

Minimal risk events (MRX) for automated vehicles – Guide

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Foreword

This BSI Flex was sponsored by the Centre for Connected and Autonomous Vehicles (CCAV). Its development was facilitated by BSI Standards Limited and it was released under licence from The British Standards Institution. It came into effect on 31 March 2025.

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The content in this version is part of an iterative process. It is likely to change from time to time with subsequent iterations.

Supersession

This version of BSI Flex 1888 supersedes BSI Flex 1888 v1.0:2024-10, which is withdrawn.

Relationship with other publications

BSI Flex 1888 v2.0 is part of BSI's Connected and Automated Mobility (CAM) Standards Programme, sponsored by the Centre for Connected and Autonomous Vehicles (CCAV). The CAM Standards Programme focuses on engaging with the UK CAM industry and developing standards for the safe development and deployment of self-driving vehicles.

Information about this document

This is Version 2 of BSI Flex 1888, which is the last planned version of the document. All comments received will be reviewed to inform the future direction of this document. Interested parties are encouraged to check the BSI website for updates regarding any future plans.

This is a full update of the document, and introduces the following principal changes:

- notes have been added to clarify the relationship between MRX and concepts from other standards, such as “fallback”;
- the potential for on-board or remote humans to request the vehicle performs an MRX has been added in **6.2.5**;
- although not an MRX, alternative responses to degraded functionality, such as “limp home mode”, have been noted;
- eCall functionality has been noted as a method for communication of incidents in **9.4**;
- all figures have been updated for clarity.

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Use of this document

As a guide, this BSI Flex takes the form of guidance and advisory recommendations. It is not to be quoted as if it were a specification or a code of practice.

Presentational conventions

The guidance in this document is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Additional commentary, explanation and general informative material is presented in smaller italic type.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

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In particular, attention is drawn to the Automated Vehicles Act 2024 [1].

Introduction

The behaviour of a self-driving or automated vehicle (AV) when its automated driving system (ADS) is unable to safely continue a journey has been an important topic throughout the development, testing and deployment of AVs. The issue is particularly critical when the AV does not have a safety driver on board who is trained and capable of taking immediate and full control of the vehicle.

A vehicle might “fail operational” and be able to operate more slowly or continue using an alternative route in some cases. However, when an ADS is unable to safely continue its journey, most regulations and standards require the AV to reduce speed and to stop in a location that is as safe as possible. This is often referred to as performing a minimal risk manoeuvre (MRM) to a location and a state known as a minimal risk condition (MRC).

In recent years, there have been efforts to describe or specify what such low-risk manoeuvres might be, or how, when and where it might be safe to stop AVs. This is a challenge for both industry and regulators, because what would be considered as safe manoeuvres, or what would be regarded as a safe place to stop, are critically dependent on the circumstances the vehicle is operating in. The nature of the road, the speed and density of other traffic, conditions such as the local weather, and the type of vehicle (whether it is carrying passengers or cargo, whether it is a light or heavy vehicle) are amongst the many parameters influencing the risks involved in these scenarios.

Assessment of the risks involved in potential manoeuvres, and of the safety of possible stopping locations, is obviously a prerequisite for choosing a low-risk option in any specific scenario, and for justifying that choice in the event of an incident or subsequent court proceedings. The approach used to combine the risks in the manoeuvres and the stopping conditions is also vital in selecting the safest option.

Accordingly, there is an urgent need for guidance to support the development, deployment, testing and regulation of AVs in relation to performing an MRM when the ADS is unable to safely continue a journey. More specifically, guidance is needed on assessing the safety of possible MRMs and/or suitable MRC stopping places, and to avoid substantially different responses by multiple AVs to the same external factors, which could lead to additional risks.

This BSI Flex provides a framework to assist automated decisions based on the assessment of risks for types of MRMs and classes of MRCs, and defines a minimal risk event (MRX) that combines the MRM to be executed with the MRC to be achieved, and the nature of the triggering event that causes the ADS to execute the MRM and MRC with the lowest combined risk. The ADS continually monitors the trigger status and risks so that the selected MRX continues to be the safest option.

The framework does not prescribe how risks are to be assessed, but provides guidance on categorizing MRMs and MRCs by the risks involved and proposes they are combined to select the lowest overall risk MRX.

