Working paper 2011–5

Development of a Worldwide Harmonized Light Vehicles Test Procedure (WLTP)

ICCT contribution No. 3 (focus on inertia classes)

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Introduction

For historic reasons we make use of inertia classes and upper limits for inertia mass during the vehicle testing procedures today. Historically, the weight of a vehicle was represented by hanging rotating inertia mass on a dynamometer. This approach required the use of discrete inertia classes and an upper limit for inertia mass. Modern electronic dynamometers no longer impose these limitations. As a result it is now possible to revise existing test procedures and provide more accurate emission and fuel consumption values to consumers.

This document builds on explanations that were given in the documents WLTP-DTP-LabProcICE-054, 067, 077 and WLTP-DTP-06-11.[1] It presents new analysis on the implications of the current inertia class based system and outlines two alternative approaches for discussion within the WLTP-DTP working group.

Shortfalls of the current inertia class approach

In 2011 for the first time detailed data on EU new passenger car registrations at the vehicle version level was published in the context of the European Commission CO_2 monitoring system.[2] This data also contains the reference mass for each entry. This allows a thorough analysis of the distribution of new vehicle registrations by mass for the European new passenger vehicle fleet.

As seen in Figure 1, there is a tendency for a higher number of vehicle registrations just below an inertia class step compared to the number of registrations just above an inertia class step or in between inertia class steps. When dividing the mass difference between two inertia class steps into ten equally large bins and aggregating the number of vehicle registrations along these bins, this tendency becomes even more striking (Figure 2).

When aggregating overall inertia classes the effect can be quantified more precisely. As Figure 3 demonstrates, about 28% of all vehicle registrations are associated with a reference mass that is just below an inertia class step (0-10% below a step). In contrast, less than 5% of all registrations are associated with a mass just above an inertia class step. The likelihood of a vehicle having a mass slightly below an inertia class step is more than five times higher than having a mass slightly above an inertia class step. These findings strongly suggest that manufacturers optimize the weight of their vehicles with respect to the discrete inertia class steps.[3] If no optimizing were taking place, a rectangular type distribution would be expected.

The implication of this is that while there is a strong incentive for manufacturers to reduce the weight of their vehicles marginally to make sure that they "jump" into the next lower inertia class and gain an advantage in terms of CO_2 emissions / fuel consumption testing, these lower test

1 See also http://www.theicct.org/2011/06/inertia-classes-proposal/

2 Data source: http://www.eea.europa.eu/data-and-maps/data/CO_2-cars-emission

3 Similar findings have been reported for the US fleet where this has led to a split of inertia classes to make them smaller in size and thereby reduce the incentive to optimize towards the classes. Furthermore, a similar effect has been found in the context of the US gas guzzler tax. See Sallee, J., Slemrod, J. Car Notches: Strategic Automaker Responses to Fuel Economy Policy, University of California Berkely, 2010 for details.

