User Cases and Scenario Catalogue for ML/DL-based solutions testing in Vehicles

21° Automotive SPIN Italia Workshop

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V1R2

Context: the SAFEXPLAIN project

In a nutshell

- The scene
  - **Critical Embedded Systems (CES)** increasingly rely on Artificial Intelligence (AI): automotive, space, railway, avionics, etc.
  - CES must undergo **certification/qualification**
  - AI at odds with functional safety certification/qualification processes (**lack of explainability**, **lack of traceability**, **data-dependent** software, **stochastic** nature)
- SAFEXPLAIN ambition: architecting DL solutions **enabling certification/qualification**
  - Making them **explainable** and **traceable**
  - Preserving **high performance**
  - Tailoring solutions to varying safety requirements by means of **different safety patterns**

OCT 2022 – SEP 2025

SAFEXPLAIN

Safe and Explainable Critical Embedded Systems based on AI

BARCELONA SUPERCOMPUTING CENTER (BSC)
https://www.bsc.es/

IKERLAN, S. Coop (IKR)
https://www.ikerlan.es/

AIKO SRL (AIKO)
https://www.aikospace.com/

RISE RESEARCH INSTITUTES OF SWEDEN AB (RISE)
https://www.ri.se/

NAVINFO EUROPE BV (NAV)
https://www.navinfo.eu/

EXIDA DEVELOPMENT SRL (EXI)
https://www.exida-eu.com/

Introduction (role in the project)

- As one of the contributions by exida to WP2 “Satety Assessment”, a set of relevant use cases and scenarios including known triggering conditions to perform vehicle testing has been selected to verify/demonstrate:
  - The adequacy of the sub-components of an ADAS system (sensors, algorithm, actuators).
  - The robustness and controllability of the system once integrated into the vehicle.
  - The correct interaction of the system with the other vehicle components.

Catalogue: Scope and Purpose

- The goal of this presentation is to shown the relevant driving scenario catalogue.

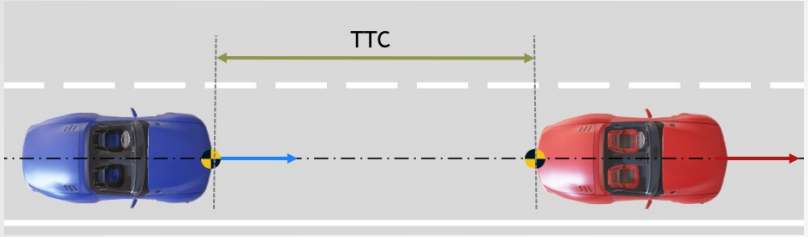
- For each driving scenarios is reported its probability of occurrence (based on catalogue of manoeuvres, e.g., VDA-702) to allow the calculation of scenario weight.

- Both collision relevant and no collision relevant driving scenarios are reported in this presentation to analyse also False-positive detection by the intended functionality.

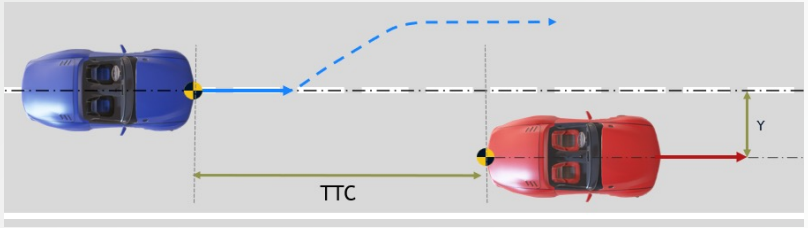
Scenarios catalogue summary 1/11

- The following list reports all the driving scenario contained in the driving scenario catalogue [with ID (e.g., DS-x) and title).
- For all the details on a given scenario, please refer to the dedicated scenario sheets.

