MOTORBIKE USERS SAFETY ENHANCEMENT

Deliverable 4.2

CAR TO PTW LSS PROTOCOL

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Executive Summary

The main objective of Work Package 4 is to provide a test procedure that could be implemented in the future Euro NCAP active safety assessments for the protection of vulnerable road users, in this case in the form of powered two-wheeler (PTW) users. For this purpose, a selection of systems and scenarios has been done in Work Package 5 by considering the main scenarios identified in Work Package 1 and the technical state of the art.

This report focus in the scenarios that could be address by Lane Support or Blind Spot systems and expose the procedures for Car to Motorbike scenarios with On coming and Overtaking traffic.

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1 Introduction

1.1 MUSE project

Despite representing a small part of the road users (e.g. 2% of the traffic in France) the percentage of motorcyclists in the total deaths is the highest of the VRUs (World road deaths in 2010: 23% PTWs, 22% pedestrian and 5% Cyclist). A motorcyclist is between 9 to 30 times more likely to be killed in a traffic crash than a driver (OECD 2015).

In recent years, we have observed a decrease in the number of deaths on the roads. However, this reduction is not equal for all the different road users. If we take a look at the evolution of the mortality depending of the type of road user we see that, while in the case of cars it has been reduced by 50%, in the case of the motorcyclist this reduction it has been only of the 30%. (European Comission, Directorate General for Transport 2016)

Concerned by this problematic, the French Government decide in 2015 to perform a study in collaboration with UTAC to evaluate the accidentology of the motorcyclists and the possibility of avoiding them or mitigating the consequences using the new ADAS systems. Knowing the importance of Euro NCAP in motivating the OEMs to invest in safety, in May 2016 the Interior Minister Mr. Bernard Cazeneuve and the Transport Minister Mrs. Ségolène Royal write a letter to Euro NCAP claiming for a safety rating involving PTWs. At the beginning of 2017 Euro NCAP includes the scenarios with motorcycles in their Roadmap 2020/2025 and the possibility of start to assess the presence of security systems in motorcycles.

However, how will it be possible to evaluate the systems without the necessary tools to do so? At the beginning of the project it did not exists the testing equipment who will allow us to evaluate the systems, not even a protocol in which the main scenarios and their characteristics are defined.

Furthermore, which will be the best systems to avoid the accidents? Will it generate new accidents? What about ADAS systems in the motorcycle? Is it feasible to perform real test to assess the systems?

The aim of this project was to answer these issues and to provide the OEMs and TIERs1 the tools that will enable them to develop and evaluate their systems. A first task consisted in studying the main accident scenarios and possible systems that could help to avoid them or, at least, reduce their consequences. Simultaneously, tools enabling to improve these systems and to evaluate their performances were developed.

1.2 Objectives of this report

The objective of this report is to provide a test procedure to assess the efficiency of Lane Support and Blind Spot systems for the scenarios identified in Work Package 5 as the ones with more potential to be addressed a short term. For the descriptions and methodology the existent protocol of Euro NCAP for LSS (Euro NCAP, 2019) has been used.

The final goal of this protocol is to serve as basis for the discussions of the future Euro NCAP protocols and regulatory test assessments.

2 Definition

Throughout this protocol, the following terms are used:

Peak Braking Coefficient (PBC) – the measure of tyre to road surface friction based on the maximum deceleration of a rolling tyre, measured using the American Society for Testing and Materials (ASTM) E1136-10 (2010) standard reference test tyre, in accordance with ASTM Method E 1337-90 (reapproved 1996), at a speed of 64.4km/h, without water delivery. Alternatively, the method as specified in UNECE R13-H.

Emergency Lane Keeping (ELK) – default ON heading correction that is applied automatically by the vehicle in response to the detection of the vehicle that is about to drift into oncoming traffic in the adjacent lane.

Vehicle under test (VUT) – means the vehicle tested according to this protocol with a Lane Keep Assist and/or Lane Departure Warning system.

Vehicle width – the widest point of the vehicle ignoring the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mud-guards and the deflected part of the tyre side-walls immediately above the point of contact with the ground.

Global Motorbike Target (GMT) – means the motorbike target used in this protocol as defined in the deliverable D2.1 of the MUSE project (Fritz and Wimmer 2019).

Time To Collision (TTC) – means the remaining time before the VUT strikes the GMT, assuming that the VUT and GMT would continue to travel with the speed it is travelling.

3 Reference system

3.1 Convention

3.1.1 For the VUT and GMT use the convention specified in ISO 8855:1991 in which the x-axis points towards the front of the vehicle, the y-axis towards the left and the z-axis upwards (right hand system), with the origin at the most forward point on the centreline of the VUT for dynamic data measurements as shown in Figure 2.

