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EUROPEAN NEW CAR ASSESSMENT PROGRAMME
(Euro NCAP)

TEST PROTOCOL – Lane Support Systems

Version 1.0
November 2015

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1 INTRODUCTION

Road departure is one of the main causes of single vehicle and frontal crashes. By implementing lateral support systems a significant amount of these accidents can be avoided.

Typical accidents are normally occurring due to unintentional lane change where the driver swerves towards and across the line identifying the edge of the lane. Very often, the driver will be unaware that the car is in a potentially dangerous situation until the situation is critical: the wheels of the car may be on the grass or gravel at the side of the road or, in extreme cases, the car may find itself in the path of oncoming traffic. This sudden, late realisation by the driver may prompt a panic response: the driver loses control of the car and a crash is often the result. Injury severities are usually high, but this type of accident is relatively easy to avoid with a lateral support system resulting in potentially large safety improvements.

Several manufacturers have developed technologies which warn the driver when the car is getting close to a lane marking. Different systems use different warnings: some give an audible signal while others use a vibrating steering wheel to simulate the feeling of the car running over a ‘rumble strip’. The intention is simply to make the driver aware that the car is in danger of crossing the line. Some systems need a line only on one side of the vehicle while other systems rely on having a distinct marking on either side.

Manufacturers take great care to ensure that the signal does not irritate drivers unnecessarily and stay in control at all times. Most systems operate only at highway speeds and suppress the warning signal if the direction indicator is used.

This protocol specifies the Lateral Support Systems test procedure, which are part of the Safety Assist assessment. Both Lane Departure Warning and Lane Keeping Assist systems are tested, if applicable. To be eligible to score points for LSS, the vehicle must be equipped with an ESC system meeting the regulatory requirements.

2 DEFINITIONS

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.

Lane Keeping Assist (LKA) – heading correction that is applied automatically by the vehicle in response to the detection of the vehicle that is about to drift beyond a delineated edge line of the current travel lane.

Lane Departure Warning (LDW) – a warning that is provided automatically by the vehicle in response to the vehicle that is about to drift beyond a delineated edge line of the current travel lane.

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.

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

Time To Line Crossing (TTLC) – means the remaining time before the VUT crosses the line, assuming that the VUT would continue to travel with the same lateral velocity towards the lane marking.

Distance To Line Crossing (DTLC) – means the remaining lateral distance (perpendicular to the line) between the inner side of the lane marking and most outer edge of the tire, before the VUT crosses the line, assuming that the VUT would continue to travel with the same lateral velocity towards the lane marking.

3 REFERENCE SYSTEM

3.1 Convention

3.1.1 For the VUT 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 1.

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.