- DS-1 – Driving following a target vehicle on highway

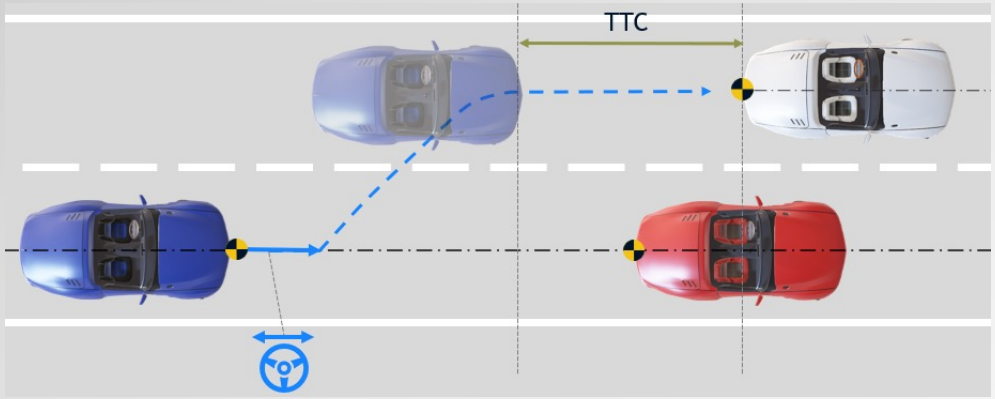


- DS-2 – Performing a lane change

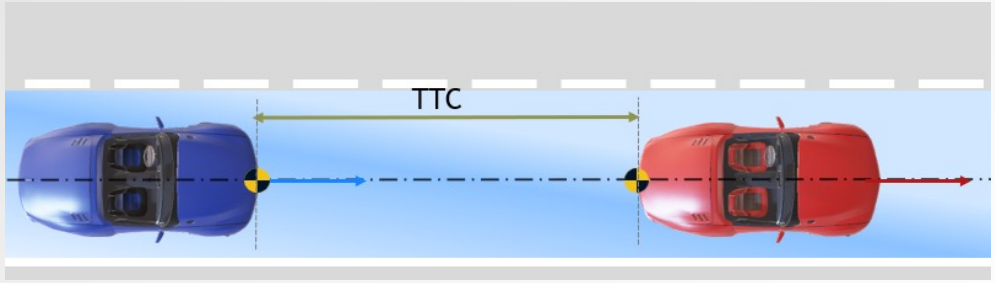


Scenarios catalogue summary 2/11

- DS-3 – Performing an overtaking and approaching a new target vehicle

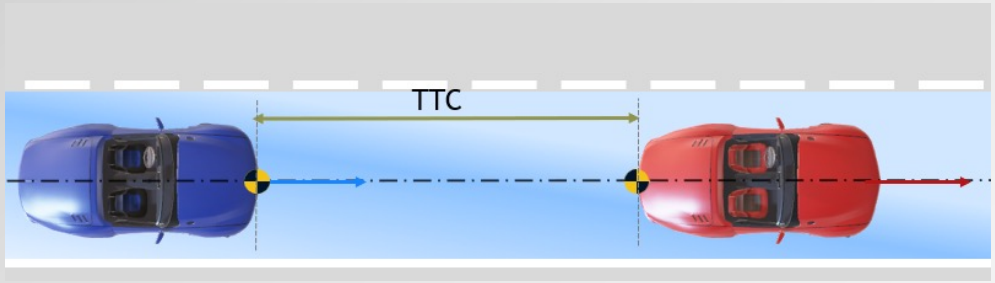


- DS-4 – Driving on road with reduced friction coefficient (μ < 0,8 ± -0,1)

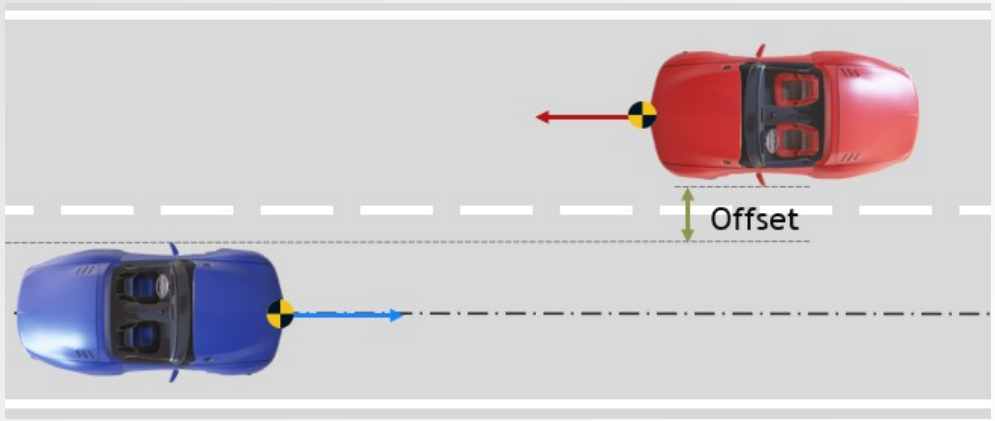


Scenarios catalogue summary 3/11

- DS-5 – Driving on road with low friction coefficient (μ < 0,5 ± -0,1 (e.g., snow, ice))