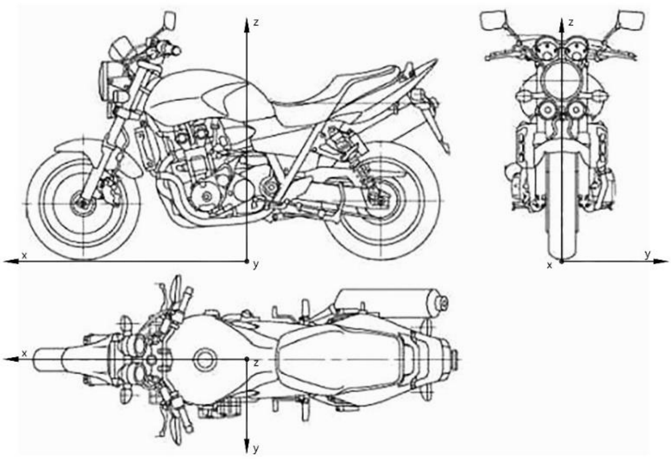

Figure 1 Coordinate system of Motorbike

3.1.2 Viewed from the origin, roll, pitch and yaw rotate clockwise around the x, y and z axes respectively. Longitudinal refers to the component of the measurement along the x-axis, lateral the component along the y-axis and vertical the component along the z-axis.

3.1.3 This reference system should be used for both left and right hand drive vehicles tested.

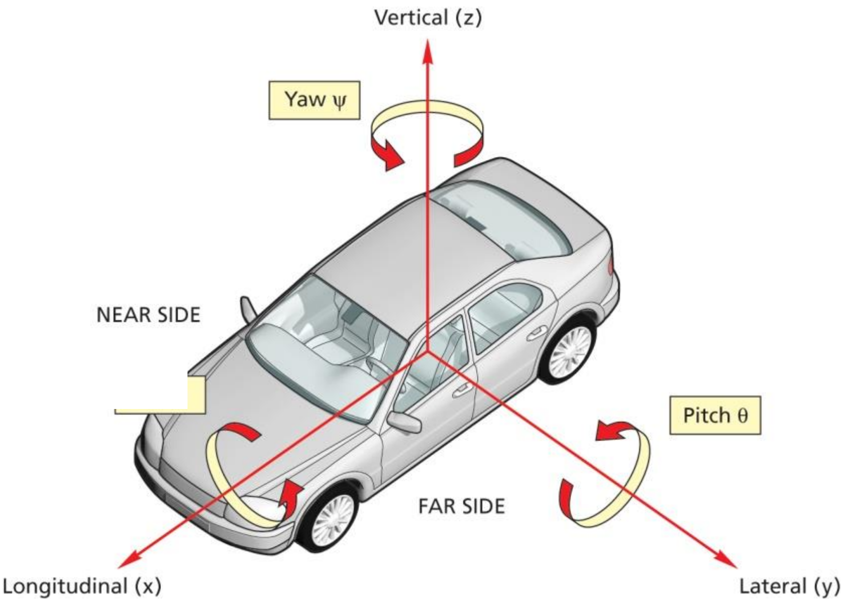

Figure 2 Coordinate system and notation

3.2 Lateral path error

3.2.1 The lateral path error is determined as the lateral distance between the centre of the front of the VUT when measured in parallel to the intended path as shown in the figure below. This measure applies during both the straight-line approach and the curve that establishes the lane departure.

Lateral Deviation from Path = Y_{VUT} error

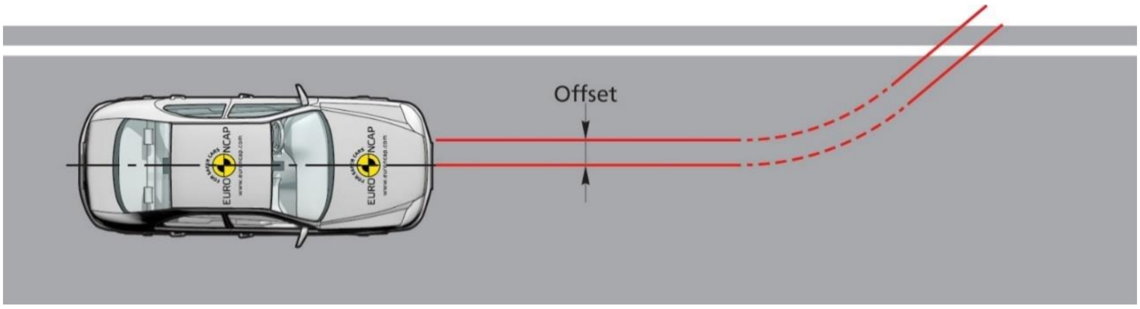

Figure 3 Lateral Path Error

3.3 Profiles for impact speed and hitpoint determination

3.3.1 A virtual profiled line is defined around the front end of the VUT. This line is defined by straight line segments connecting seven points that are equally distributed over the vehicle width minus 50mm on each side. The theoretical x,y coordinates are provided by the OEMs and verified by the test laboratory. These points will be used to define the Hitpoint for Oncoming scenarios.

