboard features described above:

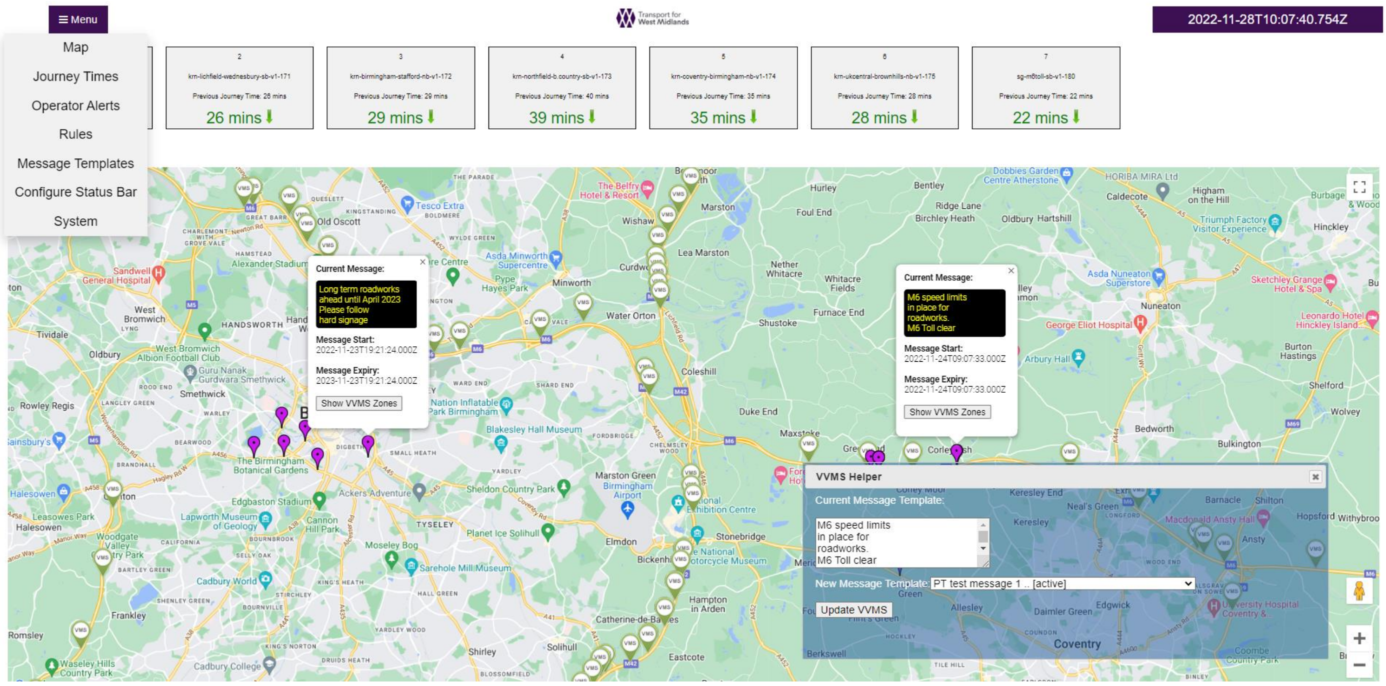

Figure 10 - Web Dashboard layout (sidebar collapsed)

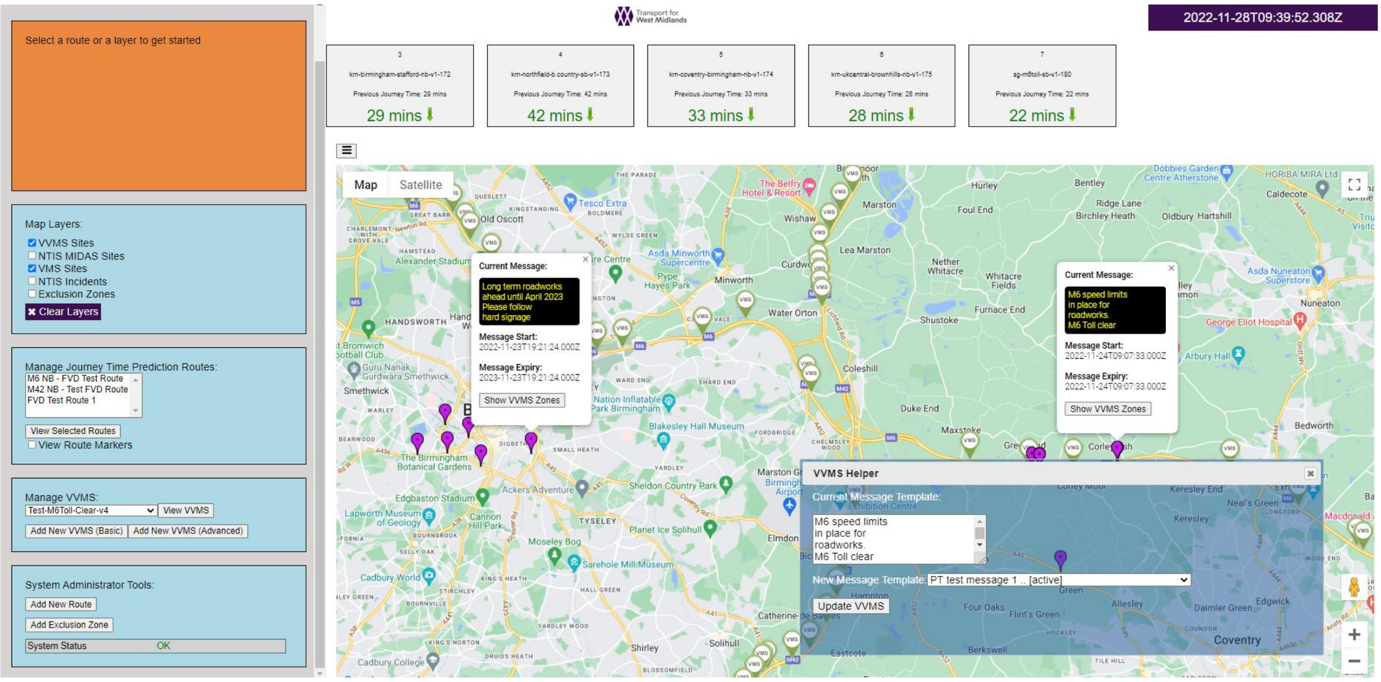

Figure 11 - Web Dashboard layout (sidebar open)

3.2. V2X End User Delivery

3.2.1. KLS integration on Polestar vehicle and future developments

During the project the KL System was also integrated on a Polestar vehicle. This successfully demonstrated the system's seamless functionality directly on the infotainment system of a Polestar 2. The integration was made smoother by leveraging Polestar's use of Android Automotive as their infotainment operating system. This decision not only facilitated a seamless incorporation of external functionalities but also allowed for a more cohesive user experience due to the inherent compatibility of Android Automotive with various applications and services. As we continue to push the boundaries of technology innovation, it is possible that forthcoming developments will lead to the full integration of diverse elements within their infotainment framework. This has the potential to cover a wide range of features, from sophisticated driver assistance systems to overlays of augmented reality and could lead to the introduction of a fresh phase where vehicles offer interactive and intelligent information.

Figure 12 - KLS integration on Polestar vehicle

4. Extended Survey To Capture Attitudes Towards IVMS in Potential M6Toll Users

An anonymous survey has also been implemented to help to capture a broader overview of potential road user habits and their views relating to in-vehicle technology and messaging. The survey was administered using Prolific, an online panel service[3] to reach as many participants as possible within the following criteria:

- England only
- Hold a full driving licence
- Drive for more than 1 hour per week

The survey was carried out on the 27th April 2023 and 540 responses were collected. The survey was then redistributed to a further 463 participants on 21st June 2023, making the total responses collected 1,003. This version of the technical note records the findings from all 1,003 participants combined.

4.1. High level findings

4.1.1. General breakdown

- 97% of participants said that they mostly use cars
- There was a range of durations that driving licences have been held, but 38% of respondents had held them between 10-24 years
- 68% of respondents reported spending between 1 and 6 hours driving per week
- Top 3 journey types were visiting family and friends, commuting and leisure
- There was a range of vehicle ages…
  - the most frequently selected was 10-14 years – which accounted for one quarter of the respondents (25%)
  - 9% had cars less than two years old

4.1.2. Technology insights

- Participants were asked about their use of smart home devices with the examples given in the question being those that work predominantly using voice (Amazon Alexa, Google Home Assistant or Apple Homepod):
  - 28% of respondents reported having no smart home devices and no plans to get one; 7% did not have one but were curious
  - 18% had one or more but didn't use them very often
  - 32% had one and use some of the skills and capabilities some of the time
  - 15% had one or more smart home devices and use them a lot
- When asked what technologies they had in their vehicles, respondents suggested a broad range (Figure 13):

[3] https://www.prolific.co/

- Only 7% were aware of eCall despite 9% reporting having new cars
- 35% reported having smartphone mirroring (Apple CarPlay or Android Auto).

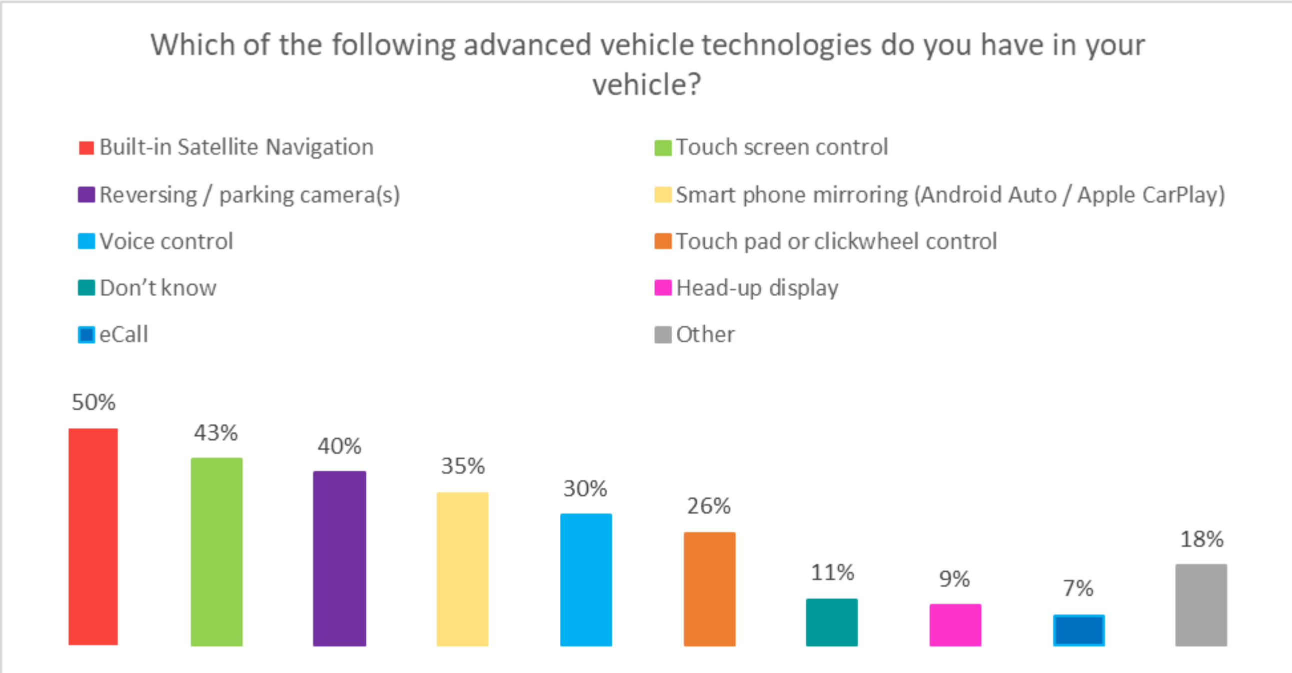

Figure 13 - Advanced vehicle technologies in participants' vehicles

4.1.3. Journey planning tools and route choice

A range of different information were used to plan journeys, with Google Maps and Sat Nav being the most popular (Figure 14)

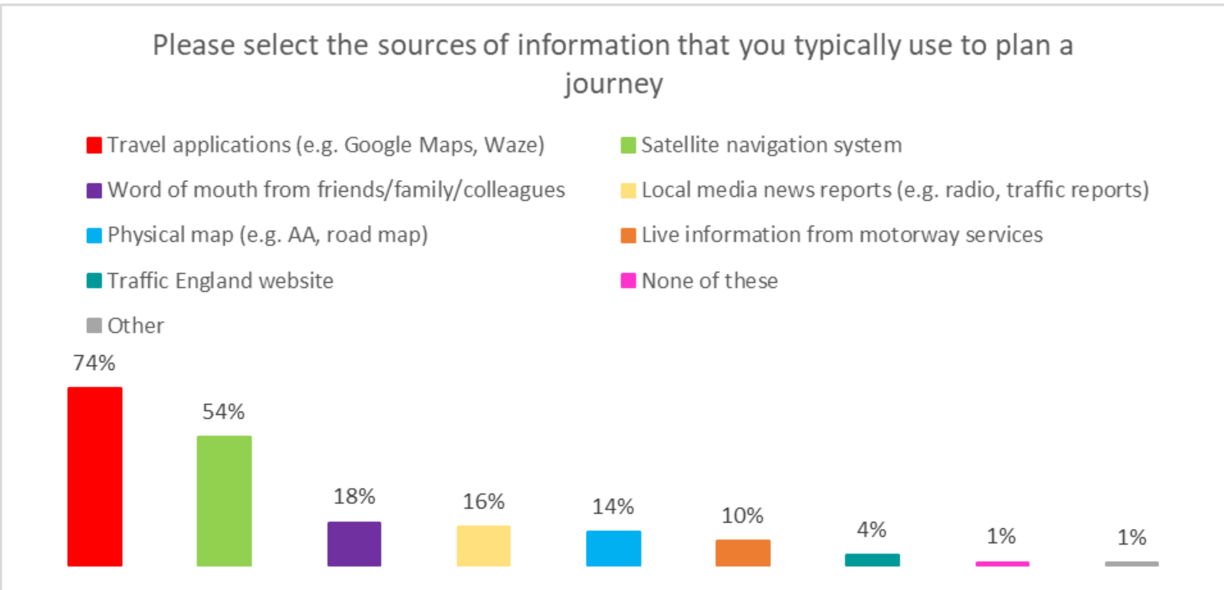

Figure 14 - Information participants use to plan a journey

Sat-Navs, mapping tools or travel applications were mostly selected as used for unfamiliar or new journeys (63%, Figure 15):

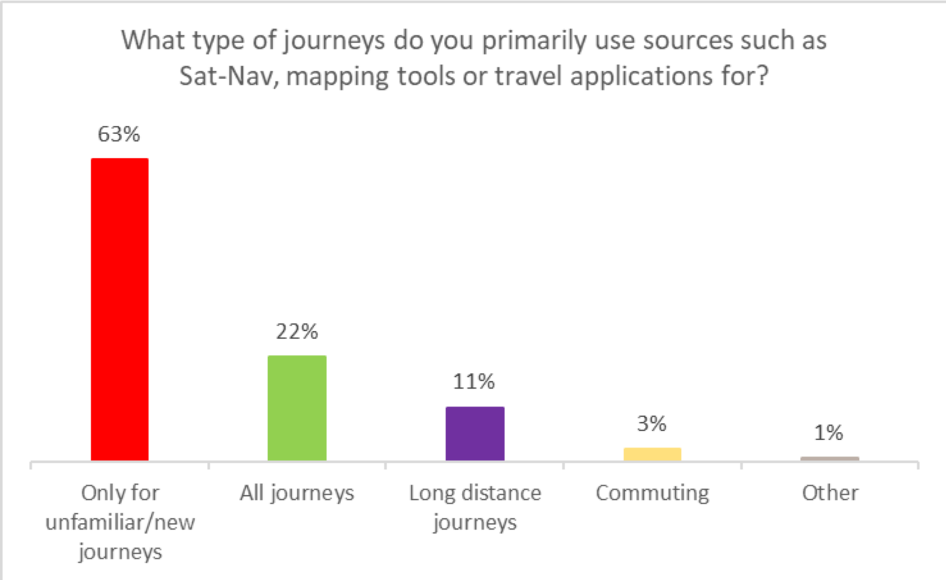

Figure 15 - Types of journeys participants' primarily use Sat-Nav etc for

Respondents indicated that travel applications like Google Maps and Waze as well as their Sat-Nav systems were what they would typically use to reroute a journey after setting off should their initial route be unavailable:

- 30% of respondents reported that they felt uncomfortable interacting with their device when this happened, 60% felt comfortable and 10% were neutral.

