Designing representative vehicle tests

Lessons for EU regulations

October 2017

Summary

This briefing summarises the important lessons for design of future EU vehicle regulations that have been concluded from an extensive programme of more than 400 real world car tests. The tests have been performed on Peugeot Citroën Group (PSA) cars as part of programme conducted by PSA in collaboration with Transport & Environment, France Nature Environnement and Bureau Veritas. The purpose was to provide PSA customers with reliable real world information on fuel economy and emissions. The views expressed in this briefing are solely those of T&E, but a technical report agreed by PSA and T&E has already been published presenting the comprehensive data.

From T&E's perspective there are 3 key lessons from the results:

Lesson 1: Road tests conducted under controlled conditions are reproducible within 5%. This shows that whilst a road test is not as reproducible as a laboratory test it does provide a robust basis from estimating real world emissions.

Lesson 2: Databases of real world fuel use and other real world tests are a good basis for deriving real world fuel efficiency; but the new WLTP test underestimates emissions. The results validate earlier work by T&E and ICCT of a wide gap (42%) between NEDC and real world performance. It also shows the gap with WLTP is smaller but still appreciable (20-30%) and can be reduced by re-weighting the different parts of the WLTP test. It also shows databases like Spritmonitor are a good indication of real world performance so long as there is a sufficiently large sample of customers driving the model in the database.

Lesson 3: The driving style in the Real World Driving Emissions (RDE) test protocol as agreed by the EU is excessively passive and share of urban driving seriously under-estimated.

As part of the RDE4 package that is presently being negotiated the Commission should investigate the impact of the cross polluting effects of low speed rural and motorway driving on the measured emissions to ensure the urban emissions are not being systematically under estimated. It should also revise the position of the upper and lower dynamic boundary condition lines in order to ensure these truly reflect excessively aggressive and passive driving.

Introduction

This briefing summarises the important lessons for design of future EU vehicle regulations that have been concluded from an extensive programme of more than 400 real world car tests. The tests have been performed on Peugeot Citroën Group (PSA) cars as part of programme conducted by PSA in collaboration with T&E, France Nature Environnement and Bureau Veritas. The purpose was to provide PSA customers with reliable real world information on fuel economy and emissions. The views expressed in this briefing are solely those of T&E, but a technical report agreed by PSA and T&E has already been published presenting the comprehensive data.

Vehicle emissions regulations designed to reduce both global warning and air pollution have been seriously undermined by obsolete laboratory tests, and a weak system of approvals. To date, compliance with regulatory limits has been assessed only through laboratory tests (although new real-world CO_2 tests are commencing for nitrogen oxides and particle numbers). Laboratory tests are reproducible but are entirely unrepresentative of the way the car is driven on the road. Some are also poorly specified leading to the misuse of test flexibilities. As a result emissions on the road are much higher than in laboratory tests. For example:

1. There is a widening gap between test and real world performance for fuel efficiency and carbon dioxide (CO_2) emissions that has grown from around 7% in 2001 to 42% in 2015[1] comparing type approval values of new cars and actual fuel consumption information. In the last 5 years there has been no improvement in average real world emissions from new cars supplied by all manufacturers.
2. The Dieselgate scandal has exposed the high real world NOx emissions from cars which routinely turn off or down exhaust after-treatment systems. As a result a typical new car is still producing over 500mg/km NOx despite the Euro 6 regulations that set a limit of 80mg/km.[2]

The 400 tests performed on 60 PSA cars are designed to provide their customers with more reliable information and represent more than 1,000 model variants. The tests are performed on the road using a Portable Emissions Measurement System (PEMS) and driven in a way to represent the average PSA driver. The test methodology is transparent and tests independently witnessed and certified. This briefing outlines 3 lessons learned from the real world testing programme to make emissions tests more representative and robust.

