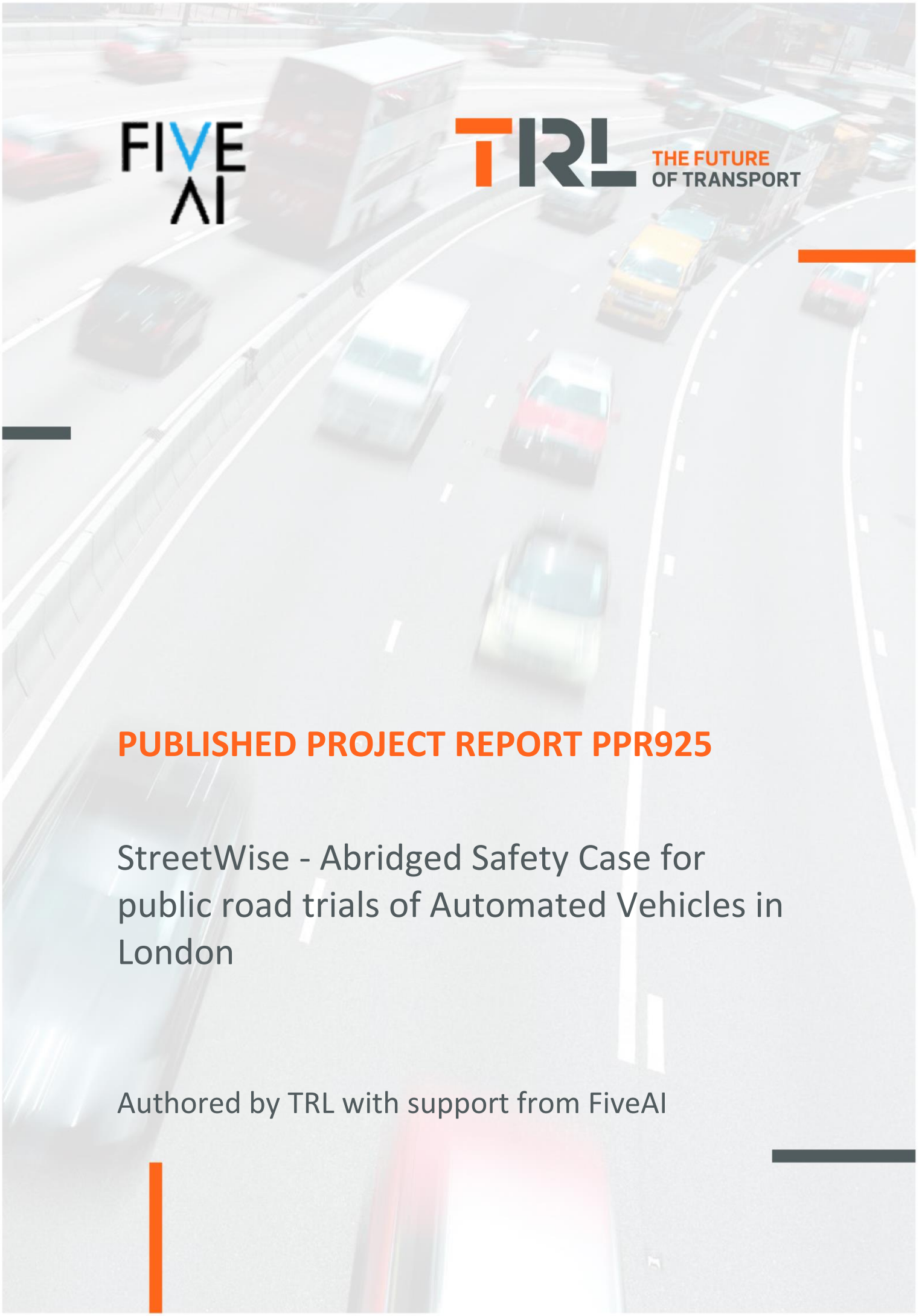

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StreetWise - Abridged Safety Case for public road trials of Automated Vehicles in London

Authored by TRL with support from FiveAI

Report details

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1 Introduction

Automated vehicles are central to the UK Government's industrial strategy because of the potential they represent for addressing several challenges facing urban areas including traffic congestion, vehicle emissions, commuting time and costs, and road traffic casualties. In purely monetary terms, the UK's market for connected and automated vehicles is estimated to be worth £52 billion by 2035[1].

