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EU Real Driving Emissions Regulation
Methodology to Fine Tune EU-RDE4 Requirements

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European Commission – Joint Research Centre

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Outline

- **EU-RDE - Overview of requirements for test validity**
- **What did we change from RDE3 to the final EU-RDE and why?**
- **Overall driving dynamics checks (MAW)**
- **Final emissions calculation**
- **Conclusions**

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EU-RDE Requirements: Main pillars

- **Instrumentation performance, installation, verification**
- **Coverage requirements (Trip shares for urban/rural/motorway driving)**
- **Boundary conditions: parameters are likely to vary but values should remain within the permitted ranges (boundaries)**

=> All requirements must be fulfilled to achieve a valid test !

=> Some requirements are checked ex-post

<u>When testing vehicles, which parameters should be varied while testing vehicles and why?</u>

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EU-RDE Trip Parameters (1)

Parameter	EU Settings	Reason
Total trip duration	[90-120 min]	Minimum size of the data set required to achieve statistical significance and coverage of the operating conditions (urban/rural/motorway or speed bins)
Cold start duration Cold start operational requirements	[max 5 min]	Defines the maximum cold start duration Ensures that the vehicle is conditioned properly and driven "normally" during the cold start phase to avoid excessively low or high emissions
Minimum distances Distance shares for the U/R/M conditions	[min 16 km] [34/33/33% ±5%]	Minimum coverage of the operating conditions (urban/rural/motorway or speed bins). Each operating condition is likely to cover various areas of the engine map, thermal conditions of the engine system and driving dynamics (e.g. more dynamics in the city)
Cumulative altitude gain Difference between start and end points	[max 1200 m] [<=100 m]	Ensures that the whole trip is not uphill or downhill and that the energy consumption used for "climbing" remains within EU normal values Ensures "Energy consumption neutrality" and (almost) forces a round trip.

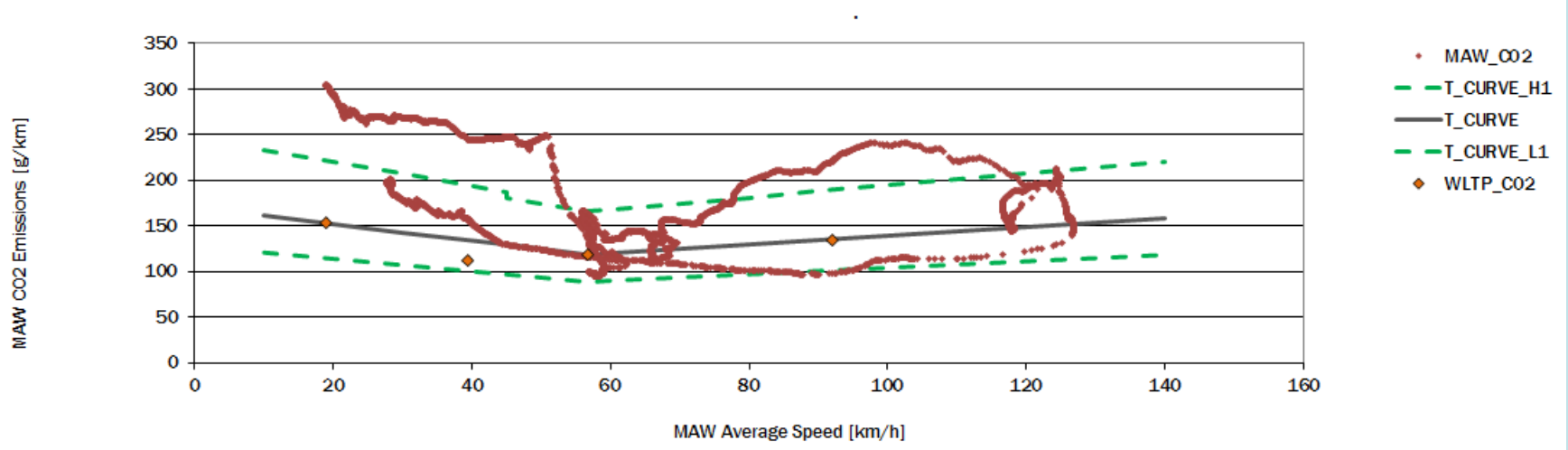
EU-RDE Trip Parameters (2)

Parameter	EU Settings	Reason
		Operating conditions which could cause (for some technologies) emissions levels which are not comparable to the average RDE emissions:
Urban average speed	[15-40 km/h]	Very low urban average speeds may include non-representative shares of vehicle idling – High urban average speeds are not representative for EU urban driving.
Motorway speed above 145 km/h	[<=3% of motorway time]	Most EU member states have motorway speed limits between 100 and 130 km/h (except Germany). Emissions driving at high speeds is possible up to 145 km/h without invalidating the tests. Emissions control at higher speeds is also ensured through provisions on emissions control strategies.
Motorway speed above 100 km/h	[>=5 min]	Minimum coverage of "real" motorway driving (See above)
Urban stop time	[6-30 %]	Limit the idling time during the test (potential effects on distance specific emissions, possible effects on cold start, etc…)

EU-RDE Trip Parameters (2)

Parameter	EU Settings	Reason
Overall driving dynamics	50% of U/R/M windows within the tolerances	The vehicle CO2 emissions encompass the effects of the driver's behavior, the vehicle payload, the wind, the road grade The severity of the driving conditions is assessed using the vehicle RDE CO2 emissions in comparison with the ones from the reference cycle (WLTP) - First at an intermediate scale using the MAW method; - Second at the trip scale for the final emissions calculation.
Excess of absence of driving dynamics	Below or above the limit curves	Additional kinematic indicators were introduced to assess: - The presence of excessive driving dynamics (e.g. a few strong accelerations) using the statistics of instantaneous Speed*Acceleration (VxA) product. - The absence of driving of driving dynamics (e.g. constant speed driving using a cruise control in an excessive manner) using the Relative Positive Acceleration (RPA). NB: To assess such effects, the MAW CO2 was not found sensitive enough.