1 Scope

This BSI Flex gives guidance for selecting the minimal risk manoeuvres (MRMs) and minimal risk conditions (MRCs) that highly automated vehicles (AVs) require when the automated driving system (ADS) is degraded or fails, or when other events demand.

It provides a framework for consideration of the risks involved in AV manoeuvres and the risks related to the conditions at the location where the vehicle stops, with the objective of minimizing the overall risk and achieving the safest possible outcome. The nature of the event triggering the MRM is key to selecting the combined MRM and MRC with the lowest overall risk.

This BSI Flex covers:

- functionality or manoeuvres beyond the normal expected behaviour of an ADS;
- the minimal risk event (MRX) concept, combining MRM, MRC and MRX trigger;
- categorizing MRMs by the risks involved;
- categorizing MRCs by the risks involved; and
- combining MRM and MRC, and selecting the lowest overall risk using MRX trigger information.

This BSI Flex applies to AVs used in developmental testing, advanced trials and deployment. It covers prototype vehicles, passenger and freight carrying services, as bound by and proportionate to the relevant operational design domain (ODD). It is primarily intended to apply to the operation of AVs on public roads.

This BSI Flex reflects existing good practice, but it is not exhaustive.

This BSI Flex does not cover:

- functionality or manoeuvres associated with the normal expected behaviour of an ADS;
- changes of destination or route requested by passengers;
- manoeuvres or control functions independent of an ADS;
- manoeuvres that do not result in the AV stopping at an MRC; or
- manoeuvres commanded by an external agent (e.g. safety enforcement agency).

This BSI Flex supports organizations developing, operating, regulating and certifying AVs or an ADS.

It might also be of use to road authorities, local authorities, emergency services, testbeds, vehicle agencies and insurers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BSI Flex 1890 v5.0:2023-04, *Connected and automated mobility – Vocabulary*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in BSI Flex 1890 v5.0:2023-04 and the following apply.²⁾

3.1 current conditions modification factor (CCMF)

risk factor related to transitory factors during an MRX which either reduces the visibility of traffic, or reduces vehicle braking, steering or driving capabilities, hence increasing risk of collision

NOTE 1 CCMFs modify the generic risks of the type of MRM step and/or the class of MRC.

NOTE 2 Examples of CCMFs that affect visibility are rain, fog, snow, heavy traffic and pedestrians causing obscuration.

NOTE 3 Examples of CCMFs that affect steering and braking include ice, standing water and mud, and the volume, speed, behaviour and types of traffic that reduce the ability to manoeuvre safely.

NOTE 4 CCMFs can be regarded as having a timeframe covering the whole MRX event, including the duration at the MRC.

3.2 minimal risk event (MRX)

emergency or unexpected time-sensitive event requiring the vehicle to stop in as safe a way as possible by executing an MRM to achieve an MRC initiated by an MRX trigger recognized by the ADS

NOTE 1 MRXs are not part of normal driving manoeuvres, such as emergency braking or steering to avoid other traffic. However, in some scenarios, MRMs might include braking and/or steering.

NOTE 2 MRXs might include events requiring the vehicle to safely manoeuvre off the road where prevailing conditions suggest that this has a lower risk to safety than staying on the road.

NOTE 3 The goal of an MRX is to minimize the overall risk to the vehicle, to any occupants, to other road users and to any other persons. An ADS is expected to identify MRX options which suit its operating domain, and to select the lowest risk of these options, even if the absolute minimum risk might not necessarily be achieved. The risks might be related to the motion of the vehicle or to other reasonably foreseeable or detectable causes.

NOTE 4 Continuous monitoring of trigger signals and changing risk assessments might require the ADS to select a new MRX during execution.

NOTE 5 The concept of “fallback” is often used when an ADS cannot continue. For example, “DDT fallback” is defined in SAE J3016 and PD ISO/SAE 22736:2021 (3.12) to include handover of the DDT from an ADS to a fallback-ready user. Where a fallback-ready user is not available, fallback is the ADS response to achieve a minimal risk condition. This BSI Flex does not cover the complexities of handover to human drivers and focuses only on an ADS performing an MRX.

²⁾ This BSI Flex is based on common terms used in the UK and aligns with existing UK and international standards wherever possible.