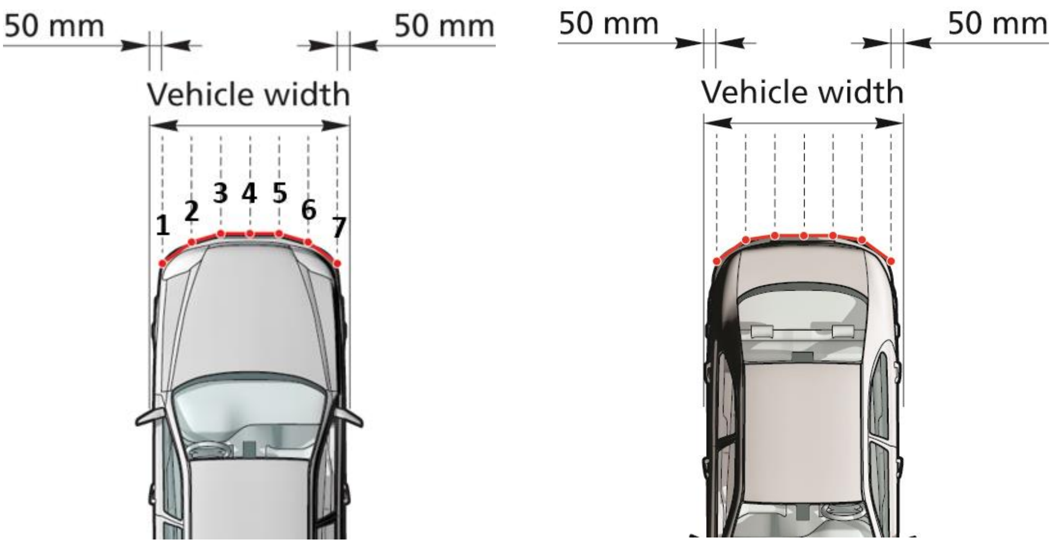

Figure 4 Virtual profiled line around vehicle front (left) end and rear end (right)

4 Measuring equipment

4.1 Measurements and variables

4.1.1 Sample and record all dynamic data at a frequency of at least 100Hz. Synchronise using the DGPS time stamp the GMT data with that of the VUT.

4.1.2	Time	T
	• T_0, time where manoeuvre starts with 2s straight path	T_0
	• T_{steer}, time where VUT enters in curve segment	T_{steer}
	• $T_{crossing}$, time where VUT crosses the line	$T_{crossing}$
4.1.3	Position of the VUT during the entire test	X_{VUT}, Y_{VUT}
4.1.4	Position of the GMT during the entire test	X_{GMT}, Y_{GMT}
4.1.5	Speed of the VUT during the entire test	$V_{long,VUT}$ $V_{lat,VUT}$
4.1.6	Speed of the GMT during the entire test	V_{GMT}
4.1.7	Yaw velocity of the VUT during the entire test	$\dot{\Psi}_{VUT}$
4.1.8	Yaw velocity of the GMT during the entire test	$\dot{\Psi}_{GMT}$
4.1.9	Steering wheel velocity of the VUT during the entire test	Ω_{VUT}

4.2 Measuring equipment

4.2.1 Equip the VUT with data measurement and acquisition equipment to sample and record data with an accuracy of at least:

- VUT and GMT longitudinal speed to 0.1km/h;
- VUT and GMT lateral and longitudinal position to 0.03m;
- VUT heading angle to 0.1°;
- VUT and GMT yaw rate to 0.1°/s;
- VUT longitudinal acceleration to 0.1m/s^2;
- VUT steering wheel velocity to 1.0°/s.

4.3 Data filtering

4.3.1 Filter the measured data as follows:

4.3.1.1 Position and speed are not filtered and are used in their raw state.

4.3.1.2 Acceleration, yaw rate, steering wheel torque and steering wheel velocity with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

5 Global motorbike target

5.1 Specification

5.1.1 Conduct the tests in this protocol using the Global Motorbike Target (GMT) as shown in Figure 5 below. The GMT replicates the visual, radar and LIDAR attributes of a typical L3 PTW.

Figure 5: Global Vehicle Target (GMT)

5.1.2 To ensure repeatable results the combination of the propulsion system and GMT must meet the requirements as detailed in xxxx

5.1.3 The GMT is designed to work with the following types of sensors:

- Radar (24 and 77 GHz)
- LIDAR
- Camera

When a manufacturer believes that the GMT is not suitable for another type of sensor system used by the VUT but not listed above, the manufacturer is asked to contact the Euro NCAP Secretariat.

6 Test conditions

6.1 Test track

6.1.1 Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a maximum slope of 1% in the longitudinal direction, < 2% for half a lane width either side of the centreline and < 3% for the outer half of the test lane in lateral direction.

6.1.2 The test surface shall have a minimal peak braking coefficient (PBC) of 0.9, must be paved and may not contain any irregularities (e.g. large dips or cracks, manhole covers or reflective studs) within a lateral distance of 3.0m to either side of the centre of the test lane and with a longitudinal distance of 30m ahead of the VUT from the point after the test is complete.

6.1.3 Lane Markings and Road Edge

6.1.3.1 The tests described in this document require use of two different types of lane markings conforming to one of the lane markings as defined in UNECE Regulation 130 to mark a lane with a width of 3.5 to 3.7m and a road edge:

1. Dashed line with a width between 0.10 and 0.25m (0.10 and 0.15m for centerlines)
2. Solid line with a width between 0.10 and 0.25m
3. Road Edge consisting of grass and/or gravel or any other approved surrogate

The inner edge of the lane marking shall be at 0.20 to 0.30m from the road edge (transition between paved test surface and road edge material), where applicable.

The lane markings and/or road edge should be sufficiently long to ensure that there is at least 20m of marking remaining ahead of the vehicle after the test is complete.