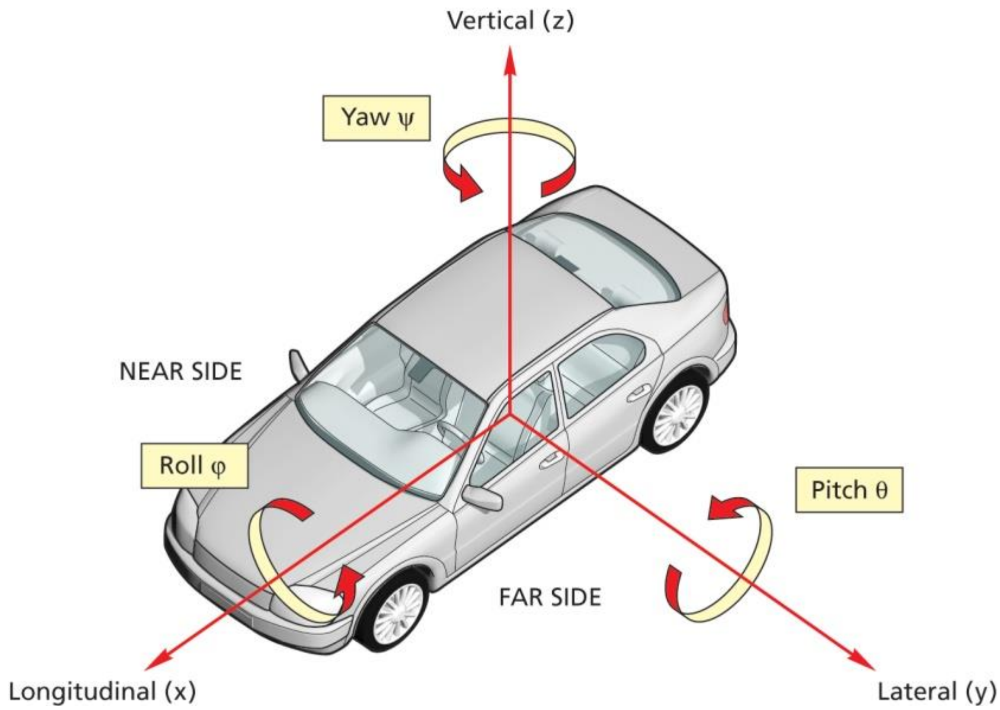


Figure 1: Coordinate system and notation

3.2 Lateral Deviation from Path

3.2.1 The lateral deviation from path 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

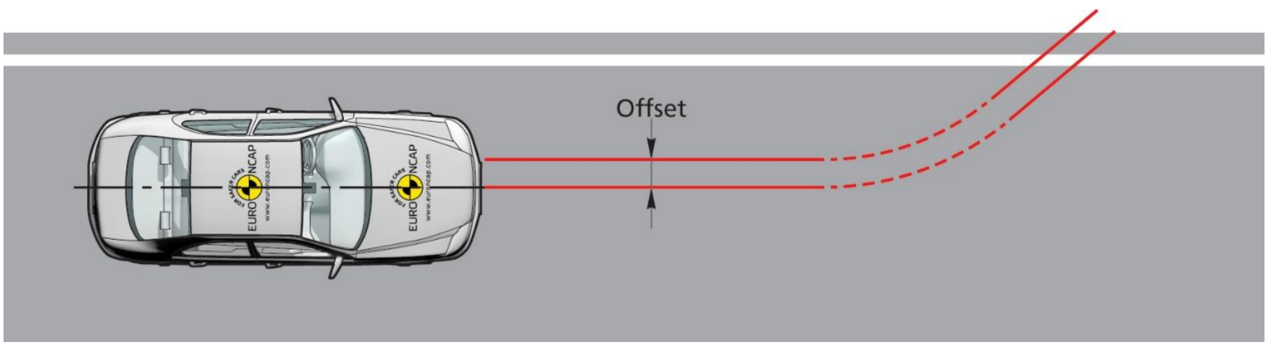


Figure 2: Lateral Deviation from Path

4 MEASURING EQUIPMENT

4.1.1 Sample and record all dynamic data at a frequency of at least 100Hz.

4.2 Measurements and Variables

4.2.1	Time	**T**
	• T_0, time where manoeuvre starts with 2s straight path	$\mathbf{T}_0$
	• T_{LKA}, time where LKA activates (for calibration purposes only if required)	$\mathbf{T}_{LKA}$
	• T_{LDW}, time where LDW activates	$\mathbf{T}_{LDW}$
	• $T_{crossing}$, time where VUT crosses the line	$\mathbf{T}_{crossing}$
4.2.2	Position of the VUT during the entire test	$\mathbf{X}_{VUT}$, $\mathbf{Y}_{VUT}$
4.2.3	Speed of the VUT during the entire test	$\mathbf{Vlong}_{VUT}$ $\mathbf{Vlat}_{VUT}$
	• $V_{crossing}$, speed when VUT crosses the line	$\mathbf{V}_{crossing}$
4.2.4	Yaw velocity of the VUT during the entire test	$\dot{\Psi}_{VUT}$
4.2.5	Steering wheel velocity of the VUT during the entire test	$\mathbf{\Omega_{VUT}}$

4.3 Measuring Equipment

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

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

4.4 Data Filtering

4.4.1 Filter the measured data as follows:

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

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

5 TEST CONDITIONS

5.1 Test Track

5.1.1 Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%. The test surface shall have a minimal peak braking coefficient (PBC) of 0.9.

5.1.2 The surface 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 test line(s) and with a longitudinal distance of 30m ahead of the VUT from the point after the test is complete.

