Informal Document: **ACSF-04-07**

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Minimum Risk Manoeuvres (MRM)

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Minimum Risk Manoeuvre (MRM)

Aim:
Minimise risk in case that the driver does not take over steering control after a transition demand

Rationale:
Depending on the traffic situation and the ACSF category the vehicle shall reach a state in which it produces as less danger as possible for the vehicle occupants and the other road users

Solution:
MRM

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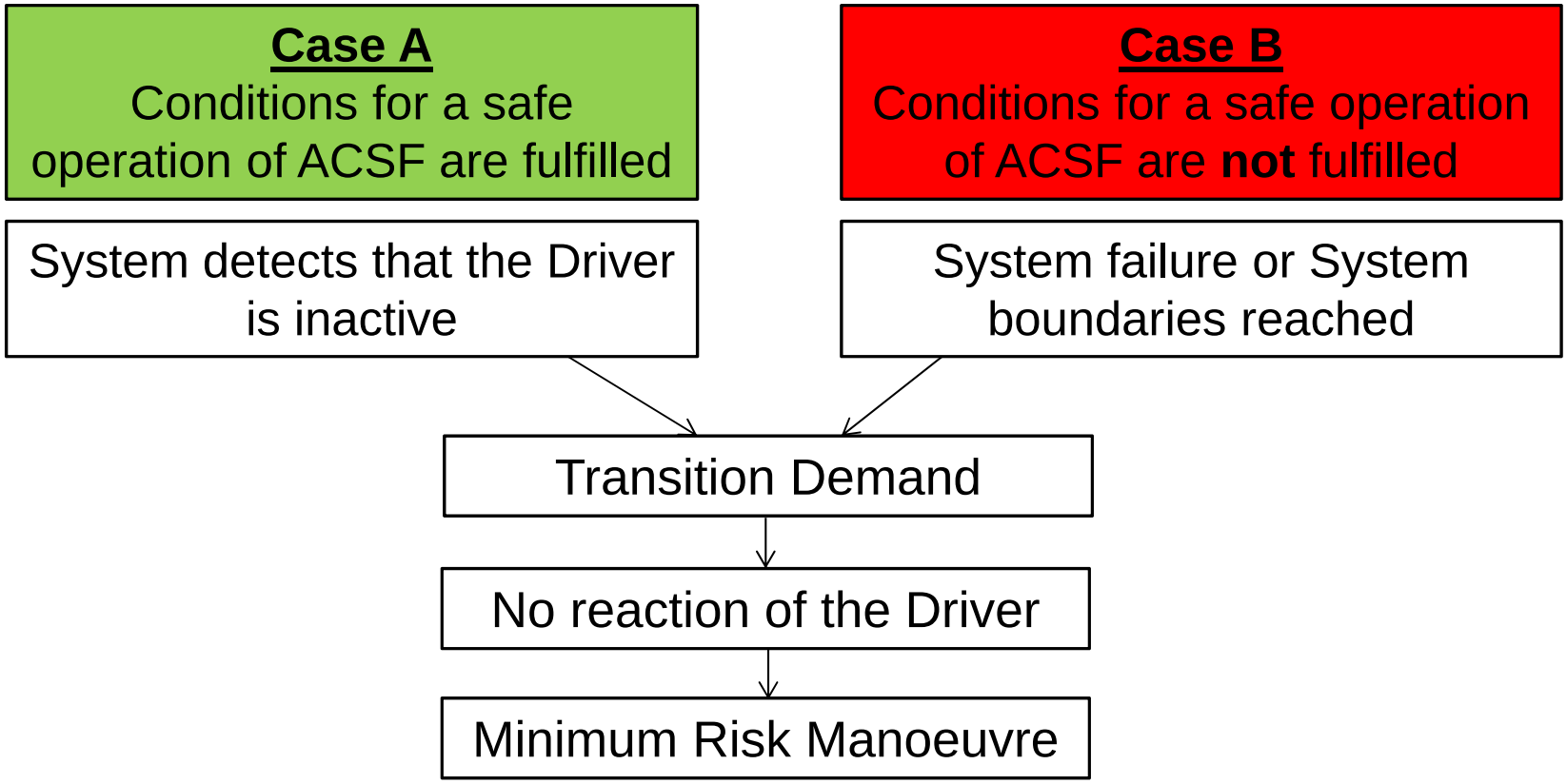
2 different cases (root causes) of a Minimum Risk Manoeuvre



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Case A - Conditions for a safe operation of ACSF are fulfilled

ACSF must comprise MRM, i. e. some strategy to reach a status with as less risk as possible in the given traffic situation, e. g. by:

- Further lane keeping for a certain time
- Enlarging gap to other road users
- Cancel motor power and decelerate smoothly
- Slowing down to standstill
- Switching hazard lights on
- If lane change is part of ACSF‘s system functionality: lane change to edge of the road

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Case A - Conditions for a safe operation of ACSF are fulfilled

Proposal for MRM that an ACSF must at least comprise

(corresponding tests in brackets)