The StreetWise project aims to develop and demonstrate the technology, safety validation methods, insurance and service models required to deliver an automated shared mobility solution, targeted at replacing the personal urban commuter car. The project is led by FiveAI, a UK-based company who are highly competent and experienced in the vehicle engineering, machine learning, artificial intelligence and safety fields. FiveAI are focused on creating the technology for fully automated, shared transport services in European cities, and are supported by other organisations working alongside them to deliver the trials. Funding for the project comes from the Industrial Strategy Challenge Fund[2] and is delivered via Innovate UK, with other investment coming directly from industry.

To ensure that the automated vehicles are safe to operate on UK public roads, key safety, cyber security and vehicle requirements have been satisfied. All automated vehicle operation on UK public roads is fully compliant with the Department for Transport's (DfT's) Code of Practice for testing automated vehicles[3], all UK road traffic laws and existing vehicle regulations. The Safety Case has been developed by TRL who are independent safety assessors and authors of BS PAS 1881 and the safety case framework for test beds within the UK. The test vehicles used for public road trials are type-approved category M1 vehicles and a Safety Driver is always present within the vehicle. All Safety Drivers are fully trained and competent for their role.

Safety is the priority and the Safety Case has been developed by TRL in line with the Code of Practice as well as to meet the necessary legal requirements to conduct testing on UK public roads and secure insurance for the trial. The key purpose of the Safety Case is to manage and reduce the potential risks of trialling automated vehicle technology on public roads to as low as reasonably practicable (ALARP). This document is an abridged version of the full Safety Case. Its purpose is to provide a publicly available overview of the trial and approach to risk management to give assurance that the trial will be conducted safely, and risks are appropriately managed. Although this abridged Safety Case applies specifically to public road trials in London, FiveAI adhere to the same principles when testing automated vehicles elsewhere in the UK.

[1] Market forecast for connected autonomous vehicles. Transport System Catapult, July 2017.

[2] https://www.ukri.org/innovation/industrial-strategy-challenge-fund/

[3] Code of Practice: Automated vehicle trialling. Centre for Connected & Autonomous Vehicles, February 2019.

This abridged Safety Case is freely available and provides members of the public with high-level information regarding the operational safety of FiveAI automated vehicle trials conducted in London.

The project, and London-based trials, are led by FiveAI which is part of a consortium consisting of the following organisations:

- TRL;
- Direct Line Group;
- Transport for London;
- Claytex;
- Warwick Manufacturing Group;
- Oxford University Torr Vision Group;
- McLaren Applied Technologies.

Information contained within this abridged Safety Case is related to several key topics applicable to operational safety:

- Risk assessment, evaluation and tolerability of risk decisions;
- Operational guidance and incident response;
- Safety Driver and Test Engineer selection, training, roles and responsibilities;
- Vehicle platform and Automated Driving System (ADS);
- Route selection, safety assessment and controls;
- Compliance with the DfT's Code of Practice for testing automated vehicles, UK vehicle standards, and UK driving rules and road traffic laws.

Figure 1: FiveAI test vehicle.

The test vehicles are 2015–2017 Ford Mondeo Hybrids (see Figure 1 above). Their standard build and modifications are described in Section 5. The goal of the test vehicle is to ensure safe automated driving in an urban environment. To help achieve this, the ADS requires the use of multiple sensor types to ensure redundancy in all driving environments. Multiple sensors make it possible for the vehicle to deduce where it is in the world, how fast it is moving and what 'objects' it is likely to encounter. These sensors also enable the vehicle to identify and localise other road users and pedestrians and provide information on how to predict a scene ahead and what action to take. In parallel, the vehicle must demonstrate compliance with UK driving rules and road traffic laws. Compliance with these rules and laws is part of FiveAI's Safety Driver training programme; this is covered in more detail in Section 4.2.

1.1 Trial aims and objectives

The aim of the automated public road trials in London is to demonstrate how automated technology might deliver mobility as a service (MaaS) through the provision of automated vehicles that can be used by members of the public as part of a ride-sourcing service.

