Department for Transport

Data elements proposal and results of TRL project

UK Department for Transport

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Department for Transport

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TRL Project purpose

It is recognised that there is a need to optimise the data elements list within DSSAD, to balance the data burden that comes with recording and storing the data, against obtaining all the essential information to confidently understand everything relevant that an ADS did during an incident.

To help with this issue, the UK initiated a project with the Transport Research Laboratory (TRL) to determine the **minimum dataset** the DSSAD needs to record to understand what an ADS did during an incident, so that this dataset can be the first reference when used to decide if further investigation into an ADS or the incident is necessary.

TRL were tasked to develop this minimum dataset as they have extensive experience in collision investigation and investigation of non-collision incidents involving automated vehicles from trials they have been involved in

The funding for the project was via a particular arrangement, the conditions of which meant that the final project output had to be shared publicly.

This output of this work is the professional view from TRL, without prejudice or influence by what the Informal Working Group has done so far. Hence, some of their output has needed adjustment to better reflect the language already in the guidance document.

Project method

Approach to identifying recommended data elements

- Building on VMAD's work on occurrences, the task for TRL was to define the minimum set of time series data elements (including their respective recording interval, sample rate, range, accuracy, and resolution) that should be recorded to provisionally investigate an incident and determine what the vehicle did during this incident. This was done via:

1. Literature Review:
    - A rapid review of international proposals, national legislation, and relevant technical standards to collate a list of data elements and the approaches that are recommended by these sources
    - This task mapped those data elements with the recommended data format, range and resolution by reviewing available information.

2. Expert workshop:
    - Develop a recommended minimum dataset for DSSAD by utilising the findings from literature review and our insights from in-depth collision investigations for expert witness, collision data collection programme (Road Accident In-Depth Studies – RAIDS) and TRL's understanding of data used by automated vehicles to perform the dynamic driving task
    - TRL’s Collision Investigation and AV Regulation experts reviewed, refined and updated the draft list of data elements

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Framework for use of time series data

- The general architecture of an Automated Driving System (ADS) typically consists of modules for **perception**, **planning**, and **action**; and

- As the **DSSAD** (Data Storage System for Automated Driving) time-series data is designed to provide information for understanding "what happened" and "what the ADS did," TRL recommends that DSSAD time-series data capture elements relevant to **perception** and **action**, while excluding the **planning** module. Additionally, incorporating vehicle dynamics data is essential to analyze the observed driving behavior.

- The following slides outline a **framework** for assessing the relevance of DSSAD data elements. The framework also identifies potential sources of inconsistencies, which can support the determination of whether further investigation is required.

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Framework for use of time series data

Dataset vs. Safety Expectations

DSSAD Time Series Data

Perception

Visual Represe ntation

Object Detection

* Visual-based info only

Action

ADS Requested Actions

Outcome

Vehicle Dynamics

What was in the field of view?

What did ADS observe?

What did the ADS decide to do?

What was the observed driving behaviour?

What ADS recognise as relevant to the operation?

Planning

Event recogni tion

Context-aware planning

External factors
e.g. road surface

What ADS was expected to (visually) observe?

What happened?

What would be appropriate responses?

What would be expected execution outcome?

What are relevant to the operation?

Expectations

Standard: 'A Careful and Competent Driver'

Reference: Safety Arguments + Safety Cases

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Framework for use of time series data

In what circumstances would the regulator initiate further investigation

Indicators from Time Series Data for Further Investigation

- Single incident
  - Inconsistency between intended action and observed behaviour
  - Inconsistency between expected action and ADS requested action
  - Inconsistency between expected outcome and observed outcome

- Across instances of the same incident type or the same scenario
  - Inconsistency of ADS behaviour

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Framework for use of time series data

TRL

DSSAD Time Series Data

Perception

Visual Representation

Object Detection

* Visual-based info only

Action

ADS Requested Actions

Failed Execution

Outcome

Vehicle Dynamics

What was in the field of view?

What did ADS observe?

What ADS recognise as relevant to the operation?

What did the ADS decide to do?

What was the observed driving behaviour?

Planning

Event recognition

Context-aware planning

What happened?

External factors

What ADS was expected to (visually) observe?