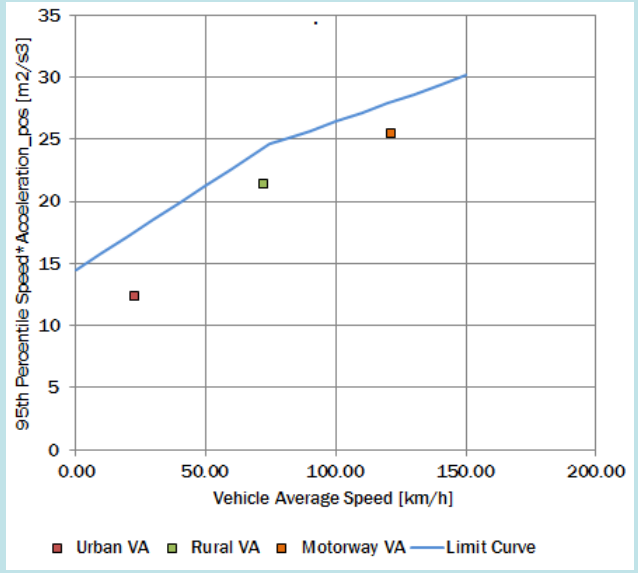
EU Trip Evaluation (Moving Window)

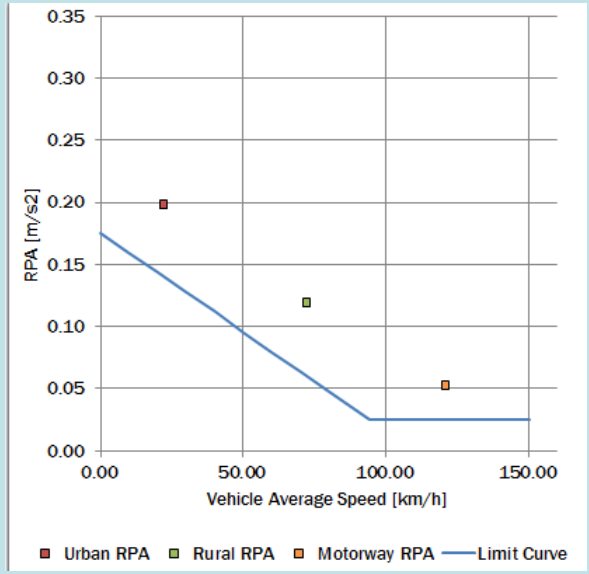


Tolerances around the vehicle CO2 characteristic curve: The upper tolerance of the vehicle CO2 characteristic curve is tol_{1H}=45% for urban driving and tol_{1H}=40% for rural and motorway driving. The lower tolerance of the vehicle CO2 characteristic curve is tol_{1L}=25% for ICE and NOVC-HEV vehicles and tol_{1L}=100% for OVC-HEV vehicles.

Verification of test validity: The test is valid when it comprises at least 50% of the urban, rural and motorway windows that are within the tolerances defined for the CO2 characteristic curve.

EU Trip Evaluation (Additional Indicators)





Verification of test validity: 95th Percentile of the v · apos values and the Relative Positive Acceleration values have to be respectively below and above the limit curves for the urban, rural and motorway speed bins.

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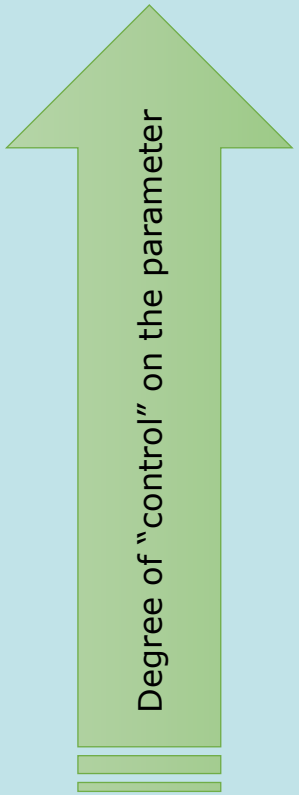
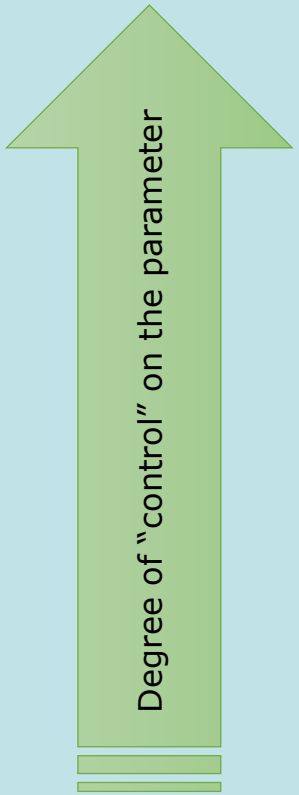
EU-RDE – Effect of Key Parameters



Parameters	Energy consumption / CO2 ~ Overall driving dynamics	Excess of absence of driving dynamics	ICE out emissions
Vehicle payload	+++	++	++
Total trip duration	N/A	N/A	N/A
Minimum distances and distance shares for the U/R/M conditions	N/A	N/A	N/A
Cold start duration - Cold start operational requirements	-	---	++
Trip operational requirements (Urban average speed and stop time, motorway speeds)	+	-	++
Altitude profile (Cumulative altitude gain & difference between start and end points)	+++	+	++
Driver, Surrounding traffic, Weather (wind, rain…) and road condition	+++	+++	+++

Recommended parameter variations



Parameters varying in the data sets	Vehicle ID				
	1	2	3	4	5
Vehicle payload	✗	✗	✓	✗	✗
Total trip duration	Within the prescribed ranges				
Minimum distances and distance shares for the U/R/M conditions	Within the prescribed ranges				
Cold start duration - Cold start operational requirements	✓ (cold-hot test) but limited effect on CO2 / severity				
Trip operational requirements (Urban average speed and stop time, motorway speeds)	Within the prescribed ranges				
Altitude profile (Cumulative altitude gain & difference between start and end points)	✓	✓	✓	✓	✓
Driver, Surrounding traffic, Weather (wind, rain…) and road condition	✓	✓	✓	✓	✓

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Ex-post Assessment of Trip Validity

- **Many parameters/requirements are – to some extent – controlled through the vehicle conditioning and the route selection but need to be verified ex-post.**
- **A proper route selection increases the probability to achieve a valid test for the required distances and shares for U/R/M driving and the cumulative altitude gains**
- **The effect of "uncontrolled" parameters (driver, weather, traffic) requires the ex-post evaluation of the affected parameters (driving dynamics and energy consumption both in potential relation with the tailpipe emissions)**
- **NB: We assume that extended conditions (temperature, altitude) influence the pollutant emissions mainly.**