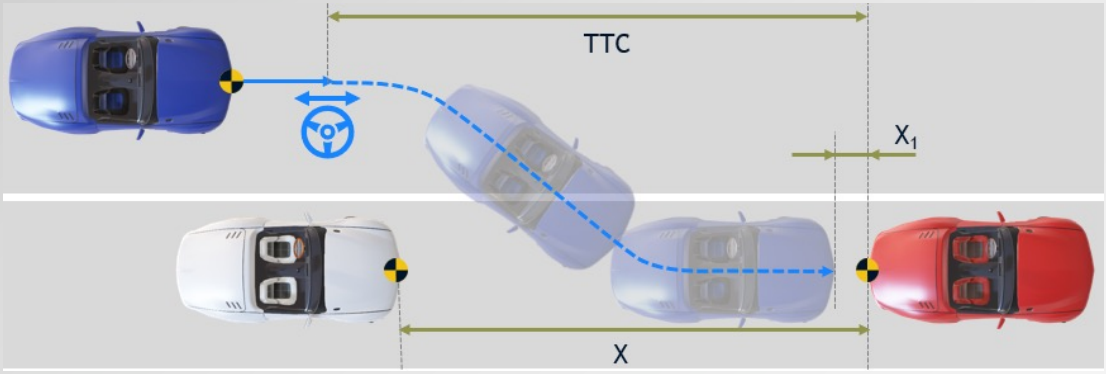


- DS-6 – Driving with a target vehicle coming from opposite direction

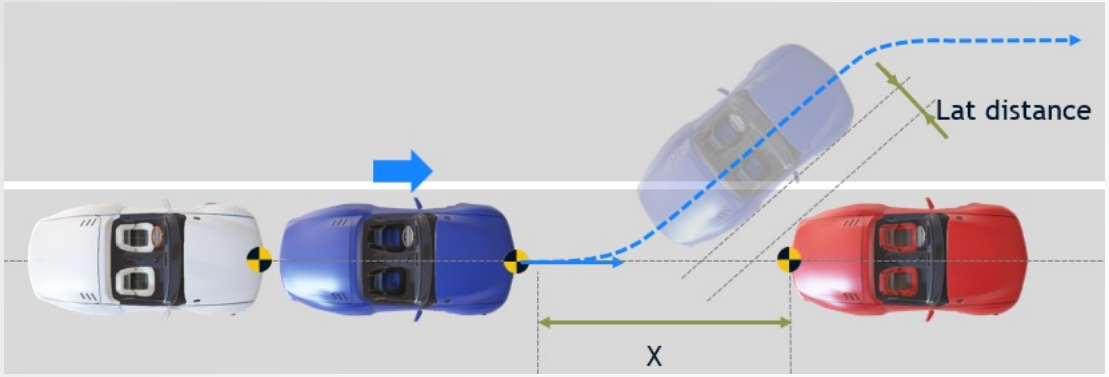


Scenarios catalogue summary 4/11

- DS-7 – Enter in a parking space in longitudinal direction

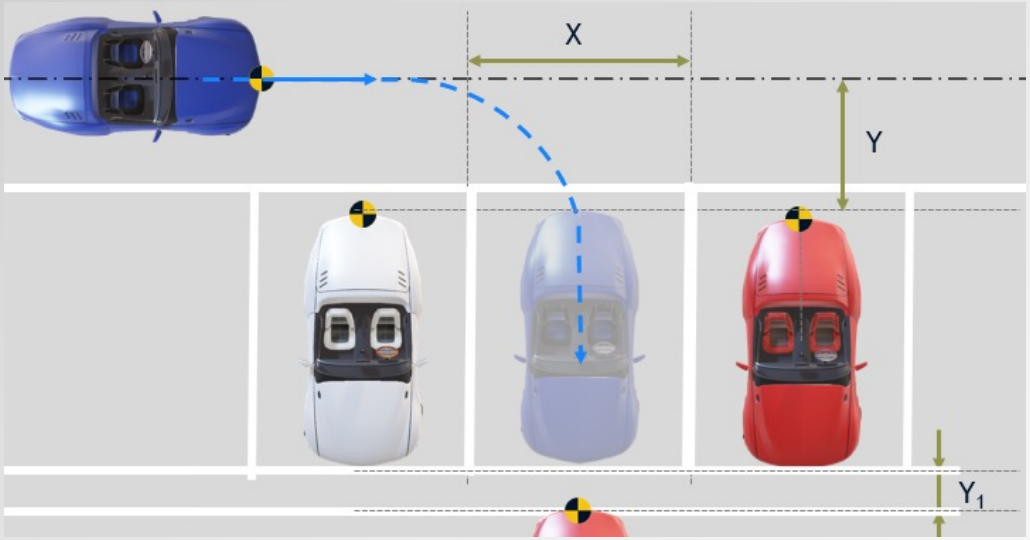


- DS-8 – Exit from a parking space in longitudinal direction

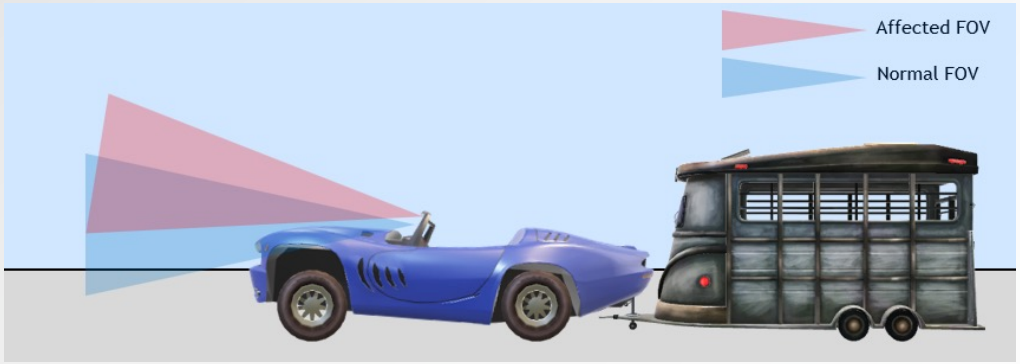


Scenarios catalogue summary 5/11

- DS-9 – Enter in a parking space in cross direction