When asked about how they choose their routes, 32% of respondents said that they wouldn't pick a toll road if there was an easy alternative, whereas 23% decide on a trip-by-trip basis (Figure 16):

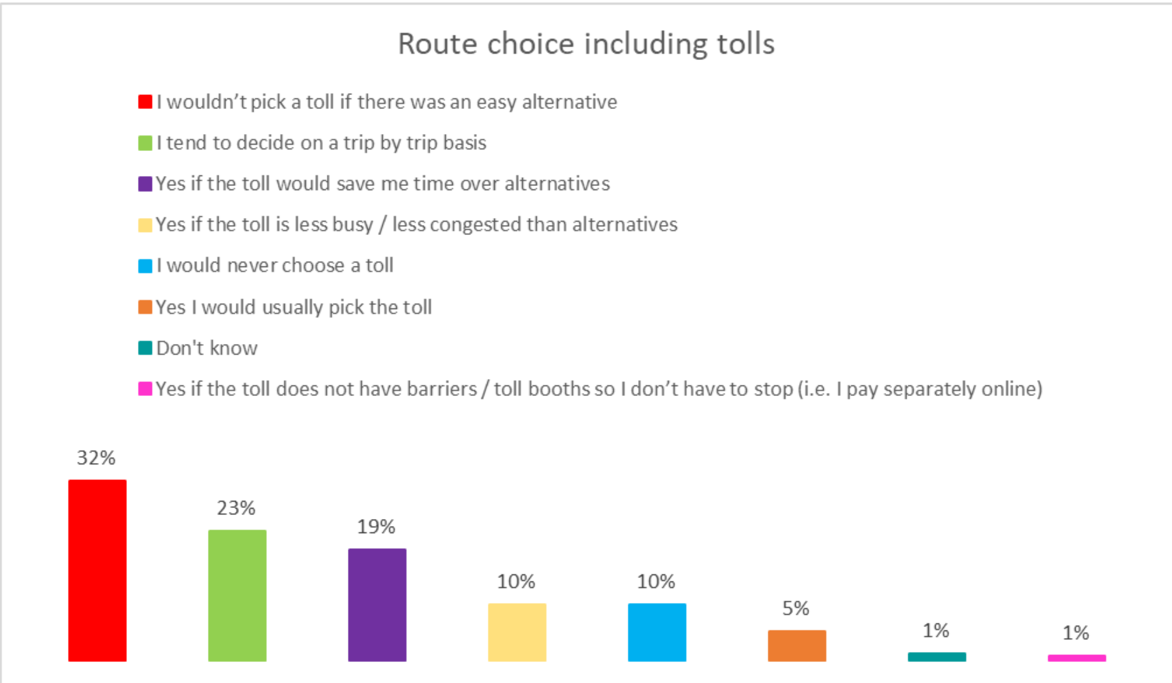

Figure 16 - Participants' preferences over picking a toll road

4.1.4. Trust in sources of information

Participants reported that they had the highest level of trust in information given by national bodies such as National Highways (Figure 17):

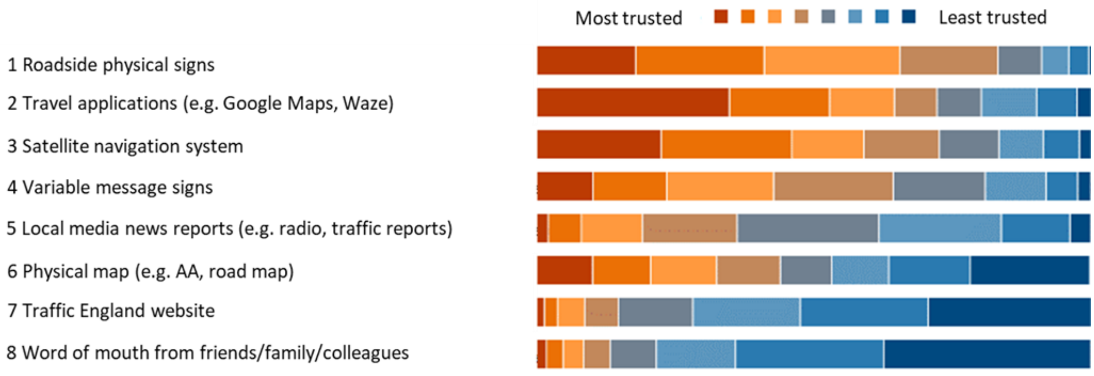

Figure 17 - Participants' trust in different types of organisations

The following sources of information represent the level of trust placed in them (Figure 18):

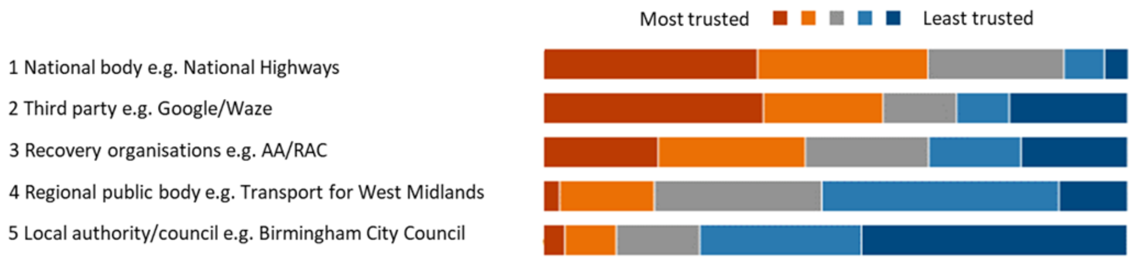

Figure 18 - Participants' trust in different sources of information

Clear information and reliable information were the two main reasons for people trusting these sources.

4.1.5. What they want to know, and how to tell them

When asked about their preference for receiving information about their journeys while driving, 53% of respondents said that they would prefer a combination of audio and visual messages (Figure 19):

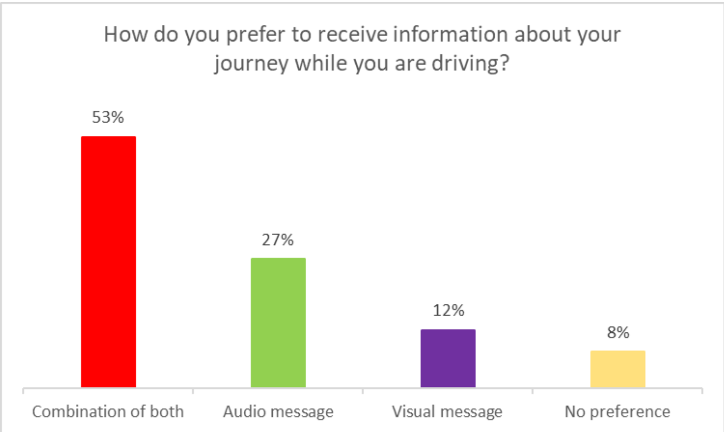

Figure 19 - Participants' preferences for how they receive messages

Respondents seemed to place equal levels of trust in information received whilst driving on both motorways and urban roads, and showed no clear preference with regard to whether they would trust a variable message sign or satnav more in the event of conflicting information (Figure 20):

Figure 20 - Participants' trust in VMS vs Sat-Nav/Google Maps

When asked to rank the types of information that they were most interested in receiving while driving, participants ranked road closures and journey times the highest. Cost and environment were ranked as being of the least interest (Figure 21):

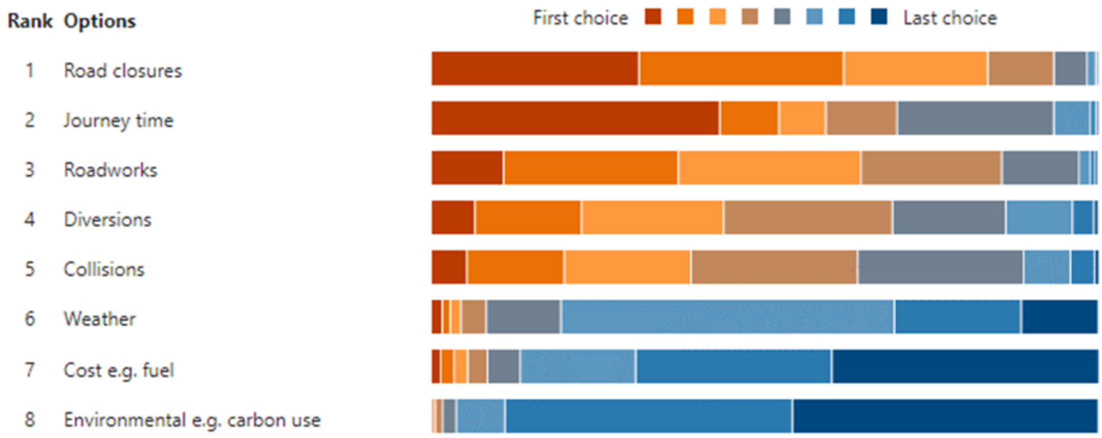

Figure 21 - Participants' preference for different types of messages

Participants were finally asked to pick between similar pairs of example messages:

Slightly over half of participants preferred the message:

“A456 Hagley Road is the quickest route to the M5” over “The A456 Hagley Road is 10 minutes quicker to the M5 than the A41 Holyhead Road”.

Suggesting a narrow preference for brevity and focussing on key info only (Figure 22).

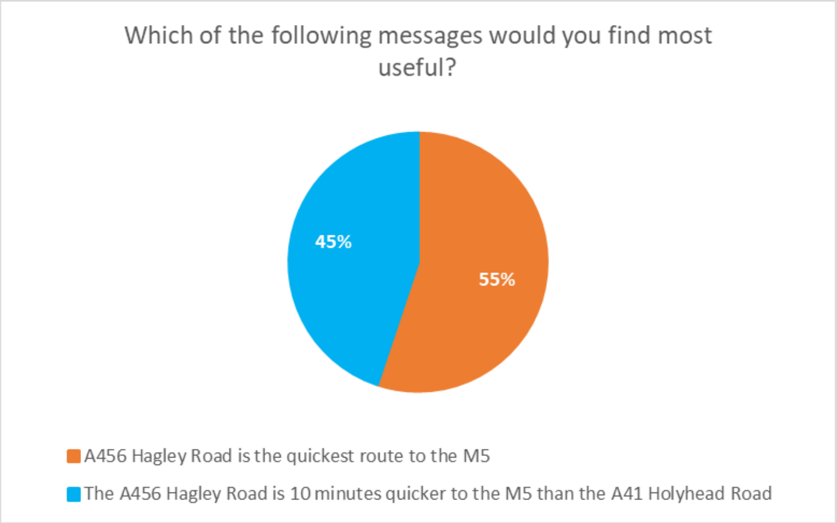

Figure 22 - Example message 1 participant preference

Most participants preferred the message:

“M6toll will save you 8 mins” over “M6toll will avoid an 8 minute delay”.

Suggesting a reported preference for positive messaging over loss aversion (Figure 23).

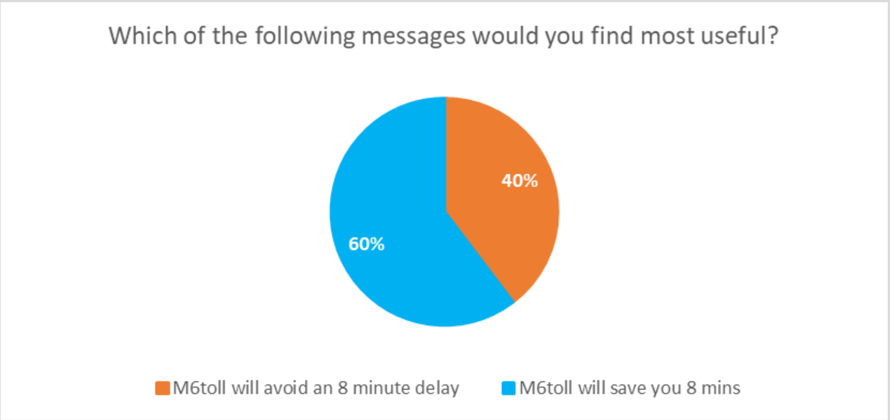

Figure 23 - Example message 2 participant preference

Almost all participants preferred:

“Major event at NEC this weekend, local delays expected Saturday morning and Sunday afternoon” over “Avoid NEC this weekend”,

Suggesting that people prefer to receive more information about route choice over a minimal message (Figure 24).

Figure 24 - Example message 3 participant preference

4.2. What does this mean for the messaging trial?

4.2.1. Participant and technology context

- 65% of participants had smart home technology devices, indicating a good level of technology adoption and familiarity with voice commands and messaging.
- Half reported that they had built-in sat nav in their vehicle with approximately one third reporting having smart phone mirroring. This indicates a good level of familiarity with in-vehicle technology, although findings did indicate some very low awareness of features such as eCall.
- There was a strong preference (almost 2/3 of participants) for using sat nav or mapping apps only on unfamiliar journeys.
- 32% of respondents said that they wouldn't pick a toll route if there was an easy alternative, however the next largest group at approx. 23% said they would decide regarding toll use on a trip by trip basis – and as such represent a reasonable size of cohort for whom in-vehicle messaging relating to a toll road could influence their decision.

4.2.2. Messaging trial

Message type

- Road closures and journey times were the message types respondents were most interested in receiving whilst driving; cost and environment were ranked lowest preferences.
- 53% of respondents said that they would prefer a combination of audio and visual messages (27% preferred the idea of an audio message whereas 12% preferred the idea of a visual message, 8% reported having no preference for the way in which messaging was communicated).

Message content

- There was no clear preference for whether a roadside variable message sign or sat nav / mapping apps would be trusted more in the event that they displayed conflicting information.

- In this study, there was one message which used loss aversion regarding delays, and this was rated by respondents as a less popular way of framing compared to a more positive message.
- Participants tended to narrowly favour shorter messages, but not where the shorter message omitted some specific information.

Transport for West Midlands

5. In-Vehicle Messaging Trial: GG 104 safety risk assessment

5.1. Introduction

This section gives an overview of the risk assessment for M6 Toll in vehicle messaging trial. It follows the framework of National Highways' requirements document GG 104 *Safety Risk Requirements*[4] as a best practice approach for assessing and managing safety risk on the highway network. Although this is not a National Highways project they were a key stakeholder and it took place in vehicles which were using the Strategic Route Network (SRN) which National Highways have responsibility for.

5.2. Safety risk assessment planning

The purpose of this safety risk assessment is:

- to determine whether the M6 Toll in vehicle messaging trial materially affected road user risk, and
- to identify reasonably required risk controls for the execution of the trial in order to meet the safety objective.