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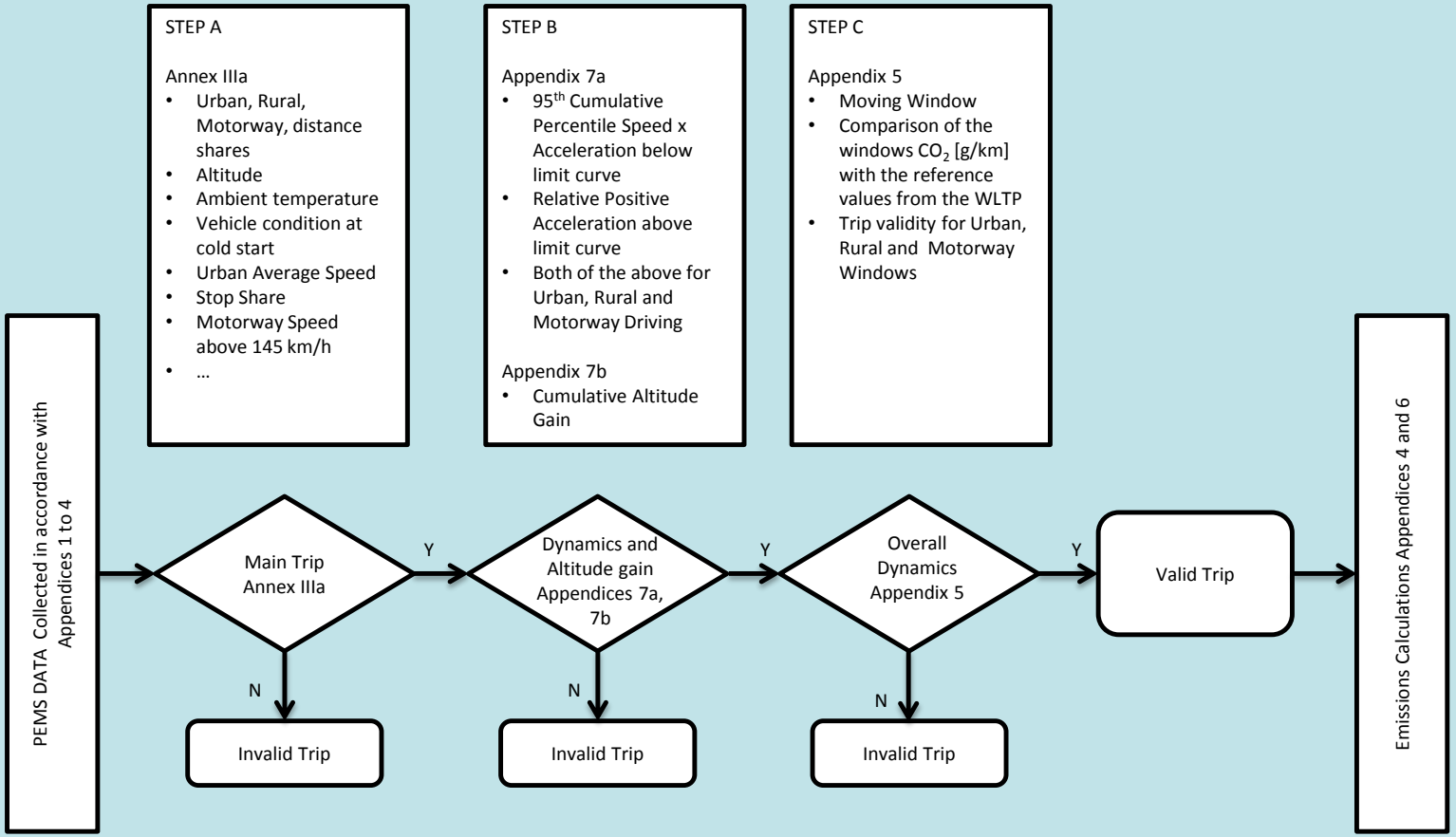
Trip verification and emissions calculation



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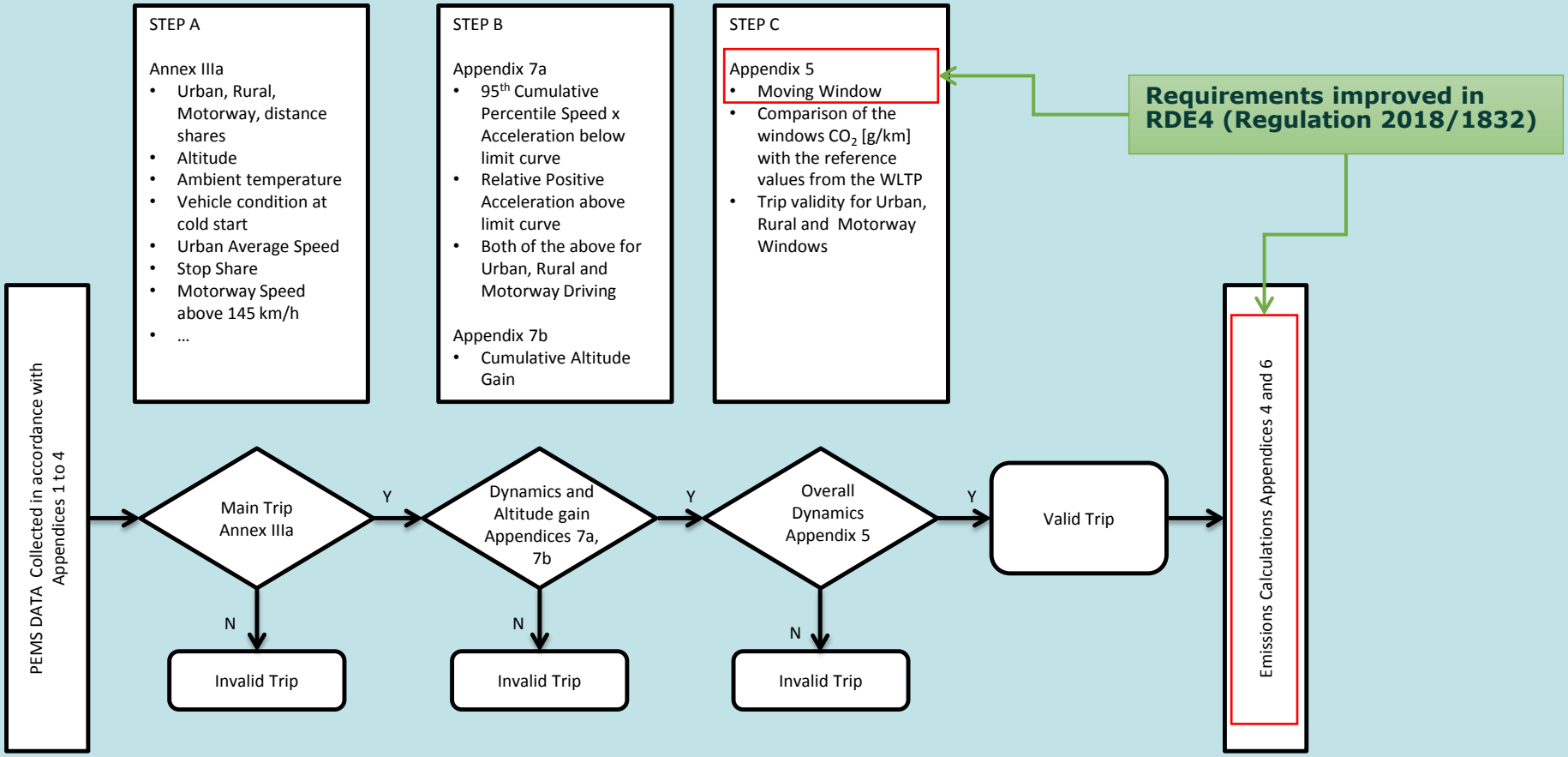
Outcome of RDE monitoring exercise

