1 INTRODUCTION

EUROPEAN COMMISSION
DG CLIMA

Brussels,
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Working document for the methodology drafting for the

CO_2 monitoring of HD vehicles

This document is an informal working document for the methodology of the CO_2 determination of HD vehicles and does not represent a final Commission Proposal.

The text represents a draft proposal for discussion in the expert group.

Document Status

Section	Status	Date
All	Draft	May, 15th 2014

Comments edited in this document by:

ACEA:	'RBICKEL', 'CHa', 'AH', 'HE', ‚PA';
JRC:	'g'
TÜV NORD:	'LES', 'HMR', 'LESS', 'NEN', 'TNG';
TU GRAZ:	RM

Yellow marked text indicates issues not finally decided. Comments are in the text for explanation of open work to support the next steps of the project.

CONTENT

1 INTRODUCTION

DEFINITIONS

Air drag or Air resistance	Means the force opposite the relative motion of an object moving through air;
Applicant or Manufacturer	Means the person or body who is responsible to the approval authority for all aspects of the type-approval or authorization process and for ensuring conformity of production. It is not essential that the person or body be directly involved in all stages of the construction of the vehicle, system, component or separate technical unit which is the subject of the approval process;
Auxiliary	Means a device providing additional support to a component or system;
Axle	Means a central shaft for a rotating wheel or gear;
Axle alignment	Means the geometrical setting of vehicles axles regarding the alignment parameters toe, (tandem axle) parallelism & perpendicularity, camber and caster.
VECTO-CSE Tool	Means the evaluation tool for the constant speed test (Constant Speed Evaluation Tool);
Cycle	Velocity and slope profile over distance to be followed by the simulated HDV
Dataset	Measurement data recorded over one valid measurement section.
Engine	Means the motive propulsion source of a vehicle for which type-approval as a separate technical unit, as defined in point 25 of Article 3 of Directive 2007/46/EC, may be granted;
Engine family	Means a manufacturers grouping of engines which, through their design as defined in Section 6 of Annex I of EC 582/2011, have similar exhaust emission characteristics; all members of the family shall comply with the applicable emission limit values;
Engine system	Means the engine, the emission control system and the communication interface (hardware and messages) between the engine system electronic control unit or units (hereinafter ECU) and any other powertrain or vehicle control unit;”
Gross vehicle weight (GVW)	The gross vehicle weight (GV) is the maximum operating weight of a vehicle as specified by the manufacturer
Measurement area	The measurement area consists of at least one measurement section and a stabilization section.
Measurement section	Each measurement section shall have a length of 250 m.

PTO (Power take off)	Means a device supplying power from the engine to perform external work, other than needed for auxiliaries;
Stabilization section	The first measurement section of a measurement area is preceded by a stabilization section (>100 m, length depending on the geometry of the track at the specific section) to stabilize the constant speed & constant torque.
Standard Body / Trailer / Semitrailer	Body, Trailer or Semitrailer with standardized specifications described in the Annex
Transfer case	A device that splits a vehicles engine power and directs it to the front and rear drive axles of a four-wheel drive vehicle. It is mounted behind the transmission and both front and rear drive shafts connect to it. It contains either gears or a chain drive system in which the power is distributed from the transmission to the axles. The transfer case will typically have the ability to shift between two-wheel drive, four-wheel drive high range, four-wheel drive low range and neutral.
Transmission	A device consisting at least of two shiftable gears, changing torque and speed with defined ratios;
VECTO	Means Vehicle Energy Consumption calculation Tool and is the simulation tool used for the calculation of the vehicle specific CO_2 value and provided by the European Commission