What are relevant to the operation?

What would be appropriate responses?

What would be expected execution outcome?

Expectations

Standard: 'A Careful and Competent Driver'

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Framework for use of time series data

DSSAD Time Series Data

Perception

Visual Represe ntation

Object Detection

* Visual-based info only

What was in the field of view?

What did ADS observe?

What ADS recognise as relevant to the operation?

Planning

Event recogni tion

Context-aware planning

What happened?

What ADS was expected to (visually) observe?

What are relevant to the operation?

Action

ADS Requested Actions

What did the ADS decide to do?

Inadequate Control – Response and timing

What would be appropriate responses?

Outcome

Vehicle Dynamics

What was the observed driving behaviour?

External factors

What would be expected execution outcome?

Expectations

Standard: 'A Careful and Competent Driver'

Reference: Safety Arguments + Safety Cases

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Exemplar real-world incidents

Case summaries

- Simplified incident or collision scenarios
  - Based on real cases investigated by TRL collision investigation experts

- Each case demonstrates need for different time-series data elements
  - Particular attention to object detection and identification, and duration of data required

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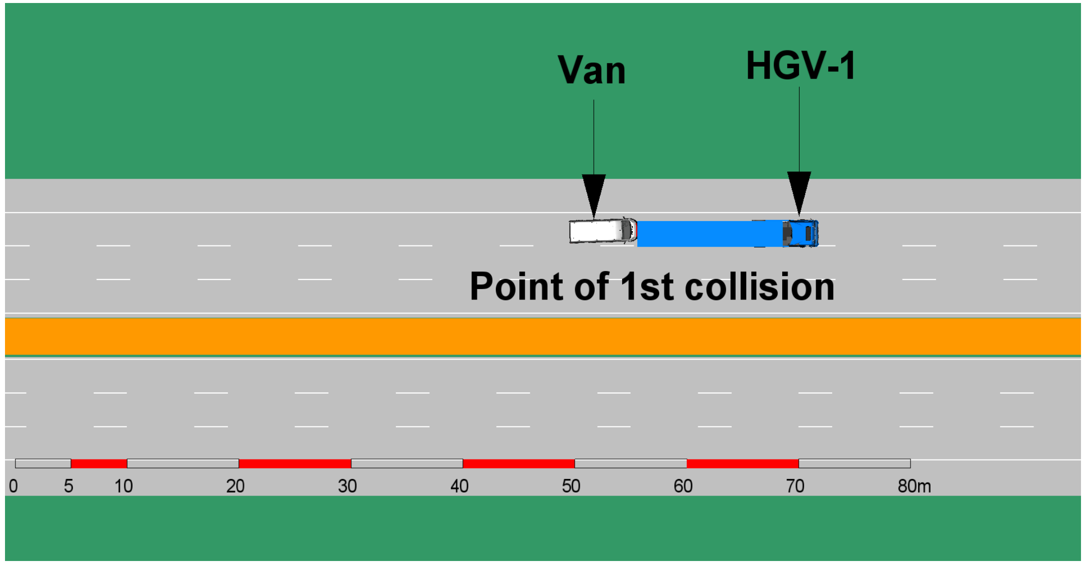
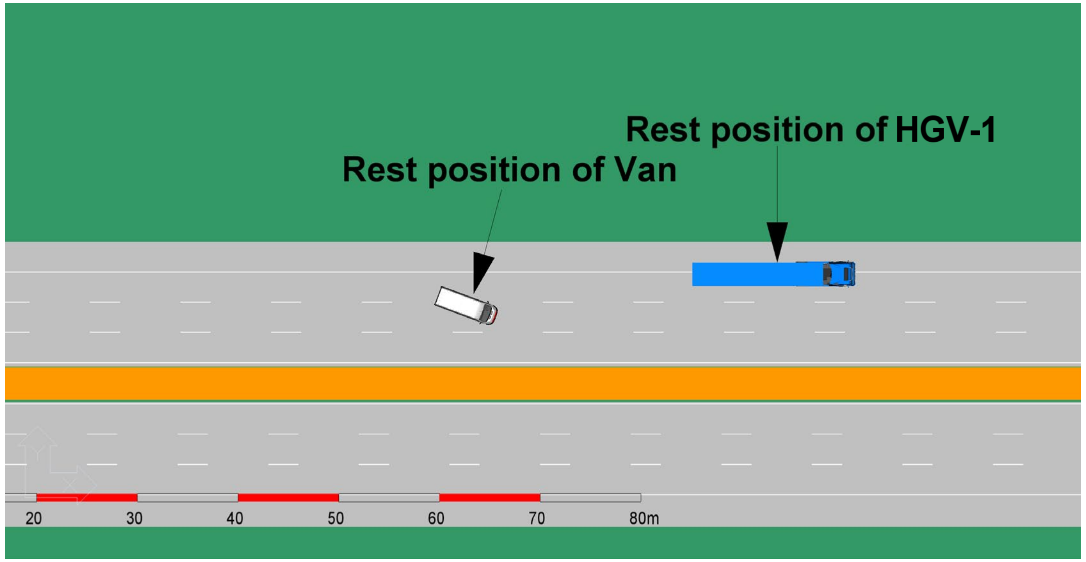
Exemplar real-world incident