TNO study (TNO 2017 R11015)

- **”60% of trips with valid BC (trip composition/trip dynamics) are considered invalid according to the specific MAW boundary conditions”.**
- **“For MAW, motorway share and the urban part of the CO2 band are important factors for invalidity on MAW test normality”.**
- **“It was shown that MAW BC are sensitive to the WLTP input values”**

Differences in Requirements: RDE3 vs RDE4



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EU data set

Parameters varying in the data sets	Vehicle ID and number of tests per condition											
Vehicle ID	**VW036**	**PE003**	**VW037**	**NN008**	**FT059**	**PT009**	**VW038**	**VW032**	**OEM01**	**TUG01**	**TUG02**	
Vehicle payload Normal payload (= PEMS+driver) Additional payload	9 0	7 0	9 0	6 0	6 0	6 2	2 0	4 0	2 0	10 2	140	
Altitude profile <1200 m cumulative altitude gain > 1200 m cumulative altitude gain	9 0	7 0	9 0	6 0	6 0	8 0	2 0	4 0	2 0	6 6	5 9	
Driver influence Special instructions to the driver	3 D	3 D	2 D	0	2 D	2 D	0	1 H 2 E 2 BC	0	2 D 1 L 1 P 2 P+L	2 D 3 P+L 2 P+L+A	
Extended conditions *(all within10%-15%)*	0	0	0	0	0	0	0	0	0	6	9	

D = Dynamic - P = Emission provoking - L = Additional Load - A = Alpine
E = Emode - BC = Battery charge - H = Hybrid

Example of instructions to the drivers:

- **Eco-driving (follow the gearshift indicator)**
- **Aggressive driving (reach as fast as possible the posted speed)**
- **Other (...)**

These instructions remain intentional and may or may not result in the expected effect as some test parameters influencing the CO2 emissions are uncontrolled (wind, surrounding traffic).