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FORMULA SYMBOLS AND INDICES

GENERAL

GVW_X	=	The actual gross vehicle weight for vehicle of class 1-3. (In the range of 7.5-16 tons) [t]
GVW_1	=	Lower limit of the GVW for vehicle classes 1-3: 7.5 tons [t]
GVW_2	=	Upper limit of the GVW for vehicle classes 1-3: 16 tons [t]
PL_{1-3}	=	Calculated Payload for vehicle classes 1-3, depending on GVW and vehicle application [t]
PL_A	=	Payload value depending on vehicle application specified in Table 4-3
PL_B	=	Payload value depending on vehicle application specified in Table 4-3
F_{res}	=	total driving resistance [N]
F_{roll}	=	rolling resistance [N]
F_{air}	=	air drag [N]
F_{acc}	=	acceleration resistance [N]
F_{grd}	=	gradient resistance [N]
F_{roll}	=	rolling resistance [N]
RRC	=	rolling resistance coefficient [-]
m	=	total vehicle mass [kg]
g	=	gravitational acceleration = 9.81 [m/s²]
α_S	=	slope [rad]
$s_{(i)}$	=	relative axle load [-]
$RRC_{ISO(i)}$	=	tyre RRC according to ISO 28580 [-]
m	=	vehicle mass plus loading [kg]
g	=	gravitational acceleration = 9.81 [m/s²]
$w_{(i)}$	=	number of tyres (4 if twin tyres, else 2) [-]
$FzISO_{(i)}$	=	tyre test load acc. to ISO 28580 (85% of max. load) [N]
γ	=	constant parameter = 0.9 [-]

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AIR DRAG

F_{air}	=	air drag [N]
C_d	=	air drag coefficient [-]
A_{cr}	=	cross sectional area of the vehicle [m²]
$\rho_{air,\ ref}$	=	air density at reference conditions 1.188 [kg/m³]
v_{veh}	=	vehicle velocity [m/s]
$C_{d(0)}$	=	drag coefficient in windless conditions (yaw angle β=0) [-]
$f_{cd}\ (v_{veh})$	=	vehicle speed dependent correction factor for cross-wind conditions [-]
$C_{d(0)}$	=	drag coefficient in windless conditions (yaw angle β=0) [-]
$f_{cd}\ (v_{veh})$	=	vehicle speed dependent correction factor for cross-wind conditions [-]
v_{wind}	=	average wind velocity for European conditions = 3 [m/s]
β	=	yaw angle, between air flow direction and driving direction [rad]
$v_{hms,avrg}$	=	average of vehicle speed per 10 s measurement section [km/h]
$v_{hm,avrg}$	=	1 s moving average of vehicle speed [km/h]
$T_{hms,avrg}$	=	average of T_{sum} per 10 s measurement section [Nm]
T_{sum}	=	T_L+T_R; sum of corrected torque values left and right wheel [Nm]
$T_{hm,avrg}$	=	1 s moving average of T_{sum} [Nm]
$v_{lms,avrg}$	=	average of vehicle speed per X_{ms} seconds measurement section [km/h]
$v_{lm,avrg}$	=	moving average of vehicle speed with X_{ms} seconds time base [km/h]
X_{ms}	=	time needed to drive 25 meter distance with low speed [s]
$T_{lms,avrg}$	=	average of T_{sum} per X_{ms} seconds [Nm]
T_{sum}	=	T_L+T_R; sum of corrected torque values left and right wheel [Nm]
v_{veh}	=	calibrated vehicle speed [km/h]
$v_{veh,CAN}$	=	vehicle speed from CAN front axle signal [km/h]

$f_{v,veh}$	=	calibration factor for vehicle speed [-]
$\bar{v}_{ref,avrg}$	=	average reference speed for all datasets of the calibration test (see 5.1.2.4 ii)
$\bar{v}_{veh,CAN,avrg}$	=	average CAN vehicle speed for all datasets of the calibration test
$v_{air,ic}$	=	instrument corrected air speed signal [m/s]
$v_{air,ar}$	=	air speed anemometer reading [m/s]
f_{vie}	=	proportional calibration factor from instrument calibration [-]
d_{vie}	=	constant calibration factor from instrument calibration [m/s]
f_{vpe}	=	speed position error correction factor [-]
$v_{veh,avrg}$	=	average vehicle speed during calibration test [m/s]
$v_{air,ic,1}$	=	average air flow speed after instrument correction during calibration test, measured in driving direction 1 [m/s]
$v_{air,ic,2}$	=	average air flow speed after instrument correction during calibration test, measured in driving direction 2 [m/s]
v_{UF}	=	air speed in undisturbed flow conditions [m/s]
f_{vpe}	=	speed position error correction factor [-]
$v_{air,ic}$	=	instrument corrected air speed signal [m/s]
β_{ic}	=	instrument corrected yaw angle signal [°]
β_{ar}	=	yaw angle anemometer reading [m/s]
f_{aie}	=	proportional calibration factor from instrument calibration [-]
d_{aie}	=	constant calibration factor from instrument calibration [°]
β_{ame}	=	angle misalignment error [°]
$\beta_{ic,1}$	=	average yaw angle for driving direction 1 [°]
$\beta_{ic,2}$	=	average yaw angle for driving direction 2 [°]
β_{UF}	=	yaw angle at undisturbed flow conditions [°]
β_{ic}	=	instrument corrected yaw angle signal [°]
β_{ame}	=	angle misalignment error [°]
f_{ape}	=	angle position error correction factor [-]
hv	=	vehicle height [m]