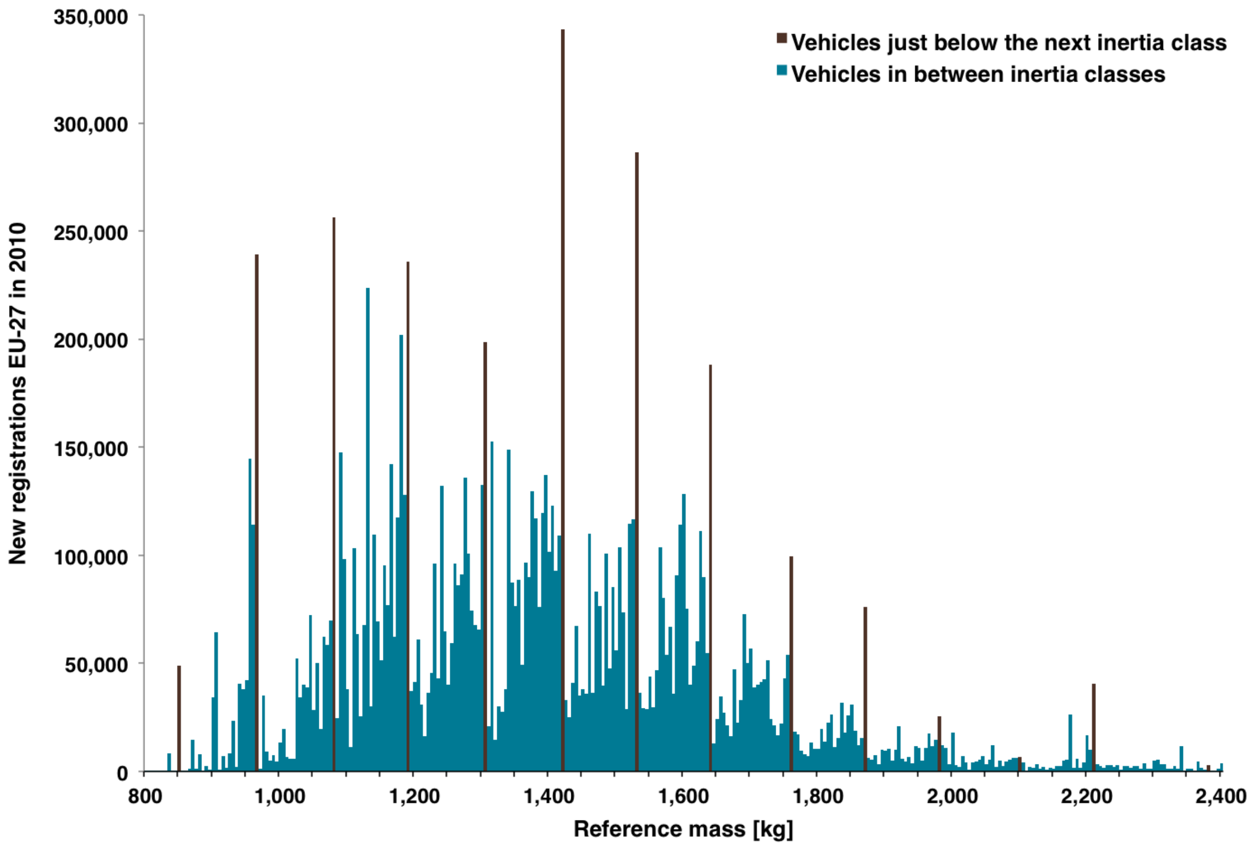

Figure 1. Distribution of new passenger car registrations by reference mass in EU-27 (2010)