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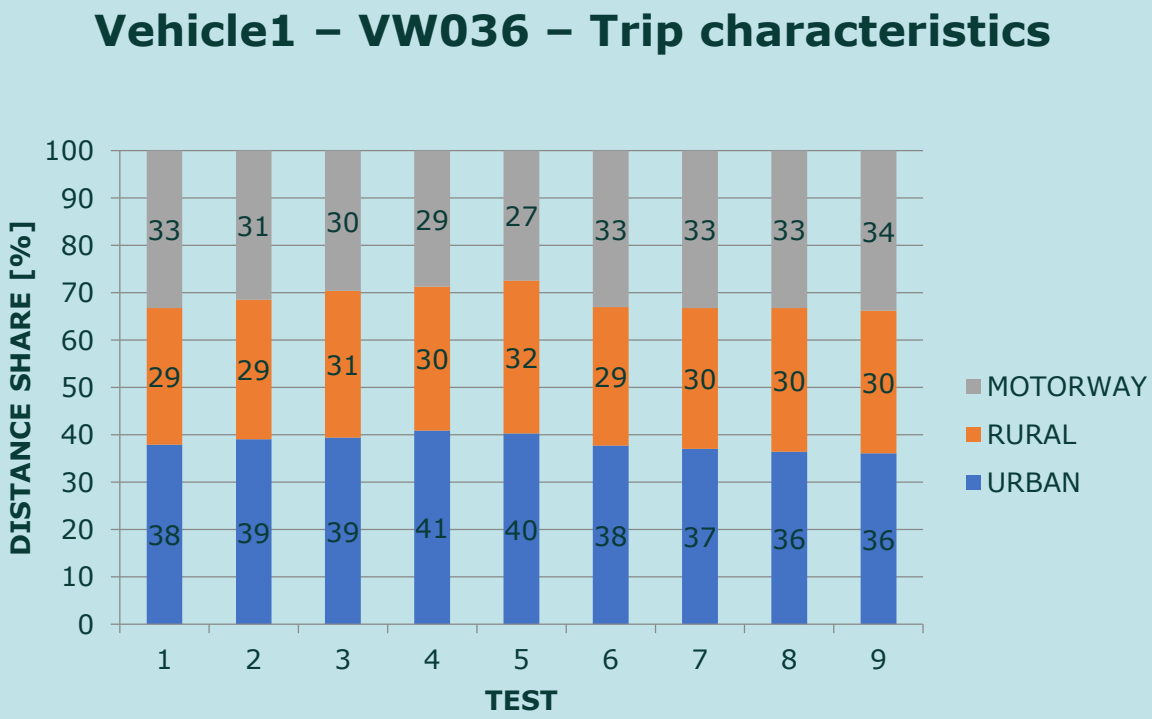
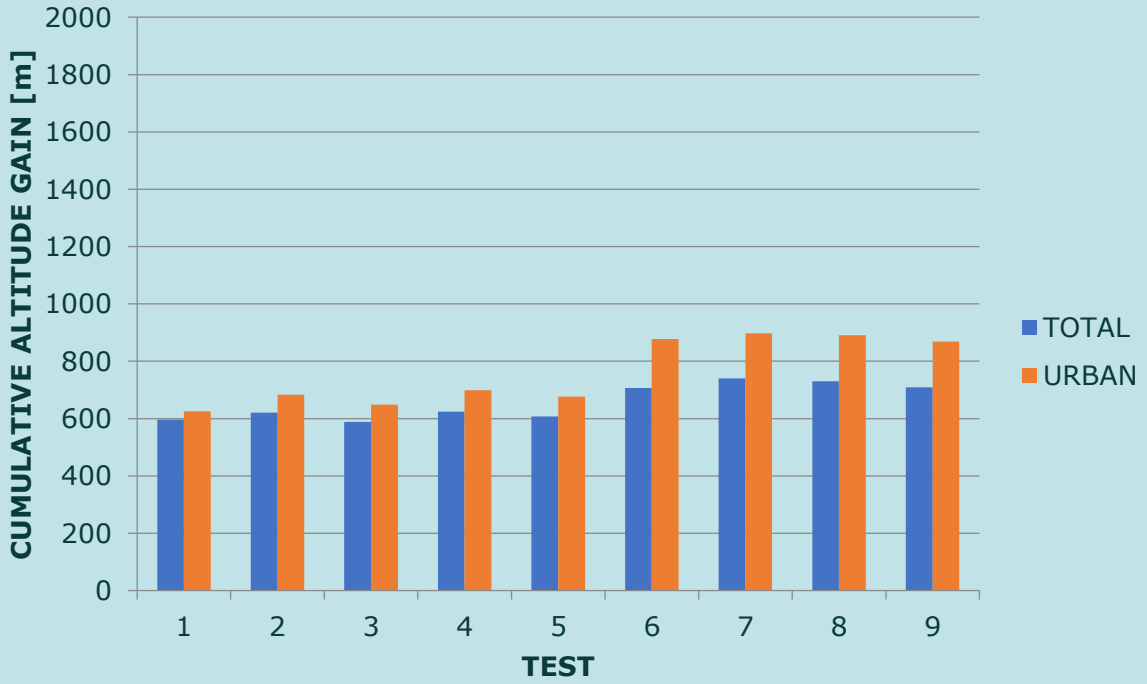
Trip Evaluation (MAW) - Examples





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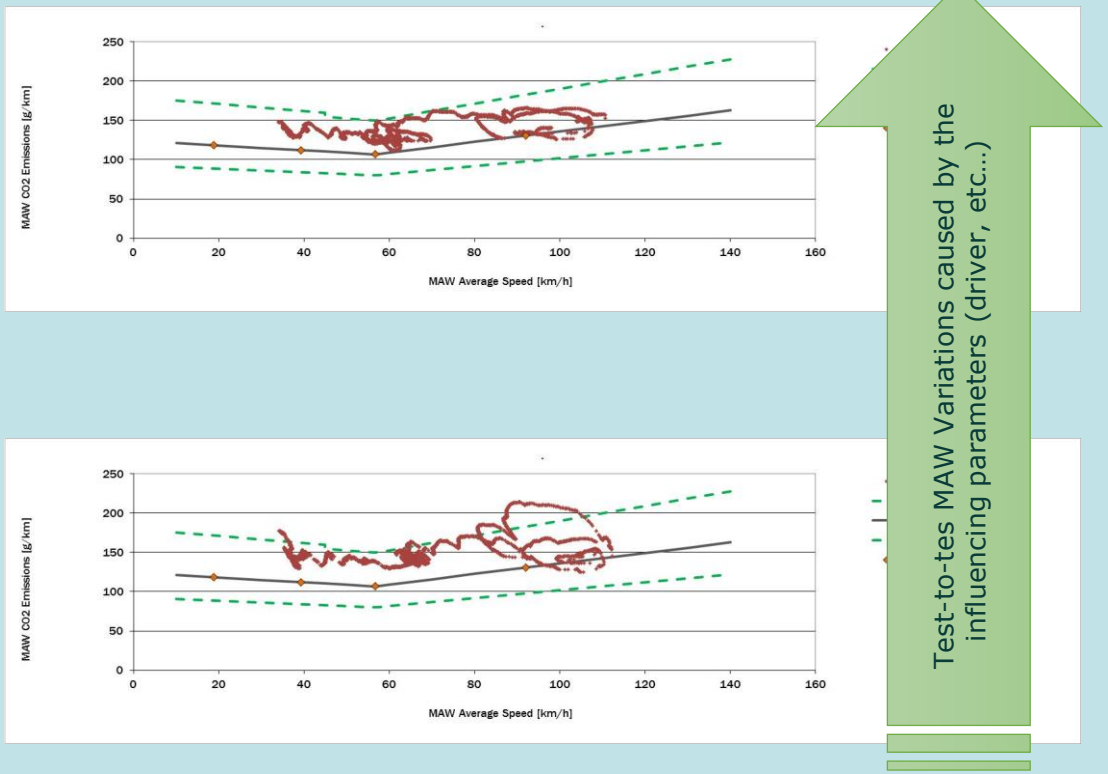
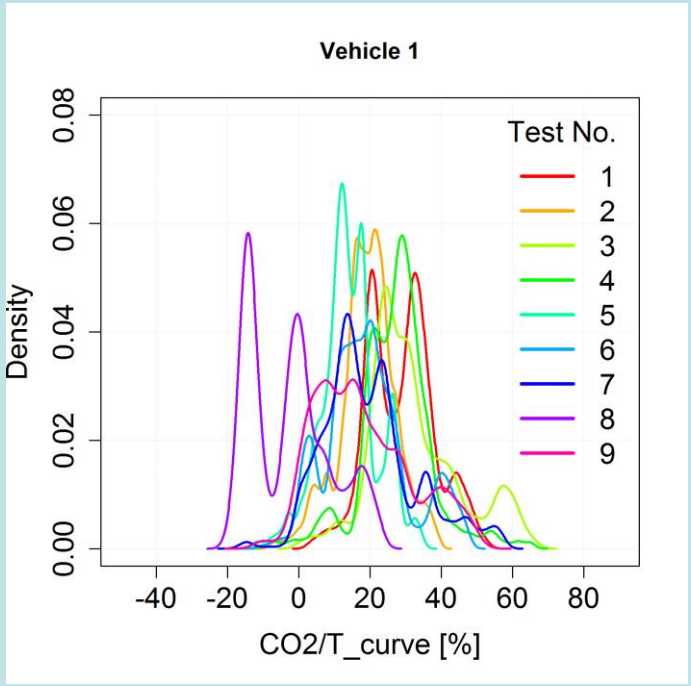
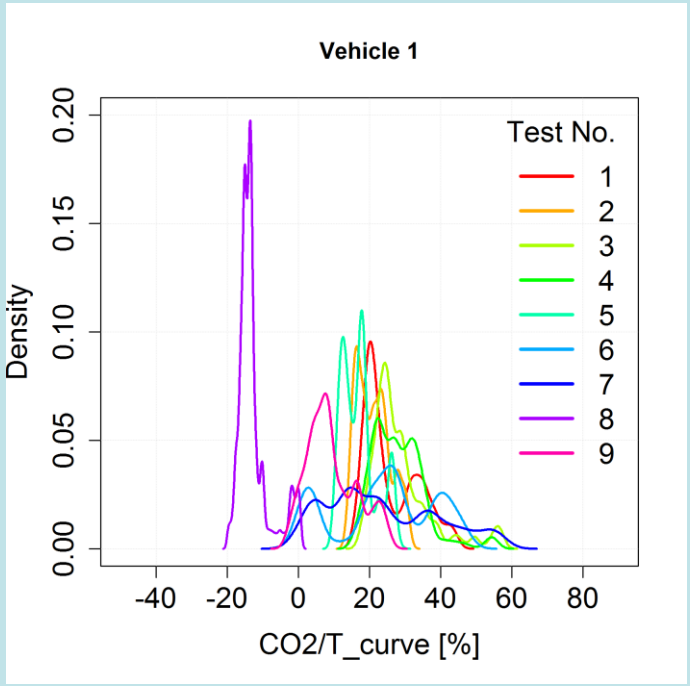
Trip Evaluation (MAW) - Examples