5.3. Categorisation of activity type

The activity type for the trial were categorised in accordance with the feature types in GG 104, which were written before the trial and are summarised below:

GG 104 FEATURES	DESCRIPTION (para-phrased from GG 104)	Application to this project and feature type selection
Extent of prior experience of activity	The degree of knowledge available from undertaking the activity previously or the degree to which knowledge is available from the activity being undertaken by other industries or organisations.	There is significant relevant knowledge relating to in-vehicle messaging, distraction and behaviours. *Type A*
Statutory and formal processes and procedures	Consideration of the applicability of current standards, formal processes and procedures, guidance and legislation.	Messaging trial will be within current processes, procedures and legislation. Development with TfWM and supply chain will assure quality and compliance of the messaging / app content. *Type A*
Impact on the organisation	The effect that the activity will have on current National Highways processes, procedures, structure, roles and responsibilities, competencies, policies and strategy, in addition to contractual and workforce arrangements.	This trial is carried out initially when vehicles are on the SRN and could result in some re-routeing of participants in order to reduce congestion. But impacts on National Highways are otherwise negligible and require no process changes. *Type A*
Activity scale	Consideration of the size and/or scale of the activity. Does or can the activity have an impact on the motorway and all-purpose trunk roads, either directly or indirectly?	This trial is initially expected only to take place in a relatively localised area in the West Midlands on selected strategic and major roads and impacts on the SRN would be modest and indirect. *Type A*

[4] https://www.standardsforhighways.co.uk/tses/attachments/0338b395-7959-4e5b-9537-5d2bdd75f3b9?inline=true

GG 104 FEATURES	DESCRIPTION (para-phrased from GG 104)	Application to this project and feature type selection
Technical	Measure of technical and / or technological novelty and / or innovation the activity involves.	This trial brings together existing elements of technology to provide focussed and timely information for road users using local expertise of TfWM. In reality many road users are already experiencing dynamic and specific in-vehicle messaging via apps such as Waze and Apple Maps. This trial is an evolution of an existing technology eco-system. *Type A*
Stakeholder impact and interest	The quantity and/or impact of stakeholders, their interest in and resulting ability to influence or/ impact on the safety activity. The degree to which these safety issues (as perceived) are capable of being understood and fully addressed.	Stakeholders are principally TfWM, National Highways and M6 Toll. Safety issues are well understood and mitigated, leaving very limited operational impact at this trial stage. *Type A*

Table 3 - Activity type

All features were classified as Type A, indicating that this trial was a Type A activity overall. As such approvals were via the project manager at TfWM.

In addition to the TfWM project manager, the project had an advisory board which was able to review and accept proposals, including this safety risk assessment. The advisory board was cross-organisational and included a member of National Highways as well as regional stakeholders. Therefore, this trial was expected to be subject to a level of assurance which exceeds the minimum required for a Type A activity.

OBSERVATION POINT
Note that any subsequent tranches or roll-out beyond this trial would require that the activity type assessment to be updated

5.4. Identification of affected populations

Road users were impacted – which included sub-groups of trial participants and non participants (who, if in the vicinity, could be affected by the injudicious actions of a trial participant).

It was assumed that in-vehicle messaging would have been delivered to road users whilst they were on the M6 (although the subject of the message could relate to the M6 Toll, or another downstream route on TfWM's Key Route Network (KRN)). As such, the direct impacts of the messaging were limited to users of motorways – it would not be reasonable to draw a link between a message delivered on the motorway and the driving standards of the participant sometime later on another class of road, even if the message influenced their decision to take that road. Therefore, it is concluded that only road users on the strategic road network were impacted. However, if the above assumption developed such that the trial included messages being delivered to vehicles whilst they were on the KRN, a wider sub-set of user populations would have required consideration – as the KRN space may be shared with cyclists, pedestrians etc. This trial did not directly or materially affect road workers or other parties.

5.5. Safety risk assessment scope

The safety risk assessment investigated the potential on-network safety impact of the M6 Toll in-vehicle messaging trial (Figure 25). The main objective of the trial was to better inform trial users regarding route selection and conditions ahead, which would deliver journey time and satisfaction benefits, and eventually better information and more appropriate vehicle routeing should have associated safety benefit – although this is not being progressed as a safety-driven intervention, and any future scaling up of the work would be accompanied by a new or revised safety risk assessment.

Figure 25 - Example of an in-vehicle VMS message displayed via an Android Auto connection

The type, length and complexity of messages transmitted were determined partly by any constraints placed as risk controls identified herein, and partly following the social and behavioural recommendations of what would comprise effective messaging (see Section 6)

The geographical scope included:

- M6 and M42 approaches to the M6 Toll – i.e. messages were delivered to vehicles / devices on the M6 (even if the subject of the message relates to another route ahead). The M6 Toll was the primary focus of this trial.
- TfWM's Key Route Network (KRN) – some selected sections of local routes could be sites for trial messaging deployment, i.e. relevant messages delivered whilst the vehicle were on the KRN (even if the subject of the messages pertains to a road or route on another network). The KRN is illustrated below:

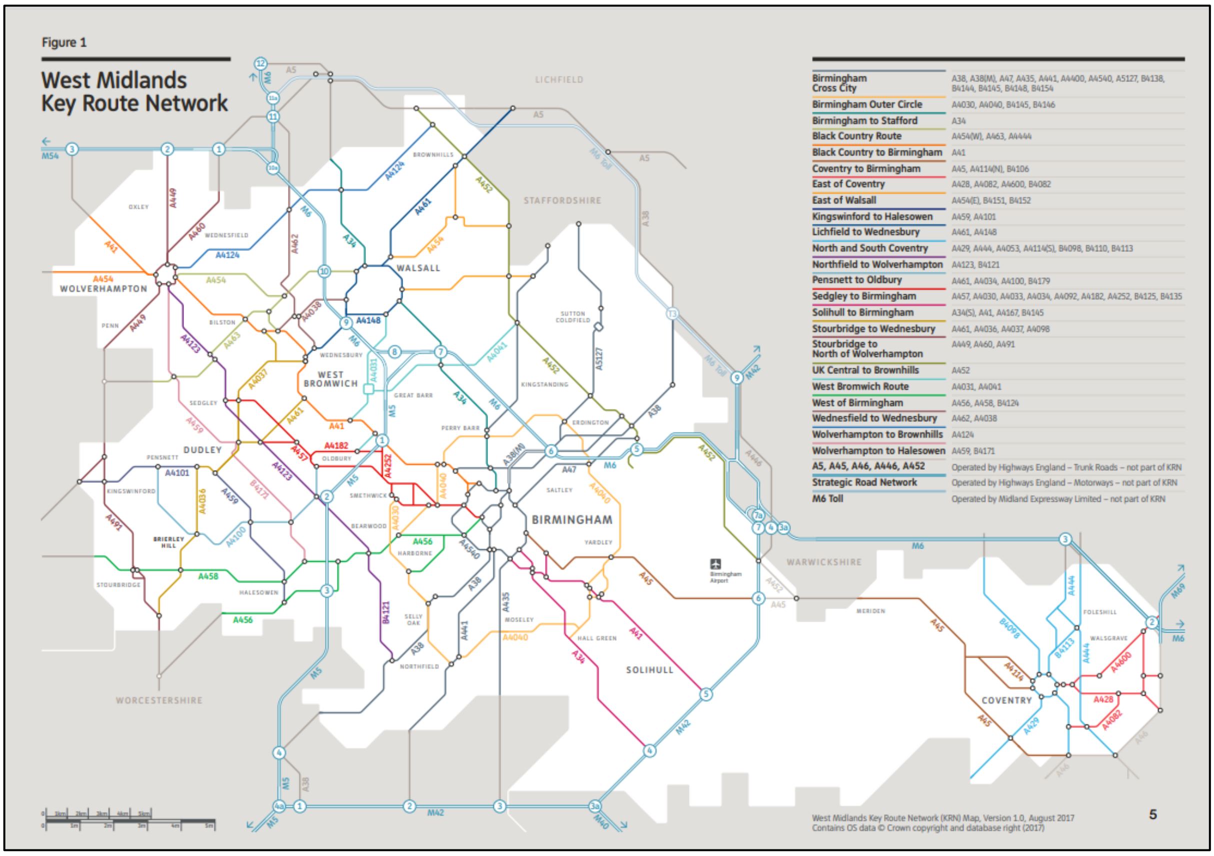

Figure 26 - West Midlands KRN[5]

5.6. Safety baseline and objective

This messaging trial has come about, in part, to investigate the impact of alternative means of providing road users with timely and dynamic information about their journeys, beyond providing an electronic roadside message sign.

As such, the level of safety of users on the network where electronic message signs were currently in widespread use was taken as the safety baseline. In effect the baseline was the existing general safety performance of the affected motorways. It was necessary to assess this qualitatively as a measure such as motorway collision rate would not isolate the effects of this trial.

The safety objective was that this messaging trial did not adversely affect the safety of road users (both trial participants and non-participants) by providing a more complex or distracting environment than was present from existing (baseline) roadside signals, signs and in-car navigation system use. A suitable judgement reached by assessment and a well-reasoned argument determined whether the safety objective was likely to be achieved; a qualitative measure of collision rates would not be specific enough for a meaningful objective.

In practice this baseline and objective meant that the trial participants (and those in their vicinity who would be directly affected by their actions) continued to be exposed to a level of risk similar to that of other road users on the affected motorways.

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[5] Source: [west-midlands-key-route-network-evidence-report-2018-2.pdf (tfwm.org.uk)](west-midlands-key-route-network-evidence-report-2018-2.pdf)

5.7. Hazard identification

The over-riding hazard condition which this safety risk assessment was concerned with was driver distraction and the potential for in-vehicle messaging to cause, prolong or exacerbate distraction.

In general, a distracted driver pays reduced attention to the driving task and a gap emerges between the requirements for safe driving and the attention that a driver gives it – creating a hazard condition. This means that distracted drivers are more likely to make an error in their own driving task (e.g. drifting out of lane), increasing risk to themselves and others; and that they are less able to respond appropriately to a hazardous condition ahead (e.g. sudden braking).

Distraction in this context could take four forms, with potential application to this trial identified:

1. cognitive distraction; i.e. driver's attention away from the driving task and given instead to reading the message, processing the message or reacting to the message.
2. visual distraction; i.e. driver gaze directed away from the core driving task.
3. auditory distraction, i.e. driver attention taken by an auditory cue, which is often then accompanied by other types of distraction e.g. looking for / at the source of the noise.
4. manual distraction, i.e. driver using their hands (typically) to carry out a task other than driving, e.g. operating a control; tapping, swiping or typing. Touching a mobile phone whilst driving is specifically prohibited in law and the trial ensured that messaging delivery can be paused or cleared from the screen without the need for touch (i.e. it auto-clears, and / or is responsive to a voice command to clear).

The four forms of distraction should also be understood in the context of time. A brief warning chime is likely to be less distracting than some minutes spent in conversation; a momentary button press is likely to be less distracting than navigating a series of sub-menus to do the same thing.

Hazard analysis was therefore considered the nature, potential severity and duration impact of distraction.

5.8. Hazard analysis

Regardless of this trial, in general, the distraction hazard is ever-present from sources inside and outside of vehicles and drivers, for the most part, are able to successfully segregate their attention and safely navigate a complex environment.

Driver discipline remains the ultimate safeguard, i.e. a responsible driver complies with the Highway Code to dedicate suitable attention to the driving task throughout their journey regardless (within reasonable limits) of what distraction opportunities they are faced with. Legally, drivers retain ultimate responsibility for their conduct.

However, it is widely recognised in psychology that humans are error prone, and that electronic devices are very effective at capturing attention. This is why, regarding risk controls, the ERIC-PD hierarchy[6] places 'discipline' at the bottom of the list; for the purposes of this trial it was not reasonable to lean solely on the driver's legal responsibility and duis no more to assess and control associated risks.

Applying a safe systems approach, this document assessed and put other reasonable controls in place, to carefully manage message delivery to minimise requirements on driver discipline as a mitigation for potential distraction during this trial. The approach to managing driver distraction and workload was informed by WSP human factors experts, who have applied principles from academic research and from applied experience such as the existing National Highways Variable Signs and Signals policy. Their findings have been incorporated into the hazard and risk control identification as per the table below.

Their recommendations placed certain proportionate limitations on the in-vehicle messaging design and delivery in order to address the hazard of driver distraction.

Several similar trials of in-vehicle messaging have been carried out, for example on the A2/M2 corridor in Kent. Safety documents from that exercise, and in particular the principles adopted to control risk, were then reviewed and incorporated here where appropriate – in addition to the factors from our human factors specialists.

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[6] Eliminate, Reduce, Isolate, Control, PPE, Discipline

Risk controls for this specific trial are identified below, and associated actions and action owners to deliver them are detailed in a subsequent section.

Hazard Ref	Hazard description	Risk control or principle	Residual risk
1	Device positioning obstructs view through windscreen or mirrors, or requires long glances away from road to read, impairing the driving task	Participants to agree that they have and will use a suitable mounting device if mobile phone is used for navigation, and connect directly to vehicle display using Android Auto or CarPlay where possible Participants to be reminded of legal requirements and provided information on safe location of mobile devices in-car.	Does not apply to Polestar participants. Relatively low risk – only materially changed if involvement in this task is what causes the participant to locate the device improperly; suitable placement of devices is an existing risk which the introduction of this trial is unlikely to materially change.
2	Messaging causes long glances away from the road – visual distraction	a) Over-riding principle that the message can be digested with a similar visual and cognitive workload to that of reading a gantry ahead (typically 4-5 units of information per message or fewer, absolute maximum of 7 units[7]). b) Messages to be read out using text to speech by default, like a sat nav instruction. c) Message language and complexity to be carefully developed and controlled in line with best practice; part of messaging design task. d) Message to be displayed temporarily but will be present on-screen for long enough that drivers would not miss it if they did not immediately read it – suggested display time of 8 seconds initially[8]. e) Initial testing with user base of staff who will provide feedback on workload / distraction potential prior to public use.	Relatively low risk in context of the motorway environment and existing sat nav use – a temporary message will minimise a desire to interact with a device to clear it, but maintaining a suitable duration will ensure the user knows they do not have look at it immediately.

[7] National Highways *Variable signs and signals policy* v4.0; section 2.9

[8] Aligns with Google automotive default notification time before automatic dismissal [Notifications on Android Automotive OS | Android Developers]

Hazard Ref	Hazard description	Risk control or principle	Residual risk
3	Messaging delivered or displayed such that it startles or ‘grabs’ driver’s attention – visual or auditory distraction (often leading to cognitive distraction)	a) Messaging delivery will be in line with other typical information delivery, e.g. displayed with similar prominence to sat nav instructions for an upcoming junction. b) Message will be static, not scrolling or flashing (i.e. all displayed on one screen). c) Message will be carefully developed to align with best practice from research. d) Message delivery tone and volume to be aligned to device norms for navigation. e) Initial trial phase with staff or other ‘control’ participants to gather feedback on real world use and any anomalies.	Relatively low risk in context of the motorway environment and sat nav use. The information will always be notified in the same way as a non-urgent guidance message.
4	Messaging requires significant cognitive effort to interpret – cognitive distraction	a) Over-riding principle that the message can be digested with a similar visual and cognitive workload to that of reading a gantry ahead. b) Messages to be read out using text to speech by default, like a sat nav instruction. c) Message length and complexity (units of information, language) to be carefully developed and controlled in line with best practice. d) Initial trial phase with staff or other ‘control’ participants to gather feedback on real world use and any anomalies.	Relatively low risk in context of the motorway environment and sat nav use. Trial participants will have a level of prior explanation to set expectations that the system will not be delivering critical messages.
5	Messaging arrival coincides with time or place of high driver workload – cognitive / visual distraction	a) App to include simple restrictions on message delivery dependent on vehicle speed – messages not displayed if vehicle is travelling at over 70mph. b) API relevance zones able to be tailored to exclude pre-determined high workload areas (e.g. a known weaving length at or around peak time). c) Guidance for TfWM staff on exclusion zones to help consistency and quality of guidance positioning.	Existing sat nav and similar systems do not contain similar safeguards; these control measures help to ensure low risk from these additional messages.