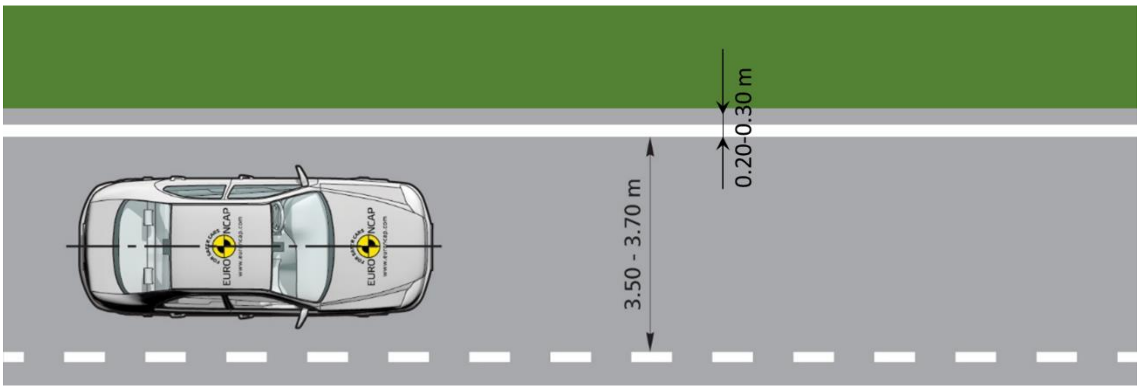

Figure 6 Layout of the lane markings

6.1.4 Weather conditions

6.1.4.1 Conduct tests in dry conditions with ambient temperature above 5°C and below 40°C.

6.1.4.2 No precipitation shall be falling and horizontal visibility at ground level shall be greater than 1km. Wind speeds shall be below 10m/s to minimise VUT disturbance.

6.1.4.3 Natural ambient illumination must be homogenous in the test area and in excess of 2000 lux for daylight testing with no strong shadows cast across the test area other than those caused by the VUT. Ensure testing is not performed driving towards, or away from the sun when there is direct sunlight.

6.1.4.4 Measure and record the following parameters preferably at the commencement of every single test or at least every 30 minutes:

a) Ambient temperature in °C;
b) Track Temperature in °C;
c) Wind speed in m/s;
d) Wind direction in azimuth ° and/or compass point direction (monitoring);
e) Ambient illumination in Lux.

6.2 VUT Preparation

6.2.1 System settings

6.2.1.1 Set any driver configurable elements of the system (e.g. the timing of the Lane Departure Warning or the Lane Keep Assist if present) to the middle setting or midpoint and then next poorer performing setting similar to the examples shown in Figure 4. Lane centering functions should be turned OFF.

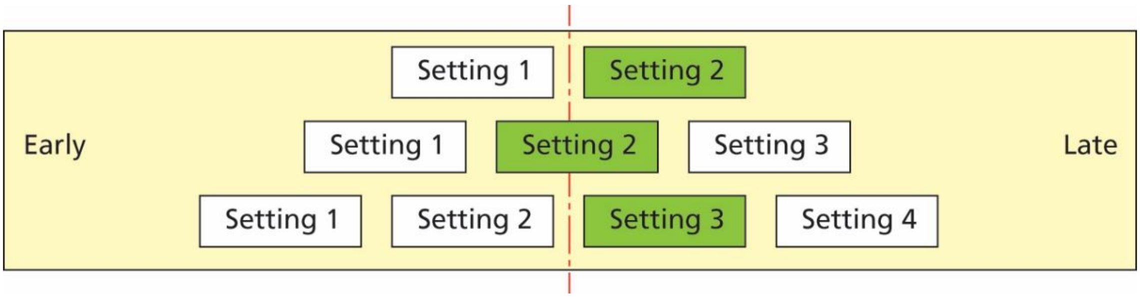

Figure 5 System setting for testing

6.2.2 Tyres

Perform the testing with new original fitment tyres of the make, model, size, speed and load rating as specified by the vehicle manufacturer. It is permitted to change the tyres which are supplied by the manufacturer or acquired at an official dealer representing the manufacturer if those tyres are identical make, model, size, speed and load rating to the original fitment. Use inflation pressures corresponding to least loading normal condition.

Run-in tyres according to the tyre conditioning procedure specified in 7.1.3. After running-in maintain the run-in tyres in the same position on the vehicle for the duration of the testing.

6.2.3 Wheel alignment measurement

The vehicle should be subject to a vehicle (in-line) geometry check to record the wheel alignment set by the OEM. This should be done with the vehicle in kerb weight.

6.2.4 Unladen kerb mass

6.2.4.1 Fill up the tank with fuel to at least 90% of the tank's capacity of fuel.

6.2.4.2 Check the oil level and top up to its maximum level if necessary. Similarly, top up the levels of all other fluids to their maximum levels if necessary.

6.2.4.3 Ensure that the vehicle has its spare wheel on board, if fitted, along with any tools supplied with the vehicle. Nothing else should be in the car.