5.1.3 Line Markings

5.1.3.1 The LDW and LKA 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:

1. Dashed line with a width between 0.10 and 0.25m
2. Solid line with a width between 0.10 and 0.25m

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

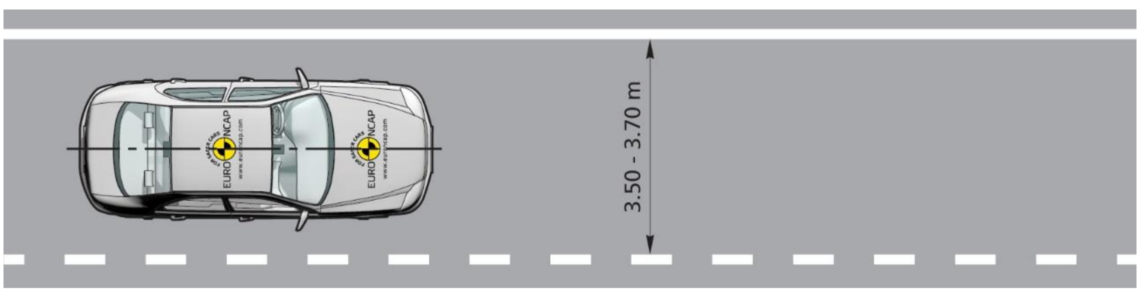


Figure 3: Layout of the lane markings

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

5.1.5 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.

5.1.6 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.

5.1.7 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 and direction in m/s;
d) Ambient illumination in Lux.

5.2 VUT Preparation

5.2.1 <u>LKA and LDW System Settings</u>

5.2.1.1 Set any driver configurable elements of the LKA and/or LDW 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 latest setting similar to the examples shown in Figure .

		Setting 1	**Setting 2**		
Early	Setting 1	**Setting 2**	Setting 3		Late
	Setting 1	Setting 2	**Setting 3**	Setting 4	

Figure 4: LKA and/or LDW system setting for testing

5.2.2 <u>Tyres</u>

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 6.1.3. After running-in maintain the run-in tyres in the same position on the vehicle for the duration of the testing.

5.2.3 <u>Wheel Alignment Measurement</u>

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.

5.2.4 <u>Unladen Kerb Mass</u>

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

5.2.4.2 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.

5.2.4.3 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.

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

5.2.4.5 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.

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

5.2.5 Vehicle Preparation

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

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

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

5.2.5.4 Compare these loads with the "unladen kerb mass"

5.2.5.5 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.

5.2.5.6 Repeat paragraphs 5.2.5.3 and 5.2.5.4 until the front and rear axle loads and the total vehicle mass are within the limits set in paragraph 5.2.5.5. 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.

5.2.5.7 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.

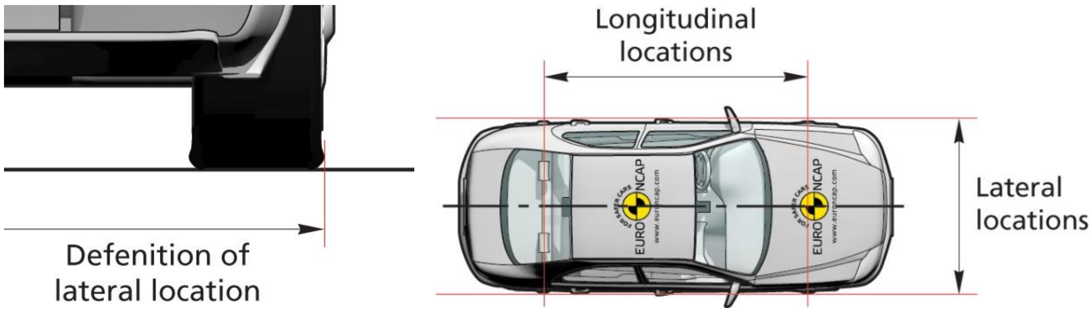


Figure 5: Vehicle dimensional measurements

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

6 TEST PROCEDURE

6.1 VUT Pre-test Conditioning

6.1.1 General

6.1.1.1 A new car is used as delivered to the test laboratory.

6.1.1.2 If requested by the vehicle manufacturer, 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.

6.1.2 Brakes

6.1.2.1 If not performed already for other tests, or when the vehicle manufacturer requests, condition the vehicle’s brakes in the following manner:

- Perform ten 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.
- Initiation of the first test shall begin within two hours after completion of the brake conditioning

6.1.3 Tyres

6.1.3.1 Condition the vehicle’s tyres in the following manner to remove the mould sheen:

- 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.