Hazard Ref	Hazard description	Risk control or principle	Residual risk
6	Messaging is not obviously relevant to the driver (either time or location mismatch) – cognitive distraction	a) Messages timing and content will be reviewed to ensure relevance – e.g. M6 Toll time saving information will not be displayed once the user has passed the M6 / M6T bifurcation and will be displayed where the road user still has time to make an informed decision over routeing. b) Message selection and initiation criteria by TfWM staff will apply local knowledge as a further check for relevance. c) Initial trial phase with staff or other 'control' participants to gather feedback on real world use and any anomalies.	Safety impacts are likely to be minor only; this is more a risk relating to frustration / credibility of the system.
7	Message is not easily comprehensible if/ when delivered via text to speech (e.g. M6 S is easy to interpret as M6 south when written down, but is much less clear if read aloud as "M6S") – audible / cognitive distraction	a) Message content to be developed and tested for clarity and usability via text to speech, i.e. speech script could differ from that in displayed messages and offer naturalistic speech (e.g. in the way road numbers are spelt out – A449 is read out "A four four nine", rather than "A four hundred and forty nine"). b) Initial trial phase with staff or other 'control' participants to gather feedback on real world use and any anomalies.	Relatively low risk in context of the motorway environment and existing sat nav use.
8	Message acknowledgement creates a task - leads to manual / visual + cognitive distraction	Messages will not require acknowledgement and will self-clear.	Relatively low risk in context of the motorway environment and existing sat nav use.

Table 4 - Risk controls

5.9. Analysis of safety risk

Hazard analysis above identified mechanisms by which this trial could contribute to driver distraction. Risk controls were identified and incorporated as part of core trial design and delivery; these left a level of residual risk to road users that was unlikely to be materially higher than that to which drivers are generally exposed. With controls in place it was considered likely that the safety objective not to increase risks to road users, were likely to be met.

Put another way, this trial was likely to present a user with a relevant message a small number of times during a journey; during that same journey the user might have received dozens of sat nav instructions, be listening to the radio and see countless sights which did not relate to the driving task but which nevertheless could distract. Set against the context of the already high level / rate of potential distractions every journey, the residual (post risk control) risks from this trial were likely to be negligible; i.e. the messaging was unlikely to present a tipping point to driver overload and subsequent error. There remains significant potential for customer and congestion benefits in having a more direct real-time influence over routeing.

A key risk control was the monitoring of the trial itself, which recorded participant responses to messaging and any feedback relating to distraction or safety. Monitoring was split by cohort, and applied in the first instance by teams from Mustard and from WSP.

Should it have become known that a trial participant had been involved in a collision at the time of message delivery to their vehicle (and for a short time thereafter) the trial (i.e. issuing of messages) would have paused until the team could investigate the circumstances and ascertain the likelihood of a causal link between trial messaging and the collision. For example, if the participant's vehicle was otherwise proceeding normally and was hit from behind by another vehicle this could be judged unlikely to be linked to the trial and messaging; whereas if a trial driver did not maintain suitable lane positioning in the seconds following message delivery then a distraction element may have been associated.
The teams from Mustard and WSP were in regular contact with each other and the TfWM staff to retain this 'abort' control. This forms part of the trial abort criteria, but it should be stressed that is not expected to occur as mitigated risks have been assessed as low and unlikely to materially exceed the existing level of risk in the baseline scenario.

5.10. Evaluation of safety risk

Hazard analysis concluded that, with risk controls in place, there was unlikely to be a material impact on risk to road users associated with conducting this trial. These risk controls had all been judged to meet the criteria of 'reasonably required'. This means that the safety objective, of not materially exceeding the current road user safety risk, was likely to be achieved.
Sat nav, used appropriately, can be seen as neutral in risk terms. Although the device almost certainly draws the driver's visual attention to view the route / instructions, or auditory / cognitive attention to listen to and process the instructions, it does this in place of the potentially more acute cognitive and visual load of navigating without an in-car aide. Moreover, sat nav gives users a level of service and comfort that helps to reduce stress, anxiety or frustration – which are all states which can be detrimental to the driving task. This trial of in-vehicle messages took this approach and extended it with an additional layer of up to date travel and navigation information. For the purposes of this trial, users were briefed on the likely deployment and type of messages to expect – e.g. around travel information for the M6 & M6 Toll.
In this spirit the messaging trial was seeking to deliver useful and timely information to enable better journeys and reduce distraction (typically cognitive) downstream relating to route selection and journey time management. Frustration and anxiety should also be improved with better information.
Although no material change in road user risk has been found to be likely as a result of this trial, the trial outcomes should further help to address road user risk as a secondary benefit of providing better journey information. Trial monitoring helps to assure that the risk controls behave as anticipated.

5.11. Safety risk controls

Safety risk controls identified in the above hazard assessment are listed the below table, along with associated assumptions and actions that were considered at the time of the trial. This section was also re-visited during trial delivery to ensure that mitigation measures were being used and responding as intended.

Controls	Assumption	Action & owner	Status
Participants to receive guidance on signing up. Encourage use of Carplay or Android Auto if available. App to remind of legal requirements and provide link to guidance upon installation / initiation (not whilst active in car). Consider asking users to send a photo of their phone / device cradle set-up and conduct dip-sampling to ensure suitability / legality.	That users will be provided with the latest information and act accordingly in terms of device positioning and use. Integration with car systems / HMI will be used wherever technically possible for that user.	WSP to supply suitable material – Highway Code (Rule 148, 149 and 150) for requirements and guidance note on device placement. WSP and Mustard to work with TfWM to ensure suitable participant briefing.	To align with trial design. Guidance material on safe device placement and use has been drafted
Message content and complexity to be comparable to existing messaging (in terms of units of information, length etc) – although wording / language will differ	That there is a good body of evidence around driver distraction and units of information during the driving task.	WSP to establish simple ground rules specifically for assuring message design language and to apply VSS policy guidance relating to units of information. The messaging approach is to be reviewed in a multi-organisation stakeholder workshop (27th Jan '23). The output will be a message builder 'picklist' from which TfWM trial operators can assemble a suitable message, with reachback available to WSP for support guidance as required.	Information on unit guidance established from VSS policy and from primary research. Messaging design undertaken and shared in workshop – near complete, pending trial plan / permutations development.
Message display – time-bound (will self-clear)	That a message which self-clears but offers a reasonable chance to read will offer the lowest balance of risks. Android developer guides (automotive) to used as starting point or for default approach and only deviated from where a clear point of difference can be documented. Consider adding ability for a user to select / ask for last message to be repeated.	WSP to work with app developer (KL Systems) – Google rules for Android Auto notifications will set the initial framework – app would not deviate without a suitable rationale.	Agreed – use of Android Auto framework for message display rules.

Controls	Assumption	Action & owner	Status
Messaging delivery / notification is comparable to other routine navigation type prompts	Although this information is time-bound it is not critical and should not unduly attract the driver's attention when displayed	KL Systems to ensure delivery is appropriate and consistent with in-car navigation norms as part of remit to deliver the app solution.	Provisionally complete, current app build is giving these sort of prompts using Google voice assistant to verbalise the message. Messages will therefore sound and feel similar to those given by the most popular navigation aid, Google Maps.
Message delivery will not occur in certain circumstances – e.g. while navigating a complex junction (deliver on approach instead), if vehicle is exceeding the posted maximum speed limit by a certain parameter (messaging would be suppressed by the device).	The technology used in this trial is flexible and powerful enough to add an extra layer of protection against inadvertent distraction when drivers are engaged in known risky or high workload circumstances	TfWM to ensure relevance zones exclude certain key areas, informed by local knowledge. This will be built in initial guidance /examples from WSP. App developer to build in vehicle-specific logic relating to vehicle speed.	In progress, software builds allow for these safeguards.
Messaging will be relevant to the driver's time and location	That messaging is easier to absorb (lower cognitive distraction) where it is obviously relevant.	API and app give message time functionality; WSP to assist with setting boundaries regarding location. Message development for location and timeliness to be reviewed with software development team and TfWM to ensure local applicability. Process for trial deployment to be derived.	Technology solution underway; WSP to consider supplementary advice.
Messaging speech will be natural and easy to understand (e.g. abbreviations will be spoken in full)	That messages delivered vocally are least likely to provide a distraction.	Use of Google Assistant (or Siri) will ensure natural speech – e.g. abbreviations are not vocalised and road numbers are read out conventionally. WSP to check and advise e.g. on speech pauses and cadence during development.	Underway
Trial will be monitored and feedback sought; technology will undergo initial testing and messaging will be tested before going to general public	That monitoring provides a vital feedback loop and that initial testing will not involve the general public	Amey test plan to incorporate suitable testing time prior to go-live with the public, and make resource available to monitor the trial.	Underway – initial test plans to be reviewed

Controls	Assumption	Action & owner	Status
Initial part of trial will be with a controlled group of staff or similar (not general public) to establish functionality	That there is a likelihood of some unforeseen outcomes on the road and that more closely briefed / controlled participants will be better able to react and feedback.	Amey to develop trial phasing and initial testing with stakeholders.	Underway – initial test plans to be reviewed

Table 5 - Identified safety risk controls

6. In-Vehicle Messaging Trial: Message Assessment

6.1. Introduction

The in-car messaging for users on the M6 in the West Midlands aims to influence driver behaviour, route selection and efficient use of the network. The goal of this work is to demonstrate the potential for affecting driver and network outcomes by providing messaging in this new way and better understand any implications of doing so.
To develop the message set for the trial, behaviour change and human-centred design principles were used to create messages for presentation to drivers within their vehicles using their in-vehicle systems.

6.1.1. Approach

Recommendations for messaging to be used in the trial have been developed with the following approach:

a) Initial identification of suitable journey time messages from existing VMS legends. The variable signs and signals (VSS) policy messages [3] were used as a starting point, but then were adapted to improve the user experience and build on the information received on the roadside.
b) Further development to ascertain desirable messages from network operators and to identify desirable messages for behaviour change (e.g. improve safety or efficiency behaviours); advise on potential added value and collaborate with stakeholders to reach acceptance.
c) Ascertain message suitability for delivery in car – e.g. clarity, simplicity, suitable no. of characters for display.
d) Ascertain criteria for message delivery – e.g. timing, vehicle location, any other requirements from safety case (e.g. not if vehicle is travelling over certain speed).
e) Recommend and agree final message set and delivery criteria with stakeholders.

The following method was used to approach the task:

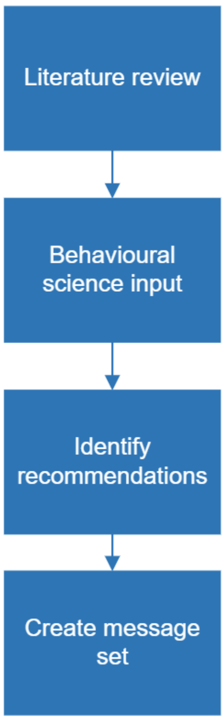

Figure 27 - Method for developing trial message set

Firstly, a literature review was conducted to examine the current research which would impact the in-vehicle messaging. This specifically looked into theories around behavioural influence, the types of messages

customers want, research into the content of information and presentation of information. The key findings from the literature review were identified and will be explored further in section 6.3.
Our Behavioural Science team examined driver attitudes, beliefs and decision-making with regard to opting to drive on a toll road and a series of behavioural messages were validated for use in the main experimental trial. Consequently, the messages used were designed using up-to-date behavioural science knowledge and techniques.
A shortlist of feasible messages was created. All messaging were assessed against the EAST Framework, a structured approach to applying behavioural insights (see Figure 28). The final set of behavioural messages were tested as part of the main study trial.

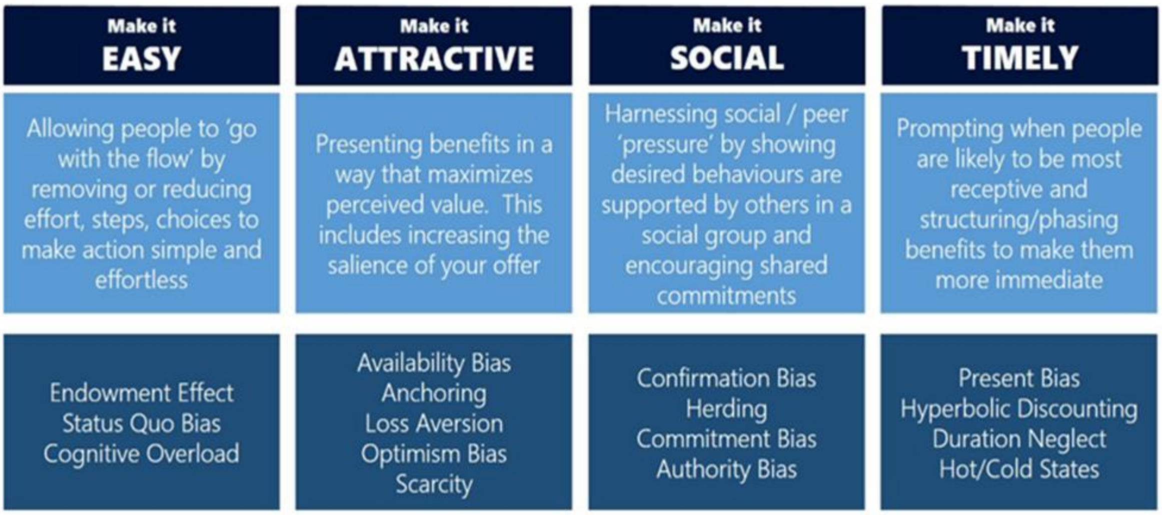

Figure 28 - EAST Framework

6.2. Behavioural insights

The theory behind behavioural insights is to encourage people to make better choices for themselves and society. The approach is based on the idea that interventions such as messaging aimed at encouraging people to make better choices (i.e. influencing driver behaviour, route selection and efficient network use) will be more successful if they are based on insights from behavioural science. To support TfWM in developing messages that follow behavioural insights-based principals, WSP have used human factors and behavioural experts to provide behavioural insights into what might influence people to change their behaviour.

6.2.1. How can behavioural insights help TfWM develop messages to encourage change?

There are many different models for behaviour change. A review was undertaken to understand the key features of behaviour change models that could help TfWM meet its objectives. Several models were reviewed in detail (e.g. the EAST model [4], the COM-B model [5] and the Theory of Planned Behaviour [6]). This section summarises the key relevant principles identified.

EAST model

Messaging should be **simple**, **attractive** to the driver (i.e. benefit them) and where possible, should make use of **social norms** (the unwritten rules of beliefs, attitudes, and behaviours that are considered acceptable in a particular social group or culture).

  - *What does this mean for TfWM?* If possible, use messaging to convey that most other people are engaged in the desired behaviour and that not many are doing the unwanted behaviour. However, this may be difficult for the trial itself as receiving a message that other drivers are taking a certain route may instead discourage that route choice.
- Messaging should be **timely** (i.e. it should come at a point where people are most likely to be receptive). Messages should give drivers sufficient time to consider the immediate costs and benefits to plan their response.
  - *What does this mean for TfWM?* Messages should only be presented at locations where drivers have less other stimuli (e.g. not at the same time other information is being presented), and where they have time to consider and change their route.