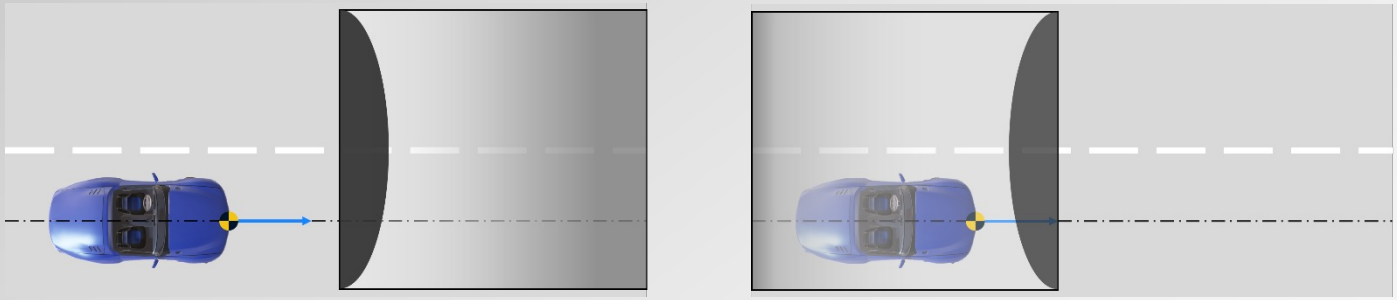


- DS-10 – Driving with trailer attached



Scenarios catalogue summary 6/11

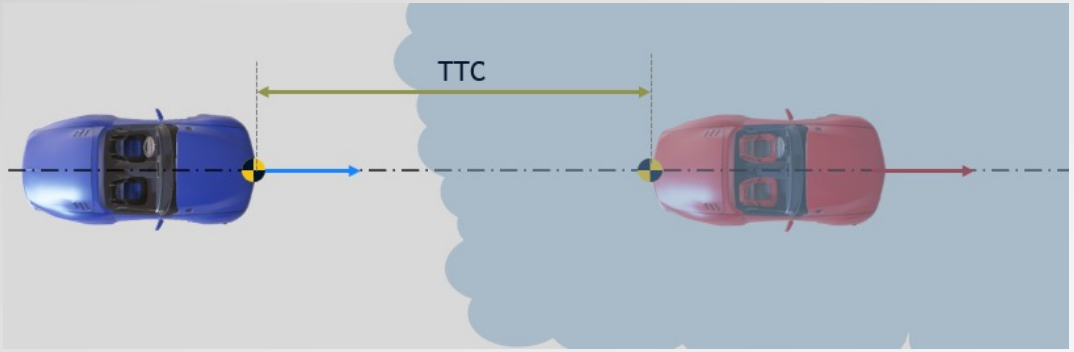
- DS-11 – Driving in a tunnel



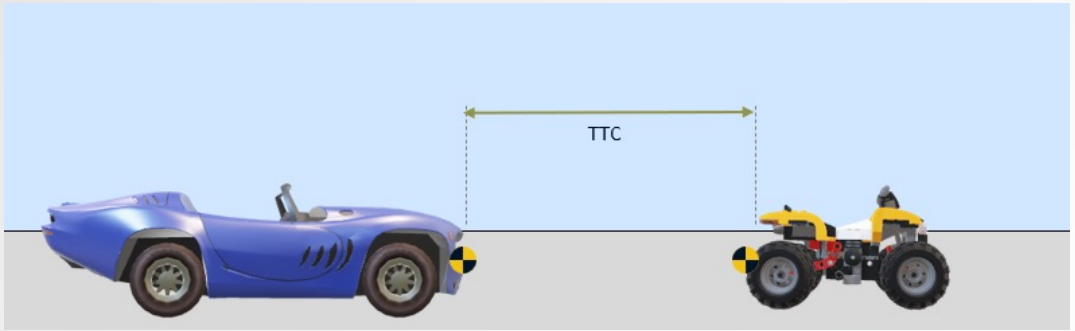
- DS-12 – Passing a crossroads

Scenarios catalogue summary 7/11

- DS-13 – Driving with low visibility (fog)

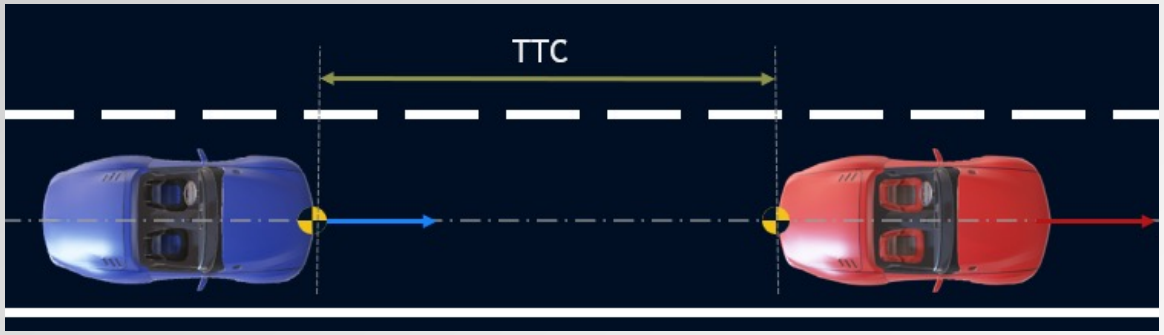


- DS-14 – Driving following a target vehicle (no normal configuration)