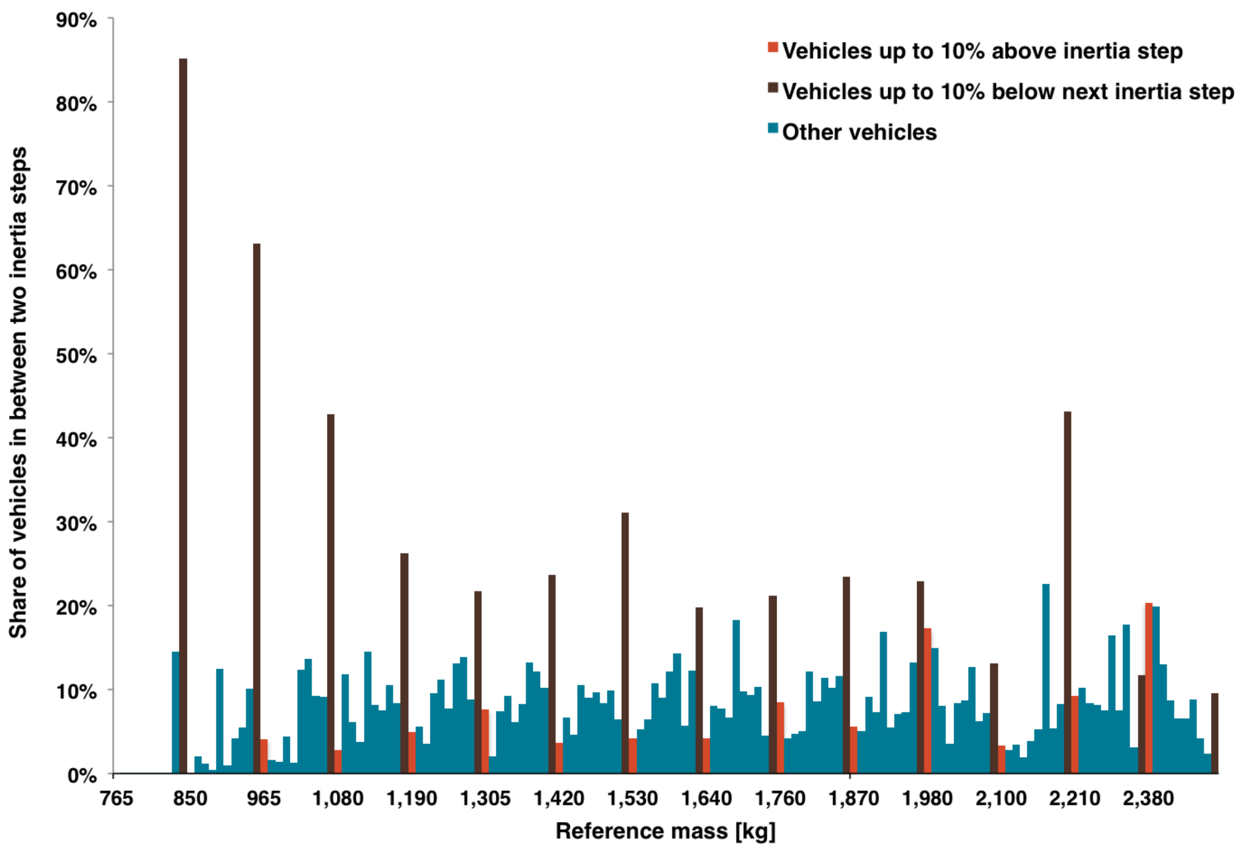

Figure 2. Distribution of new passenger car registrations by reference mass in EU-27 (2010) - Binned into 10 categories for each inertia class