Vehicle 1 - VW036 – MAW Results variations/distributions for different tests





All Windows



Urban Windows

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Trip Evaluation (MAW) - Examples

Vehicle 10 - TUG01 – Main test settings / Intentions

Parameters varying in the data sets	TEST#											
	1	2	3	4	5	6	7	8	9	10	11	12
Vehicle payload Additional payload	No	No	No	No	No	No	No	No	No	No	No	No
Altitude profile > 1200 m cumulative altitude gain	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Driver influence Special instructions to the driver (*)	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes

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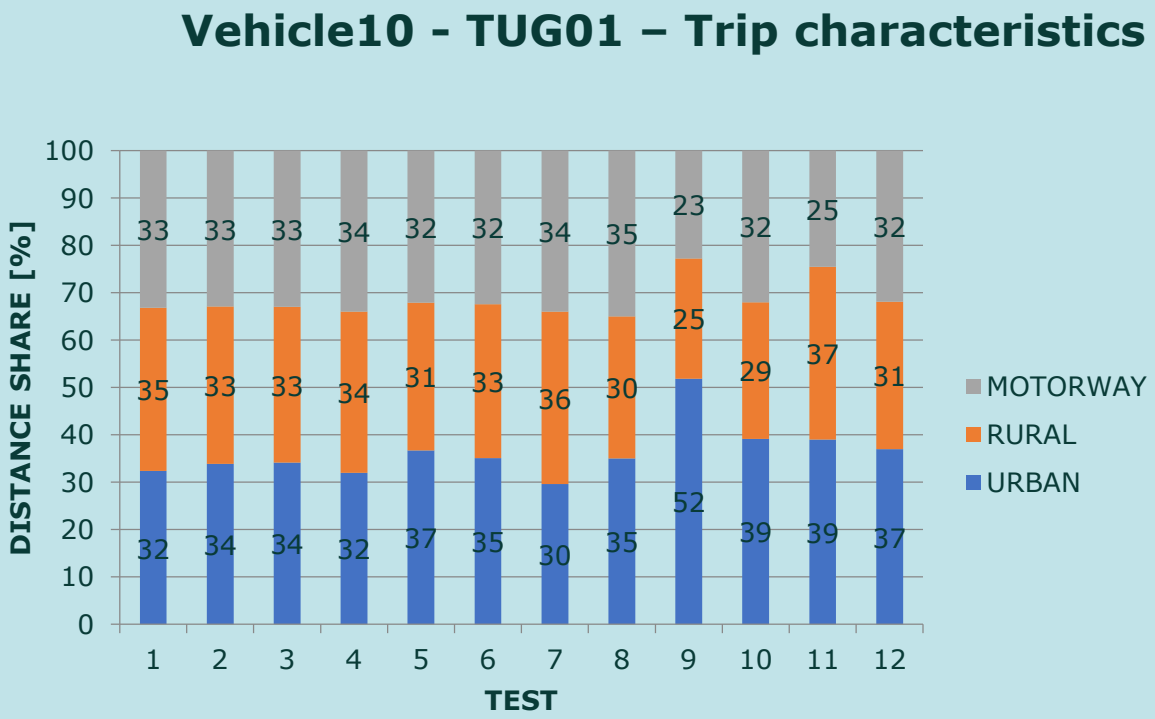
Trip Evaluation (MAW) - Examples