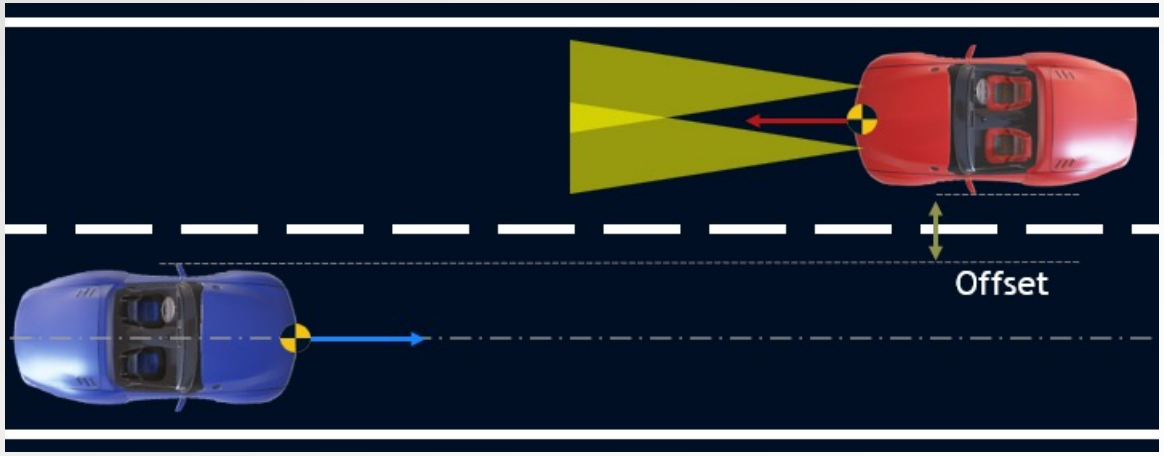


Scenarios catalogue summary 8/11

- DS-15 – Driving at darkness without remaining light

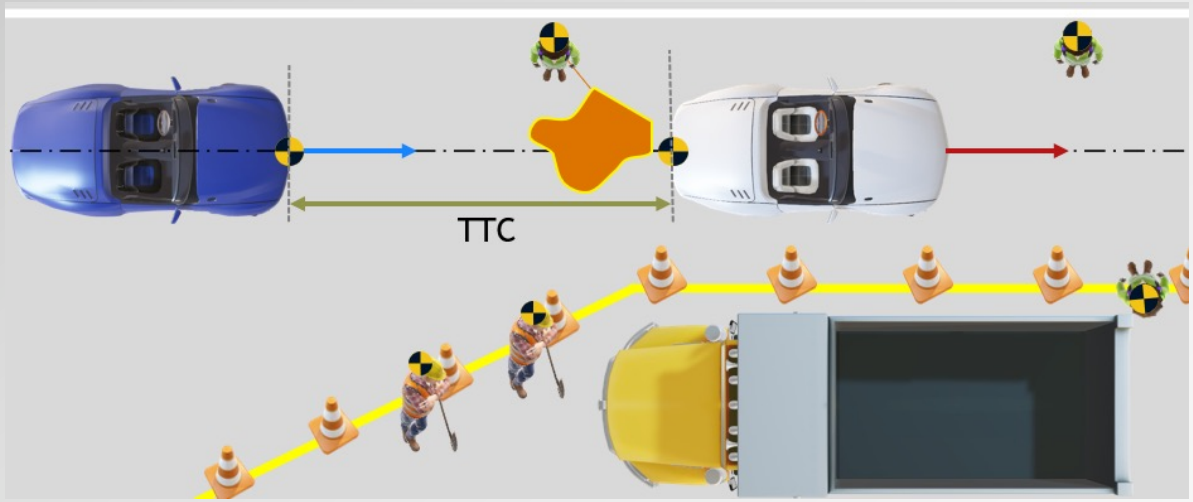


- DS-16 – Driving at darkness with an oncoming vehicle with headlights on

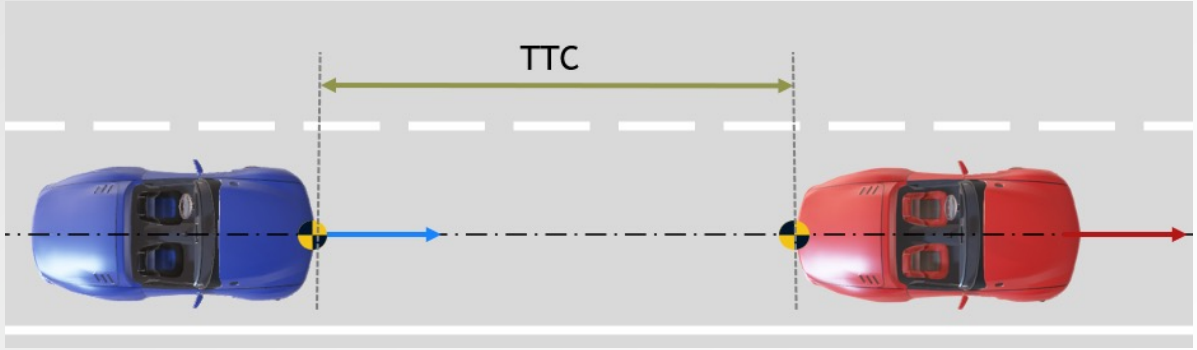


Scenarios catalogue summary 9/11

- DS-17 – Driving in road construction works site