The key aim of the passenger trial is to gain credible and real-world insights on willingness to use, willingness to pay and attitudes toward a shared automated passenger service. These insights can then be used to:

- Understand how a shared automated service can meet end-user needs, such as supporting more seamless multimodal journeys;
- Direct future research that increasingly hones-in on opportunities and challenges to the deployment of automated vehicles and new services.

1.2 Synopsis of the trial

The trials are on public roads in the London boroughs of Bromley and Croydon.

Trial participants will be required to attend safety briefings to ensure their upmost safety during the trial. In addition, a high level of care will be provided by both TRL and FiveAI staff prior to and throughout the journey.

No costs will be incurred by participants invited to take part in the trials.

The recruitment pool is restricted and already set; therefore, there will be no opportunity for wider involvement in the trial by members of the public.

The trial route consists of a mixture of road types in urban areas and contains typical road features, such as junctions, roundabouts, cycle lanes and different types of crossing provision for pedestrians. The route links major transport hubs to facilitate the wider use of public transport. However, for the purposes of the trial the route will be run as a loop with the same start and end location.

2 Operational Design Domain

An Operational Design Domain (ODD) is defined as the operating conditions under which a given ADS or feature is specifically designed to function including, but not limited to, environmental, geographical and time-of-day restrictions.

FiveAI's test vehicles are governed by an ODD that promotes safe automated operation along the designated trial route in Bromley and Croydon. The ODD allows the self-driving vehicles to negotiate a variety of road features commonly found on urban roads, such as roundabouts, signalised junctions and crossings. The test vehicle's automated features have been designed to ensure vehicle behaviour is compliant with both the UK Highway Code and road traffic law.

Extensive testing, both off-road, in a controlled, track testing environment, and on-road, has been conducted to demonstrate that the test vehicle performs in line with expectations and can safely negotiate the ODD. The Safety Driver is responsible for taking full control of the vehicle when hazards or conditions outside of the ODD occur and for situations within the ODD where the automated vehicle fails to perform as expected.

3 Safety and risk management

3.1 Methodology overview

The operational Safety Case, which is separate to this document, outlines how FiveAI safely operates its automated vehicles on public roads and provides the body of evidence to document the progression of testing and demonstrate that the vehicles are safe and reliable within a defined ODD. The operational Safety Case also demonstrates the following requirements to ensure that the trial is safe:

- A robust risk assessment identifying hazardous scenarios, potential causes, person(s) impacted and mitigations implemented to ensure all risks are reduced as low as reasonably practicable;
- Compliance with existing legislation, standards and guidance; and
- Provision of the required evidence and safety assurance to the Boroughs of Bromley and Croydon, and to the trial and vehicle insurers (Direct Line Group).

The operational Safety Case is a live, managed, version-controlled document based on a comprehensive risk assessment, with supporting evidence for each of the risk decisions made. The key operational risks related to the trial identified from the risk assessment include:

- Passenger safety (both during vehicle ingress/egress on the road);
- Incidents (during automated or manual modes);
- Occupant injuries in the event of a collision;
- Unsafe acts by other road users;
- Safety Driver impairment or distraction;

- Passenger illness during a journey.

Appropriate mitigations have been implemented to ensure that all risks identified are reduced to a tolerable level throughout the trials.

Monitoring, reporting and continuous improvement are embedded in the Safety Case and all on-road operations through FiveAI's continuous improvement programme with data capture taking place for all manually-driven data gathering trips and automated testing/trialling. In addition, FiveAI has developed a disengagement reporting process to support automated testing and the continuous improvement process. Full cooperation with the appropriate London authorities will be provided in the event of an incident, including provision of all pertinent data recorded. Incident and disengagement reporting, data-gathering and Safety Driver reviews all contribute to FiveAI's continuous improvement programme.

Compliance with existing legislation, standards and guidance also forms an essential part of the Safety Case and is evidenced appropriately in the full Safety Case. FiveAI's compliance with the DfT's Code of Practice is discussed in Section 7.1, and compliance with vehicle assessment and UK road traffic law and vehicle assessment is covered in Sections 5 and 7.2 respectively.