6.2.4.4 Ensure that all tyres are inflated according to the manufacturer's instructions for the least loading condition.

6.2.4.5 Measure the front and rear axle masses and determine the total mass of the vehicle. The total mass is the 'unladen kerb mass' of the vehicle. Record this mass in the test details.

6.2.4.6 Calculate the required ballast mass, by subtracting the mass of the test driver and test equipment from the required 200 kg interior load.

6.2.5 Vehicle preparation

6.2.5.1 Fit the on-board test equipment and instrumentation in the vehicle. Also fit any associated cables, cabling boxes and power sources.

6.2.5.2 Place weights with a mass of the ballast mass. Any items added should be securely attached to the car.

6.2.5.3 With the driver in the vehicle, weigh the front and rear axle loads of the vehicle.

6.2.5.4 Compare these loads with the 'unladen kerb mass'

6.2.5.5 The total vehicle mass shall be within ±1% of the sum of the unladen kerb mass, plus 200kg. The front/rear axle load distribution needs to be within 5% of the front/rear axle load distribution of the original unladen kerb mass plus full fuel load. If the vehicle differs from the requirements given in this paragraph, items may be removed or added to the vehicle which has no influence on its performance. Any items added to increase the vehicle mass should be securely attached to the car.

6.2.5.6 Repeat paragraphs 6.2.5.3 and 6.2.5.4 until the front and rear axle loads and the total vehicle mass are within the limits set in paragraph 6.2.5.5. Care needs to be taken when adding or removing weight in order to approximate the original vehicle inertial properties as close as possible. Record the final axle loads in the test details. Record the axle weights of the VUT in the 'as tested' condition.

6.2.5.7 Vehicle dimensional measurements shall be taken. For purposes of this test procedure, vehicle dimensions shall be represented by a two-dimensional polygon defined by the lateral and longitudinal dimensions relative to the centroid of the vehicle using the standard SAE coordinate system. The corners of the polygon are defined by the lateral and longitudinal locations where the plane of the outside edge of each tyre makes contact with the road. This plane is defined by running a perpendicular line from the outer most edge of the tyre to the ground at the wheelbase, as illustrated in Figure 5.

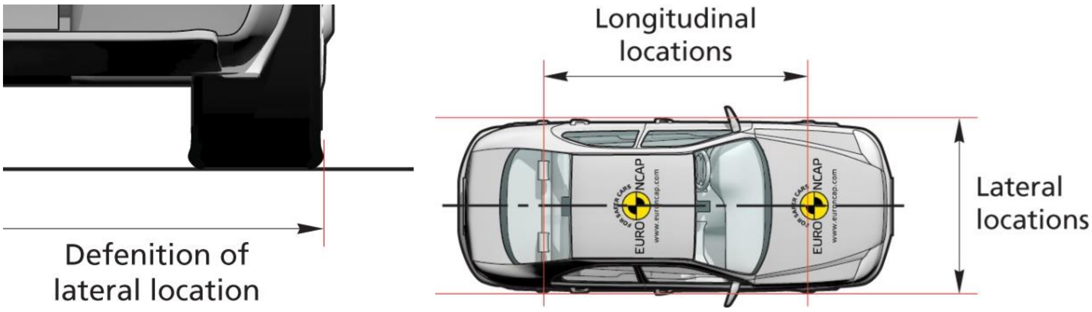

Figure 6 Vehicle dimensional measurements

6.2.5.8 The vehicle's wheelbase and the lateral and longitudinal locations shall be measured and recorded.

7 Test procedure

7.1 VUT Pre-test conditioning

7.1.1 General

7.1.1.1 A new car is used as delivered to the test laboratory, however a car may have been used for other Euro NCAP active safety tests

7.1.1.2 If requested by the vehicle manufacturer and where not already performed for other tests, drive a maximum of 100km on a mixture of urban and rural roads with other traffic and roadside furniture to 'calibrate' the sensor system. Avoid harsh acceleration and braking.

7.1.2 Brakes

7.1.2.1 Condition the vehicle's brakes in the following manner, if it has not been done before or in case the lab has not performed a 100km of driving:

- Perform twenty stops from a speed of 56km/h with an average deceleration of approximately 0.5 to 0.6g.
- Immediately following the series of 56km/h stops, perform three additional stops from a speed of 72km/h, each time applying sufficient force to the pedal to operate the vehicle's antilock braking system (ABS) for the majority of each stop.
- Immediately following the series of 72km/h stops, drive the vehicle at a speed of approximately 72km/h for five minutes to cool the brakes.

7.1.3 Tyres

7.1.3.1 Condition the vehicle's tyres in the following manner to remove the mould sheen, if this has not been done before for another test or in case the lab has not performed a 100km of driving:

- Drive around a circle of 30m in diameter at a speed sufficient to generate a lateral acceleration of approximately 0.5 to 0.6g for three clockwise laps followed by three anticlockwise laps.
- Immediately following the circular driving, drive four passes at 56km/h, performing ten cycles of a sinusoidal steering input in each pass at a frequency of 1Hz and amplitude sufficient to generate a peak lateral acceleration of approximately 0.5 to 0.6g.
- Make the steering wheel amplitude of the final cycle of the final pass double that of the previous inputs.

7.1.3.2 In case of instability in the sinusoidal driving, reduce the amplitude of the steering input to an appropriately safe level and continue the four passes.