Reaction to a previous collision

- Scenario
  - 3-lane motorway at night, no streetlamps
  - Incident 1 – A Van rear-ends an HGV (HGV-1) travelling in Lane 1 resulting in
    - Van heavily damaged and stationary in Lane 2
    - HGV-1 slightly damaged and parked partially on the hard shoulder, partially in Lane 1





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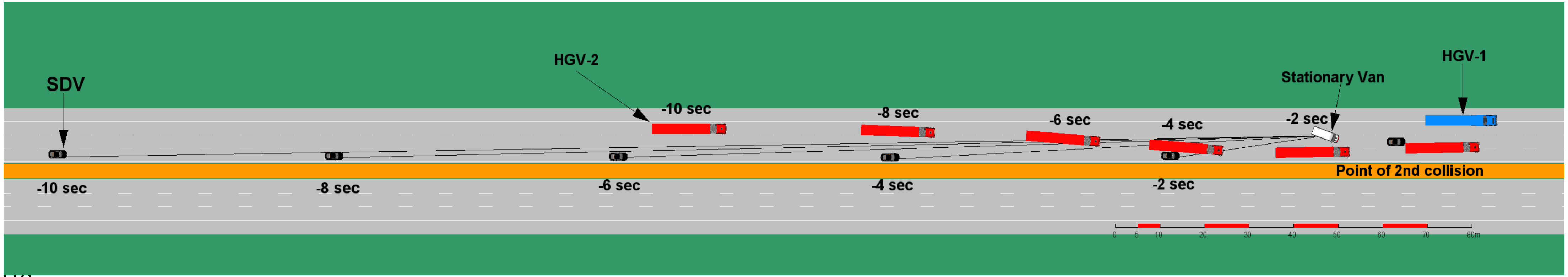
Exemplar real-world incident

Reaction to a previous collision

- Scenario (continued)
  - Incident 2 – One minute later, a following HGV (HGV-2) approaches the collision scene from Incident 1
    - HGV-2 is travelling at 85 km/h in Lane 1
      - Realising that Lane 1 is partially blocked by HGV-1, driver of HGV-2 indicates and moves over to Lane 2
      - Realising that Lane 2 is blocked by Van, driver of HGV-2 indicates and moves over to Lane 3
    - SDV is travelling at 110 km/h in Lane 2 and approaching HGV-2 as it moves from Lane 1 to Lane 2
      - SDV moves to Lane 3
      - Typical SDV sensor range and enables identification of stationary vehicle (HGV-1) partially in Lane 1 and stationary vehicle (Van) in Lane 2 at 6-7 seconds
      - Clear sight lines to HGV-1 and Van are available at multiple time points from 8 seconds before the location



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Exemplar real-world incident

Reaction to a previous collision

- SDV likely can identify the potential hazard earlier than a human driver (dark road)
  - SDV should expect HGV-2 to continue to move across to Lane 3 and reduce speed early and appropriately
  - Having identified the potential hazard, a ‘careful’ approach can be chosen
  - If SDV takes the ‘careful’ approach, no data will be recorded
    - Data only recorded if the observable hazard is not acted upon AND this results in a collision, near miss or emergency manoeuvre