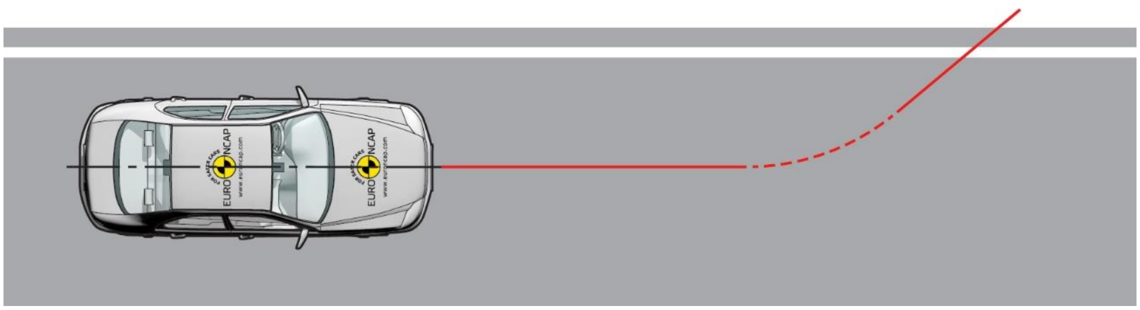
6.1.3.2 In case of instability in the sinusoidal driving, reduce the amplitude of the steering input to an appropriately safe level and continue the four passes.

6.1.4 LKA/LDW System Check

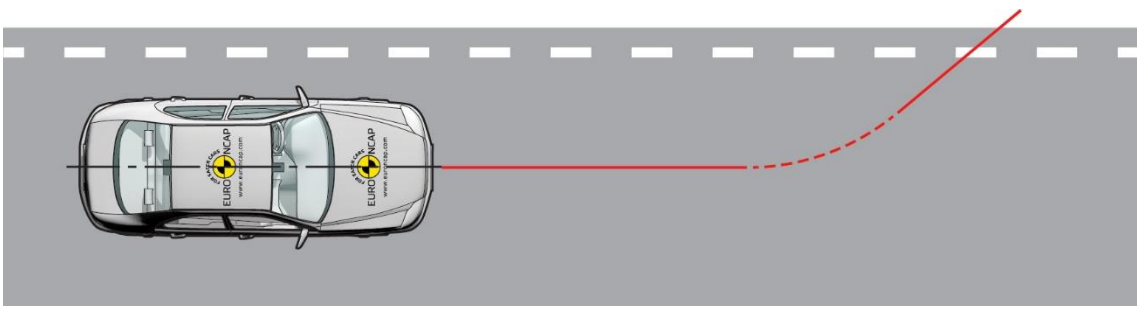
6.1.4.1 Before any testing begins, perform a maximum of ten runs, to ensure proper functioning of the system.

6.2 Test Scenarios

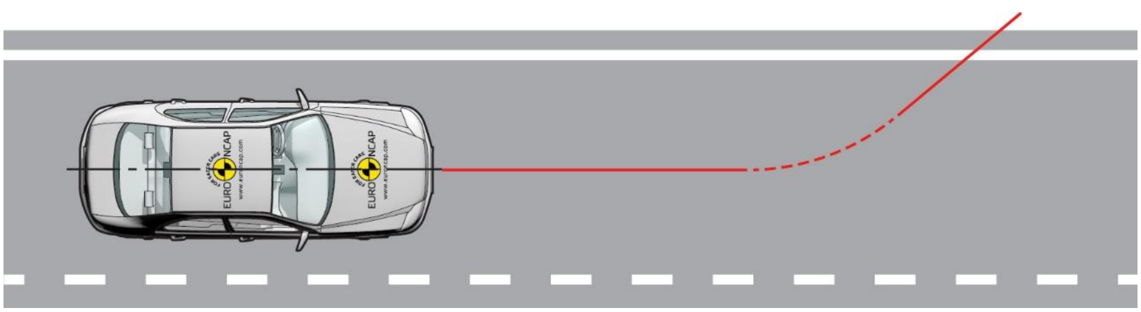
6.2.1 The performance of the VUT LSS is assessed in the LDW-SL, LDW-DL, LKA-SL scenarios as shown below.