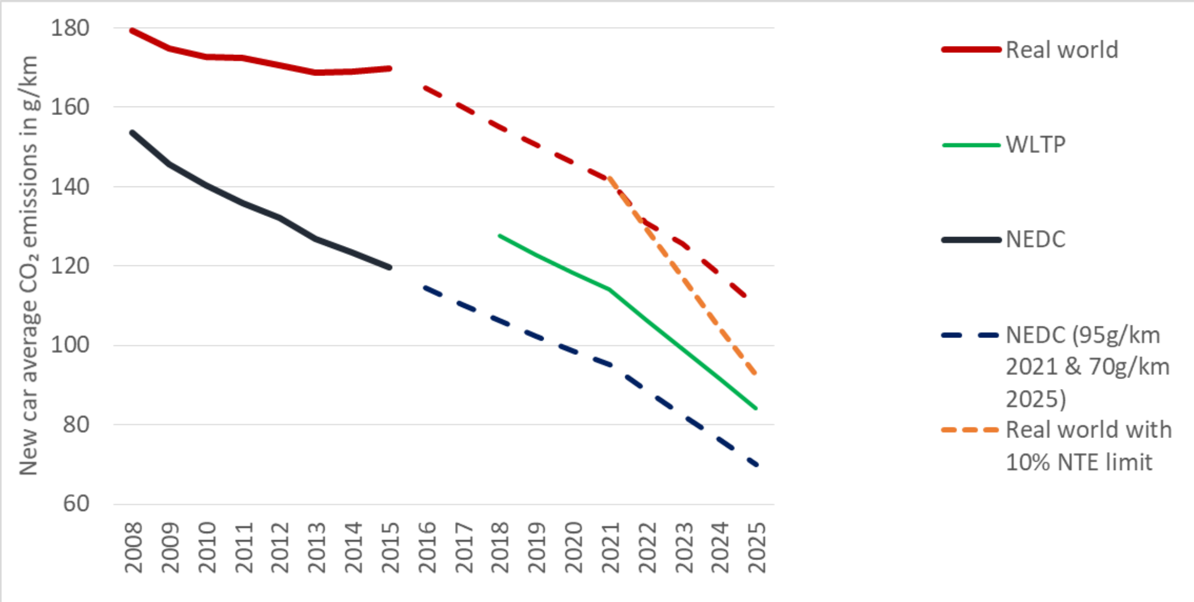
Lesson 1: Road tests conducted under controlled conditions are reproducible within 5%

One of the limitations of real world tests is that they are less repeatable than laboratory tests. However, by driving on a standard route and requiring the drive to be within specific dynamic boundary conditions (as happens for the RDE test) and with a limited amount of data normalisation, test results are reproducible within +/- 0.3l/100km - equivalent to about 5% on the average 6l/100km car. The PSA tests have been conducted with a variety of drivers and at different times and weather conditions. None of these factors have materially affected the reproducibility of the results.

If a road test for CO_2 emissions is acceptably reproducible it can be used for regulatory purposes. The forthcoming car CO_2 regulation that is expected to set targets for 2025 and 2030 will be based upon the new WLTP test. But the tests on PSA cars show real world performance deviates from WLTP by around 10% (less than expected because the full test procedure was not followed) and other studies show this is expected to increase from around 20% in 2020 and 30% by 2025 as manufacturers make use of technology that over-performs in the test and make use of flexibilities in the test procedure.

The figure illustrates the growing gap between NEDC and real world emissions 2008-15 and that real world emissions are effectively unchanged since 2011. Projecting forward to 2021 (assuming the gap between NEDC to real world grows to 49%) in 2021 cars will, on average, achieve 95g/km on the NEDC test and 142g/km on the road. By 2025 (if NEDC test values were reduced to 70g/km) on the road cars will achieve 110g/km. This is approximately what was expected for 2020 in the original 2008 car regulation impact

[1] T&E Mind the Gap report, https://www.transportenvironment.org/publications/mind-gap-2016-report
[2] T&E Dieselgate report, https://www.transportenvironment.org/publications/dieselgate-who-what-how



assessment. In effect 5 years of real world improvement has been lost through the widening gap. Also shown in the figure above is the projected WLTP emissions based upon a gap with NEDC values of 120%. By 2025 WLTP emissions would be 84g/km (if NEDC values were lowered to 70g/km).