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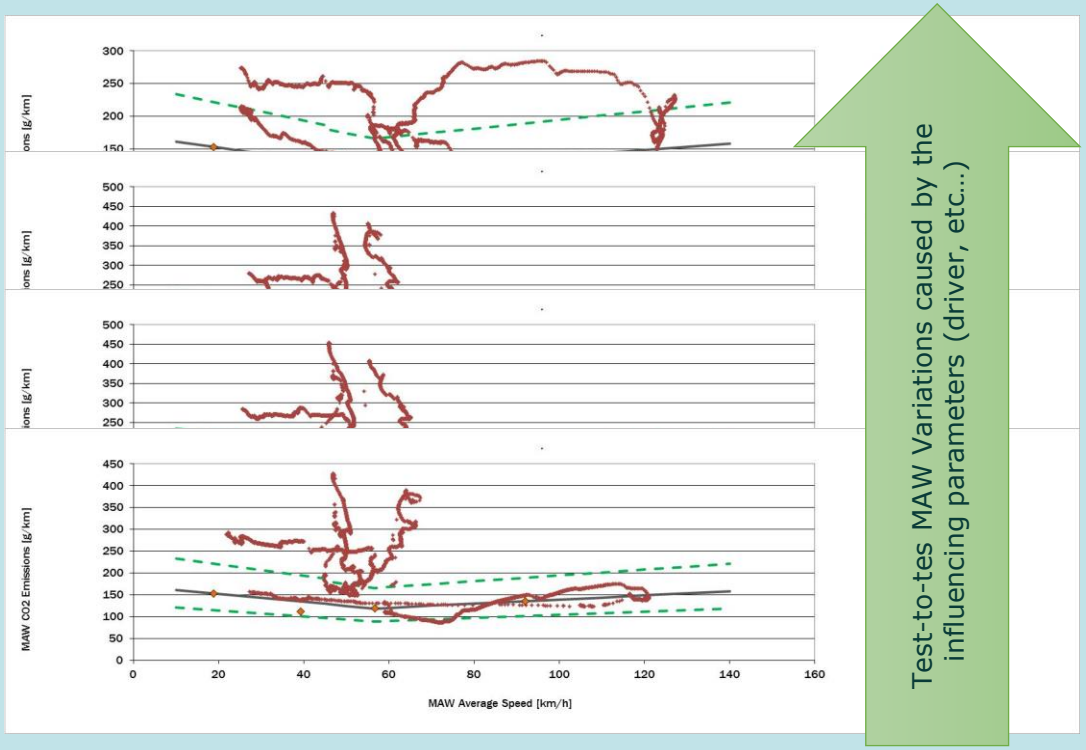
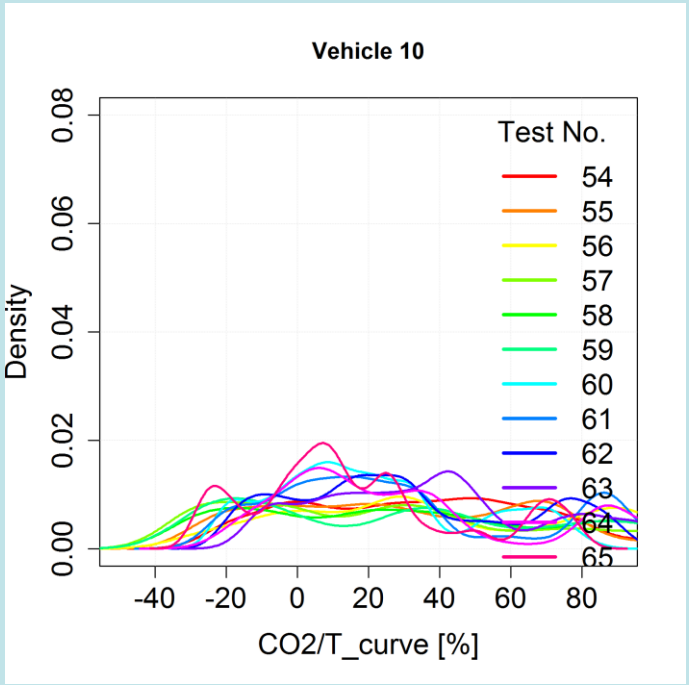
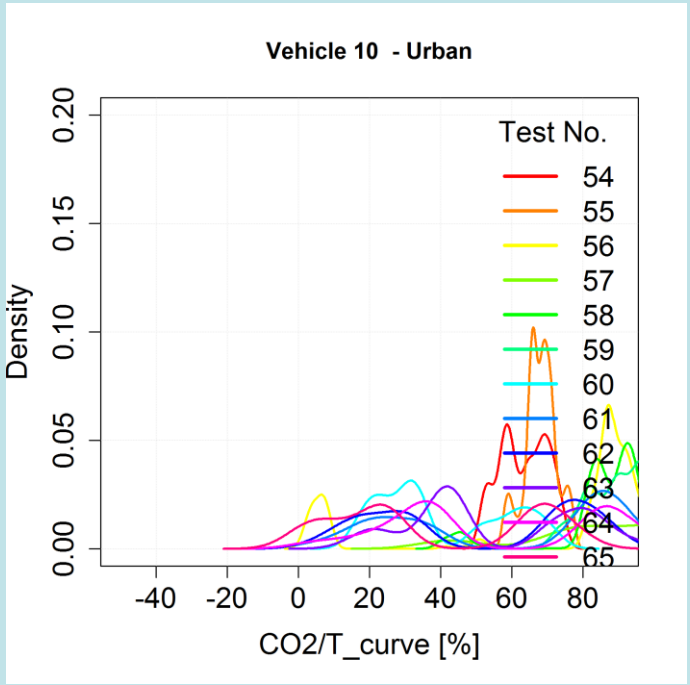
Trip Evaluation (MAW) - Examples

Vehicle 10 - TUG01 – MAW Results variations and distributions for different tests





All Windows



Urban Windows

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Trip Evaluation (MAW) - Examples