Loss aversion

- Messaging should consider adopting **"loss aversion"** i.e. being mindful that people dislike losing something more than they dislike missing out on something [7].
  - *What does this mean for TfWM?* Messages should try to communicate potential loss rather than gain (e.g. theory suggests that drivers would be more motivated by not losing 10 minutes of time than they would be about gaining 10 minutes of time).

6.2.2. What does research tell us about customer needs?

Driver differences

The first thing to note from research into decision making behaviour and route choice is that different types of drivers have different "profiles". One research study identified six profiles of route choice [8]:

- "Staying" traveller sticks consistently with the same route
- "Trying" traveller tries both routes once and continues using preferred route
- "Occasionally curious" traveller occasionally curious about alternative route and tries it once or twice
- "Exploring" traveller explores both routes before deciding their preferred alternative
- "Switching" traveller has no clear preference and switches between both routes
  - *What does this mean for TfWM?* There may need to be subtly different messages to influence different types of drivers.

Customer preferences

Research conducted by WSP on behalf of National Highways [9] involved a literature review into what types of messages customers want to receive in their vehicles. The following findings were identified:

- 50% of drivers chose the shortest/fastest route from their origins to destinations
- Road users want to feel in control of their situation e.g. option to turn off features
- Road users are concerned that information is inaccurate and they then do not trust it
- Road users do not want information to contradict roadside info - they may get confused or not trust it as much as a result
- Road users want to see information on roadworks, cost of journey, diversions, services areas (particularly for disabled users)
  - *What does this mean for TfWM?* If possible, give participants the option to turn off features. Include that the message is from TfWM to validate its legitimacy. Ensure messages do not contradict roadside information. Include messages on journey time, roadworks, cost and diversions.

6.2.3. What does research tell us about presentation of information for messaging?

Research has suggested that the way in which information is presented for messaging may have an impact on how successfully it influences people. The following findings were identified:

Units of information

Research conducted by TRL in 2018 on behalf of National Highways [10] showed that drivers can only recall four to five pieces of information. VMS should contain as few as possible, with a maximum of seven pieces of information.

- *What does this mean for TfWM?* Where possible, restrict messages to contain only to four to five pieces of information, with a maximum of seven.

Agreed European best practice is to only display strategic legends twice between junctions. Simulator trials carried out in 2018 by TRL on behalf of National Highways, have shown that repeating strategic messages more than twice between a junction does not improve driver behaviour or recall [10].

- *What does this mean for TfWM?* Only display message twice between each junction.

Order

TRL's 2018 [8] research also found that when constructing VMS, the location, problem, effect, and guidance (LPEG) order provides the most effective means of communicating succinctly with drivers.

- *What does this mean for TfWM?* Use location, problem, effect, guidance when constructing messages. Figure 2 shows how to create a message with the LPEG order.

Location	Where is the problem? (M6 J32/M25 J20-21)
Problem	What is the problem? (Accident/Major Event/Closed)
Effect	What has the problem caused? (Delays/45 MIN DELAY)
Guidance	What should be done? (Slow Down/Use M1/Follow Diversion)

Figure 29 - LPEG order

Terminology

RoadPeace is campaigning for a move away from the term 'accident' to 'crash' to avoid suggesting collisions are unintentional or beyond control [11]

- *What does this mean for TfWM?* Avoid using the term accident, and use the terms crash or collision instead of accident to align with the latest guidance.

Appearance

Lowercase letters have a more distinctive shape than capital letters, therefore they can be perceived more quickly than uppercase letters [12]. The varying height of the letters helps people to process and understand the words, compared to upper case letters which make it more difficult to differentiate the letters due to them all being the same height.

- *What does this mean for TfWM?* To increase the chance of drivers comprehending messages easily and therefore more likely to utilise the information, use lowercase letters.

Mechanism for information

A study by TRL found that touch features have been found to be more distracting than voice features [13].

- *What does this mean for TfWM?* Limit any requirements for drivers to use touch when receiving in-vehicle messages.

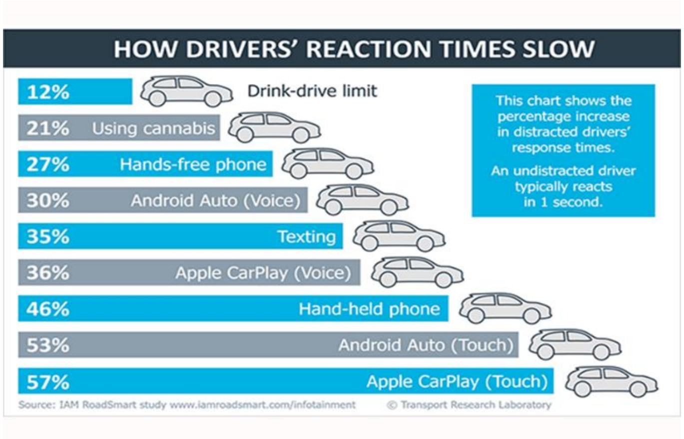

Figure 30 - Increase in distracted drivers' response times - TRL

6.3. Recommendations

6.3.1. Message content

- **Units of information:** Restrict to 4-5 pieces of info.[9]
- **Order**: Use location, problem, effect, guidance: e.g M6 toll accident ahead - significant congestion, take the next exit
- **Order:** Or, messages should try to communicate potential loss rather than gain (e.g. theory suggests that drivers would be more motivated by not losing 10 minutes of time than they would be about saving 10 minutes of time).
- **Customer preferences:** Include messages on journey time, roadworks, cost, diversions.
- **Terminology**: Use term crash or collision instead of accident.
- **Trust:** Include that the message is from TfWM to validate its legitimacy.
- **Types of drivers:** There may need to be subtly different messages to influence different types of drivers.
- **Social influence:** If possible, use messaging to convey that most other people are engaged in the desired behaviour and that not many are doing the unwanted behaviour.

6.3.2. Message delivery

- **Quantity:** Only display a maximum of 2 messages between each junction
- **Location:** Messages should be presented at locations where drivers have fewer other stimuli (e.g. not at the same time other information is being presented) but still have sufficient time to respond and re-route.

[9] According to the VSS policy [1], for VMS, a piece of information is: "a word that is meaningful when read on its own or multiple words read together as one subject. For example, 'HARD SHOULDER' and 'JCT 25' each represent one piece of information even though they both contain two words. However, the individual words carry no meaning on their own on a VMS legend, and require the context that the other words give."

- **Appearance:** Use lowercase letters.
- **Mechanism:** Give participants the option to turn off features.
- **Mechanism:** Limit requirement to use touch.
- **Trust:** Ensure messages do not contradict roadside information.

6.4. Message Options

Using the recommendations outlined in section 3.1, the following message options were created and assessed[10]:

Message examples	Message pro-forma
There are delays on the M6 from here to Junction 8. The M6 Toll is currently clear.	There are delays on the M6 from here to Junction XX. The M6 Toll is currently clear
There is a one hour 20 minute delay between M6 Junction 6 and Junction 8. The M6 Toll is currently clear.	There is a XXX minute delay between M6 Junction XX and Junction XX. The M6 Toll is currently clear
There are speed limits on the M6 for road works. The M6 Toll is currently clear.	There are speed limits on the M6 for road works. The M6 Toll is currently clear
The M6 Toll is 8 minutes quicker than the M6 to Junction 11a.	The M6 Toll is XXX minutes quicker than the M6 to Junction XX
The M6 is 8 minutes longer than M6 Toll to Junction 11a.	The M6 is XXX minutes longer than M6 Toll to Junction XX
You can reduce your carbon footprint by avoiding congested routes. The M6 Toll is currently clear.	You can reduce your carbon footprint by avoiding congested routes. The M6 Toll is currently clear
You can reduce your fuel cost by avoiding congested routes. The M6 Toll is currently clear.	You can reduce your fuel cost by avoiding congested routes. The M6 Toll is currently clear
The M6 Junction 4 to 6 will be closed for roadworks Saturday 9pm to Monday 6am. The M6 Toll will be open.	The M6 Junction 4 to 6 will be closed for roadworks Saturday 9pm to Monday 6am. The M6 Toll will be open.
There will be lane closures on the M6 Junction 5 to 6 this weekend for roadworks. Delays are expected.	There will be lane closures on the M6 Junction XX to XX this weekend for roadworks. Delays are expected
There is a major event at the NEC this weekend. Delays are expected Saturday morning and Sunday afternoon.	The NEC is expected to be busy this weekend. Expect delays around Junction 6 of the M42
Rush hour journeys on the M6 Toll are 37% quicker than the M6 on average.	Rush hour journeys on the M6 Toll are 37 percent quicker than the M6 on average
Rush hour journeys on the M6 Toll are 21% faster than the M6 on average	Rush hour journeys on the M6 Toll are 21 percent faster than the M6 on average
Journeys on the M6 Toll typically save 10-15 minutes compared to A-roads.	Journeys on the M6 Toll typically save between 10 and 15 minutes compared to A-roads
Journey times are more predictable and consistent on the M6 Toll.	Journey times are more predictable and consistent on the M6 Toll
You saved 10 minutes by choosing the M6 Toll today.	You saved XXX minutes by choosing the M6 Toll today
You avoided a 10 minute delay by choosing M6 Toll.	You avoided a XXX minute delay by choosing M6 Toll

Table 6 - Message options for the message trial identified

[10] Please note that the exact detail of the messages identified may adapt and evolve as the project nears the trial itself.

7. In-Vehicle Messaging Trial: Participants, Results and Behavioural Insights

7.1. Trial participants

The research on participants was divided into three distinct phases, encompassing fieldwork that took place between April and June 2023. In the initial phase, a total of 24 thirty-minute surveys were conducted during the weeks commencing on April 3rd, 10th, and 17th, 2023. The subsequent phase involved the installation of the IVMS app by 22 users throughout May 2023, out of which 14 users successfully completed a journey diary. The final phase consisted of 14 thirty-minute and 7 forty-five minute in-depths wrap-up conducted during the weeks commencing on June 12th and 19th, 2023.
Participants for the research project were recruited from TfWM internal sources and two external sources: the "Keep WM Moving!" online community and an external recruitment partner. Participants recruited through the "Keep WM Moving!" online community received a compensation of £150, while those recruited via the external partner received £170 for their participation.
The project initially included a total of 24 participants, with 3 individuals recruited through the "Keep WM Moving!" online community and 11 individuals recruited via the external recruitment partner. In terms of gender distribution, 46% of participants identified as male, while 54% identified as female. The age distribution of participants was as follows: 33% were between the ages of 35 and 44, 29% were between 25 and 34, 17% were between 16 and 24, 13% were between 45 and 59, and 8% were 60 years or older. The racial composition of the participants consisted of 67% White British individuals, with the remaining 33% representing Asian, Black, and Chinese backgrounds. Geographically, the majority of participants hailed from Birmingham (42%), followed by Walsall (17%), Dudley (8%), and Coventry (8%).

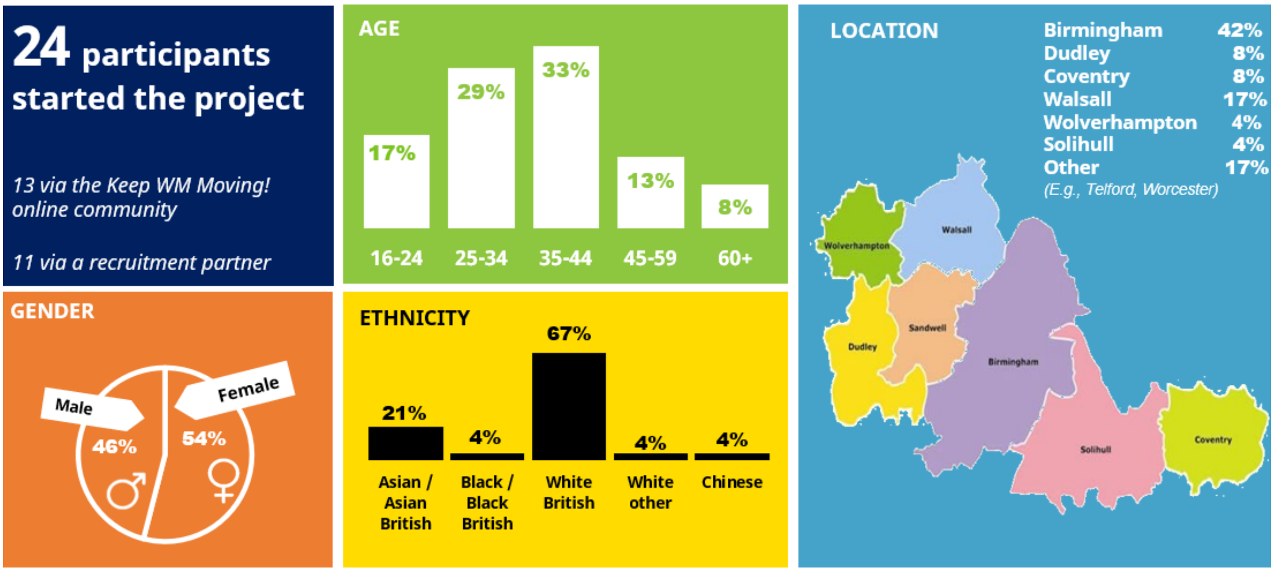

Figure 31 - Participants demographics

7.2. Current participant travel behaviour

7.2.1. Journey types made by car

Regarding the general travel behaviours, it was found that participants predominantly rely on cars for their journeys.
The car is considered a flexible mode of transportation, allowing for multiple stop-offs and requiring less planning compared to public transport. Additionally, participants perceive cars to be faster than other

modes of transportation. The regular purposes for car journeys include commuting, travelling for work, engaging in sports or hobbies, socializing with friends, shopping, and driving children to school or other activities.
For journeys that do not involve cars, participants often opt for walking or using public transportation, especially for short trips. The primary benefits of non-car trips are related to health, exercise, and the convenience of not needing to plan for parking. Participants also mentioned non-car trips for social and work-related purposes.

7.2.2. Car journey planning

Although the majority of participants reported planning their car journeys, this was more common for longer or unfamiliar routes. Planning and preparation are especially necessary when travelling on motorways, which are known for experiencing heavy traffic. Before embarking on their journeys, most participants consult Google Maps to check for significant delays or traffic on their intended route. Some individuals heavily rely on this tool and set up traffic alerts or consult multiple travel apps for information.
Satellite navigation (satnav) systems are widely used by all participants, albeit with varying degrees of reliance. Short and familiar routes that are taken regularly are the only instances where participants do not utilize any navigation tools. While on the road, many participants rely on map apps such as Google Maps, Apple Maps, or Waze due to their up-to-date information, user-friendly interfaces, familiarity, and affordability. The most common placement of a satnav system is attaching it to the car's windscreen using a suction holder. Bluetooth or MirrorLink connections via cord are also popular options, as they allow syncing with the car's built-in screen and sound. Participants highly appreciate the notifications, alerts, and live updates provided by map apps, particularly during long or unfamiliar journeys, rush hours, or when navigating complex motorway junctions. Listening to updates and notifications rather than reading them from the screen helps drivers stay focused on the road, emphasizing the need for concise written notifications.

7.2.3. Road signs and symbols perception

While participants do take notice of road signs, their attention is typically brief, primarily due to familiarity with the routes. Speed signs receive particular attention, but participants struggle to read signs when travelling at high speeds or when they are obstructed or dirty. Digital signs elicit polarized views among participants. Some find them easy to read and appreciate the relevant information provided, while others express distrust in their accuracy, consider them to offer only basic information, or find them challenging to read in adverse weather conditions.
In conclusion, participants exhibit a preference for car travel, citing its flexibility and convenience. Planning and consultation of mapping tools are common, particularly for longer or unfamiliar routes. Satnav systems play a vital role during journeys, and map apps are widely used due to their up-to-date information and user-friendly interfaces. The notifications and updates provided by these apps are highly valued, as they assist drivers during complex situations. Participants generally pay attention to road signs, with a particular focus on speed limits, but struggle to read them under certain circumstances. The opinions regarding digital signs vary, reflecting differences in trust, information provided, and readability in adverse weather conditions.