CAT A

• Stop immediately (TR 0)

Cat B

• Hazard lights on + Stop safely in the current lane (TR1 and TR 2)

CAT C

• Hazard lights on + Stop safely in the current lane (TR 1 and TR 2)

CAT D & E

• Hazard lights on + Leave overtaking lane(s) and stop safely on the most outer available right (left) lane, if traffic situation allows, otherwise stop safely in current lane
(TR 1 and TR 2 and TR 3)

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Case B – Cond. for a safe operation of ACSF are not fulfilled

Case B1: automatic steering is not possible anymore

ACSF must comprise MRM, i. e. some strategy to reach a status with as less risk as possible in the given traffic situation, e. g. by:

- Failure warning
- Transition demand
- Keeping last steering angel for a certain time
- Cancel motor power and decelerate smoothly
- Slowing down to standstill
- Switching hazard lights on

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Case B – Cond. for a safe operation of ACSF are not fulfilled

Case B2: protective braking is not possible anymore

ACSF must comprise MRM, i. e. some strategy to reach a status with as less risk as possible in the given traffic situation, e. g. by:

- Failure warning
- Transition demand
- Keeping lane for a certain time
- Cancel motor power and decelerate smoothly
- Slowing down to standstill
- Switching hazard lights on

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Corresponding Tests

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TR 0 (driver does not control remote device, switch or button anymore; control too far away)

Check minimum risk manoeuvre

Drive with ACSF CAT A activated

i) Driver releases the control device or switch

ii) Max range of remote control is exceeded

Test is passed:

- Vehicle comes to standstill within [1] s

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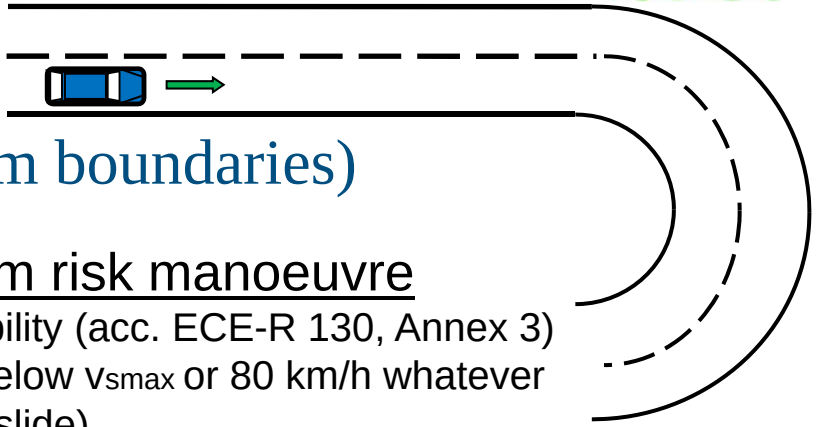

TR 1 (tight curve: a_y beyond system boundaries)

Check transition demand and minimum risk manoeuvre

- drive on a track with road markings of good visibility (acc. ECE-R 130, Annex 3) at each side of the lane at a speed of 10 km/h below v_{smax} or 80 km/h whatever is lower (test track availability reasons see next slide)
- after a straight section of at least 200 m the vehicle shall approach a curve of more than 90° that would demand an a_y of more than 3 m/s²
- test driver shall not take over manual steering control again before the minimum risk manoeuvre is finished

Test is passed:

- transition demand was given at least when the lateral acceleration exceeds 3 m/s²
- the minimum risk maneuver was finished: hazard lights are activated and vehicle comes to standstill
- vehicle did not cross any lane marking before the minimum risk manoeuvre was finished

or

- Vehicle has by itself reduced speed such that 3 m/s² are not exceeded

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Justification for 3 m/s²

- 3 m/s² at 120 km/h correspond to a curve radius of 370 m (test track available?)
- 3 m/s² at 76.4 km/h test speed correspond to a curve radius of 150 m
  (test track should be available)
- Minimum curve radii (Germany) from Road Construction Directive are:

V [km/h]	R_{min} [m] @ 6%*	R_{min} [m] @ 2,5%*	a_y [m/s²] @ 6%*	a_y [m/s²] @ 2,5%*
80	280	930	1,76	0,53
90	370	1200	1,69	0,52
100	470	1500	1,64	0,51
120	720	2300	1,54	0,48
130	900	2700	1,45	0,48

*Cross slope of the lane

=>With a max a_y of 3 m/s² the systems have enough safety margin to manage all curves also with ACSF; normal driving with ACSF with appropriate speed would never cause lateral accelerations of 3 m/s² or beyond on usual roads.