ha	=	installation height of anemometer above ground [m]
h	=	height above ground [m]
δ	=	atmospheric stability coefficient [-]
v_{windx}	=	wind speed in x-direction [km/h]
v_{windy}	=	wind speed in y-direction [km/h]
v_{air}	=	air speed [km/h]
T_L	=	corrected torque left wheel [Nm]
T_R	=	corrected torque right wheel [Nm]
T_{Lr}	=	torque meter reading left wheel [Nm]
T_{Rr}	=	torque meter reading right wheel [Nm]
f_{TLie}	=	torque meter left - instrument error correction factor [-]
f_{TRie}	=	torque meter right - instrument error correction factor [-]
f_{TLd}	=	drift correction factor left torque meter [Nm]
f_{TRd}	=	drift correction factor right torque meter [Nm]
F_{trac}	=	traction force [N]
T_L, T_R	=	corrected torque for left and right wheel [Nm]
n_{eng}	=	engine speed [rpm]
i_{gear}	=	transmission ratio of engaged gear [-]
i_{axle}	=	axle transmission ratio [-]
v_{veh}	=	vehicle speed [m/s]
$F_{trac,ref}$	=	traction force at reference air density [N]
F_{trac}	=	traction force at measurement conditions [N]
$\rho_{air,ref}$	=	air density at reference conditions 1.188 [kg/m³]
ρ_{air}	=	air density at measurement conditions [kg/m³]
$C_d(\beta_{avrg}) * A_{cr}$	=	average result for product of air drag coefficient and cross sectional area from constant speed tests comprising an average absolute yaw angle of β_{avrg}
$\Delta C_d * A_{cr}(\beta_{avrg})$	=	yaw angle correction applying the generic curve for $\Delta C_d * A_{cr}$ as a function yaw angle for the value of β_{avrg}. In this correction the applicable generic curve for the particular vehicle class and vehicle configuration (rigid or with trailer) shall be used.

ENGINE

BsFc	=	Brake specific fuel consumption [g/kWh positive engine work]
FCi	=	Sum of fuel interpolated for a WHTC-sub-cycle [g]
Wref x	=	Average positive reference power in WHTC sub-cycle x sub-cycle duration [kWh]
Σ FCmi	=	Sum of fuel measured in a WHTC-sub-cycle [g]
Wposx	=	Average positive power measured in WHTC sub-cycle x sub-cycle duration [kWh]
i	=	mission profile according to Table 5-2. For each vehicle class the corresponding mission profile is defined as default value. For some HDV classes more than one mission profile is allocated (see LOT 2 report and ACEA white book), thus more than one CF_{Tot-i} is computed

TRANSMISSION

$T_{l,in}$	=	Torque loss at the input shaft in Nm
T_{dx}	=	Drag torque at x rpm in Nm
N_{in}	=	Speed at the input shaft in rpm
f_T	=	1-η; η = efficiency
	=	f_T=0.01 for direct gear
	=	f_T=0.04 for indirect gears
T_{in}	=	Torque at the input shaft in Nm
T_{maxin}	=	Maximum allowed input torque in any gear of transmission in Nm (= max($T_{maxin,gear}$), where $T_{maxin,gear}$ is the maximum allowed input torque in *gear*, where *gear* = 1, 2, 3,…*top_gear*)
$T_{l,in}$	=	Torque loss on input shaft in Nm
T_{idle}	=	Drag torque from testing without load in Nm
n_{in}	=	Speed at the input shaft in rpm
f_T	=	1-η_T; η_T = efficiency (to be calculated)
	=	0.005 (η_T=0.995) for direct gear
T_{in}	=	Torque at the input shaft in Nm
η_T	=	Gear dependent efficiency [-]
$\eta_{m,splitter}$	=	Efficiency of the active splitter gear mesh = const. = 0.99 [-]