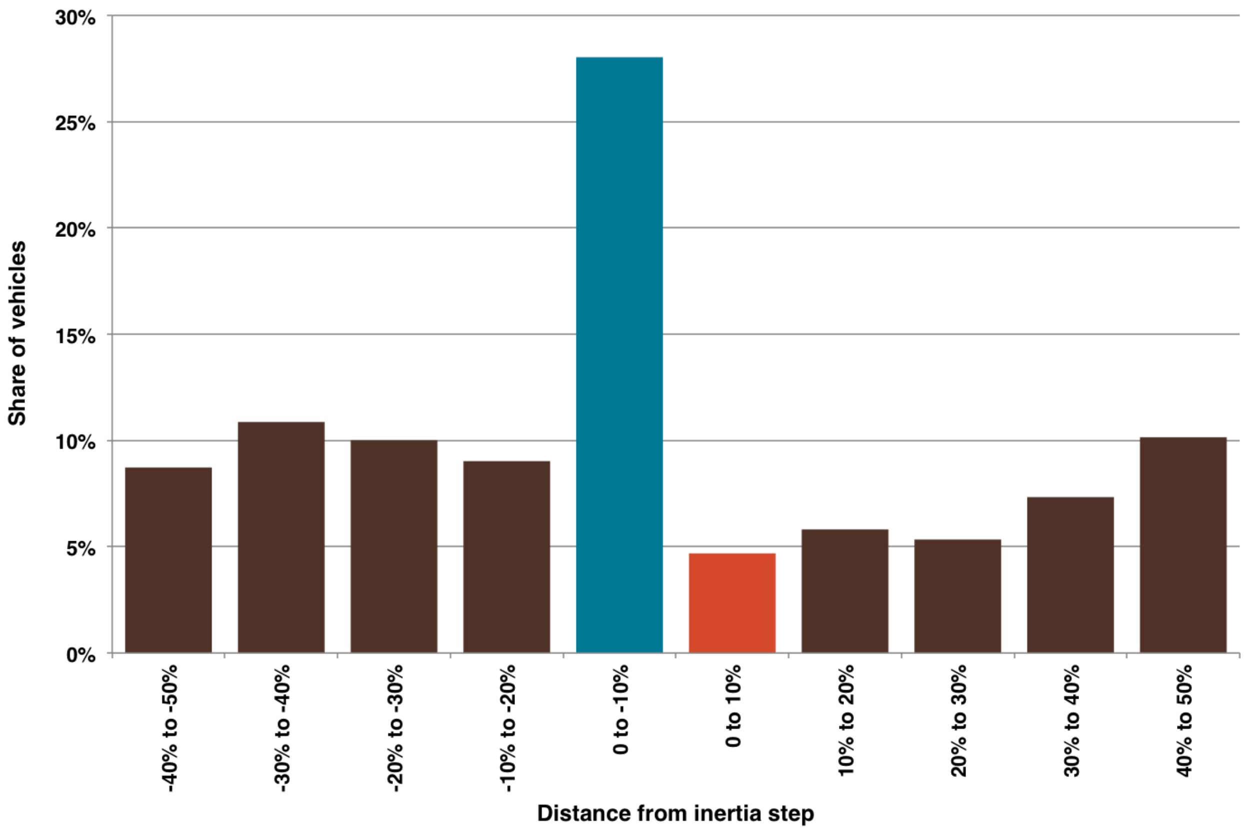

Figure 3. Distribution of new passenger car registrations by reference mass in EU-27 (2010). Binned into 10 categories for each inertia class and aggregated over all inertia classes

