International Council on Clean Transportation
Working Paper #4

Inertia Classes in Worldwide Harmonized Light Vehicles Test Procedure Development

Submission to the UNECE GRPE informal subgroup on the development of a worldwide harmonized light vehicles test procedure (WLTP-DTP) regarding the inertia classes to be used in the development of the WLTP

INTRODUCTION

The definition of vehicle weight used for testing procedures is an important decision when drafting the regulation on determining emission values under the WLTP. Currently, different inertia class systems are used in the US, EU and Japan.[1] A comparison of the current systems was compiled in WLTP-DTP-LabProcICE-011. The issue was discussed at the WLTP-DTP meeting on 12 January 2011 but no final decision was taken. The intention of this document is to provide a summary of the historical background, the current situation (with focus on the US and EU), and different options discussed for the future; together with a proposal for moving forward based on the compiled facts. It is our hope that this fact sheet will assist the group in having a well-informed discussion in the next WLTP-DTP and WLTP meetings.

HISTORICAL BACKGROUND

The weight of a vehicle on a chassis dynamometer was originally represented by hanging rotating inertia mass on the dynamometer, i.e. the rotating inertia of flywheels was used to simulate mass inertia of a vehicle. This approach required a) the use of discrete inertia classes (higher class = larger flywheel) and b) an upper limit for inertia mass (as otherwise flywheels would exceed the dynamometers capacity). Modern electronic dynamometers can simulate any vehicle weight and generally have much higher inertia limits. Due to this infinitely variable nature of modern test equipment, there is no longer a need for maintaining inertia classes and an upper limit for

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[1] In this document the term "inertia class" will be used in the context of general explanations or when referring specifically to European and Japanese regulations, in order to clearly differentiate from the US.

vehicle weight being tested. As it was discussed earlier in the group, electronic dynamometers are already widely in use in virtually all regions of the world.

GENERAL PRINCIPLES

When reviewing the currently applied systems as well as potential future options the following generally-agreed principles apply. The methodology used to account for vehicle weight in a dynamometer test should:

- Provide accurate emission / fuel consumption values, that reflect actual in-use vehicle weight as closely as possible.
- Avoid placing any unnecessary testing burden on manufacturers.
- Avoid incentives for manufacturers to increase or decrease the weight of their vehicle for the sole purpose of achieving a more favorable test weight and/or avoid the situation where increases or decreases in vehicle weight are not adequately reflected in new test weights.
- Include all light-duty vehicles on the market and impose equitable requirements on all of them.

STEP-BASED APPROACH

Currently, due to historical reasons, inertia classes are used in the US, EU and Japan. This means that vehicles within predefined mass ranges are grouped into classes and the mass for all vehicles within each group is simulated on the dynamometer by one inertia mass value. The steps used to group vehicles with similar weight vary for the different regions. In the US the size of the steps is 57 kg (125 lb) for lighter vehicles, 114 kg (250 lb) for vehicles above 4,000 lb ETW, and 228 kg (500 lb) for vehicles above 5,500 lb ETW. In the EU the step size is between 55 kg and 120 kg and all vehicles heavier than 2,210 kg are represented by an inertia mass of 2,270 kg.[2] For Japan the step-size is between 55 kg and 250 kg.[3] The plots at the end of this document illustrate the current situation in the US, EU and Japan. It should be noted that the definition of vehicle weight (reference mass / test vehicle basis) is slightly different for each region. In the US it refers to the weight of the vehicle including fuel plus 136 kg (300 lb). In the EU it is weight of the vehicle including fuel plus 100 kg and in Japan the weight of the vehicle plus 110 kg.[4]

A step-based approach with large steps tends to fall short of providing accurate emission values to consumers. Generally, a 10% change of vehicle mass is associated with an approximately 6.5% change in fuel consumption / CO_2 emissions if assuming engine downsizing while maintaining equivalent vehicle performance, and approximately 3.5% for small amounts of mass reduction without engine downsizing.[5] There-

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[2] 93/116/EC.

[3] For vehicles above 3,000 kg the step-size is 500 kg. See WLTP-DTP-LabProcICE-011.

[4] There are further differences with respect to the filling of the tank, including / excluding spare wheel / tools. For a summary of details please refer to e.g. Mercedes-Benz “Emissions, Fuel Economy” booklet.