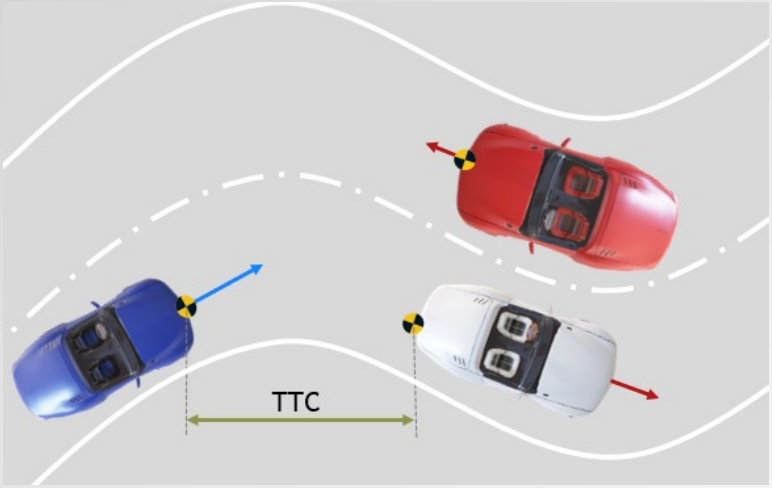


- DS-18 – Driving with longitudinal acceleration above 4 m/s^2

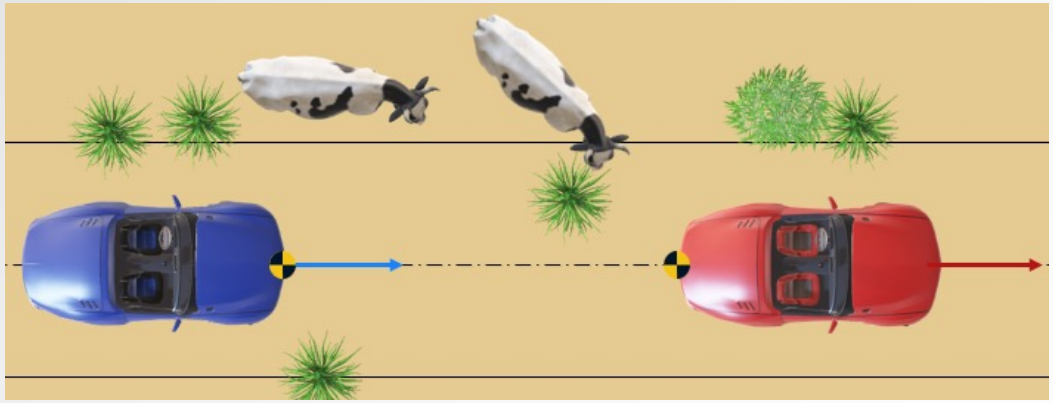


Scenarios catalogue summary 10/11

- DS-19 – Driving on mountain pass

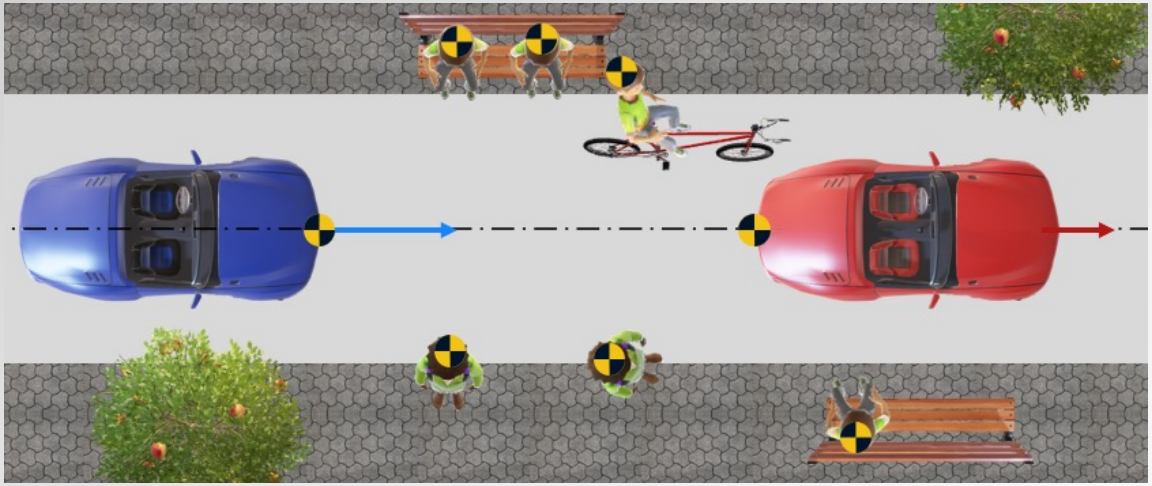


- DS-20 – Driving on country road



Scenarios catalogue summary 11/11

- DS-21 – Driving in the city (shared space with pedestrians and vehicle)