$\eta_{m,main}$ = Efficiency of the active main section gear mesh = const. = 0.99 [-]

η_{range} = Efficiency of the range section [-]
= const. = 0.998 for high range (direct)
= $\eta_{lowrange}$ for low range (see below)

$\eta_{bearings}$ = Efficiency of the bearings = const. = 0.998 [-]

$\eta_{m,ring}$ = Efficiency of the ring meshes of the range section = const. = 0.995 [-]

$\eta_{m,sun}$ = Efficiency of the sun meshes of the range section = const. = 0.99 [-]

z_{sun} = Number of teeth of the sun gearwheel of the range section [-]

z_{ring} = Number of the ring of the range section [-]

RETARDER

$T_{l,Ret,input/prop}$ = Retarder torque loss referred to the transmission input or propeller shaft in Nm

$n_{input/prop}$ = Speed of transmission input or propeller shaft in rpm

AXLE

$T_{l,in}$ = Torque loss at the input shaft in Nm

T_{d0} = Basis drag torque over the complete speed range [Nm]

f_T = 1-η; η = efficiency [-]

T_{in} = Torque at the input shaft in Nm

T_{loss} = torque loss of the axle [Nm]

T_{in} = Inlet torque [Nm]

i_{gear} = axle gear ratio [-]

T_{out} = Outlet torque [Nm]

AUXILIARIES

U = Unloaded – pumping oil without steering pressure demand

F = Friction – friction in the pump

B = Banking – steer correction due to banking of the road or side wind

S = Steering – steer pump power demand due to cornering and manoeuvring

P_{tot}	=	Total power demand [W]
P_U	=	Unloaded power demand [W]
P_F	=	Friction power demand [W]
P_B	=	Banking power demand [W]
P_S	=	Steering power demand [W]
CF_U	=	Correction factor unloaded [-]
CF_F	=	Correction factor friction [-]
CF_B	=	Correction factor banking [-]
CF_S	=	Correction factor steering [-]
P_{tot}	=	Total power demand [W]
P_{el}	=	Electrical power demand [W]
η_{alt}	=	Alternator efficiency [-]

CO_2 EMISSIONS OF HEAVY-DUTY VEHICLES

1 INTRODUCTION

1.1 This document is an informal working document to describe the methodology of the CO_2 determination for Heavy-Duty Vehicles (HDV) on basis of application specific mission profiles. It does not represent a final Commission proposal.

2 SCOPE

2.1 This Annex shall apply to motor vehicles of categories N2, N3 and M3 as defined in Annex II of Directive 2007/46/EC with a reference mass exceeding 7500 kg. The vehicle segmentation and exclusions from this regulation are listed in paragraph 2.1.

3 TECHNICAL APPROACH

3.1 The CO_2 certification procedure for HDV described in this handbook is based on a combination of vehicle specific component measurements and a standardized simulation approach of longitudinal vehicle dynamics.

3.2 The testing of components and the final simulation of the CO_2 value shall be verified in accordance with XXX (CoP not decided yet/ ex-post validation).

3.3 The applicant shall provide the data specified in Table 3-1:

Input Parameters				
No.	**Input File**	**Parameter**	**Type**	**Unit**
1	Job (.vecto)	Path to Vehicle File	string	-
2	Job (.vecto)	Path to Engine File	string	-
3	Job (.vecto)	Path to Gearbox File	string	-
4	Job (.vecto)	Aux - Input File / Technology (array)	string / sel	-
5	Job (.vecto)	Engine Start Stop - Enabled	bool	-
6	Job (.vecto)	Eco-Roll - On	bool	-
7	Vehicle (.vveh)	Vehicle Category	sel	-
8	Vehicle (.vveh)	Axle Configuration	sel	-
9	Vehicle (.vveh)	Curb Weight Vehicle	dec	[kg]
10	Vehicle (.vveh)	Max. Gross Vehicle Weight	dec	[t]
11	Vehicle (.vveh)	Drag Coefficient - Truck & Trailer	dec	[-]
12	Vehicle (.vveh)	Cross Sectional Area - Truck & Trailer	dec	[m²]
13	Vehicle (.vveh)	Drag Coefficient - Rigid	dec	[-]
14	Vehicle (.vveh)	Cross Sectional Area - Rigid	dec	[m²]
15	Vehicle (.vveh)	Axles / Wheels - Twin Tyres (array)	bool	-
16	Vehicle (.vveh)	Axles / Wheels - RRC ISO (array)	dec	[-]
17	Vehicle (.vveh)	Axles / Wheels - Fz ISO (array)	dec	[N]
18	Vehicle (.vveh)	Retarder - Mode	sel	-
19	Vehicle (.vveh)	Retarder - Ratio	dec	[-]
20	Vehicle (.vveh)	Retarder - Input File	string	-
21	Vehicle (.vveh)	Tire Dimension	sel	-
22	Retarder Loss Map	Retarder Speed (array)	dec	[1/min]
23	Retarder Loss Map	Loss Torque (array)	dec	[Nm]
24	Engine (.veng)	Make and Model	string	-
25	Engine (.veng)	Displacement	dec	[cm³]
26	Engine (.veng)	Idling Engine Speed	dec	[1/min]
27	Engine (.veng)	Path to .vfld (array)	string	-
28	Engine (.veng)	Assigned Gears (array)	string	-
29	Engine (.veng)	Path to Fuel Consumption Map (.vmap)	string	-
30	Engine (.veng)	WHTC Urban	dec	[g/kWh]
31	Engine (.veng)	WHTC Rural	dec	[g/kWh]
32	Engine (.veng)	WHTC Motorway	dec	[g/kWh]
33	Full load curve (.vfld)	Engine Speed (array)	dec	[1/min]
34	Full load curve (.vfld)	Max. Torque (Static full load) (array)	dec	[Nm]
35	Full load curve (.vfld)	Motoring Torque (array)	dec	[Nm]
36	FC map (.vmap)	Engine Speed (array)	dec	[1/min]
37	FC map (.vmap)	Torque (array)	dec	[Nm]
38	FC map (.vmap)	Fuel Consumption (array)	dec	[g/h]
39	Gearbox (.vgbx)	Make and Model	string	-
40	Gearbox (.vgbx)	Transmission Type	sel	-
41	Gearbox (.vgbx)	Axle & Gears - Ratio (array)	dec	[-]
42	Gearbox (.vgbx)	Axle & Gears - Loss Map or Efficiency (array)	string/dec	-/[-]
43	Torque Loss Map	Input Speed (array)	dec	[Nm]
44	Torque Loss Map	Input Torque (array)	dec	[Nm]
45	Torque Loss Map	Torque Loss (array)	dec	[Nm]

Table 3-1: Data to be provided by the applicant

3.3.1 The vehicle specific data shall be provided by the applicant in accordance with paragraph 4 of this regulation.

3.3.2 The transmission specific data shall be provided by the applicant in accordance with paragraph 5.3.1 of this regulation.

3.3.3 The axle specific data shall be provided by the applicant in accordance with paragraph 5.3.3 of this regulation.

3.3.4 The air resistance specific data shall be provided by the applicant in accordance with paragraph 5.1.2 of this regulation.

3.3.5 The rolling resistance / tyre specific data shall be provided by the applicant in accordance with paragraph 5.1.1 of this regulation.

3.3.6 The auxiliary specific data shall be provided by the applicant in accordance with paragraph 5.3.7 of this regulation.

3.3.7 The data specific to driver assistance functions shall be provided by the applicant in accordance with paragraph 5.3.8 of this regulation.

3.4 The provided data is used as input data for the simulation tool to calculate the application specific CO_2 emissions of the vehicle.

3.4.1 The simulation tool, named “VECTO” (Vehicle Energy Consumption calculation Tool), is provided by the European Commission, which is also responsible for the maintenance of the software and for updates of the tool according to updated regulations.

3.5 The resulting, specific CO_2 values are calculated in form of the following metrics:

i. Trucks: g/t-km, optional g/m³-km

ii. Buses/Coaches: g/passenger-km

3.6 The technical part of the CO2 declaration process is depicted in Fig. 3-1.

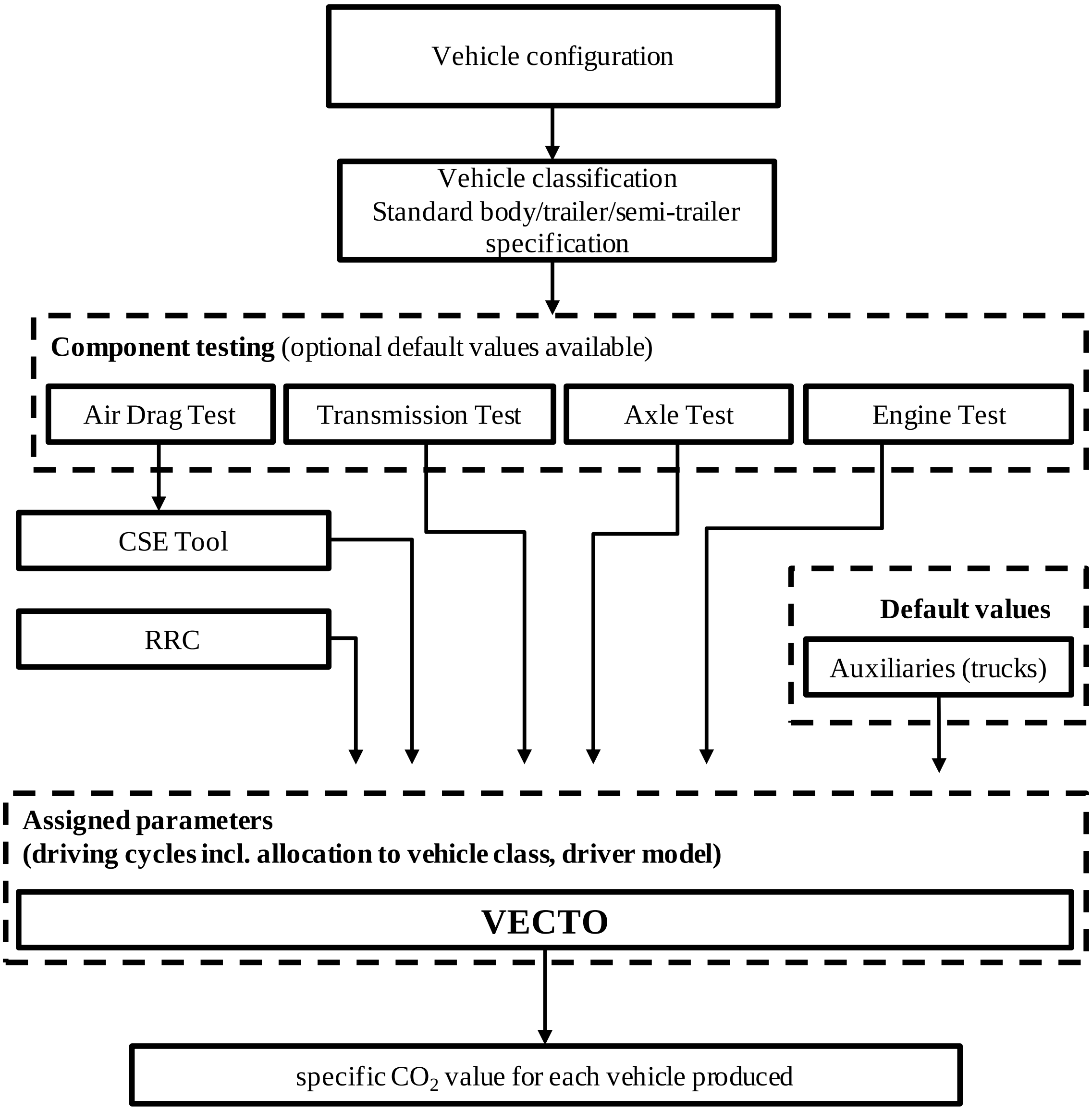

Fig. 3-1: Process scheme

4 VEHICLE SELECTION AND CYCLE ALLOCATION

4.1 VEHICLE SEGMENTATION

For trucks the vehicle shall be allocated to a vehicle segment in accordance with Table 4-1.