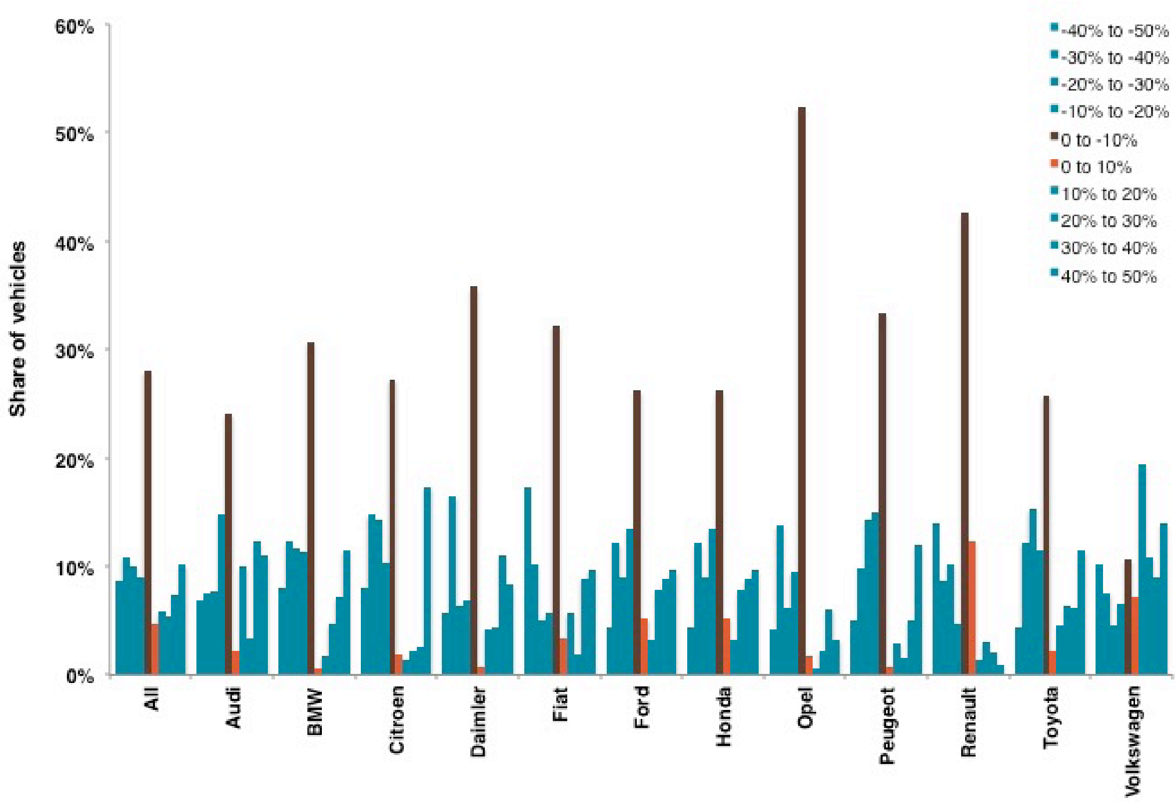

Figure 4: Distribution of new passenger car registrations by reference mass in EU-27 (2010) – Binned into 10 categories for each inertia class by vehicle brand

values in most cases will not substantiate for consumers under “real-world driving” conditions. Similarly, manufacturers can increase the weight of their vehicles without the according increase in CO_2 emissions being reflected in the vehicle test results, as long as the vehicle remains within the same inertia class. The effects of these shortfalls of the current inertia-class based system in terms of CO_2 ultimately depends on the respective inertia class but can amount to as much as 120 kg or 4-8 g/km CO_2 for typical classes.

In general, a test procedure should avoid any incentives for manufacturers to increase or decrease the weight of their vehicle for the sole purpose of achieving a more favourable test weight and/or avoid the situation where increases or decreases in vehicle weight are not adequately reflected in new test weights. As the results show, this is clearly not the case under the current inertia class based system.

Figure 4 adds another aspect to the analysis. Based on the European Commission data the level of vehicle weight optimization varies by vehicle brands, with the most significant effect for the Opel brand and the least effect, with a distribution that is most similar to a rectangular distribution, for the Volkswagen brand.[4]

Overview of alternative options

As illustrated above, the current inertia class based test procedure tends not to provide accurate emissions / fuel consumption values to consumers and imposes an incentive for manufacturers to change the weight of their vehicles for the sole purpose of achieving a more favourable test weight. With these shortfalls of the current inertia class based system in mind, and based on the fact that discrete inertia classes are no longer necessary for technical reasons, there are basically two options to move forward:

a) Continue with an inertia class based system but reduce the size of the discrete steps.

Smaller steps reduce the incentive for manufacturers to optimize their vehicles to achieve a more favourable test weight and thereby are more likely to result in accurate test values for emissions and fuel consumptions. In WLTP-DTP-LabProcICE-077 this option was described in more detail and a proposal was made to reduce the size of the inertia steps to 28.35 kg. Steps of this size are expected to be a reasonable compromise between accurate test values and a limited testing burden for manufacturers. However, while reducing the disadvantages of a step based system, this option does not eliminate the shortfalls entirely, as even a step-size of 28.35 kg will result in ranges of about 2 g/km CO_2 per inertia class step.

b) Move away from an inertia class based system and introduce a step-less approach. This approach has been discussed earlier in WLTP-DTP-LabProcICE-054.

The principle idea is to make use of the actual weight of a vehicle (= the weight of the empty vehicle plus a constant or a variable weight to reflect the weight of the driver, optional equipment etc.) for emissions / fuel consumption testing, instead of introducing discrete inertia steps. This is possible as modern dynamometers are able to simulate any vehicle weight, without the need to have discrete inertia masses. This approach b) will be discussed in more detail below, with a focus on how to reduce the testing burden for manufacturers and how to deal with potential test-to-test variations.

Evaluation of a step-less approach

Figure 5 is based on data kindly provided by Volkswagen and shows the range of weight within vehicle models. As it can be seen, vehicle weight can vary by several hundred kilograms within one vehicle model. Even within a group of vehicles with the same engine power and capacity there can be weight differences of up to 200 kg and more due to differences in the optional equipment. The European definition of vehicle variant allows for a difference in engine power of maximum 30% and engine capacity of maximum 20%, whereas two vehicles have to have identical power and capacity to be considered versions of the same vehicle variant (2007/46/EC). At the same time, approval for a vehicle type may be extended up to two inertia classes higher.