[5] Actual values vary depending on vehicle type and driving situation. A study by FKA for the NEDC and HYZEM cycles finds values between 1.9-5.8% when not re-sizing the powertrain and 4.9-8.2% when re-resizing the powertrain (Forschungsgesellschaft Kraftfahrwesen mbH Aachen - FKA. Determination of weight elasticity of fuel economy for conventional ICE vehicles, hybrid vehicles and fuel cell vehicles. Report 55510, 2007). US EPA summarizes a number of existing

fore, a 60 kg weight range for a 1,000 kg vehicle (6% weight difference) corresponds to approximately 2.4-4.4 g/km CO_2. Similarly, a 200 kg weight range for a 2,500 kg vehicle (8% weight difference) accounts for approximately 5.1-9.5 g/km CO_2.[6]

Under a step-based approach there is an incentive to decrease vehicle weight to such an extent so that the next lower inertia class is reached. However, there is no incentive to decrease weight beyond the maximum allowable limit within an inertia class; in fact, there is no penalty to increasing weight as long as the vehicle remains within the same weight class. Clustering of vehicles in the upper end of the inertia classes can be the result. In the US it was decided to split the original IWC classes into ETW classes that are about half the size of the IWC classes, in order to reduce the impact of such a clustering of vehicles.[7]

The shortfalls of a step-based approach would be eliminated by use of the actual vehicle weight for testing. Modern electronically controlled dynamometers are capable of simulating any vehicle weight, which would eliminate any artificial encouragement to up-weight and would reward all down-weighting. Alternatively, the shortfalls could be substantially reduced by introducing narrower steps that would more accurately determine emission values and would be more neutral with respect to encouraging moderate up-weighting / discouraging moderate down-weighting. Defining the steps on a percentage basis (e.g. 2% of average vehicle weight in each class) would ensure similar ranges in g/km for each class (about 1-2 g/km in this example) and also take into account the potentially larger variability of varieties among heavier vehicles and trucks.

Under the US system, there are different testing requirements for emissions and for fuel economy. All emission and fuel economy testing is conducted using ETW classes, not IWC. IWC is only used for grouping vehicles for selection of fuel economy test vehicles and calculating model CAFE and label values.

For emissions testing, the regulations require testing of the "worst-case" vehicle for emissions. This usually means that the worst-case vehicle is selected from the vehicles within the heaviest ETW class and tested at this ETW. Redefining the ETW classes would not cause significant additional emission testing burden for manufacturers. If the heaviest vehicle increased in weight, this would create a new worst case configuration, and would trigger a re-testing. But this would only apply to the heaviest vehicle within the entire test group. All other vehicles could increase in weight without triggering a re-testing for emissions purposes, as long as they did not exceed the weight of the worst-case vehicle.

For fuel economy testing in the US, vehicles are grouped using the larger IWC classes, along with engine type and transmission type. Within each of these groups, the highest sales volume vehicle is required to be tested, using the narrower ETW class associated with the specific vehicle for the test weight. Thus, the definition of the IWC affects the minimum number of test vehicles and should therefore not be changed.

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studies and finds average values of 3.5% / 6.5% (EPA/NHTSA. Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards – Joint Technical Support Document. 2010).

[6] Baseline CO2 emissions of the vehicles for this calculation are assumed to be in line with the EU-2015 target value function: 0.0457*(m-1372)+130 (113 g/km and 182 g/km in this example).

[7] Similar effects of vehicle clustering in the context of fuel economy policies are demonstrated and discussed in (Sallee, J., Slemrod, J. Car Notches: Strategic Automaker Responses to Fuel Economy Policy. Energy Institute at Haas, University of California Berkeley, 2010).

ETW, on the other hand, can be redefined to more accurately reflect the actual weight of the test vehicle without any impact on the manufacturer testing burden.

In the EU minimum and maximum values for each vehicle variant are generally given. Introducing smaller inertia classes would therefore not necessarily change the number of tests needed. Only if the weight of the variants with the lowest / highest emissions would change over time and the vehicles would fall in a different class, would re-testing become necessary.

LINEAR STEP-LESS APPROACH

Given today's capabilities of modern testing facilities the use of a continuous linear system would allow each vehicle to be tested with exactly its actual weight. This would provide the most accurate emission values to inform consumers and as needed for precise emission regulation enforcement. Any potential systematic error caused by vehicles clustered at the upper end of an inertia class would be avoided. One could argue that the absence of distinct upper limits would not discourage strong weight-increase to the same extent as a step-based approach, but this argument has merit only if significant clustering of vehicle weight is assumed. A step-less approach provides the same disincentive for strong weight increases on average, plus it fully rewards any weight decrease and, therefore, encourages the use of lightweight-materials, even if the result is only a moderate weight decrease.

For practical reasons a step-less approach may need to be combined with an allowance for the size of weight change before it would trigger a new type approval. For example, it could be defined that if vehicle weight changed by less than 2% and there were no calibration or other changes, then new type approval would not be required. Similar to a step-based approach, only the worst-case vehicle (US) or the Min/Max variants (EU) would be affected. Therefore, the additional testing burden caused for manufacturers and supervising regulatory bodies is seen to be minor.