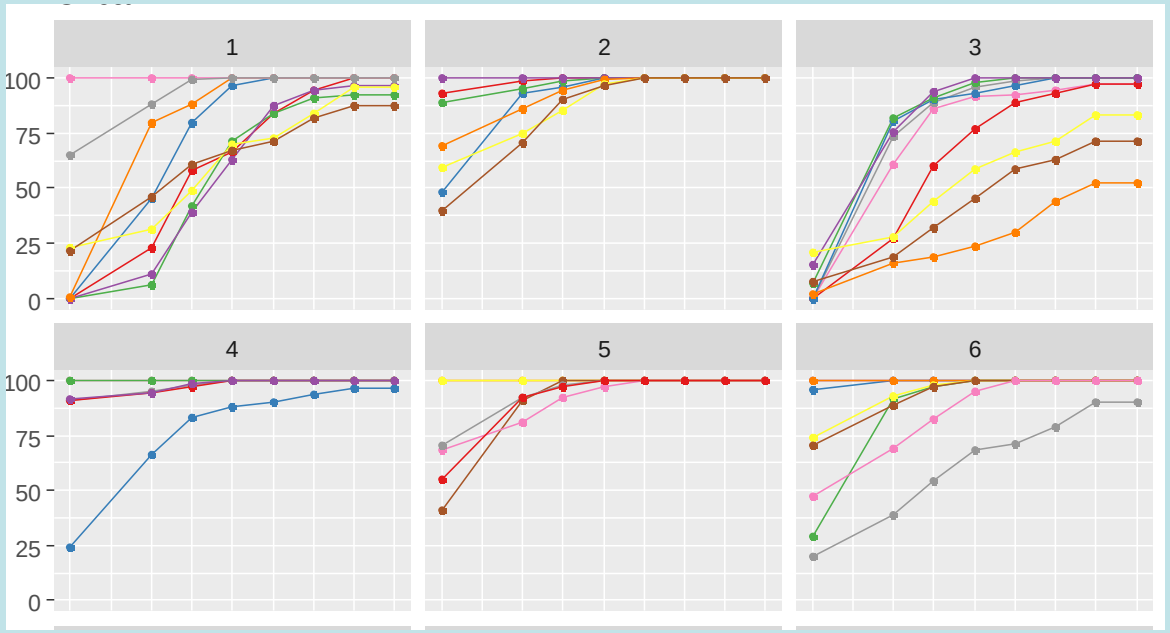
Vehicle 1 (TUG01)

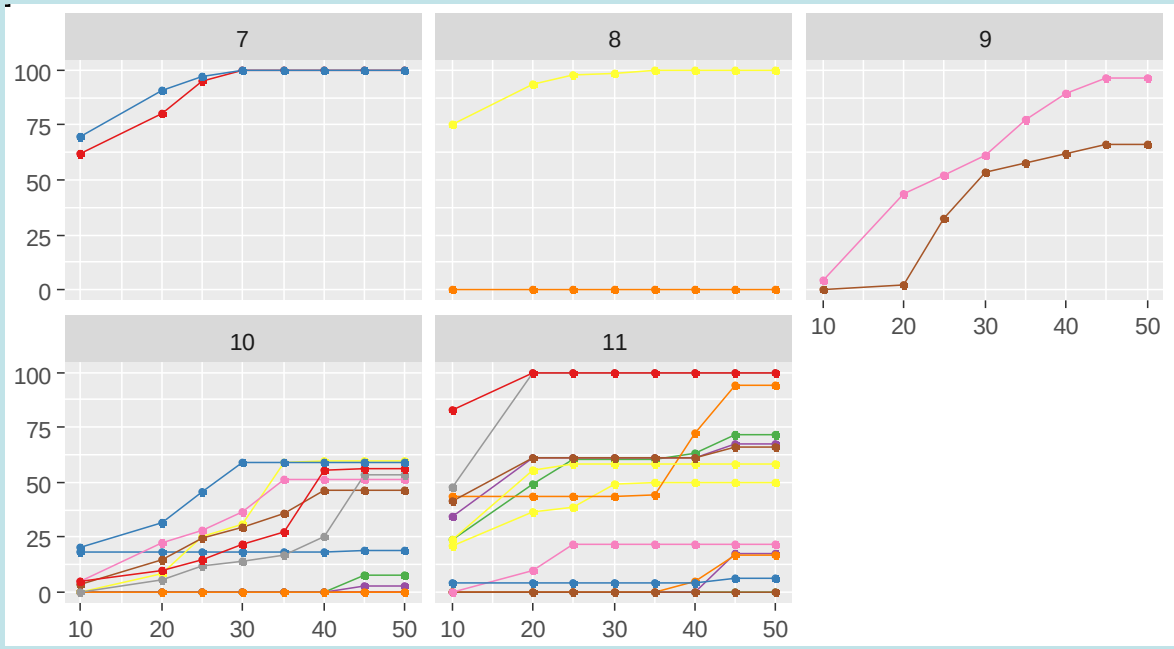
Parameters varying in the data sets	TEST#											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Vehicle payload Additional payload	No	No	No	No	No	No	No	No	No	No	No	No
Altitude profile > 1200 m cumulative altitude gain	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Driver influence Special instructions to the driver (*)	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Cumulative altitude gain – Urban (1)	Pass	Pass	Pass	Pass	Pass	Pass	Fail	Fail	Fail	Fail	Fail	Fail
Cumulative altitude gain – Total (1)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Fail	Pass	Pass	Pass
Overall dynamics (MAW) (2)	Pass	Fail	Pass	Pass	Pass	Pass	Fail	Fail	Fail	Fail	Fail	Fail
Excess of absence of dynamics (3)	Pass	Pass	Pass	Pass	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Trip validity	**Pass**	**Fail**	**Pass**	**Pass**	**Fail**	**Pass**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**

(1) Pass if <1200 m
(2) Pass if 50% of the U/R/M MAWs are within (Tol1_L) and (Tol1_H) (both set to their final values)
(3) Pass if 95th Percentile of the v · apos values and the Relative Positive Acceleration values are respectively below and above the limit curves for the urban, rural and motorway speed bins

Trip Evaluation (MAW) – Fine tuning of Tol1_H

Vehicle 10 - TUG01 – Effect of Upper Tolerance upon the % of windows in [Tol1_L - Tol1_H]





All vehicles – X-axis: Tol1_H value, Y-axis: % of windows within [Tol1_L – Tol1_H]

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Conclusions

- **Vehicle testing: it was essential to vary testing conditions to achieve the widest possible coverage of conditions (at least for the CO2 main influencing parameters e.g. altitude, cumulative altitude gains, payload, driving dynamics)**
- **The MAW tolerances (Tol1_H, Tol1_L) were selected to maximize the number of valid tests, excluding only extreme situations.**
- **Confirmed no redundancy between the MAW requirements and the additional indicators (VxA and RPA)**
- **Emissions calculations procedures simplified and corrections limited to the situations where the CO2 emissions exceed significantly the reference values set by the WLTP cycle**

Next Steps

- **The work using the EU data will be presented as a methodology in a JRC technical report**

- **Once data is available, the methodology may be used to fine tune GTR regional requirements**