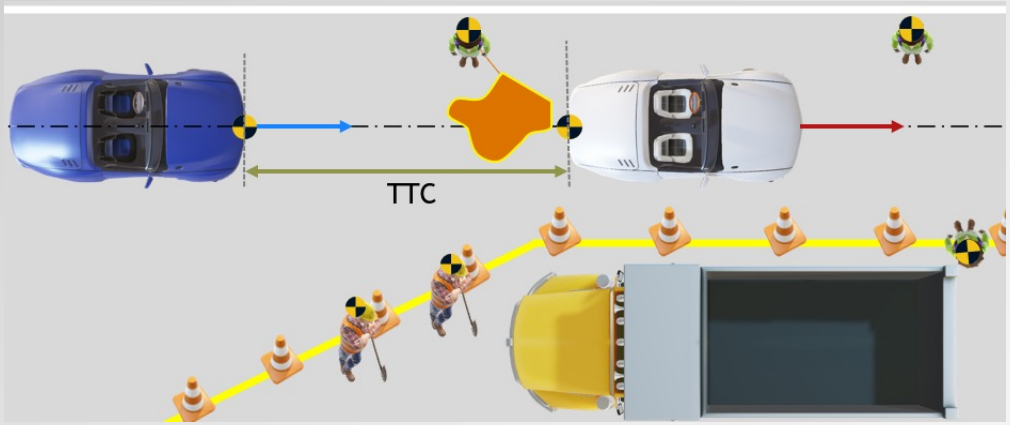
Selected Scenarios 1/3

- DS-10 – Driving with trailer attached

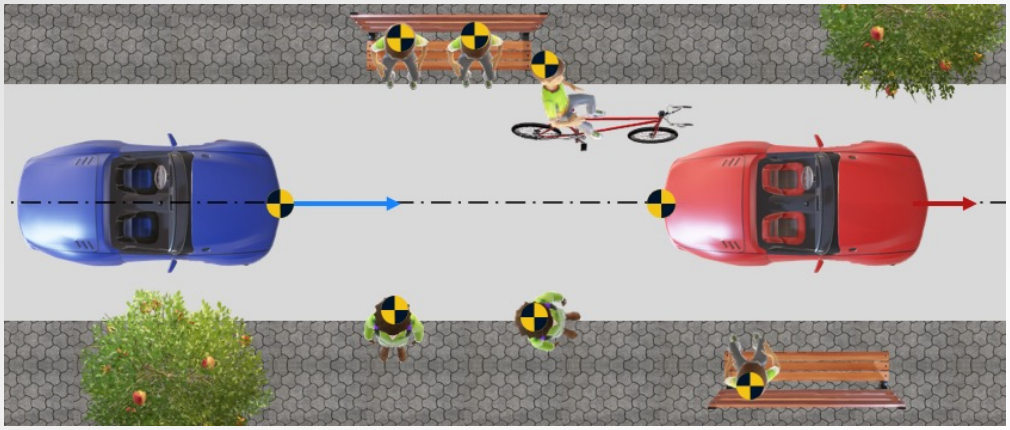
- In this use case the presence of a trailer with a load higher than the allowed one can impact both the sensor part and the algorithm part as it could affect the camera FOV and lead both false positives and false negatives.

Selected Scenarios 2/3

- DS-17 – Driving in road construction works site



- DS-21 – Driving in the city (shared space with pedestrians and vehicle)



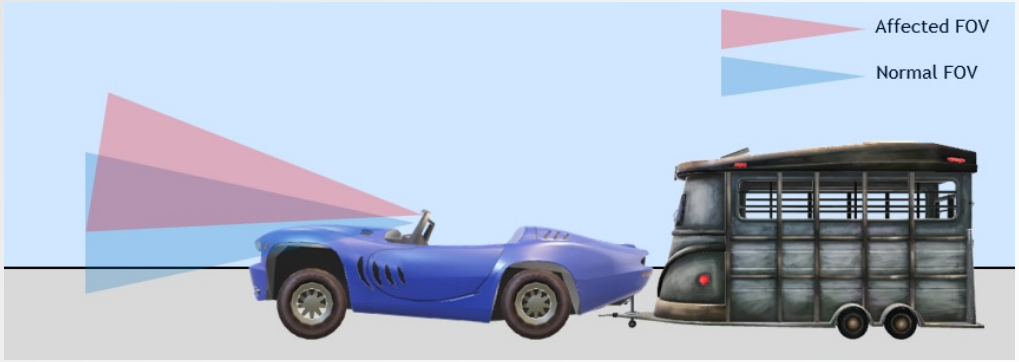
Selected Scenarios 3/3

- Both for the use cases DS-17 and DS-21 the presence of several objects (operators, vehicles, construction site items, cyclist, pedestrians, etc) put a strain on the algorithm's ability to discriminate which objects are in the vehicle's trajectory or which can lead to hazardous situations.

Scenario 10 – 1/2

- When due to the high load in the rear axle and low load in the front, the camera performance are affected, so that the FOV angle goes out of the accepted range, the indented functionality shall warn the driver about the failure (FOV out of the range), deactivate the function but shall not decelerate the vehicle.

- The probability of Exposure (duration) of these scenario conditions is E2, considering the following combinations:
  - Driving with trailer attached – E2 (<1% of average operating time)
    - E.g., lower than 80 h (with 8000h of operating time)



Scenario 10 – 2/2

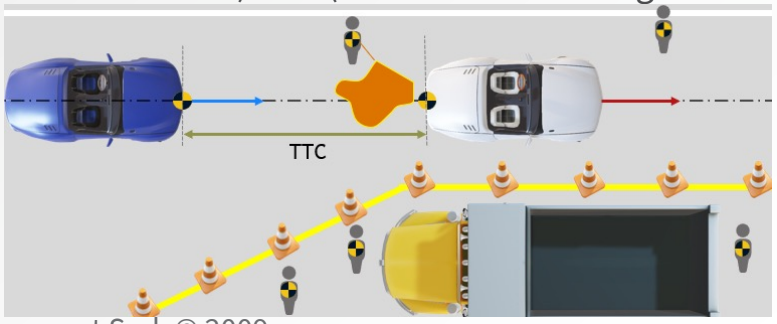
- The scenario conditions/constraints are the following:
  - The Ego vehicle drives at constant speed with high load at the rear axle.
  - The Ego vehicle speed range is [5 km/h, 80 km/h]
  - The rear axle load exceeds the allowed weight
  - The following environmental conditions shall be present:
    - Dry and daylight with minimum 1000 lux and Sun angle >15° to horizon
    - Dry and night with maximum 10 lux
  - Road surface is asphalt or concrete

"Ego vehicle" definition: Connected and/or automated vehicle, the behaviour of which is of primary interest in testing, trialling or operational scenarios [Ego vehicle - CAV Vocabulary | BSI (bsigroup.com)]

Scenario 17 – 1/2

- When the distance with the target vehicle, operators or temporary road structures decreases so that the driver is in dangerous zone (possible collision) the intended functionality shall warn the driver and, if no driver reaction occurs and the collision is imminent, shall decelerate the vehicle.