To ensure car CO_2 regulations really deliver the expected level of real world improvements there should be a complementary real world driving emissions test for CO_2. Carmakers should be required to ensure that on average real world emissions as measured in the real-world test are no more than 10-15% higher than the WLTP value. This not to exceed limit (NTEL) would ensure a carmaker:

- Cannot exploit flexibilities in the WLTP or risk failing the RDE equivalent
- Does not fit technology to the car that largely improves emissions during the lab test
- Fits technology that delivers real world improvements.

If the 110% NTEL was applied the figure shows real world emissions in 2025 would be 92g/km not 110g/km, a sizable reduction. This would help to achieve member states 2030 Effort Sharing targets.

The requirement could be introduced into legislation by a simple clause stating-
"The manufacturer shall ensure that the specific real world CO_2 emissions of the passenger car as used on the road by an average driver of that car do not exceed by more than [10-15]% the specific CO_2 emissions measured during type approval WLTP. If the value exceeds [10-15]%, the measured WLTP test value used for the purposes of compliance at type approval shall be adjusted to be no more than [10-15]% (i.e. the exceedance)."

A second clause would simply require that-
"The Commission shall adopt, by means of delegated acts, the detailed provisions for a procedure to measure the specific real world CO_2 emissions. This shall be done through a test conducted on public roads and using a portable emissions measurement system so as to ensure that the specific CO_2 emissions measured at type approval are representative of emissions measured under real driving conditions."

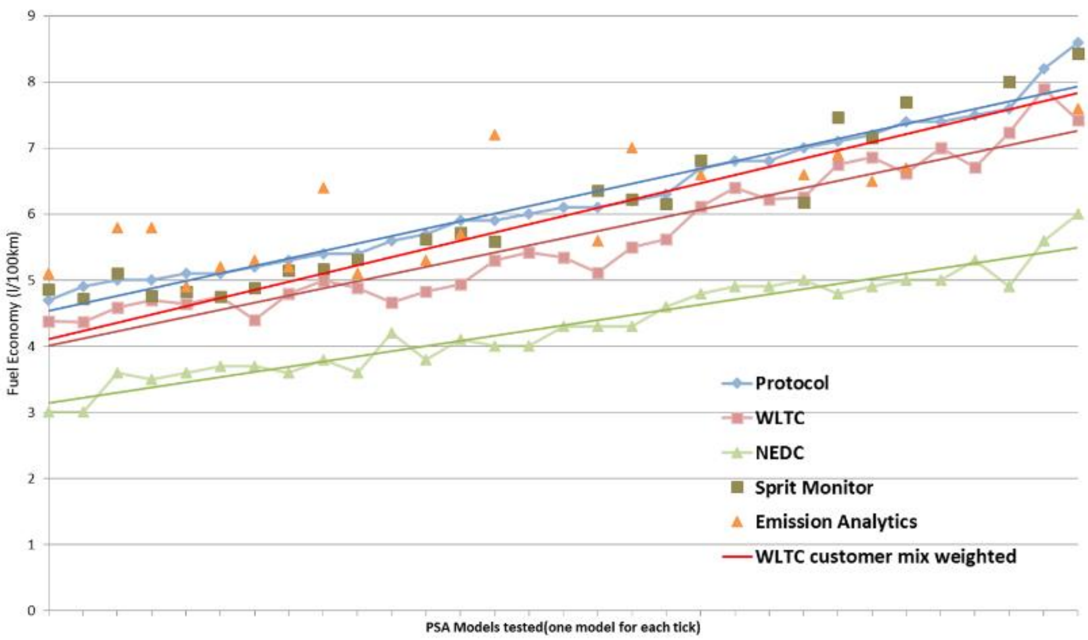
In practice this test would be defined as part of a fifth RDE package. The recommendation is entirely consistent with that of the Scientific Advisory Mechanism (SAM) report that stated:

In order to ensure the representativeness of the type approval test, a framework for the monitoring of real driving CO_2 emissions is required. This should consist of an exploitation of CO_2 data obtained from real driving *emissions testing for pollutants using Portable Emissions Measurement Systems (PEMS), the development of a targeted ex-post Real Driving Emissions (RDE) methodology for CO_2, and the introduction of a formal reporting of fuel consumption from on-board vehicle diagnostic systems*.

Other methods such as using fuel economy meters can provide an effective means of monitoring fuel economy.

Lesson 2: Databases of real world fuel use are a good basis for deriving real world fuel efficiency; but the new WLTP test under-estimates emissions

There are several competing claims as to what represents "real world driving" and some of these are illustrated in the figure below. The PSA Protocol is designed to reproduce the average use and driving style of the model being tested obtained from PSA customer surveys, and the results closely produce these results. This is considered to be a "gold standard" in terms of PSA vehicles in terms of its representativeness to average real world use. The results show the NEDC test is an outlier with difference with the Protocol 43% higher than NEDC values for an efficient (5l/100km) car and average (6l/100km) model. For a less efficient 7l/100km model the percentage difference is slightly smaller, 34%.



The comparison with WLTP shows a much smaller difference, about 10%. This is less than expected, possibly because the WLTP test performed on the tested cars did not follow the full homologation procedure. A figure of 20% is considered more likely. If the proportion of low, medium, high and very high speed driving in the WLTP test is adjusted to be more aligned with the Protocol and average PSA driver, the Protocol is only 4% higher on average across all models. This suggests a significant part of the underestimate of WLTP arises from a disproportionate amount of more efficient driving. The Spritmonitor results are typically within ±0.2l/100km, around 3% of real-life average fuel economy of the vehicle. This shows the Spritmonitor publicly measured fuel economy (the data is compiled through members of the public recording their fuel efficiency) is representative of real world performance so long as there is an adequate sample of vehicles (about 20).

The comparison with the EQUA database of Emissions Analytics (that conducts similar real world tests using PEMS following its own protocol) are mixed. Comparing the EQUA Index and PSA Protocol results finds about half the results match. For the other half of the models, Emissions Analytics values deviate significantly, especially for all the C4 Picasso (EQUA values underestimate the fuel consumption by around 0.7l/100km) and for all the DS brand (EQUA overestimate the fuel consumption by around 0.9l/100km). Attempts to explain systematic differences for certain models/brands have been inconclusive. Among the 48 vehicles in common, only 2 models have been tested by Emissions Analytics in the 2016/2017; instead EQUA is based upon a forecast model that could be the source for the difference.

In summary, publicly recorded databases of fuel economy do provide a robust basis for measuring real world fuel efficiency as do PEMS tests conducted using other protocols. WLTP values underestimate real world emissions but differences could be reduced by re-weighting the parts of the WLTP test. These are important findings in relation to providing customers of all models with more representative real world fuel efficiency information.

Lesson 3: The driving style in Real World Driving Emissions tests is excessively passive and share of urban driving seriously under-estimated