7.3. Overview of the participants' trial experiences

The trial was conducted to evaluate the effectiveness of IVMS in providing relevant and accurate information to participants regarding their routes. This section provides an overview of the participants' experiences during the trial.

7.3.1. Messaging Context: Errors & Incorrect Messages

During the trial, it was observed that a notable number of messages received by participants were deemed "incorrect" or irrelevant to the routes they were taking. Specifically, some participants reported receiving messages indicating that they had taken the M6 Toll when they had not done so. This discrepancy caused confusion and raised concerns about the accuracy of the IVMS messages.[11]

Incorrect messages received

*"The **message was to inform me** that my journey would be **11 minutes quicker via the M6 Toll**, but as I **was travelling to Birmingham**, the **message was of no use**."*
Male, 60+, Solihull, White British

*"No Change – hilarious as **I was again informed that I had saved 48 mins by using the M6 Toll (which I didn't use** 🤣)."*
Female, 35-44, Birmingham, White British

*"**Advised about journey times** while **inside Birmingham** where **no routes would involve the toll**."*
Male, 16-24, Coventry, White British

*"The **second message was just confusing** as it **said I had saved 47 min** by **using the M6 Toll**… er **I didn't use the M6 Toll** 😂."*
Female, 35-44, Birmingham, White British

*"No, my **journey was to leave the M42** and **proceed to Birmingham City Centre** via M6 North, so **the message was not useful**."*
Male, 60+, Solihull, White British

Figure 32 - Incorrect message examples

7.3.2. IVMS Diaries

The majority of journeys undertaken by participants during the trial were short trips, typically lasting less than an hour. These trips were primarily for commuting purposes or visiting friends and family. As a result, the journeys mostly occurred during peak commuting hours, although the time of day was relatively evenly spread.

The main types of messages received by participants pertained to potential impacts on journey times, roadworks, or general traffic conditions. However, participants reported receiving the fewest messages related to environmental factors. This suggests a potential gap in the IVMS system's ability to provide comprehensive information on the environment.

7.3.3. Behavioural response

One in three participants claimed to have changed their behaviour as a result of the IVMS messages. The most common behavioural changes included diverting their routes or avoiding specific areas with heavy traffic. Alternatively, some participants reported paying closer attention to the suggested route and cross-referencing it with other navigation apps. However, the majority of participants reported no change in behaviour or deviation from their intended route in response to the IVMS messages. The reasons provided for this lack of change were either the perceived insignificance of the time difference or the messages' irrelevance to their current location.

In cases where participants received irrelevant or incorrect messages, it caused confusion and scepticism among them. The need to invest additional effort in finding a new route resulted in participants feeling "confused" and less confident in the IVMS system. On the other hand, positive changes in emotion were

[11] Please note, there are multiple reasons for the message to appear incorrect: 1. As this was a trial some messages were designed to elicit behaviour change and were not based on current road conditions. 2. It was not communicated clearly enough to the participants that the messages were not personalised but may have been read as such. 3. Due to the small team size publishing the messages, some were published in error. These issues have been corrected in preparation for a wider release.

less frequent among participants. However, when they did occur, they often revolved around increased interest and engagement with the IVMS messages. It is worth noting that participants generally began their journeys with a positive mindset, which may have influenced the limited instances of positive emotional changes.

In summary, the trial revealed mixed experiences among participants regarding the effectiveness of the IVMS messages. While some participants reported behavioural changes and positive emotional shifts, the majority experienced no significant alterations in behaviour or deviation from their intended route. Issues with incorrect or irrelevant messages raised concerns and led to confusion and skepticism among participants. To improve the IVMS system, it is crucial to address these concerns and ensure the accuracy and relevance of the messages provided to users.

7.4. Participants' response to messaging

According to the gathered information, it was found that messages providing peace of mind and helping individuals avoid future frustrations were preferred. Such messages received a more positive response compared to journey times, as the latter can be obtained from other sources. Although there was a split in preference regarding messaging, it became evident that messages about delays or time loss had a greater impact on behaviour change. The prospect of losing time motivated individuals to take action.

Figure 33 - Message testing preferences

7.4.1. Message types analysis

The general sentiment towards this type of messaging was that it would be helpful for individuals to stay updated with the latest laws and regulations, benefiting both themselves and others. However, some people might find it annoying or rude, assuming they already "know" when they are doing something wrong. The ability to change routes and avoid frustrating standstills or traffic was considered the most important aspect overall and deemed highly useful. Conversely, participants showed less interest in messages related to reducing pollution levels or emissions.

The early awareness of hazards and timely messages to allow people to take appropriate actions were seen as highly important. However, it was emphasized that these messages must be as up-to-date as possible. Particularly, messages regarding hidden signs and upcoming changes to speed limits were deemed useful. Nevertheless, participants considered this a low priority since road signs already exist, and they can read them.

Although many participants acknowledged the usefulness of messages related to traffic lights, it was considered a basic expectation and not explicitly articulated why it would be useful. Some individuals had

difficulty expressing its usefulness due to it being an inherent expectation. Few participants saw the need for such messages since they could clearly see the traffic lights themselves. Safety concerns were also raised, suggesting that relying solely on an app's indication of whether it is safe to drive might be unsafe. Weather conditions were considered important, but the focus was more on informing individuals about upcoming weather rather than providing live updates. Live updates were perceived as potentially annoying, with individuals expressing a greater interest in knowing about weather conditions closer to their destination.
Among drivers, there was a strong appetite for messages related to safety issues or hazards, traffic flow, and potential route changes or diversions. Messages relating to safety or saving time were also of interest. However, there was less interest in messages received at traffic lights and those relaying road sign information, as drivers considered such information unnecessary. In fact, some drivers expressed annoyance at receiving messages alerting them that they are at fault.

7.5. Participants response to IVMS App

Technical issues were encountered by some users while using the app, including disconnections during journeys, slow launch times, and interference with music audio and quality from other apps. Many users also faced difficulties during the installation and setup process.

7.5.1. Overall Views on the App

However, from the perspective of most participants, the app is regarded as straightforward and easy to use. The key advantages cited by users include live updates and monitoring of driving and routes. However, frustrations arise from certain limitations of the app. Several users commented on the need to manually activate it before journeys and its lack of integration with in-car audio or screens. As a result, there is no significant incentive to choose this app over alternatives such as Google Maps.
Participants generally appreciate the app's retro design, considering it user-friendly. However, the orange text used in the app proves difficult to read, resembling digital road signs. Additionally, users find it confusing to determine when they are connected to the app.
While many users find it challenging to surpass existing mapping apps in terms of unique selling points offered by the IVMS, some participants liked the MPH feature, which promotes awareness of driving speeds—an attribute not found in Google Maps. The provision of up-to-date information and a simple design also garnered positive feedback.

7.5.2. Potential Additional Features and Appearance

Participants expressed their desire for greater customization options within the app. Some suggested the inclusion of a journey planner with Google Maps-like directions and pre-journey traffic updates, as well as clear notifications for manual or automatic connection to the app.
When asked to envision a new IVMS app, participants sought a simple yet accessible interface with real-time updates. They also expressed interest in customizable messages and a journey planner feature. Some participants proposed incorporating artificial intelligence (AI) capabilities that can learn from user behavior.
Additionally, participants expressed a desire for the app to draw inspiration from the accuracy of Google Maps and the user-friendliness of Waze. They emphasized the need for the app to run continuously in the background, maintaining a high level of interactivity to engage users.

Access to Restricted Areas

While participants acknowledged the potential time-saving benefits of accessing restricted areas, they did not perceive this feature as personally advantageous. Moreover, concerns were raised regarding safety, security breaches, and data privacy issues associated with this feature.

Vehicle Sensors

Participants recognized the usefulness of vehicle sensors for obtaining road information. However, questions were raised regarding their reliability and the capacity of the council to act upon the collected data. Some participants suggested utilizing these sensors for insurance purposes and drew comparisons to black boxes.

Vehicle Priority

Participants held mixed views on vehicle priority. Some considered it beneficial for improving traffic flow and reducing emissions, while others expressed concerns that its implementation would lead to confusion and be perceived as biased towards certain types of vehicles, potentially resulting in their increased use.

8. In-Vehicle Messaging Trial: Qualitative and Quantitative Research Findings Review

This section focuses on the common areas regarding the interviewed potential users of the M6 Toll the pilot for delivery of targeted in-car messaging for users and questioning where comparisons between answers and findings can be made across both of the project parts. It does not comment on findings which were established in one part only.

The messaging trial was bookended by two customer research studies, with phase one being delivered prior to the IVMS trial.

The first phase (P1) refers to the anonymous online survey distributed in concert between WSP and a third-party panel provider called Prolific described in Section 4. The second phase (P2) refers to the trial delivered by Mustard who sought to ascertain perceptions of the IVMS app and sentiment towards it, gauge appetite and interest towards the range of messaging types and to understand the impact of the app on driver behaviour across the West Midlands (Section 7).

Phase 1 (P1) participants n=1003
Phase 2 (P2) participants n=24 or less

8.1. High level findings

8.1.1. Journey types

The top 3 journey types found across both P1 and P2 participants were journeys for the purpose of visiting family and friends, commuting and leisure.

8.1.2. Technology insights

Participants in P1 were asked about their use of smart home devices with the examples given in the question being those that work predominantly using voice (Amazon Alexa, Google Home Assistant or Apple Homepod), 65% of participants reporting one or more device within their home. This is likely to increase with anticipated growth in smart home technology expected to grow significantly, growing from household penetration of 45.8% in 2022 to 98.8% in 2027.[12]

OBSERVATION POINT

[12] Smart Home - United Kingdom | Statista Market Forecast

Smart home capability is on the increase and integration is now considered the norm rather than a luxury. *TfWM may wish to consider IVMS app integration with smart home devices. This would enable users to receive added value in the form of real time traffic alerts for their planned journeys prior to setting off.* *Integration could increase uptake and overall satisfaction of the IVMS app over time.*

When asked what technologies P1 participants had in their vehicles, 50% reporting having built-in satellite navigation and 35% had smartphone mirroring (Apple CarPlay or Android Auto).

8.1.3. Journey planning tools and route choice

Participants in both P1 and P2 indicated strong preference for using satellite navigation tools for unfamiliar or long journeys. In P1 only 22% of participants indicated they would use such tools for all journeys.
All participants in P2 reported using satellite navigation tools, though for short and familiar routes they were less likely to require the need for navigation tools.

OBSERVATION POINT
Familiarity with the area / journey is likely to reduce reliance upon navigation tools and apps. It would be worthwhile to consider how to encourage take up and utilisation amongst local / regular commuters; i.e. what features would help an IVMS from TfWM add value in this use applications.

74% of P1 participants reported they used travel apps such as Google or Waze and this was replicated in P2 where the majority consult Google Maps.
54% of P1 participants reported they use a satellite navigation system, but it is unclear what kind of system that was.

OBSERVATION POINT
Market saturation towards the well-established and real time functionality of Google Maps and Google owned Waze may present a behavioural challenge when encouraging consumers adopt an additional navigation tool. Opportunities to increase added value, such as provision of other dynamic or safety-related alerts may help with adoption.

P1 participants were asked questions in relation to using toll roads, during which only 10% said they would never choose to use a toll road, with 19% of participants reported they would choose a toll if it saved them time over the alternatives and the remaining participants having varying levels of tolerance towards using a toll road.
Cost is the perceived barrier to more widespread uptake of the toll road, however this was not specifically tested during the survey.

OBSERVATION POINT
Consideration of a dynamic pricing structure on Toll Roads or similar financial incentives may encourage more users to select alternative routes and alleviate pressure on the wider network. *Further insight could be obtained regarding barriers to choosing alternative routes at times of congestion. This may provide valuable data to enable IVMS development aimed at removing those barriers.*

P1 participants indicated that well known travel applications like Google Maps and Waze and/or their Sat-Nav systems were what they would typically use to reroute a journey after setting off, should their initial route be unavailable.

30% of respondents reported that they felt uncomfortable interacting with their device when this happened, 60% felt comfortable and 10% were neutral.
53% of P1 participants respondents reported that they would prefer a combination of audio and visual messages when asked about preference for receiving information about their journeys whilst driving. Similarly P2 participants commented on the need for audio prompts and only quick on-screen information or messages. Participants had clearly given consideration regarding the potential for distraction by written information.

OBSERVATION POINT
An app that does not present complex visual information and relies primarily on audio messages is likely to be safer and less distracting for the road user. *Customers have an awareness of the potential for distraction by receiving data whilst driving.*

P2 participants were asked about Satnav placement in their car, the most common being to attach it to the windscreen using a suction holder, although some reported having an air vent holder or placing it in a cupholder.

OBSERVATION POINT
Placing devices on the windscreen is very common, however risks creating blind spots for vulnerable road users such as pedestrians and cyclists. Apps should continue to remind users about their responsibilities and give information regarding safe placement of mobile devices in vehicles.

8.1.4. Trust in sources of information

P1 participants reported that they had the highest level of trust in information given by national bodies such as National Highways, but regional public bodies such as TfWM were the least trusted for providing traffic information.
P2 participants reported a notable number of messages from the trial IVMS were incorrect or irrelevant to the route that they were taking. As a result, the majority of the participants reported no change in their behaviour as a result of either receiving messages that were not relevant, or the time difference was insufficient to warrant a deviation.

OBSERVATION POINT
Reliability and relevance of information delivered by IVMS are crucial to gaining trust and provoking a behaviour change.

P1 participants seemed to place equal levels of trust in information received whilst driving on both motorways and urban roads, and showed no clear preference with regard to whether they would trust a variable message sign or satnav more in the event of conflicting information.
P2 participants expressed a preference for receiving messages on unfamiliar, long, rush hour and motorway journeys.

8.1.5. What they want to know, and how to tell them

P1 participants expressed a preference for receiving messages relating to overall journey time and then road closures, similarly, P2 participants preferred messages that provide peace of mind and avoid frustrations.
When it came to framing / language used in messaging, P1 participants expressed preference for positive messaging rather than loss aversion messaging.

However P2 participants preferred negative message framing – for instance they would rather receive messages telling them that they would lose time travelling on a particular route, rather than if it said they could save time by going a different way. It was felt that negative messages were more likely to illicit action.
Neither set of participants expressed an interest in receiving environmental messages.

OBSERVATION POINT
Whilst environmental messages are currently the least popular type, for longer behavioural change towards Net Zero, it would be prudent to continue including information about environmental impact in some way. *It may be more impactful to add it as a bolt-on to an existing message – for instance "Using the A456 Hagley Road will save 15 minutes to the M5 and reduce your emissions", or looking for ways to gamify (i.e., to trigger certain psychological attitudes towards being environmentally friendly, being concerned for themselves and others' health, etc.) their emissions saving once their journey is complete.*

Across both surveys, there was a preference for brevity in messaging, however in P1, when it came to messages informing motorists to avoid a particular area or destination, there was a strong preference (88%) for including contextual information, even if that meant a much longer message being relayed.

OBSERVATION POINT
Minimising distraction is essential to safety, to illustrate the point, if it takes 2 seconds to look away from the road ahead to read a text message when travelling at 30mph, the vehicle will travel 26.8m. The highway code stopping distance at the same speed is 23m. Minimising distraction must continue to be a guiding principle for IVMS design and development.