- The probability of Exposure (duration) of these scenario conditions is E2, considering the following combinations:
  - Driving behind other vehicle with normal distance – E4 (>10 % of average operating time)
    - E.g., 10% of 8000h = 800 h
  - Driving in road construction works – E2 (<1% of average operating time)
    - E.g., lower than 80 h
  - Persons within danger zone (ca. 1 vehicle lenght in front of vehicle) – E3 (1% to 10% of average operating time)
    - E.g., from 80 h to 800 h



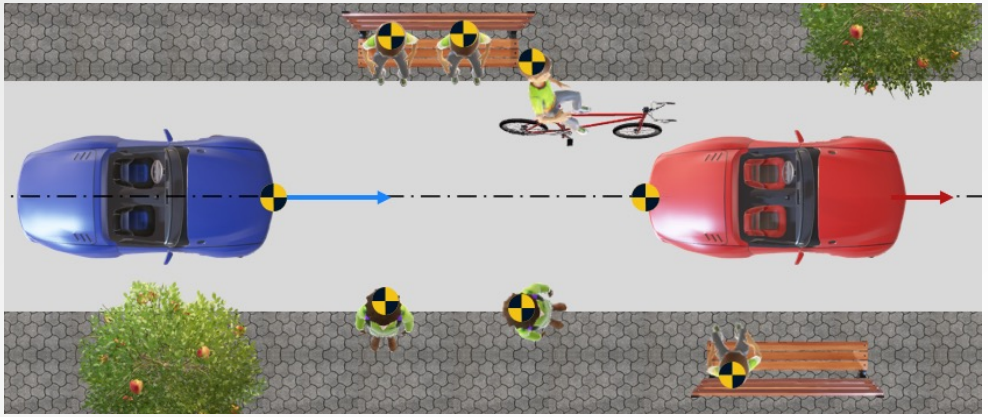
Scenario 17 – 2/2

- The scenario conditions/constraints are the following:
  - The Ego vehicle drives at constant speed in road construction works towards a moving target vehicle and is at a distance corresponding to a Time To Collision (TTC) of at least 4 s. Operators and temporary road structures are also present near the ego vehicle.
  - The Ego vehicle speed range is [5 km/h, 130 km/h]
  - The target vehicle drive at 20 km/h
  - The following environmental conditions shall be present:
    - Dry and daylight with minimum 1000 lux and Sun angle >15° to horizon
    - Dry and night with maximum 10 lux
  - Road surface is asphalt or concrete
  - The following Pre-conditions shall be met:
    - both vehicles shall keep steady speed and path
    - steering angle shall be lower than the override threshold
    - yaw rate shall be lower than the override threshold

Scenario 21 – 1/2

- When the distance with the target vehicle or vulnerable users decreases so that the driver or the vulnerable users are in dangerous zone (possible collision) the intended functionality shall warn the driver and, if no driver reaction occurs and the collision is imminent, shall decelerate the vehicle.

- The probability of Exposure (duration) of these scenario conditions is E2, considering the following combinations:
  - Driving behind other vehicle with normal distance – E4 (>10 % of average operating time)
    - E.g., 10% of 8000h = 800 h
  - Driving in the city – E4 (>10 % of average operating time)
    - E.g., 10% of 8000h = 800 h
  - Persons within danger zone (ca. 1 vehicle lenght in front of vehicle) – E3 (1% to 10% of average operating time)
    - E.g., from 80 h to 800 h



Scenario 21 – 2/2

- The scenario conditions/constraints are the following:
  - The Ego vehicle drives at constant speed in the city towards a moving target vehicle or VRUs (pedestrians and/or cyclist).
  - The Ego vehicle speed range is [5 km/h, 50 km/h]
  - The target vehicle drive at 20 km/h
  - The following environmental conditions shall be present:
    - Dry and daylight with minimum 1000 lux and Sun angle >15° to horizon
    - Dry and night with maximum 10 lux
  - Road surface is asphalt or concrete
  - The following Pre-conditions shall be met:
    - both vehicles shall keep steady speed and path
    - steering angle shall be lower than the override threshold
    - yaw rate shall be lower than the override threshold

Conclusions

- This set of use cases containing all the needed details allows recreating in a controlled way a relevant situation for the system/vehicle to be tested where the capabilities of the sensor, logic, actuators, and overall system can be verified.
- After the execution of the test, it is possible to identify the interventions of the system and its sub-components and compare the results with those obtained from a reference system to evaluate their correctness.
- In case of unwanted or incorrect interventions, it is possible to proceed with a root cause analysis to understand whose elements lead to the hazardous situation.
- Finally, identify the modification that can be made to the System or its sub-components to improve the overall performance and reduce the risk.

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Document Change History			
Date	**Version**	**Changed by**	**Change Description**
08/05/2023	1.0	G. Dallara, F. Guerrini, G. Nicosia	First emission
18/05/2023	1.1	F. Guerrini	Updated of resulting exposure value of DS-21 scenario. Replaced “probability of occurrence” with “probability of Exposure (duration)” within the document.
29/05/2023	1.2	G. Nicosia	Minor fix

Many Thanks for your Attention