Before automated vehicles can be safely and successfully integrated into urban road networks, in-depth track testing must be carried out. On-road scenarios are tested at Millbrook Proving Ground to ensure expected automated driving system performance before any new feature is included. Test results from the mocked-up test scenarios are analysed and scrutinised by FiveAI and TRL prior to on-road release. Following on from this, progressive on-road testing without passengers is carried out, adding complexity to the automated driving system and building the evidence base to demonstrate that the vehicle can safely negotiate the test routes within a defined ODD.

Significant systems safety analysis and functional safety analysis have also been carried out which followed a stringent set of test criteria prior to on-road release. Intended functions of the automated driving system have been developed to address real-world requirements identified through data gathering missions driven with the FiveAI vehicles operated manually. Simulated scenarios and replays of real-world runs have been used to validate the performance of any software updates before implementation in a vehicle and release to track testing.

3.2 Incident response plan

FiveAI have developed an incident management plan for the trials which outlines the actions to take in the event of the incident. Safety Drivers and Test Engineers, who will always be in the vehicle during trials, will decide when to suspend or abort automated sessions. FiveAI have developed a detailed protocol for handling or aborting the sessions which includes grounding the entire fleet if required due to the type of incident.

Appropriate incident notification timelines are required in order to set a context for a timely continuous improvement process to learn lessons, prevent recurrence and to ensure that the Safety Case is updated in a timely manner. The level of reporting and response times are dependent on the nature of the incident.

4 Safety Drivers and Test Engineers

4.1 Roles and responsibilities

FiveAI's Safety Drivers are responsible for two broad categories of driving: data gathering (manual driving) and ADS supervision (i.e. a combination of manual driving and autonomy supervision). The Safety Driver is the primary mitigation for the risks that exist during automated operation. Safety Drivers are trained to ensure that the vehicle remains safe in all driving conditions, taking back control of the vehicle when hazards outside of the ODD occur and for situations within the ODD where the automated vehicle fails to perform as expected. As such, the Safety Driver is responsible for disengaging autonomy by using one of several override methods.

FiveAI's Safety Drivers are supported by a Test Engineer sat in the front passenger seat who is responsible for monitoring the health and performance of the ADS and informing the Safety Driver to disengage autonomy if there is a problem with the system.

FiveAI's Safety Drivers are compliant with FiveAI's 'Driving for Work' policy which sets limits on the duration of driving to help prevent fatigue. FiveAI's 'Driving for Work' policy is fully in line with the DfT's Code of Practice for automated vehicle trialling, which states that trialling organisations should develop robust procedures, such as setting the maximum time duration for any one trial period, to ensure that Safety Drivers are sufficiently able to perform their role and do not experience fatigue.

Competence assessments are conducted with all Safety Drivers to monitor performance and workload levels using appropriate tools.

4.2 Selection and training

FiveAI have selected drivers based on a series of predefined criteria to ensure they qualify for the role. FiveAI have also implemented and followed a comprehensive Safety Driver training programme. This training programme consists of a set of modules covering track and on-road automated vehicle testing, compliance, vehicle features, scenario-specific assessment, evaluation and refresher training, and incident reporting. This Safety Driver training programme includes an accredited course for Safety Drivers delivered by an external provider with modules specifically related to advanced driving techniques, including enhanced hazard identification and situational awareness. The driver training includes a review of relevant road traffic law and the essentials of the Highway Code.

5 Vehicle and automated driving system

FiveAI own and operate all the project's test vehicles, which are 2015–2017 Ford Mondeo Hybrids, five-seat category M1 road vehicles with automatic transmission. The Ford Mondeo is recognised as a safe base vehicle platform and comprises numerous advanced safety features, helping to keep all vehicle occupants and other road users safe.

Several modifications have been made to the base vehicle to enable it to function in automated mode, including externally-mounted sensors. The base vehicle has also been

modified to accommodate computing equipment with its associate power supply. All modifications to the base vehicle have kept the test vehicle within the vehicle manufacturer's specifications, such as vehicle weight. In addition, all Safety Drivers are trained on the dynamics of the test vehicle following the modifications.