7.1.4 System check

7.1.4.1 Before any testing begins, perform a maximum of ten runs, to ensure proper functioning of the system.

7.2 Test scenarios

The performance of the VUT LSS is assessed in different scenarios that are applicable to the system:

- Emergency Lane Keeping (only when LSS system is default ON)
- Blind Spot

7.2.1 Tests in all scenarios will be performed with 0.1 m/s incremental steps within the lateral velocities specified for the test scenarios.

7.2.2 For testing purposes, assume an initial straight-line path followed by a fixed radius as specified for the test scenarios, followed again by a straight line, hereby known as the test path. Control the VUT with driver inputs or using alternative control systems that can modulate the vehicle controls as necessary to perform the tests.

7.2.2.1 The vehicle manufacturer shall provide information describing the location when the closed loop path and/or speed control shall be ended so as not to interfere with the system intervention for each test. Otherwise for each lateral velocity, two calibration runs shall be performed in order to determine when the system activates. Compare steering wheel torque, vehicle speed or yaw rate of both runs and determine where there is a notable difference that identifies the location of intervention.

Run 1: Complete the required test path with the system turned OFF and measure the control parameter

Run 2: Complete the required test path with the system turned ON and measure the control parameter

7.2.2.2 Complete the tests while ending the closed loop control before system activation as defined in 6.2.4.1. In the case of calibration runs the release of steering control should occur on the test path and no less than 5m longitudinally before the location of intervention.

7.2.3 Emergency Lane Keeping tests

7.2.3.1 *Oncoming vehicle*

7.2.3.1.1 For the oncoming scenario, the GMT will follow a straight line path in the lane adjacent to the VUT's initial position, in the opposite direction to the VUT. The straight line path of the target will be 1.00m from the inner side of the centre dashed lane marking of the VUT lane.

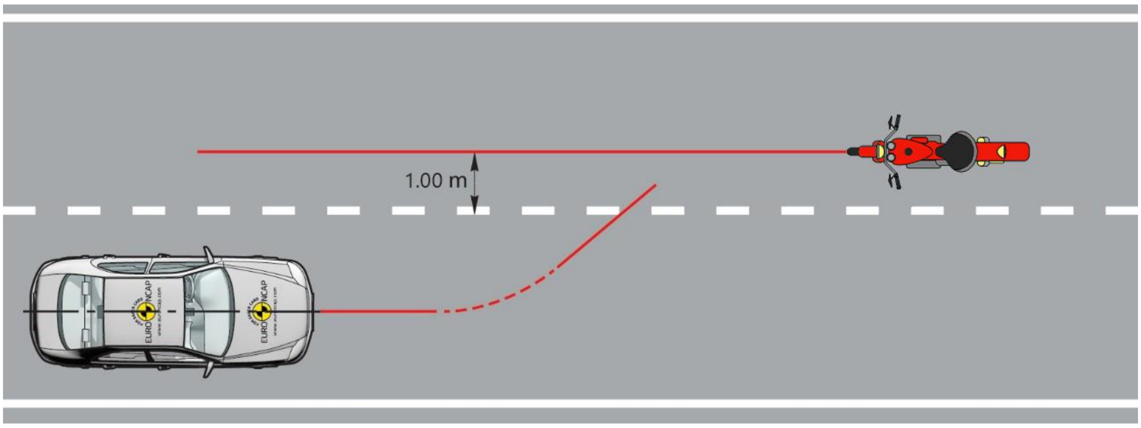

Figure 7 Oncoming scenarios path

7.2.3.1.2 The paths of the VUT and target vehicle will be synchronised so that the Hitpoint 1of the car will impact with the front reference point of the GMT (assuming no system reaction).

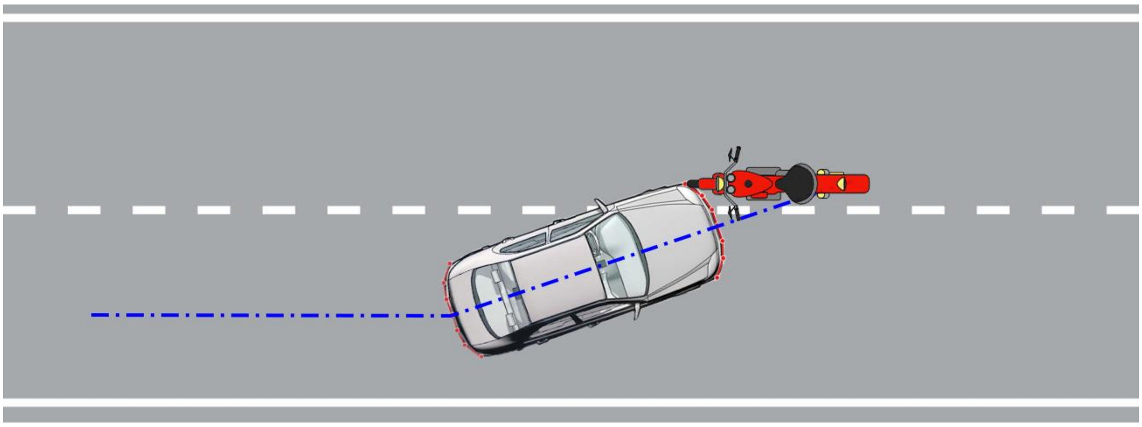

Figure 8 On Coming scenarios Hitpoint

7.2.3.1.3 Lane changes are tested in following situation:

- GMT @ 50km/h and VUT @ 72km/h.