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Justification for 3 m/s²

- Up to 3 m/s² is within the comfort zone for normal driving
- Up to 4 m/s² would still be within the linear region of tire response
- 3 m/s² marks about 1/3 of maximum achievable lateral acceleration of a tire on dry roads
- On dry roads (μ = 1.0), 3 m/s² leaves 9.5 m/s² for longitudinal deceleration
- On wet roads (μ = 0.7), 3 m/s² leaves 6.2 m/s² for longitudinal deceleration

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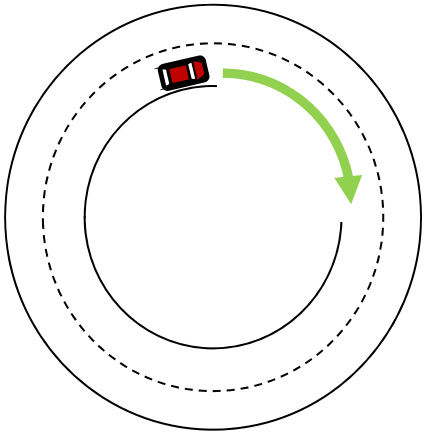
TR 2 (missing lane marking)



Check transition demand and minimum risk manoeuvre

- drive on a circle track (radius such that the lateral acceleration is between 0,5 and 3 m/s^2 for the given test speed) with road markings of good visibility (acc. ECE-R 130, Annex 3) at each side of the lane at a speed of 10 km/h below v_{smax} or 80 km/h whatever is lower
- the circle shall have a section of 90° with only one lane marking at the driver‘s side
- test driver shall not take over manual steering control again

Test is passed:

- the transition demand is given before the vehicle is entering the section with missing lane markings and the minimum risk manoeuvre was finished: hazard lights are activated and vehicle follows the initial path and vehicle comes to standstill

or

- the vehicle follows the initial path for the complete section with only one lane marking without crossing any lane marking.

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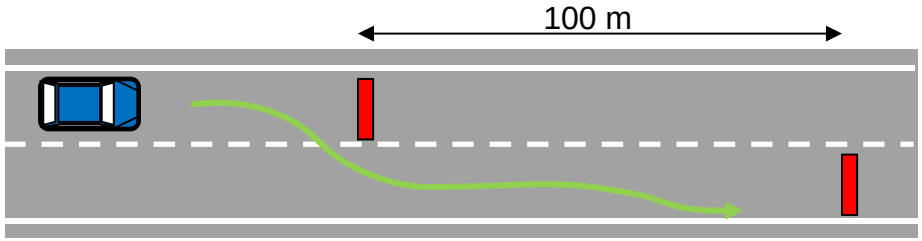
TR 3 (blocked lane)



Check transition demand and minimum risk manoeuvre

- drive on a track with 2 lanes with road markings of good visibility (acc. ECE-R 130, Annex 3) at each side of the lanes at a speed of 10 km/h below v_{smax}
- after a straight section of at least 200 m the vehicle shall approach a section where its the lane is blocked and the adjacent lane is blocked 100 m ahead
- test driver shall not take over manual steering control again

Test is passed:

- the transition demand is given at a TTC of [2 s] before the first blocking and the minimum risk manoeuvre was finished: hazard lights are activated and vehicle does a lane change and comes to standstill in the adjacent lane without collision with the second blocking

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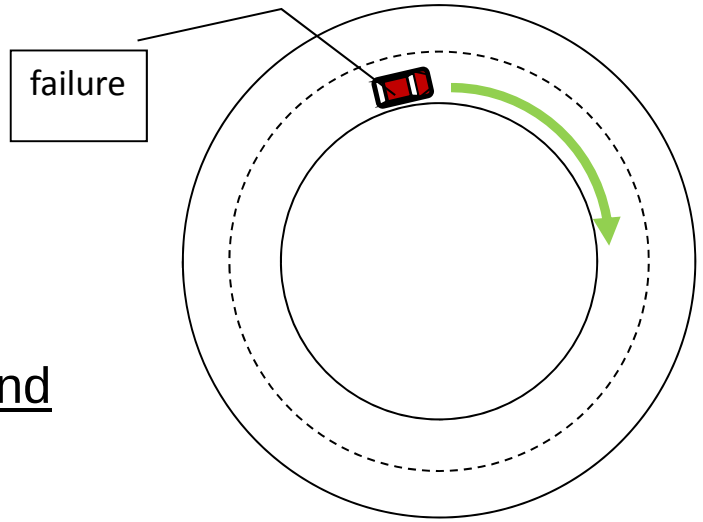

TR 4 (failure)

Check failure warning, transition demand and minimum risk manoeuvre

- drive on a circle track (radius such that the lateral acceleration is between 0,5 and 3 m/s^2 for the given test speed) with road markings of good visibility (acc. ECE-R 130, Annex 3) at each side of the lane at a speed of 10 km/h below v_{smax}
- Induce a failure of the ACSF (A: steering failure, B: protective braking failure)
- test driver shall not take over manual steering control again

Test is passed:

- A: the failure warning is given and the transition demand is given latest 1s after the failure was induced and the minimum risk manoeuvre was finished: hazard lights are activated and vehicle follows the initial path curvature and the vehicle comes to standstill within 90°
- B: the failure warning is given and the transition demand is given latest 1s after the failure was induced and the minimum risk manoeuvre was finished: hazard lights are activated and vehicle stays in the lane and the vehicle comes to standstill within 90°