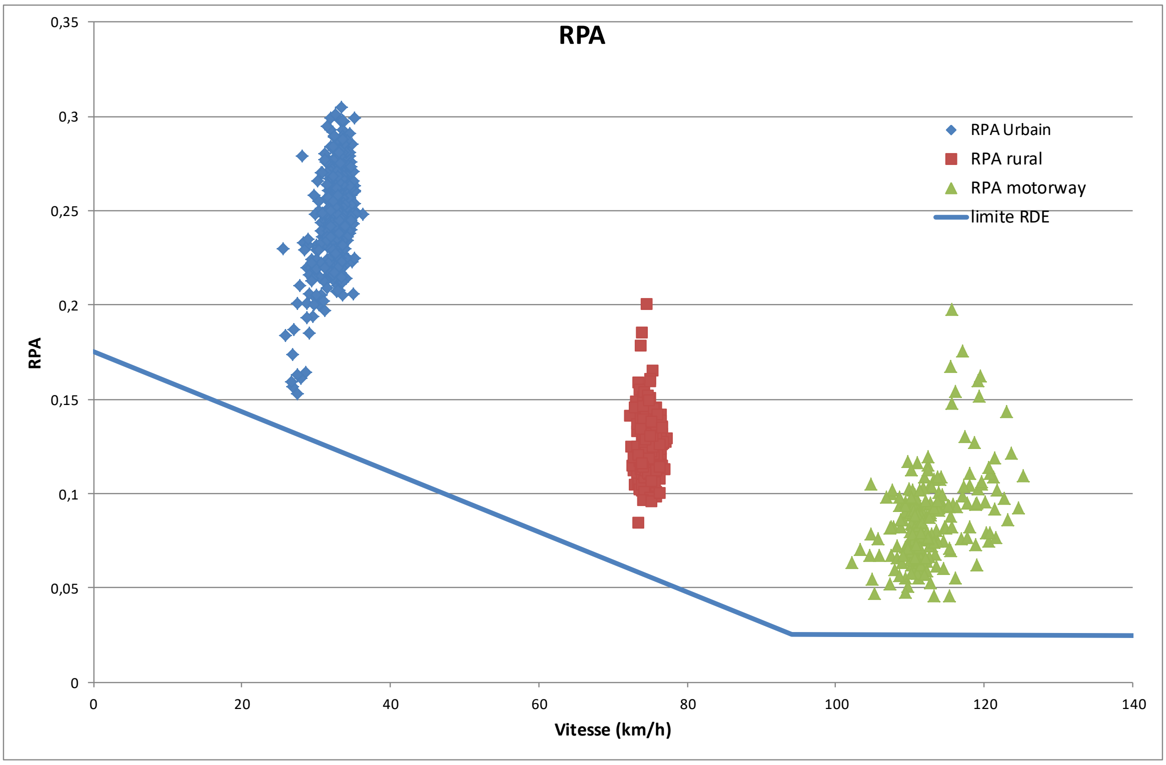
The tests performed on PSA cars are designed to reproduce the driving style of an average PSA driver of the model with boundaries set that the test must not be less passive than a 30th percentile driver or more aggressive than a 70th percentile driver. The aggressiveness of the average PSA driver of the model is derived from a survey of driver styles conducted by PSA and the aggressiveness of the driver is measured using the produce of the speed and positive acceleration – the same metric used in the RDE test. The RDE test defines dynamic boundary conditions to ensure the car is driven in an acceptable way during the test – if the drive is outside of the boundary conditions corrections are applied to normalise the data.

Analysis of the tests performed on PSA cars compared to the upper RDE boundary conditions (defining the most aggressive acceptable driving) finds that for urban driving most PSA drivers are close to but below the limit line. This suggests that most average drives are considered to be quite aggressive according to the RDE test procedure. For rural driving, all drives are also close to the limit curve, and some average drives for sporty vehicles are above the limit curve indicating some average drives are above the acceptable RDE conditions.