7.2.3.1.4 ELK oncoming vehicle tests will be performed with 0.1 m/s incremental steps within the lateral velocity range of 0.3 to 0.6m/s for departures at the driver side only.

$Vlat_{VUT}$ [m/s]	R [m]	Ψ_{VUT} [°]	d1 [m]	d2 [m]
0.3	1200	0.86	0.14	0.90
0.4		1.15	0.24	0.80
0.5		1.43	0.38	0.75
0.6		1.72	0.54	0.60

Where the lateral offset d from the lane marking or road edge:

d = d1 + d2 + Half of the vehicle width (m)

With:

d1: Lateral distance travelled during curve establishing yaw angle (m)

d2: Lateral distance travelled during V_{lat} steady state (m)

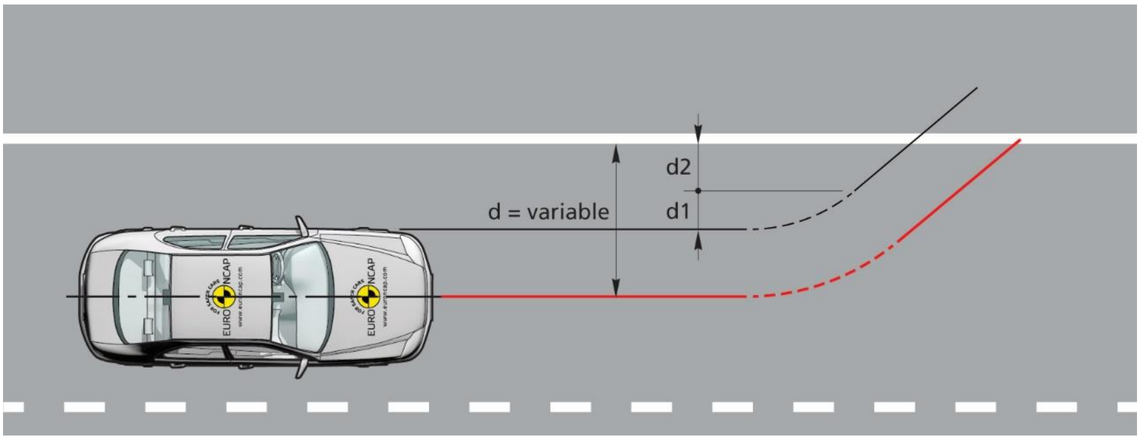

Figure 9 Definition of the lateral offset

7.2.3.2 *Blind spot*

7.2.3.2.1 For the Blind Spot scenario the GMT will follow a straight line path in the lane adjacent to the VUT's initial position at the driver side, in the same direction as the VUT. The straight line path of the target will be 1m from the inner side of the centre dashed lane marking.

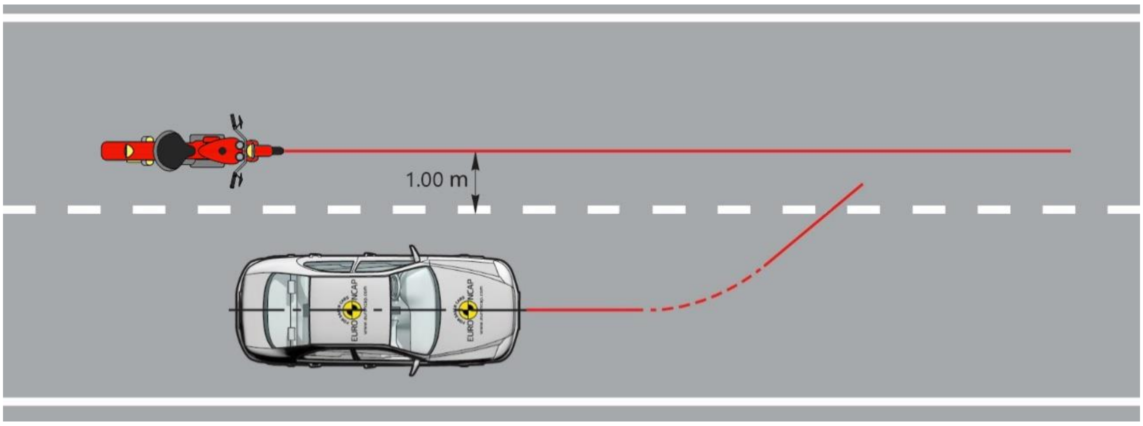

Figure 10 Blind Spot scenario paths

7.2.3.2.2 The paths of the VUT and target vehicle will be synchronised so that the front reference point of the target is equal to that of the rear axle of the VUT at the impact point (assuming no system reaction).