Typically, a vehicle model covers 3-5 inertia classes. Assuming all other parameters to be identical, this would mean that a manufacturer is usually required to run 3-5 vehicle tests per model to determine fuel consumption and CO_2 emissions. For criteria pollutant emissions the worst-case approach requires to only test the vehicle with the highest emissions. In reality most manufacturers run significantly more than the required vehicle tests per model.

Figure 5 also illustrates that most of the EU inertia steps represent a range in CO_2 emissions of about 4-7 g/km (for a detailed explanation of the CO_2 effects per weight change see WLTP-DTP-LabProcICE-077). This blurriness with respect to CO_2 is one of the reasons for the limited accurateness of CO_2 testing, and the resulting poor information for consumers under the current inertia class based system.

The most accurate way would be to test each vehicle individually with its actual weight, taking into account the optional equipment that is used in the vehicle. However, in order to limit the testing burden for manufacturers and also to ensure that there is no test-to-test variation due to small changes in weight (so that for example a heavier vehicle could be found to have less CO_2 emissions than a lighter vehicle) an alternative approach is suggested. This approach is based on four steps, illustrated in Figure 6.

This 4-step approach would allow to change from the current inertia class based system to a step-less approach without adding any significant testing burden to manufacturers, at the same time ensuring that there is no test-to-test variation. Also, it will be compatible with the definition of vehicle test weight that is being discussed as a separate topic in the WLTP-DTP group. From an international perspective, the approach is compatible with the European and Japanese system where it can be used to move away from the currently used discrete-step system. For the US, where it will most likely be required to keep the IWC classes, the smaller ETW classes can be substituted by a step-less

4 Please note that not all vehicle brands have been included in this assessment

approach.[5] The IWC classes, which are usually significantly larger in size, can be kept to group vehicles in step 2 of the above mentioned approach.

Proposal

For the next WLTP-DTP meeting in September 2011 it is proposed to have a discussion on the above mentioned step-less approach, with the goal to draft a thorough formal proposal for the next GRPE meeting in January 2012.