8.2. Summary

8.3. Lenses applied to each phase

The P1 (Prolific) survey focussed primarily on road users' preferences and usage of technology as well as the style and format of messaging that they may receive via the IVMS before the trial commenced.

The P2 (Mustard) surveys – especially the trial diary stage, were carried out post-trial, gathering information from users about satisfaction, reliability, and behaviour change.

Only areas of similarity and crossover have been featured within this technical note.

The P2 report states the below:

- *Whilst many receiving the messages claimed not to act on them, 1 in 3 did and they changed their behaviour in some way. The trial results prove that The IVMS app can have an influence on behaviour.*

Due to the small number of trial participants (n=22) and participants who have completed a journey diary (n=14), confidence levels regarding the above statement will be at the lower end. A further trial with a wider pool of participants may improve confidence levels.

8.3.1. Conclusions

Technology and our use of it will only continue to rise, as will the confident adoption of new and novel technologies. The IVMS trial demonstrated value in developing novel approaches to road use which has the potential to yield benefits including, reduced congestion, increased satisfaction, safer user experience and increased confidence in the network.

Both phases of research showed similar findings in that users are open to technology (at home and in their car) and do rely on satellite navigation and general mapping applications for their travel plans. Both phases highlighted the importance of brevity of messages and reduction of distraction to the driver, however likewise they both featured insight regarding confidence levels around accuracy being either a conduit or barrier to successful adoption.

9. In-Vehicle Messaging Trial: System Technical Assessment and Future Developments

9.1. System evaluation

This section gives a general description of the VVMS system's future advancements as well as the initial input that team members from the KRN and the RTCC have provided during the trial and after its completion.
The system has thus far received mostly excellent comments, especially during the hands-on training and experience sessions. Staff members who have used the technology recognise its significant benefits for improving public information about current traffic conditions. Additionally, they have emphasised the system's value in scheduling messages for pre-planned events and permitting rapid implementation in unexpected situations. It is important to highlight that additional changes and enhancements are anticipated when the system is used extensively in the upcoming months. The general opinion shared by staff members can be summed up as follows:

Positive Feedback

- User-Friendly Interface: The system has a user-friendly interface that makes it easy to navigate and operate.
- Journey Time forecasts: It is thought that the capacity to produce journey time forecasts is a useful feature.
- Live data integration: Adding current information to distributed messages improves their accuracy and relevancy.
- Deployment of Scheduled Messages: The system enables the scheduling of messages for later deployment, assuring timely communication.
- Message Deployment Based on Specific Journey Time Prediction Rules: By basing message deployment on specific journey time prediction rules, their efficacy is maximised.

Negative Feedback

- Lack of Intuition: Although largely user-friendly, the system could be made even more understandable.
- Limited Features in Rules System: The rules system could use more features and capabilities.
- Robustness of Internal Error Feedback: In order to give notifications that are more thorough and informative, the internal error feedback mechanism needs to be reinforced.

9.2. Future Developments

Based on feedback from the TfWM teams and SAS, the system developer, the following table compiles the system's indicated improvements and enhancements. The performance and usability of the system will be further improved by the proposed modifications, which aim to address the feedback received:

Developments	Description	
Drag and Drop VVMS and JTP route management	Extend the current VVMS web dashboard to allow JTP and VVMS routes to be dynamically modified/updated by dragging and dropping map markers. (Currently updates to JTP and VVMS routes are only possible via the VVMS admin APIs.	
Hybrid JTP route creation	Extend the current VVMS system to support the creation of routes comprising of multiple data source types e.g. NTIS MIDAS and external FVD data.	
Enhanced Journey Time Prediction Engine	Enhance current JTP Engine to provide different journey time predictions for different vehicle types/classifications. Implement Machine Learning algorithms to enhance JTP algorithm performance.	
Enhanced Rules Engine	Enhance current JTP rules engine to deal with more complete rules and possibly combining of multiple rules.	
VVMS Direct to Vehicle Messaging API	Develop a messaging API to deliver VVMS content direct vehicle. (Solution would need to be scalable to cope with large message delivery volumes and use protocols such as AMQP, MQTT etc..)	
VVMS Vehicle/driver feedback API	Develop an API that would allow VVMS mobile users/applications to provide notifications and messages back to the VVMS platform (e.g. providing positive feedback if journey delays have cleared)	
Additional data feeds	Develop and integrate additional data pipelines for the VVMS system to include data such as Air Quality, parking information etc.	
Data Layer Management	Include additional data layers for different features such as existing physical VMS location, traffic signals, etc. Allow for built in map POI's to be disabled/hidden to remove clutter	
Connectivity Heat Map	Create a heatmap of cellular signal availability to aid in accounting for internet blackspots	
UI Improvements	Improve the system UI to make it more intuitive to use	
Error Detection and Communication	Improve the system error detection and feedback system in informing operators of any system issues, i.e. forbidden characters/symbols in messages, impossible JTP calculations, etc.	
Automate VVMS Route Creation	Allow the system to automatically suggest detection zone and relevance zone areas based on the location of the VVMS and surrounding environment/road layout	
Automate JTP Route Creation	Automatically generate sub sections of routes which show delays to aid in the identification of where the delay is occurring	
Road Identification	Automatically identify the road name and/or number and present it as a suggestion to be included in the message	
Message Translation	Automatically translate any messages into other languages allowing international visitors to receive the message in their native tongue	
Automatic message generation	Use AI systems to generate a message to be deployed based on the type of incident or event and suggest it to the operator to be edited if needed.	
Drag and Drop VVMS and JTP route management	Extend the current VVMS web dashboard to allow JTP and VVMS routes to be dynamically modified/updated by dragging and dropping map markers. (Currently updates to JTP and VVMS routes are only possible via the VVMS admin APIs.	*Benefits:* Ease of use for operators, allowing for faster and more accurate message creation

Developments	Description	
Hybrid JTP route creation	Extend the current VVMS system to support the creation of routes comprising of multiple data source types e.g. NTIS MIDAS and external FVD data.	*Benefits:* Allows for an operator to create a JTP route without needing to choose on the data source. This will allow for ad-hoc JTP routes to be created quickly.
Enhanced Journey Time Prediction Engine	Enhance current JTP Engine to provide different journey time predictions for different vehicle types/classifications. Implement Machine Learning algorithms to enhance JTP algorithm performance.	*Benefits:* When used in conjunction with vehicle specific messages, allows for semi-personalisation for the customer without significantly increasing operator workload
Enhanced Rules Engine	Enhance current JTP rules engine to deal with more complete rules and possibly combining of multiple rules.	*Benefits:* Allowing for more complex rules will allow for greater levels of automation, improving accuracy for the customer and reducing workload for the operator.
VVMS Direct to Vehicle Messaging API	Develop a messaging API to deliver VVMS content direct vehicle. (Solution would need to be scalable to cope with large message delivery volumes and use protocols such as AMQP, MQTT etc..)	*Benefits:* Direct to vehicle messaging would reduce the end-to-end latency and remove a potential point of failure in terms of the third-party providers server security and reliability.
VVMS Vehicle/driver feedback API	Develop an API that would allow VVMS mobile users/applications to provide notifications and messages back to the VVMS platform (e.g. providing positive feedback if journey delays have cleared)	*Benefits:* This would allow for experimentation and to collect customer feedback in the effectiveness of the messages and can be used to improve future messages.
Additional data feeds	Develop and integrate additional data pipelines for the VVMS system to include data such as Air Quality, parking information etc.	*Benefits:* This would allow customers to receive this information and change their behaviour i.e., choosing a park and ride over driving to their destination.
Data Layer Management	Include additional data layers for different features such as existing physical VMS location, traffic signals, etc. Allow for built in map POI's to be disabled/hidden to remove clutter	*Benefits:* This would reduce workload for the operators by making the dashboard clearer to use.
Connectivity Heat Map	Create a heatmap of cellular signal availability to aid in accounting for internet blackspots	*Benefits:* Allows a message to be deployed to a blackspot as long as the device has received the message and location data which is cashed until needed.
UI Improvements	Improve the system UI to make it more intuitive to use	*Benefits:* Reduces operator workload, improving accuracy and speed of response.
Error Detection and Communication	Improve the system error detection and feedback system in informing operators of any system issues, i.e. forbidden characters/symbols in messages, impossible JTP calculations, etc.	*Benefits:* Improves accuracy of the message before being published to the customer, improving service.

Developments	Description	
Automate VVMS Route Creation	Allow the system to automatically suggest detection zone and relevance zone areas based on the location of the VVMS and surrounding environment/road layout	*Benefits:* Reduces operator workload, improving accuracy and speed of response.
Automate JTP Route Creation	Automatically generate sub sections of routes which show delays to aid in the identification of where the delay is occurring	*Benefits:* Reduces operator workload, improving accuracy in suggestions for diversion routes.
Road Identification	Automatically identify the road name and/or number and present it as a suggestion to be included in the message	*Benefits:* Reduces operator workload, improving accuracy and speed of response.
Message Translation	Automatically translate any messages into other languages allowing international visitors to receive the message in their native tongue	*Benefits:* Allows visiting customers to follow message instructions without needing to be fluent in English.
Automatic message generation	Use AI systems to generate a message to be deployed based on the type of incident or event and suggest it to the operator to be edited if needed.	*Benefits:* Reduces operator workload, improving accuracy and speed of response.

Table 7 - Future developments

10. Future VVMS Rollout Strategy

There are several important factors to take into account when developing a plan or road map for implementing a VVMS solution throughout the West Midlands and beyond. Below are the actions to be taken:

1. Identification and engagement of key stakeholders:

   Firstly, it is vital to determine key stakeholders, such as regional and local government bodies and National Highways (NH).
   The project team should learn about their technical requirements and hold meetings and workshops to be able to obtain their support for the wider rollout. An extensive plan has also to be created based on the feedback and taking into account institutional, operational, and technical factors. In order to increase the effectiveness and efficiency of VVMS, we need to cover wider road sections that include motorways and local roads. Some potential activities with key stakeholders may include:

   a. Investigating Vehicle-to-Infrastructure (V2I) communication: Involve NH and local authorities to enable V2I communication, where vehicles share data with RTCC systems. By enabling this feature, we can push real-time messages to the app through data sources used by NH and local authorities. In addition, exploring communication infrastructure requirements with NH's NRTS team can determine if roadside fibre optics can enhance communication on West Midlands motorways.

   b. Integrating with existing Mobile Apps: Explore the integration of VVMS with popular navigation and traffic mobile apps in the form of an API. This integration can reach a wider audience and ensure that users receive important messages even if they are not actively using the VVMS application.

2. Evaluation of institutional issues:

   Research on the rules and regulations governing the application of such solutions is needed. Parties involved in the development of the system need to recognise any governance, legal, or regulatory standards that must be met and take into account elements like funding sources, coordination techniques, and procurement procedures.

3. Engage with the staff of the Regional Traffic Co-ordination Centre (RTCC), Key Route Network (KRN) team and Data Insights These teams are critical to ensure the success of the service, and each will perform a different function in its operation, listed below. In addition to these roles, they will become the subject matter experts on this system and would be able to advice potential future clients on best practices.
   a. RTCC – Experts in deploying messages to customers to notify them of incidents or events
   b. KRN – Experts in creating routes to monitor traffic movement across a region.
   c. Data Insights – Experts in collecting, processing, and using the data collected effectively.

4. Examination of operational considerations:

   It is also paramount to analyse operational needs in great detail. This entails evaluating the current communication networks, traffic management systems, and transportation infrastructure. The analyst should be aware of any operational issues that require to be fixed, such as the necessity for integration with already-existing traffic control systems or for assuring interoperability among various authorities.

It is important to notice that this project started this type of system integration with RTCC which provides a great starting point for the next applications.

5. Assessment of technical requirements:

   The next step would be of identifying the requirements in terms of technical standards and specifications for the VVMS solution. All the elements like software, connection, hardware, and data management need to be assessed. The solution's scalability and compatibility with the current infrastructure should be also evaluated.
   This project gives the basis for VVMS national standards on the matter. It has produced a White Paper that was developed on behalf of the DfT; this White Paper should be advertised and communicated through transport events across the UK in order to inform other authorities and locate support for new projects that extend the current project regionally and nationally.

6. Creation of a phased rollout strategy:

   The implementation should be broken down into manageable stages. We believe that it would be best to prioritise the West Midlands areas before wider/national rollout is considered. This would be based on criticalities looking at variables like traffic volume, congestion, or strategic importance for a larger initial deployment. It is also important to plan and establish in advance completion dates, deadlines, and performance metrics for each stage. It may well be that the end user functionality will need to sit within the preferred TfWM travel App, this would support TfWM's ambition of "one app, one account, everywhere they could want to go, accessible at their fingertips".

7. Integration possibilities:

   To be able to integrate the system with other major systems in the country, distinct channels of communication and collaboration need to be created. It is possible to work together with others on operational procedures, interoperability standards, and data-sharing methods. The scope will be to obtain a seamless integration of the VVMS system into the larger national transportation network.

8. Interaction with other Local Authorities:

   Important stakeholders during this process are Local Authorities with whom the analysts need to share technical know-how, best practices, and lessons learnt. It is important to approach new Local Authorities (beyond West Midlands) to work together on cooperative projects, information sharing, and financial opportunities. For instance, regional working groups or forums can encourage collaboration and networking.

9. Establish Data Sharing frameworks:

   In order to enhance the user accessibility of data, there are opportunities for the VVMS project to create a collaborative data sharing platform. The data sharing platform could be achieved through collaborations with other transportation agencies, local authorities and private sector companies to share data and coordinate traffic management efforts. This particular data sharing platforms can help in generating more comprehensive and accurate real-time messages for drivers. To achieve this, the codebase for the system can be made open source. This will allow clients to deploy a version of the system that can be modified to suit their needs.

10. Execution of larger pilot projects and evaluations:

    Before full-scale implementation, it is fundamental to carry out larger pilot projects in a few chosen regions (as indicated at point 5) to confirm the solution's efficacy and optimise operating

procedures. The review of the results of the pilot and the customer feedback will indicate any problems or issues to take care of.
For instance, some significant findings regarding the VVMS system used during the recent small trial should be addressed before a subsequent larger pilot. The feedback on the lack of intuition has been noted as one of the technological problems. The system is mostly user-friendly, but more work has to be done to make it clearer. The rules system might also be upgraded because it has few features and capabilities. The resilience of the internal error feedback mechanism is a further area of caution. To deliver more detailed and useful notifications for errors, improvements are required.
Regarding the trial deployment and administration, the current small trial revealed that whilst many receiving the messages claimed not to act on them, 1 in 3 did and they changed their behaviour in some way. The trial results give an indication that the IVMS app can have an influence on behaviour.

a. Behavioural Change Analysis:
A larger deployment of VVMS can also guarantee a larger test cohort that can be used to understand the effect of VVMS on the costumers' behavioural change. With a sample of 500 individuals or more, a more rigorous quantitative analysis, using statistical and econometric techniques, can help better evaluate the factors influencing the travel behaviour of the costumers and understand how these factors can be adjusted to maximise the effect of VVMS

11. Enhance user catchment:

The VVMS project needs to be improved to appeal to a more diverse group of customers, as they are the primary focus of the project. The options include adding messaging in different/multi languages for non-native users and travellers.

12. Creation of a structure for maintenance and assistance:

Once the problems identified at point 9 and 10 are resolved, the analysts can start thinking about the plan for the VVMS solution's long-term maintenance, surveillance, and support. This will include standard operating procedures for routine checks, troubleshooting, and software updates. It will also incorporate the tasks of the maintenance teams and take into account service-level agreements with vendors.