The standard test vehicle has advanced safety features, such as Advanced Driver-Assist, Electronic Stability Control (ESC) and Emergency Brake Assist. These advanced safety features remain operational and unaffected by the ADS system, or by any modifications made to the base vehicle platform.

All of FiveAI's test vehicles are 5-star Euro NCAP rated for crashworthiness. All modifications made to test vehicles are within manufacturer limits and do not pose any additional risks to other road users.

6 Route selection and assessment

The trial route connects the centres of Croydon and Bromley and is approximately 7 miles (11 km) in length (in one direction). Trial participants will be travelling on a pre-determined route, with the trials being conducted on a 'loop' system, i.e. from Croydon to Bromley then returning to Croydon. Driving elsewhere in the boroughs will occur when travelling to and from the route for other data gathering and development purposes.

The trial route has been selected based on the following:

- Road types (the route predominantly comprises single carriageway urban roads);
- Speed limits (the entire route has a maximum 30 mph speed limit);
- Hazards and potential hazardous scenarios (these have been assessed through route safety assessments; key hazards or findings are communicated by TRL to FiveAI to ensure appropriate mitigations can be put in place);
- STATS19[4] collision data, particularly numbers, locations and types of killed and seriously injured collision records (these records have been assessed through expert analysis and judgement of the risks which are communicated by TRL to FiveAI to ensure appropriate mitigations can be put in place); and
- FiveAI actively consulting with Transport for London and with the London boroughs of Croydon and Bromley.

7 Compliance

7.1 DfT Code of Practice

FiveAI has issued a statement of compliance (SoC) for the DfT's Code of Practice[5], which provides guidance for any organisations wishing to conduct the testing of highly or fully

[4] STATS19 is a form used to report personal injury accidents on Great Britain's public roads to the Police.

[5] Code of Practice: Automated vehicle trialling. Centre for Connected & Autonomous Vehicles, February 2019.

automated technologies on public places. FiveAI's SoC, which fully complies with the current Code of Practice, consists of:

- Compliance with the Code of Practice – aim and scope;
- Compliance with the Code of Practice – general requirements;
- Compliance with the Code of Practice – test driver, operator and assistant requirements;
- Compliance with the Code of Practice – vehicle requirements.

7.2 Vehicle assessment

FiveAI's test vehicles are type-approved vehicle category M1, Type BA7. The test vehicles' standard-fit advanced driver-assistance systems (ADAS) have not been modified or disabled, they retain standard vehicle controls for a human driver and provide the same field of view from the vehicle cabin. The vehicles' lights are unaffected, so remain as conspicuous as a production vehicle of this type.

Test vehicles are branded with FiveAI logos on the nearside and offside panels and text on the boot hatch and roof-mounted sensor enclosure. Test vehicles also have stickers on the rear bumper which state 'self-driving vehicle' to provide explicit external indication that it is an automated vehicle.

The test vehicle, being a category M1 road vehicle, is fully compliant with Driver and Vehicle Standards Agency (DVSA) requirements, the Road Traffic Act 1988 (Part II Construction and Use of Vehicles and Equipment) and the Highway Code.

7.3 Cyber security standards

Cyber security risks have been addressed to ensure full compliance with the DfT's Code of Practice. This includes FiveAI staff having full control over the vehicle interfaces and several key cyber security issues, such as data transfer.

7.4 Data protection

FiveAI is fully aware of the legality of video and image data collection during the on-road trials, but these forms of data collection are subject to certain conditions under the Data Protection Act, or GDPR. To ensure full compliance with GDPR, FiveAI have established procedures related to the public release of information, privacy impact assessments and secure data storage. Privacy statements are also available on FiveAI's website at https://five.ai/privacy.

8 Safety and insurance for public road testing

The StreetWise project is following a gated approval process prior to any public road operation. The process involves a range of project parties, with TRL acting as independent safety assessors and Direct Line Group acting as insurance/liability assessors, to ensure that the vehicle and ADS are safe for use on public roads. In broad terms, this approval process

assesses the implementation of changes to either existing or new ADS functionality and ensures that a robust safety and insurance approval process is applied to manage safety and to scrutinise proposed on-road activities. The process has been used successfully throughout the project and remains a key part of the safety assurance ahead of any automated public road operation in the UK.

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