PROPOSAL FOR APPROACH TO BE TAKEN

Based on the above summary of the options available, a step-less inertia approach or an approach with small inertia class sizes are seen as most favorable. Concerns about increasing testing burdens should be taken serious, but can be resolved by maintaining current IWC classes for the US and slightly modifying existing regulations to introduce threshold limits for requiring new type approval. In fact, a step-less approach with a small (2% for example) threshold level would correspond to a step-based approach with small classes and would translate into CO_2 emission ranges of approximately 1-2 g/km. This is high enough to avoid significant increases in testing burden and yet small enough to provide meaningful data for consumers and regulators. Such a system would provide accurate emission values and avoid any systematic errors. Potential concerns regarding a not strong enough dis-incentive for weight-increase are not seen as valid and, in any case, could be addressed by supplemental regulation.[8]

It is also important to define a system that covers all types of passenger vehicles and does not incentivize weight changes for the sole purpose of achieving a more favorable test weight, i.e. there should not be any weight cut-offs, as it is the case in the current EU and US systems.

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[8] See for example plans of the European Commission to periodically adjust CO2 emission targets based on the development of the weight of the average vehicle fleet (2009/443/EC).

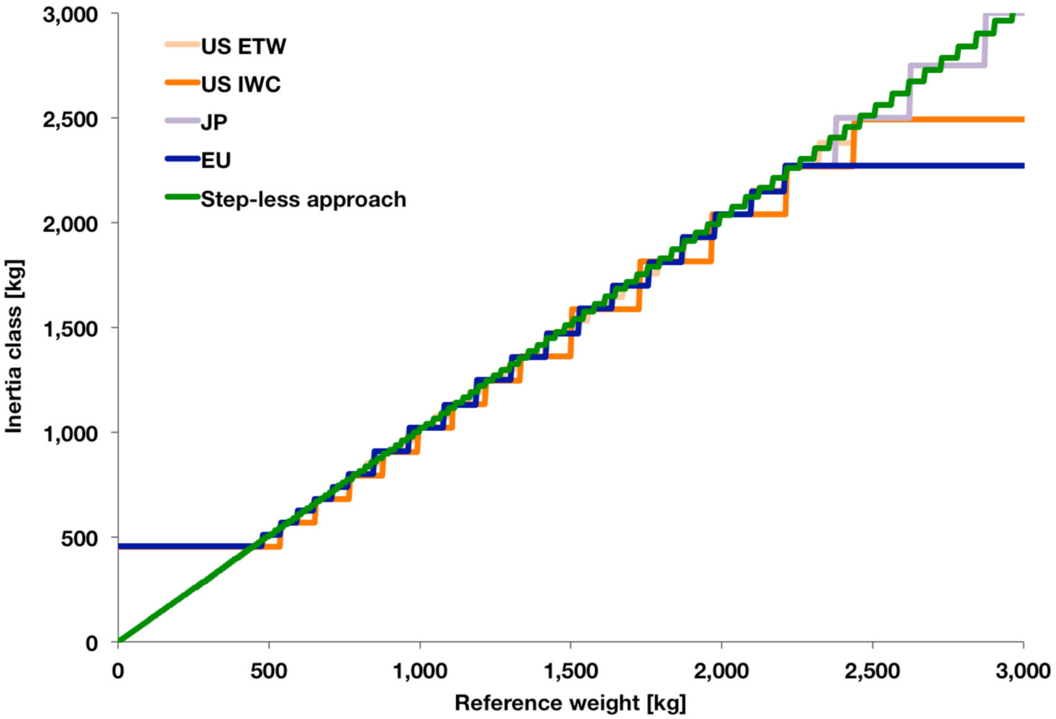

Figure 1. Overview on inertia class systems in US, EU and Japan today, including example for a step-less / small-step approach. Below 2,380 kg the EU and Japanese class system are identical and overlap in the chart. Both the US and EU system currently assume a constant single inertia mass value for vehicles above approximately 2,500 kg. For the step-less approach a 2% threshold limit for re-testing was assumed.