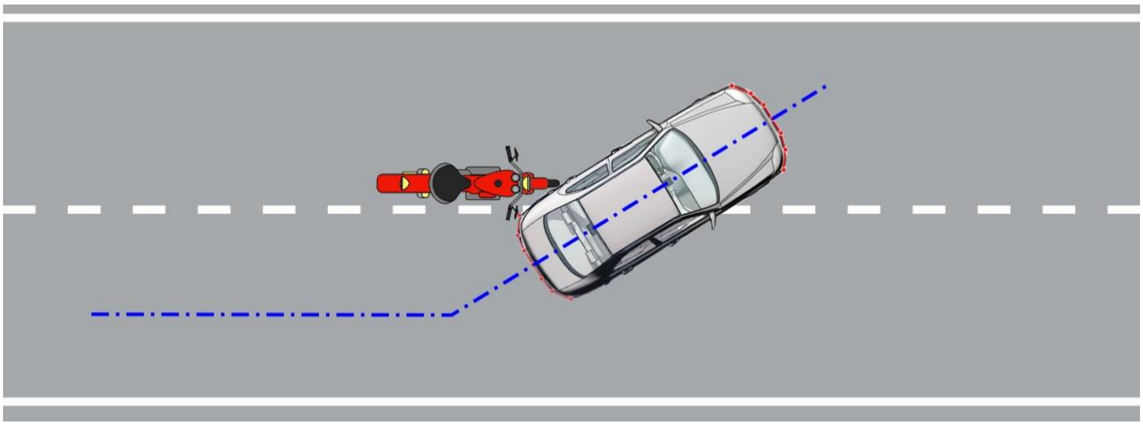

Figure 11 Hitpoint Blind Spot scenario

7.2.3.2.3 Blind Spot vehicle tests will be performed with 0.1m/s incremental steps 0.6 to 0.9 m/s for intentional lane changes for departures at the driver side only.

7.2.3.2.4 Lane changes are tested in following situation:

GMT @ 50km/h is overtaking the VUT @ 40km/h (relative velocity of 10km/h)

7.2.3.2.5 The following parameters should be used to create the test paths for the intentional lane change tests where the turn signal is applied at 1.0s ± 0.5s before T_{STEER}:

$Vlat_{VUT}$ [m/s]	R [m]	Ψ_{VUT} [°]	d1 [m]	d2 [m]
0.6	200	3,100	0,293	0,650
0.7		3,610	0,397	0,550
0.8		4,130	0,519	0,450
0.9		4,650	0,658	0,350

Where the lateral offset d from the lane marking:

d = d1 + d2 + Half of the vehicle width (m)

With:

d1: Lateral distance travelled during curve establishing yaw angle (m)

d2: Lateral distance travelled during V_{lat} steady state (m)

7.3 Test conduct

7.3.1 Before every test run, drive the VUT around a circle of maximum diameter 30m at a speed less than 10km/h for one clockwise lap followed by one anticlockwise lap, and then manoeuvre the VUT into position on the test path. If requested by the OEM an initialisation run may be included before every test run.

7.3.2 For vehicles with an automatic transmission select D. For vehicles with a manual transmission select the highest gear where the RPM will be at least 1500 at the test speed.

Between tests, manoeuvre the VUT at a maximum speed of 50km/h and avoid riding the brake pedal and harsh acceleration, braking or turning unless strictly necessary to maintain a safe testing environment.

7.4 Test execution

7.4.1 Accelerate the VUT to 72 km/h or 40 km/h depending on the test scenario.

7.4.2 Accelerate the target vehicle to 50km/h.

7.4.3 The test shall start at T_0 and is valid when all boundary conditions are met between T_0 and T_{LKA}/T_{LDW}:

ELK oncoming and Blind Spot scenarios:

- Speed of GMT (GPS-speed) from 4s TTC 50 ± 1.0km/h
- Lateral deviation from test path GVT 0 ± 0.15m

7.4.4 Steer the vehicle as appropriate to achieve the lateral velocity in a smooth controlled manner and with minimal overshoot.

7.4.5 The end of an ELK oncoming test is considered as when one of the following occurs:

- The ELK system intervenes to prevent a collision between the VUT and target vehicle
- The ELK system has failed to intervene (sufficiently) to prevent a collision between the VUT and target vehicle. This can be assumed when one of the following occurs:
  - The lateral separation between the VUT and target vehicle equal < 0.3m in the oncoming and overtaking scenario

It is at the labs discretion to select and use one of the options above to ensure a safe testing environment.

7.4.6 The end of a Blind Spot test is considered when both warnings are recorded.

7.4.7 If the test ends because the vehicle has failed to intervene (sufficiently) or if the GMT has left it's designated path by more than 0.15m, it is recommended that the VUT and/or GMT are steered away from the impact, either manually or by reactivating the steering control of the driving robot/GMT.

7.4.8 The subsequent lateral velocity for the next test is incremented with 0.1m/s.

8 References:

Euro NCAP. (2019). *Euro NCAP LSS Test Protocol v3.0.1.*

European Comission, Directorate General for Transport. (2016, June). Traffic Safety Basic Facts On Motorcycles & Mopeds.

Fritz, M., & Wimmer, T. (2019). *D2.1 Global Motorbike Dummy Specifications.*

OECD. (2015). *Improving Safety for Motorcycle, Scooter and Moped Riders.*

9 Acknowledgements:

The MUSE consortium would like to acknowledge for their support and work: