Commission Regulation (EU) 2017/1151 of 1 June 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Commission Regulation (EC) No 692/2008 (Text with EEA relevance)

Appendix 7a

Verification of overall trip dynamics

1. INTRODUCTION

This Appendix describes the calculation procedures to verify the overall trip dynamics, to determine the overall excess or absence of dynamics during urban, rural and motorway driving.

2. SYMBOLS, PARAMETERS AND UNITS

RPA Relative Positive Acceleration

Δ	— difference
$>$	— larger
$\geq$	— larger or equal
%	— per cent
$<$	— smaller
$\leq$	— smaller or equal
a	— acceleration [m/s^2]
a_i	— acceleration in time step i [m/s^2]
a_{pos}	— positive acceleration greater than 0,1 m/s^2 [m/s^2]
$a_{pos,i,k}$	— positive acceleration greater than 0,1 m/s^2 in time step i considering the urban, rural and motorway shares [m/s^2]
a_{res}	— acceleration resolution [m/s^2]
d_i	— distance covered in time step i [m]
$d_{i,k}$	— distance covered in time step i considering the urban, rural and motorway shares [m]
Index (i)	— discrete time step
Index (j)	— discrete time step of positive acceleration datasets
Index (k)	— refers to the respective category (t=total, u=urban, r=rural, m=motorway)
M_k	— number of samples for urban, rural and motorway shares with positive acceleration greater than 0,1 m/s^2
N_k	— total number of samples for the urban, rural and motorway shares and the complete trip
RPA_k	— relative positive acceleration for urban, rural and motorway shares [m/s^2 or kWs/(kg*km)]
t_k	— duration of the urban, rural and motorway shares and the complete trip [s]
T4253H	— compound data smoother
v	— vehicle speed [km/h]
v_i	— actual vehicle speed in time step i [km/h]
$v_{i,k}$	— actual vehicle speed in time step i considering the urban, rural and motorway shares [km/h]
$(v \times a)_i$	— actual vehicle speed per acceleration in time step i [m^2/s^3 or W/kg]
$(v \times a_{pos})_{j,k}$	— actual vehicle speed per positive acceleration greater than 0,1 m/s^2 in time step j considering the urban, rural and motorway shares [m^2/s^3 or W/kg].
$(v \times a_{pos})_{k}\text{-}[95]$	— 95th percentile of the product of vehicle speed per positive acceleration greater than 0,1 m/s^2 for urban, rural and motorway shares [m^2/s^3 or W/kg]

$\bar{v}_k$ — average vehicle speed for urban, rural and motorway shares [km/h]

3. TRIP INDICATORS

3.1. **Calculations**

3.1.1. *Data pre-processing*

Dynamic parameters like acceleration,
$v \times a_{pos}$
or RPA shall be determined with a speed signal of an accuracy of 0,1 % for all speed values above 3 km/h and a sampling frequency of 1 Hz. This accuracy requirement is generally fulfilled by signals obtained from a wheel (rotational) speed sensor.

The speed trace shall be checked for faulty or implausible sections. The vehicle speed trace of such sections is characterised by steps, jumps, terraced speed traces or missing values. Short faulty sections shall be corrected, for example by data interpolation or benchmarking against a secondary speed signal. Alternatively, short trips containing faulty sections could be excluded from the subsequent data analysis. In a second step the acceleration values shall be calculated and ranked in ascending order, as to determine the acceleration resolution
$a_{res} = (\text{minimum acceleration value} > 0)$
.

If
$a_{res} \leq 0{,}01\ \mathrm{m} / s^2$
, the vehicle speed measurement is sufficiently accurate.

If
$0{,}01\ \mathrm{m} / s^2 < a_{res}$
, data smoothing by using a T4253H Hanning filter shall be performed

The T4235 Hanning filter performs the following calculations: The smoother starts with a running median of 4, which is centred by a running median of 2. The filter then re-smoothes these values by applying a running median of 5, a running median of 3, and hanning (running weighted averages). Residuals are computed by subtracting the smoothed series from the original series. This whole process is then repeated on the computed residuals. Finally, the smoothed final speed values are computed by summing up the smoothed values obtained the first time through the process with the computed residuals.

The correct speed trace builds the basis for further calculations and binning as described in paragraph 8.1.2.

3.1.2. *Calculation of distance, acceleration and* $v \times a$

The following calculations shall be performed over the whole time based speed trace (1 Hz resolution) from second 1 to second t_t (last second).

The distance increment per data sample shall be calculated as follows:
$d_i = \frac{v_i}{3},6,\ i = 1 \text{ to } N_t$

where:

d_i	is the distance covered in time step i [m]
v_i	is the actual vehicle speed in time step i [km/h]
N_t	is the total number of samples

The acceleration shall be calculated as follows:

$a_i = (v_{i+1} - v_{i-1})/(2 \times 3{,}6), \mathrm{i} = 1 \text{ to } \mathrm{N_t}$

where:

a_i is the acceleration in time step i [m/s^2]. For $i = 1$: $v_{i-1} = 0$, for $i = N_t$: $v_{i+1} = 0$.

The product of vehicle speed per acceleration shall be calculated as follows:

$(v \times a)_i = v_i \times a_i \,/\, 3{,}6, \mathrm{i} = 1 \text{ to } \mathrm{N_t}$

where:

$(v \times a)_i$ is the product of the actual vehicle speed per acceleration in time step i [m^2/s^3 or W/kg].

3.1.3. *Binning of the results*

After the calculation of a_i and $(v \times a)_i$, the values v_i, d_i, a_i and $(v \times a)_i$ shall be ranked in ascending order of the vehicle speed.

All datasets with $v_i \leq 60 \text{ km} / h$ belong to the ‘urban’ speed bin, all datasets with $60 \text{ km} / h < v_i \leq 90 \text{ km} / h$ belong to the ‘rural’ speed bin and all datasets with $v_i > 90 \text{ km} / h$ belong to the ‘motorway’ speed bin.

The number of datasets with acceleration values $a_i > 0{,}1 \text{ m} / s^2$ shall be bigger or equal to 150 in each speed bin.

For each speed bin the average vehicle speed $\bar{v}_k$ shall be calculated as follows:

$\bar{v}_k = (\sum_i v_{i,k})/N_k, \mathrm{i} = 1 \text{ to } \mathrm{N_k}, \mathrm{k} = \mathrm{u,r,m}$

where:

N_k is the total number of samples of the urban, rural, and motorway shares.

3.1.4. *Calculation of* $v \times a_{pos-}[95]$ *per speed bin*

The 95[th] percentile of the

$v \times a_{pos}$
values shall be calculated as follows:

The
$(v \times a)_{i,k}$
values in each speed bin shall be ranked in ascending order for all datasets with
$a_{i,k} > 0{,}1 \text{ m} / s^2$
$a_{i,k} \geq 0{,}1 \text{ m} / s^2$
and the total number of these samples M_k shall be determined.

Percentile values are then assigned to the
$(v \times a_{pos})_{i,k}$
values with
$a_{i,k} \geq 0{,}1 \text{ m} / s^2$
as follows:

The lowest
$v \times a_{pos}$
value gets the percentile $1/M_k$, the second lowest $2/M_k$, the third lowest $3/M_k$ and the highest value
$M_k / M_k = 100 \%$.

$(v \times a_{pos})_{k\text{-}}[95]$
is the
$(v \times a_{pos})_{j,k}$
value, with
$j / M_k = 95 \%$.
If
$j / M_k = 95 \%$.
cannot be met,
$(v \times a_{pos})_{k\text{-}}[95]$
shall be calculated by linear interpolation between consecutive samples j and j+1 with
$j / M_k < 95 \%$
and
$(j + 1)/M_k > 95 \%$
.

The relative positive acceleration per speed bin shall be calculated as follows:
$$\text{RPA}_k = \sum_j \left(\Delta t \times (v \times a_{pos})_{j,k}\right) \Big/ \sum_i d_{i,k}, j = 1 \text{ to } M_k, i = 1 \text{ to } N_k, k = u,r,m$$

where:

RPA_k	is the relative positive acceleration for urban, rural and motorway shares in [m/s^2 or kWs/(kg*km)]
Δ_t	is a time difference equal to 1 second
M_k	is the sample number for urban, rural and motorway shares with positive acceleration
N_k	is the total sample number for urban, rural and motorway shares

4. VERIFICATION OF TRIP VALIDITY

4.1.1. *Verification of*

$v \times a_{pos-}[95]$

per speed bin (with v in [km/h])

If

$\bar{v}_k \leq 74{,}6\ \text{km} / h$

and

$(v \times a_{pos})_{k-}[95] > (0{,}136 \times \bar{v}_k + 14{,}44)$

is fulfilled, the trip is invalid.

If

$\bar{v}_k > 74{,}6\ \text{km} / h$

and

$(v \times a_{pos})_{k-}[95] > (0{,}0742 \times \bar{v}_k + 18{,}966)$

is fulfilled, the trip is invalid.

4.1.2. *Verification of RPA per speed bin*

If

$\bar{v}_k \leq 94{,}05\ \text{km} / h$

and

$\text{RPA}_k < (-0{,}0016 \times \bar{v}_k + 0{,}1755)$

is fulfilled, the trip is invalid.

If

$\bar{v}_k > 94{,}05\ \text{km} / h$

and

$\text{RPA}_k < (-0{,}025)$

is fulfilled, the trip is invalid.