- Why extended data is needed
  - Detection of objects supports assessment of observable hazard
  - Longer period of data recording shows that the hazard was observable for long enough to support a more cautious decision

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Recommendations

Summary of data element implications from literature review and exemplar

Data collection pre-event

- Incident sequence and event build-up (scenario)
- General driving behaviour (e.g. lane changing, following distance, acceleration/deceleration)
- Operation status and condition (e.g. operator, system status)
- Interaction between operators (onboard driver, remote assistant or driver, and automated driving system) and vehicle
- Vehicle operation information (e.g. speed, control inputs, impact)
- Compliance with traffic rules (e.g. demonstrating that appropriate, early signalling of and intended manoeuvre was provided to other road users)
- Environmental factors (e.g. traffic conditions, road geometry, lighting)
- Mitigation efforts before the crash and timing of the response

- Data collection post-event
    - Incident sequence, including impact and vehicle resting state
    - Operational actions of the vehicle operator(s) after the crash
    - Contributions of other stakeholders to the event and injuries

- Recommend up to 10 seconds to record pre-event build-up described in the scenarios above
- Recommend up to 10 seconds to record post-event to record the minimum risk manoeuvre in most scenarios that could be envisaged

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Recommendations

Final data element list – 27-05

[EDR-DSSAD-IWG-27-05 Minimum data set for Time Series Data in DSSAD_v2.xlsx]

Timestamp (UTC)
Geolocation (horizontal)
Geolocation (vertical)
Vehicle Heading
Visual Representation
ADS Requested Lateral Vehicle Motion Control
ADS Requested Gear
ADS Requested Braking
ADS Requested Longitudinal Vehicle Motion Control
ADS Requested Hazard Flasher
ADS Requested Exterior Lighting
ADS Requested Turn Signals
ADS Requested Audible Warning System (e.g. horn)
ADS Determined - Vehicle (Longitudinal) Speed
ADS Determined - Longitudinal Acceleration
ADS Determined - Lateral Acceleration
ADS Determined - Vertical Acceleration
Vehicle Indicated – Gear Position
Vehicle Indicated – Braking Status (Parking)
Vehicle Indicated – Braking Status (Service)
Vehicle Indicated - Hazard Flasher Status
Vehicle Indicated - Exterior Lighting status
Vehicle Indicated - Turn Signal Status
Audible Warning System Status (e.g. horn)

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UK provided documents

27-05

Previously 26-15, this spreadsheet has been produced from the research project with the Transport Research Laboratory (TRL). This lists the **minimum dataset** TRL have identified to help describe to us what happened during an incident for an ADS and their justifications for it.

27-06

Previously 26-11, this is our **formal proposal** of data elements to include in the guidance document adapted from 27-05 (26-15) to incorporate with the prevailing work on the guidelines. The justifications for those are on the following slides and can be also found in 27-05

EDR-DSSAD-IWG-27-05 – Minimum data set

There are similarities to the EC/JP proposal (25-05) of time series data elements. That proposal had perception, control and dynamics as categories for their data elements. Whereas TRL have framed these as time, location, perception, control - ADS requested action, and dynamic vehicle data.

EC/JP proposal	TRL project output
Time stamp from time-series data trigger	Time
(Perception - Geolocation)	Location
Perception	Perception
Control	Control - ADS requested action
Dynamics	Dynamic vehicle data

EDR-DSSAD-IWG-27-05 – Control/Dynamics

There are similarities between the data elements in the EC/JP proposal and what has been produced by TRL in 27-05. The table below shows the naming of these data elements in each proposal and the current wording in the guidance document. It is important to note these are not different data elements, they are the same but have slightly different terminology.