13. Documentation and Knowledge Transfer:

It is also important to document all aspects of the rollout strategy, such as institutional arrangements, technical requirements, and implementation directions. This will enable us to create educational resources and hold seminars to help stakeholders with knowledge transfer.
By using case studies, conferences, and knowledge-sharing platforms, a larger community can be informed about the experience and the results of the VMS rollout and new Local Authorities can be approached as per point 7.

14. Ongoing evaluation of the solution's effectiveness, user input collection, and implementation revision based on lessons gained. This also includes studies on the VVMS overall benefits:

a. Performance Benefits:
VVMS is a far more flexible and user friendly solution than fixed VMS; Messages can be switched on and off as required and display customisable messages that extend beyond the physical fixed location options. Maintaining a VVMS solution is a technical support exercise, it requires no lane or road closures to install or perform maintenance, it keeps operatives off the roads and safe from harm.

b. Financial Case:
A key opportunity will arise from the cost savings that can be delivered by ceasing to purchase new or replacement fixed location VMS, this will include carbon savings and pure financial benefits of not purchasing and powering steel and concrete gantries. VVMS delivers demand responsive messages without the limitation of a fixed location, electrically powered, and difficult to support infrastructure. VVMS is not shackled by the limitations of a fixed location.

c. Carbon Savings Case:
A study should be undertaken that illustrates the overall carbon reduction benefits of VVMS, these carbon savings should be integrated with the cost savings to build a compelling business case to justify the further expansion and development of the VVMS solution. The use of VVMS to modify drivers' routes is designed to cut journey times and therefore cut Carbon production, these reductions should be quantified and become part of the convincing Use Case to extend this service beyond this trial.

15. Continuous Operational consideration – management of operation

    Medium to long term support for the system needs factoring in, the system requires an annual review of operation and a clear strategy that keeps it aligned with the overall TfWM vision. Beyond break-fix of the system the operational environment will change over time, the annual review should consider how the system interacts with other systems and incorporate feedback provided through the system and consider other anecdotal feedback. The relationship with the RTCC will need to be maintained and managed, their priorities and motivations may change, and the system needs to be optimised for their usage and continue to deliver sufficient benefits so that they remain positive and engaged.

16. Incident Management and Response:

    Enhance VVMS incident management offering by working with emergency and roadside assistance stakeholders. This will enable faster response times to incidents and enhance overall road safety. Areas of focus could include operational procedures, data-sharing strategies and response mechanisms that can be mutually beneficial not just to road users, but also to the RTCC operators and wider transport authorities.

17. Monitoring Funding Opportunities:

    New sources of funding for innovative projects such as this do continue to be made available; TfWM should continue to check for new Innovate UK / SBRI funding opportunities. Additionally, they should be keeping in close contact with DfT for opportunities to take this trial to a greater marketplace, where the benefits of VVMS can be escalated, and the highlighted benefits can be realised at a far greater scale, this will deliver positive impacts locally, regionally and nationally helping TfWM and UK PLC run better.

10.1. Rollout Roadmap

The below illustration shows a conceptual timeline working from the top downwards, of all the future VVMS Rollout Strategy items that have been described through this chapter. This is a visual reference to help understand a pathway through the options and opportunities that will lead to an eventual National Rollout of VVMS. It should be noted that the timeline below is highly dependent on identification of a developmental funding source and a maintenance funding source. These sources of funding would need to be linked as the system will require ongoing, continuous development while it is being used. It should also be noted that

National Highways has recently announced a project with similar goals and deployment strategy. There is an opportunity for the systems to feed data to each other, enhancing the experience for the customer.

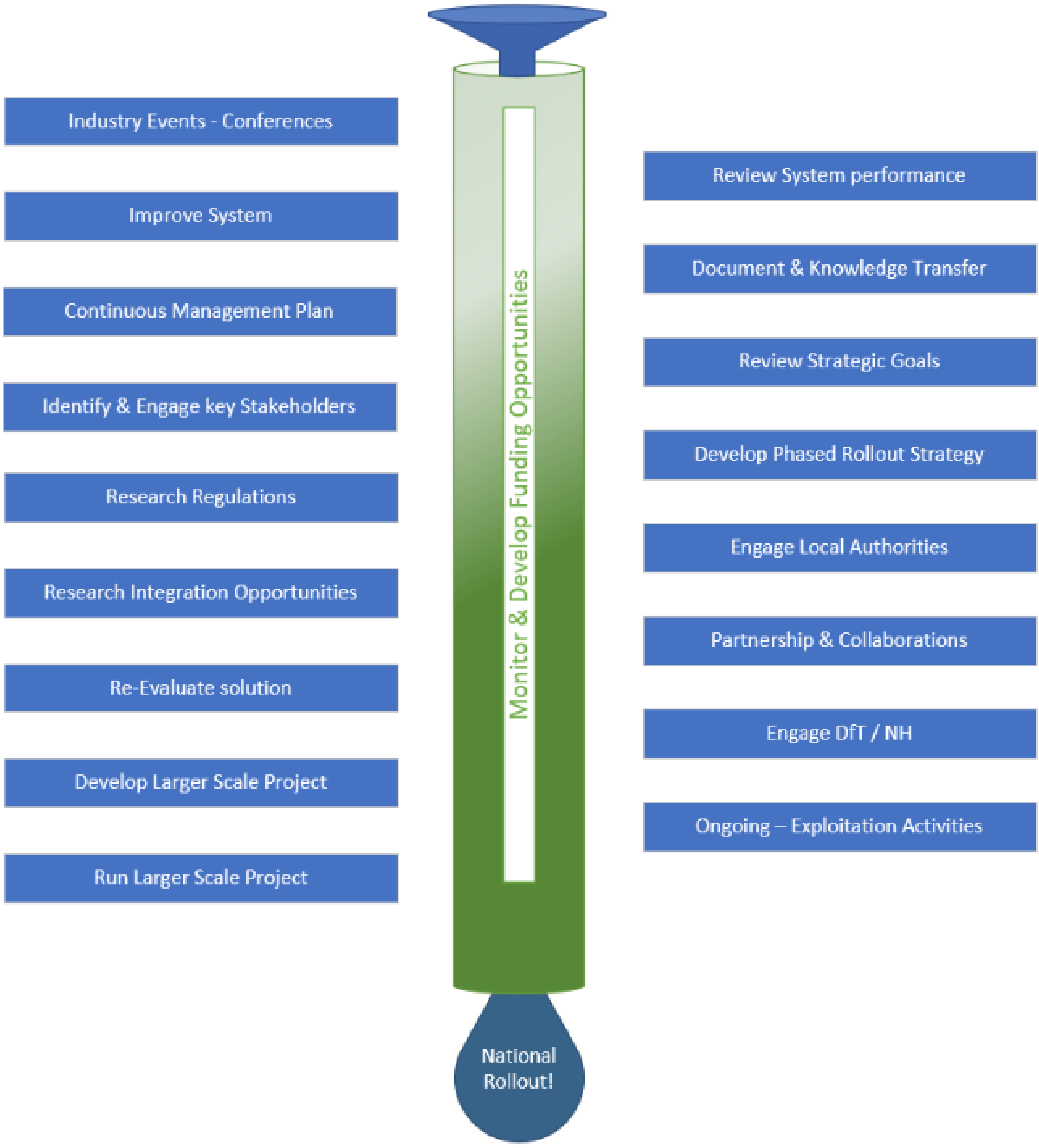

Figure 34 - Future Exploitation Activities

11. Conclusions

This M6 Toll System provides a virtual service that is independent of actual sign positions, more adaptable, and responsive to network conditions; as a result, it may have an effect on the results mentioned. By enabling a better/more efficient use of infrastructure (i.e., the M6 Toll and surrounding road networks), these significant system characteristics generate a wider positive impact on the roads in and around Birmingham by improving travel times, reducing congestion, and reducing pollution. Using messages that are sent directly to drivers' vehicles, the service informs drivers. Targeting particular decision-making locations throughout the network, these messages promote the use of the M6 toll where necessary. These messages are produced after a process of gathering real-time data from local and national data sources, which is followed by analytical procedures, the application of protocols, and the execution of algorithms that produce information packets (messages) that are authorised and provided to drivers by TfWM and/or its partners.

During the project, a complete end-to-end service has been implemented around the M6 Toll system. This end-to-end service includes five main stages: data ingress, the M6 Toll solution integration, data export, V2X communication services and V2X end-user delivery.

Two types of tests have been successfully performed to test the system: the FAT and SAT. These made sure that the M6 Toll system was set up and operated efficiently. As part of the FAT, the system is first put through rigorous testing to ensure its dependability, performance, and conformity to predefined criteria. This includes evaluating the hardware, software, and communication interfaces in addition to the system's overall operation. After passing the FAT, the system advances to the SAT, where it is tested in the actual setting in which it will be used. The SAT, which certifies the system's optimum performance at the particular site conditions, including environment illumination, weather, and connection, ensures the system's effectiveness and readiness for deployment.

Subsequently, the goal of the trial was to demonstrate the potential for affecting driver and network outcomes by providing messaging in this new way and better understanding any implications of doing so. To develop the message set for the trial, behaviour change and human-centred design principles were used to create messages to present to drivers within their vehicles using their in-vehicle systems.

In summary, these are the most important results from the trial:

IVMS App Trial / Diary:

- During the journey diary exercise, people were primarily making short journeys to familiar destinations.
  - Visiting friends & family or commuting were the two most prominent journey types, with most also doing trips of less than an hour.
  - Due to this, few actually received messages. This could mean that for a large proportion of the journeys people are making, the app is a little bit redundant as it focuses more on motorways and A Roads. How can IVMS support drivers on these shorter, familiar routes to ensure frequent use of the app? Is there a way to position the app so that it could also be beneficial to use on shorter or more familiar routes where people are likely to drive on ‘auto-pilot’?
- Many of the messages were not perceived to be relevant to their journey – either incorrect or totally irrelevant. There should be caution around this as incorrect messages may lead to confusion, distrust and less usage of the app! This is apparent in the change of emotions seen within the diaries – where people went from ‘Happy’, ‘Encouraged’ or ‘Joyful’ to ‘Confused’.
- Whilst many receiving the messages claimed not to act on them, 1 in 3 did and they changed their behaviour in some way. The trial results give an indication that the IVMS app can have an influence on behaviour.
  - If everything was working perfectly with the app and messages (i.e. the right message at the right time), then we can assume the proportion changing their behaviour could have been higher.

Messaging:

- There is a preference for messages which provide a sense of peace of mind for drivers, supporting them in avoiding future issues or frustrations.
    - Among app users, interest is strongest when it comes to messages which alert drivers of upcoming safety issues or hazards, messages relating to traffic flow, and messages relating to potential route changes or diversions.
- However, when it comes to messages received at traffic lights, messages relaying information typically found in road signs, and messages alerting the driver that they are at fault in some way, there is less of an appetite.
    - With drivers noting that such messages are unnecessary and could become repetitive. Others also expressed frustration at the prospect of receiving messages alerting them that they were doing something wrong as a driver. Some found these messages to be patronising.
- When it comes to messages focussed on 'saving time' vs 'losing time', drivers are divided. However, it is worth noting that messages related to delays or losing time are more likely to change driver behaviour, with the prospect of losing time (and this being perceived as the more drastic of two messages) prompting drivers to take action.

IVMS App

- The app is generally user-friendly with a positive concept of live updates and route monitoring. However, there are certain aspects of the app that could be improved. To improve user experience TfWM should:
    - Consider developing a feature that automatically activates the app when it senses movement. This can eliminate frustration for users who often forget to turn it on before their journey.
    - Integrate the application with in-car audio or entertainment systems so that drivers don't have to constantly switch between the phone and the car screen.
- While the app has a user-friendly interface and some users appreciate its retro design, it may benefit from improved readability by adjusting the colour of the orange text.
    - Considering that some have commented on its resemblance to digital road signs, incorporating more unique visual features could enhance overall appeal and differentiation.
- A few participants liked the MPH feature which promotes driving speed awareness but found the other features lacking compared to popular apps like Google Maps and Waze. Some users commented on wanting more customisation options, including a journey planner and pre-journey traffic updates. How can you make the IVMS app stand out amongst the others?
- When creating and developing a new IVMS app, participants recommended making the app simple and user-friendly while offering real-time updates.
    - One of the key principals of UX design is about creating designs that have a level of familiarity. Drawing inspiration from apps like Google Maps for accurate navigation and Waze for its ease of use, could also aid in making this app more appealing.
    - Customisable messages and journey planner features are highly desired. The option to personalise can give the user a sense of control over the app, though finding the balance of what can and can't be personalised may need further investigation.
    - Additionally, the incorporation of AI features that learn from user behaviour would be beneficial for enhancing the overall experience.
- Views on technologies beyond the IVMS app were varied. While some individuals welcomed the concept of sharing their data to enhance road conditions and transportation in the area, others expressed concerns about issues such as privacy, safety, and fairness.

For what concerns the technical assessment, The system has received mostly excellent comments, especially during the hands-on training and experience sessions. Staff members who have used the technology recognise its significant benefits for improving public information about current traffic conditions. Additionally, they have emphasised the system's value in scheduling messages for pre-planned events and permitting rapid implementation in unexpected situations. It is important to highlight that additional changes and enhancements are anticipated when the system is used extensively in the upcoming months.

Finally, the Future VVMS Rollout Strategy will involve crucial steps for implementing the VVMS solution in the West Midlands and beyond.
Key actions will include identifying and engaging stakeholders, such as government bodies and National Highways, and establishing Vehicle-to-Infrastructure communication. Institutional factors, like regulations and funding, need a thorough evaluation and collaboration with RTCC, KRN, and Data Insights teams is vital for effective operation. It is also important to analyse the operational needs to develop communication networks and interoperability.
Technical requirements for the VVMS solution, covering software, hardware, and scalability, will need further assessment, especially during the rollout starting in critical West Midlands areas and beyond.
Integration channels for national transportation network inclusion should be developed in collaboration with Local Authorities to promote information sharing and cooperative projects.
In the next steps, larger pilots will be crucial for solution validation, with users and costumers' feedback guiding improvements. Moreover, a maintenance and support structure should be designed for long-term upkeep.
Therefore, planning for ongoing operational and incident management, considering system evolution, priorities and collaboration with emergency stakeholders, will be crucial for successful VVMS implementation to enhance traffic management and user experience.

11.1. Appendix A

11.2. Table of acronyms

Acronym	Definition
ANPR	Automatic Number Plate Recognition
ASN.1	Abstract Syntax Notation One
AWS	Amazon Web Services
B2B	Business-to-Business
C-ITS	Cooperative Intelligent Transport Systems
DfT	Department for Transport
Eco-AT	European Corridor – Austrian Testbed for Cooperative Systems
ETSI	European Telecommunications Standards Institute
FAT	Factory Acceptance Test
FVD	floating vehicle data
GLOSA	Green Light Optimised Speed Advisory
ITS	Intelligent Transport Systems
IVI	in-vehicle information
IVIM	In-Vehicle Information Messages
IVMS	In-Vehicle Message Sign
JTP	Journey Time Predictions
KLS	KL Systems
KRN	Key Route Network
MIDAS	Motorway Incident Detection and Signalling
NTIS	National Traffic Information Service
RDS	Relational Database Service
RTCC	Regional Transport Coordination Centre
SAT	Site Acceptance Test
SBRI	Small Business Research Initiative
SRN	Strategic Route Network
SSE	Server-Sent Events
TfWM	Transport for West Midlands
UPER	Unaligned Packed Encoding Rules
V2X	Vehicle-to-Everything
VMS	Variable Message Sign
VMS	Variable Message Signs
VVMS	Virtual Variable Message Sign

Table 8 - Table of acronyms

11.3. Appendix B

11.4. References

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