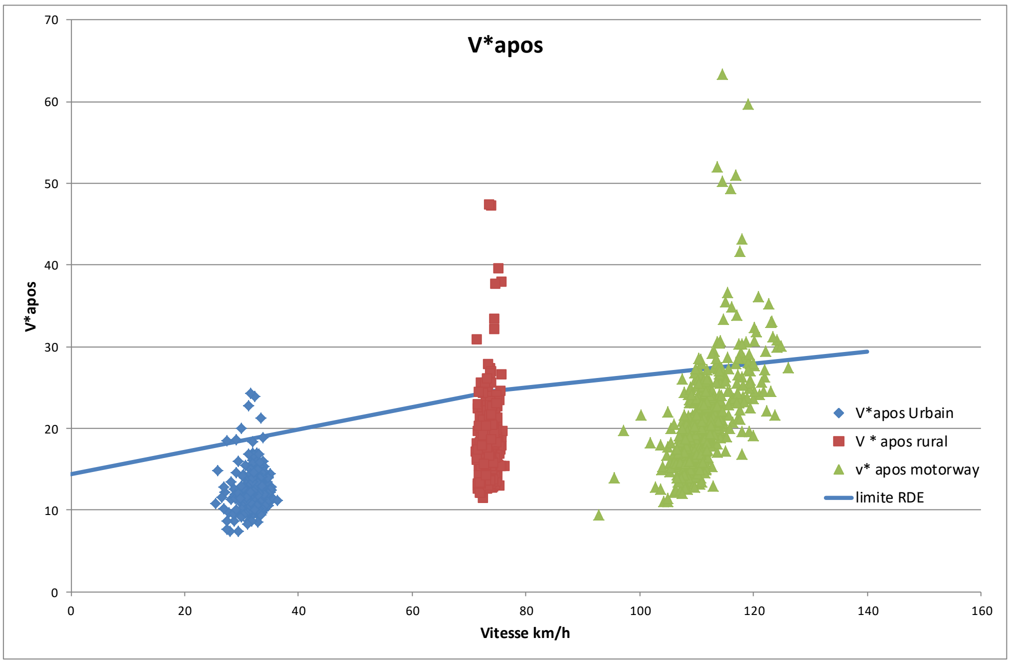
For the motorway section, many drives are considered too aggressive for the purposes of RDE. This is particularly the caser for larger, high powered vehicles.

For the low dynamic condition (defining the most passive acceptable driving in an RDE test); all of the drives are well above the limit curve, including those that were considered to be too passive for the purposes of the Protocol (less than a 30th %ile driver) and even some cases in which the driving was more passive than a customer 0%.

As part of the RDE4 package that is presently being negotiated the Commission should consider revising the position of the upper and lower dynamic boundary condition lines in order to ensure these truly reflect excessively aggressive and passive driving.



The Protocol used to make the on road measurements closely matches the RDE trip requirements, but some criteria of the trips differs from the legal requirements of RDE, in particular what constitutes urban, rural and motorway driving is defined on the basis of a map whereas the RDE legislation uses typical driving speeds on these types of roads. The cartographic (mapping) approach defines the type of road by the immediate surroundings to classify the type of operation. The cartographic approach reduces the "cross-polluting" effect when low speed driving occurs in a non-urban area (e.g. following a tractor on a rural road; or entering a highly congested motorway). This cross polluting has a significant impact on the estimated share of urban, rural and motorway driving based upon the test results using the protocol. Using the cartographic approach the Protocol is 25% urban driving on the road (this is weighted upward in the final assessment of the emissions to be representative of the typical use of the model). However using the speed bin approach urban driving would be estimated to be around 40.



	Urban	Rural	Motorway
Cartographic	25%	43%	32%
Speed bins	40%	35%	25%

The results show the speed bin approach significantly overestimates the amount of time the car is being driven in urban environments compared to reality. This is important as urban emissions of NOx tend to be particularly high and fuel efficiency much worse in urban areas. The speed bin approach in effect means the urban emissions are underestimated – but incorporated into the other parts of the trip in which the emissions are generally much lower. It should be stressed that this result is based upon a single route – however, the nature of the speed bin approach is likely to cause this effect on other routes.

As part of the RDE4 package that is presently being negotiated the Commission should consider investigating the impact of the cross-polluting effects of low speed rural and motorway driving on the measured emissions to ensure the urban emissions are not being systematically under estimated.

Further information

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