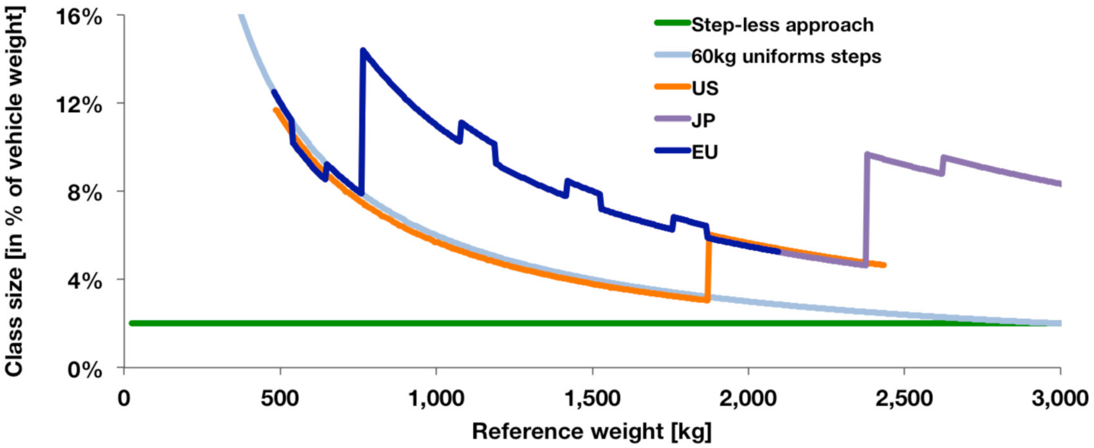

Figure 2. Size per inertia class, expressed in percentage of vehicle weight. Assuming a constant inertia class size in absolute kg values the percentage in relation to vehicle weight would decrease (for example, a 100 kg step would equal 10% for a 1,000 kg vehicle but only 5% for a 2,000 kg vehicle). However, varying step-sizes cause spikes in this type of illustration (for example in the EU system step sizes start with 60 kg, then drop to 55 kg and then go up to 110 kg for vehicles above 765 kg causing a significant spike from 8 to 14% based on vehicle weight). It should be noted that the EU and Japan lines overlap for vehicles below 2,380 kg. For the step-less approach a 2% threshold limit for re-testing was assumed, hence the inertia class size is constantly 2%. For comparison, a system with uniform 60 kg steps was included.

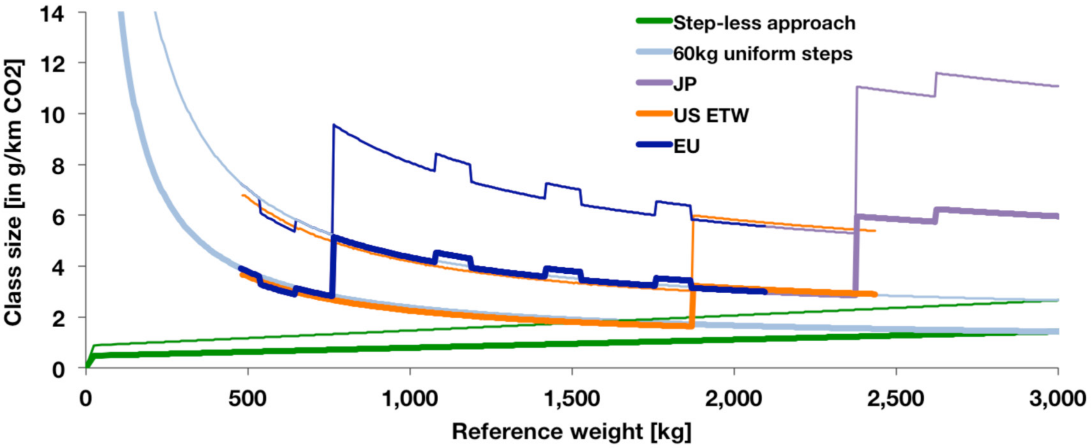

Figure 3. Size per inertia class, expressed in g/km CO$_2$. Assuming that a 10% in vehicle weight corresponds to approx. a 6.5% (weak lines) / 3.5% (bold lines) in CO$_2$ emissions the size of steps in g/km CO2 was calculated. In order to estimate the baseline emissions of a vehicle the EU-2015 target value function was used: 0.0457*(m-1372)+130. For example, a 10% step-size in terms of vehicle weight would correspond to a 6.5% change in CO$_2$ emissions. If the vehicle weight was 1,000 kg this would translate into roughly 115 g/km CO$_2$ according to the EU target line and 6.5% of this baseline emission level would be 7 g/km (4 g/km when assuming a 3.5% effect for a 10% vehicle weight reduction). The spikes seen in figure 2 are also reflected in this chart. Similarly, the lines for EU and Japan overlap for vehicles below 2,380 kg. The g/km equivalent under a step-less approach is increasing with vehicle weight as the baseline emission level increases with vehicle weight while the percentage effect per step remains constant. It should be noted that the resulting CO$_2$ values in this chart are estimates for illustration purposes but in reality will vary depending on vehicle type and region.

About the International Council on Clean Transportation

The International Council on Clean Transportation (ICCT), a nonprofit organization, is a central actor in efforts to reduce the negative impacts from all transportation sectors. Our goal is to protect public health, minimize climate change and improve quality of life for billions of people as the world's transportation infrastructure grows. Our work, focused in the top ten largest motor vehicle markets globally, falls into four general categories: (1) producing reports that identify international best practices, (2) working with consultants and organizations to lay the technical groundwork for future regulations, (3) working with government agencies directly to provide technical assistance in the drafting of regulatory documents and data collection and analysis, (4) holding public workshops as well as invite-only meetings among key regulators.

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