5 For an explanation of IWC and ETW classes, please see WLTP-DTP-LabProcICE-054 and 077

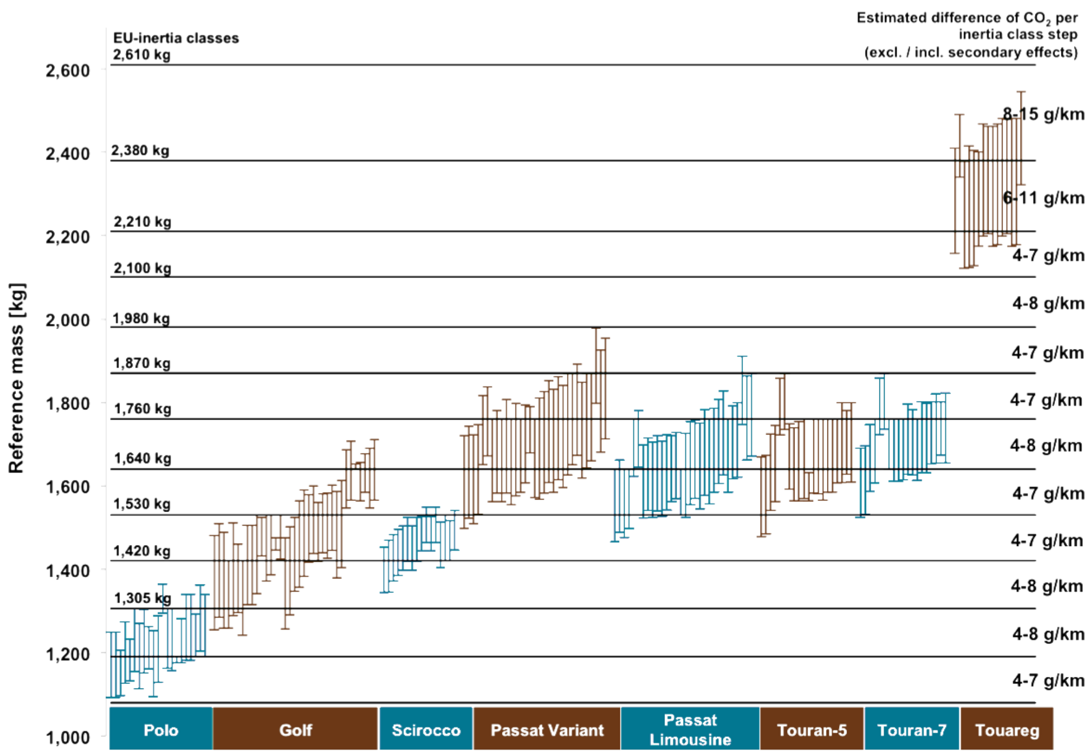

Figure 5: Vehicle weight ranges for some models of the Volkswagen passenger car fleet. Each line represents a vehicle version with the minimum and maximum reference mass, taking into account no/all available optional equipment

1. Adjust the mass of the empty vehicle to reflect constant and variable weights that are typically added to the mass of the vehicle. This can be all or a representative part of the optional equipment of a vehicle, the weight of the driver and passengers as well as additional equipment. The exact approach for this weight adjustment is outside the scope of this proposal but also discussed within the DTP working group. The resulting weight per vehicle will be called test mass for the purpose of this working paper.

2. Group a number of vehicles with the same attributes but different vehicle test mass. This could be done at the vehicle model level. Determine the vehicle variants with the highest and the lowest vehicle test mass as well as one additional vehicle that is closest to the median of the range. If there is only one version of a vehicle model, then this step is not applicable.

3. Test the vehicles with the highest and the lowest vehicle test weight as well as the one version close to the median for CO_2 emissions. Based on the measured CO_2 emissions a linear regression line can be determined, which is describing the physical relationship between weight and CO_2. This regression line would be vehicle model specific.

4. Making use of the linear regression line, the CO_2 emissions for all other vehicles within a model group can now be calculated. As the regression line is model specific it will result in an accurate representation of the CO_2 emissions per kg of additional weight, without the danger of having test-to-test variations. At the same time it will limit the testing burden of manufacturers, as it is only necessary to test a maximum of three vehicle versions to determine the regression line. For vehicle models with less than three versions it will not be possible to determine a regression line and the vehicle versions can be tested directly for CO_2.

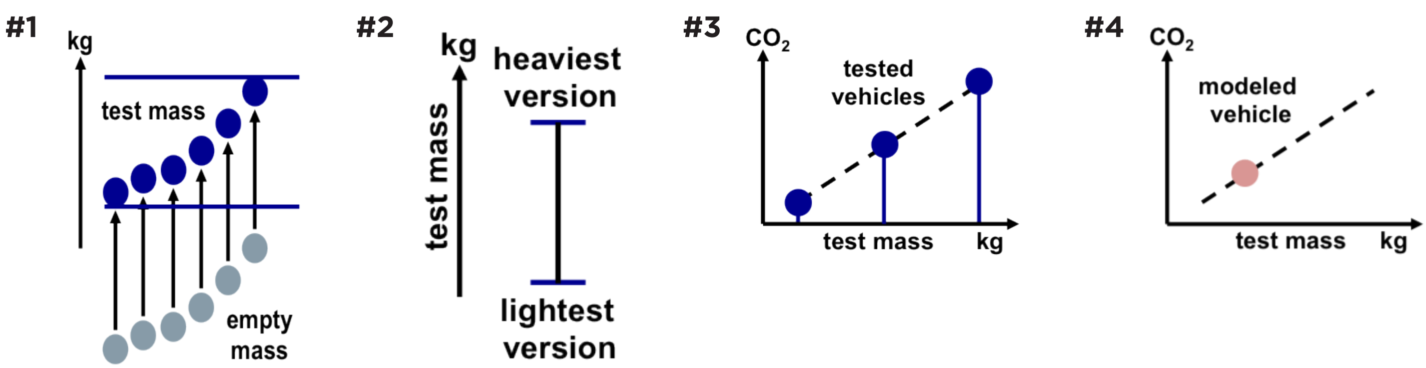

Figure 6. This 4-step approach would allow to change from the current inertia class based system to a step-less approach