LDW-Solid Line



LDW-Dashed Line



LKA-Solid Line (Full lane marking)

6.2.2 For testing purposes, assume an initial straight line path followed by a fixed radius of 1200m 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.

6.2.3 LDW tests will be performed with lateral velocities of 0.3m/s and 0.5m/s for both left and right hand side departures.

6.2.4 LKA tests will be performed with 0.1 m/s incremental steps (see 6.4.5) within the lateral velocity range of 0.1 to 1.0m/s for both left and right hand side departures. For lateral velocities of 0.6m/s and greater, continue testing as long as the LKA system continues to intervene.

6.2.4.1 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 LKA intervention for each test. Otherwise for each lateral velocity, two calibration runs shall be performed in order to determine when the LKA 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 LKA intervention.

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

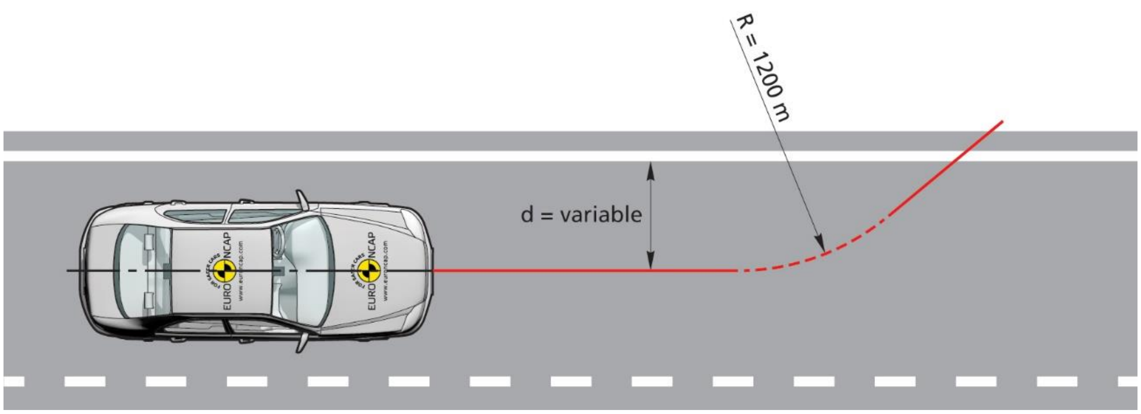
Run 2: Complete the required test path with LKA turned ON and measure the control parameter

6.2.4.2 Complete the LKA tests while ending the closed loop control before LKA 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 LKA intervention.

6.2.5 The following parameters should be used to create the test paths:

Lateral velocity [m/s]	Radius of Turn [m]	Yaw Angle [°]	Lateral deviation during curve establishing yaw angle [m]	Lateral distance travelled during Vlat steady state [m]	Lateral Offset [m]
0.1	1200	0.29	0.02	0.40	$d = d1$
0.2		0.57	0.06	0.70	
0.3		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	
0.7		2.01	0.74	0.53	
0.8		2.29	0.96	0.40	
0.9		2.58	1.22	0.23	
1.0		2.86	1.50	0.00	

Where the offset from lane marking (d1):
d1 = Lateral distance travelled during Vlat steady state (m)
+ Lateral deviation during curve establishing yaw angle (m)
+ Half of the vehicle width (m)



6.3 Test Conduct

6.3.1 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.

6.3.2 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.

6.4 Test Execution

6.4.1 Accelerate the VUT to 72 km/h.

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

- Speed of VUT (GPS-speed)	72 ± 1.0km/h
- Lateral deviation from test path	0 ± 0.05m
- Steady state lane departure lateral velocity	± 0.05m/s
- Steering wheel velocity	± 15.0°/s

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

6.4.3 The end of an LDW test is considered as when the warning commences.

6.4.4 The end of an LKA test is considered as when one of the following occurs:

- The LKA system fails to maintain the VUT within the permitted lane departure distance.
- The LKA system intervenes to maintain the VUT within permitted lane departure distance, such that a maximum lateral position is achieved that subsequently diminishes causing the VUT to turn back towards the lane.

The test is considered complete 2 seconds after one of the above occurs.

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