EC/JP proposal – data elements	EC/JP proposal - category	Outcome of TRL research project – data elements	Outcome of TRL research project - category	Guidance document equivalent
Accel command	Control	ADS Requested Longitudinal Vehicle Motion Control	Control – ADS requested action	ADS-requested accel demand
Brake command		ADS requested braking		ADS-requested service braking demand
Steer command		ADS requested lateral vehicle motion control		ADS-requested steer demand
Indicator command		ADS Requested Turn Signals		[ADS-requested direction indicator demand]
Vehicle acceleration, longitudinal	Dynamics	ADS Determined – Longitudinal Acceleration	Dynamic vehicle data	Vehicle acceleration, longitudinal
Vehicle acceleration, lateral		ADS Determined - Lateral Acceleration		Vehicle acceleration, lateral
Vehicle yaw rate		-		Vehicle yaw rate
Vehicle indicated speed		ADS Determined - Vehicle (Longitudinal) Speed		ADS determined speed

EDR-DSSAD-IWG-27-06 – Data elements proposal

UK additions to the guidance document have been added in red (added into 26-16), those in **bold red** are further additions (27-06).

These elements have been extracted from 27-05 to form our proposal for a minimum dataset to be recorded by the DSSAD, however some data elements have been adjusted to reflect the language already being used in the guidance document (e.g. *ADS requested lateral vehicle motion control* in 27-05 is the same as *ADS requested steering demand* in 27-06).

The new data elements that have been added are:

Geolocation (horizontal and vertical),

Vehicle heading,

ADS requested gear,

Vehicle indicated direction indictor status, hazard warning signal status, exterior lighting status, audible warning system status

ADS requested direction indictor status, hazard warning signal status, exterior lighting status, audible warning system status - *only if 'failure' resolution of vehicle indicated equivalent does not include communication failure*

Vehicle acceleration, vertical

EDR-DSSAD-IWG-27-06 – Data elements proposal

Geolocation (horizontal and vertical) – replace GNSS positioning as it has inaccuracies and is unlikely to be used to fully locate the vehicle. This is needed understand where the vehicle was during an event and crucial for identifying what lane and section of the road the vehicle was in; it is proposed to use WGS84 which is a commonly used global standard.

Vehicle heading – provides absolute orientation of the vehicle and replaces yaw rate. Heading is more relevant for the ADS's actions whereas yaw rate is more relevant for the dynamics of a crash. Calculating heading from yaw rate would require additional parameters which would generate a large uncertainty for the calculated heading measurement.

ADS requested gear - can help detect potentially dangerous situations where the ADS selects an inappropriate gear, such as shifting into reverse while moving forward or engaging drive while in reverse.

EDR-DSSAD-IWG-27-06 – Data elements proposal

Vehicle indicated direction indictor status, hazard warning signal status, exterior lighting status, audible warning system status – conspicuity-based elements are critical for the ADS making itself aware to other road users. These are valuable for looking at how the situational awareness of the ADS, and its ability to recognise and respond appropriately to various traffic scenarios and potential hazards.

ADS requested direction indictor status, hazard warning signal status, exterior lighting status, audible warning system status – if the ‘failure’ resolution of vehicle indicated equivalent does not include communication failure between the ADS and the relevant light or auditory source then these are mandatory too so as to understand whether any ADS request is achieved.

Vehicle acceleration (vertical) - this data can reveal rollover events and inconsistencies or anomalies in the ADS's behaviour with respect to road surface irregularities which could have contributed to an incident.

EDR-DSSAD-IWG-27-06 – Data elements proposal

Visual representation – this will present an absolute ground truth for what happened during an incident with the ADS and can be used to assess whether the driving behaviour of an ADS was safe and proportionate to the incident it was involved in. Object detected elements only provide what the ADS interpreted the scene to be so does not represent an objective view of the situation.

Vehicle acceleration (lateral, longitudinal, vertical) - If the ADS utilises a separate sensor to determine acceleration, then the **ADS determined acceleration** in that plane (e.g. longitudinal, lateral and vertical) shall be recorded as an additional data element. Discrepancies in what the ADS is considering, and the vehicle dynamics could be a contributing factor in an incident.

Conclusion

This proposed revision of the list of data elements is to provide a **minimum dataset** for a DSSAD to record, which can help with the data burden of storing these data elements.

This is to determine all the actions an ADS carried out during an incident and if these were done in the **safest manner possible.**

This list will provide an overview for authorised entities to review and assess what happened during an incident and determine if it did not behave like a careful and competent driver and that **further investigation into the ADS may be necessary**.