	Identification of vehicle class				**Segmentation** (vehicle configuration and cycle					Norm body allocation		
Axles	Axle configuration	Chassis configuration	Maximum GVW [t]	<-- Vehice class	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction	Standard body	Standard trailer	Standard semitrailer
2	*4x2*	*Rigid*	*>3.5 - 7.5*	*0* $^{**)}$		*R*	*R*			*B0*		
2	4x2	Rigid or Tractor	7.5 - 10	**1**		R	R			B1		
		Rigid or Tractor	>10 - 12	**2**	R	R	R			B2		
		Rigid or Tractor	>12 - 16	**3**		R	R			B3		
		Rigid	>16	**4**	R+T	R		R		B4	T1	
		Tractor	>16	**5**	T+S	T+S						S1
	4x4	Rigid	7.5 - 16	**6**				R	R	*(B3)*		
		Rigid	>16	**7**					R	*(B5)*		
		Tractor	>16	**8**					T+S			*(S1)*
3	6x2/2-4	Rigid	all weights	**9**	R+T	R		R		B6	T1	
		Tractor	all weights	**10**	T+S	T+S						S2
	6x4	Rigid	all weights	**11**					R	*(B7)*		
		Tractor	all weights	**12**					R			*(S2)*
	6x6	Rigid	all weights	**13**					R	*(B7)*		
		Tractor	all weights	**14**					R			*(S2)*
4	8x2	Rigid	all weights	**15**					R	*(B8)*		
	8x4	Rigid	all weights	**16**					R	*(B9)*		
	8x6 & 8x8	Rigid	all weights	**17**					R	*(B9)*		

R = Rigid & Body

R+T = Rigid & Body & Trailer *)

T+S = Tractor & Semitrailer

() =no (Cd*A) measurement, only vehicle weight and frontal area

*) Whether it is sufficient to simulate the truck-trailer combination based on cd*A for Rigid & Body or the full-vehicle test for aerodynamic drag has to be performed additionally with Rigid & Body & Trailer has to be clarified

**) Suitability of cycles and entire process for segment <7.5t GVW to be evaluated

Table 4-1: Vehicle segmentation *(for classes 6, 8, 13, 14, 15, 17 it is under discussion if and how these HDV shall be included, see test below)*

At the current state for the following applications it is discussed, if they shall be excluded from this methodology or if simplified options shall be allowed (e.g. generic Cd values):

i. Applications ≤ 7,5 tons

ii. Vehicles with 2 axles and 4x4 axle configuration with the following weights

  a. Rigid ≤ 16t

  b. Tractor > 16t

iii. Vehicles with 3 axles and 6x6 axle configuration

iv. Vehicles with 4 axles and 8x6 or 8x8 axle configuration

Following classes are under development:

v. Buses and coaches (to be added in next step)

vi. Applications with PTO (open)

4.1.1 Standard vehicle configurations

The CO_2 declaration is based on standard vehicle configurations. Therefore, 9 standard bodies, 3 standard semitrailers and 2 standard trailers are defined for trucks >7.5 t. These are specified in Annex 8.1. The allocation of standard bodies, trailers and semitrailers for the different vehicle segments shall be done in accordance with Table 4-1.

4.1.2 Non-standard vehicles / bodies / trailers / semi-trailers

t.b.d. /not part of pilot phase: Consideration of multi-stage type approval according to 2007/46/EC(framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles)

4.2 DRIVING CYCLES

For each application a separate test cycle is defined. The cycles are defined as slope profile versus distance and desired speed versus distance. See Annex 0.

4.2.1 Trucks

For trucks > 7,5t five specific cycles are defined:

i. Long haul

ii. Regional delivery

iii. Urban delivery

iv. Municipal utility

v. Construction

The cycle allocation is done in accordance with Table 4-1. For each combination of vehicle configuration and cycle a separate CO_2 calculation is performed within the simulation tool.

4.2.2 Buses and Coaches

For Buses and coaches five cycles are defined:

i. Three cycles for city class I (heavy urban, urban, sub-urban)

ii. One cycle for interurban class II

iii. Once cycle for coach class III

4.3 WEIGHT AND LOAD DEFINITION

For the pilot phase: The CO_2 declaration shall be performed without load, with a standard payload and with full payload in accordance with the the GVW based on the local legislation.

The CO_2 declaration shall be performed with a standard payload as specified in the following. The curb weight is defined in accordance with 2007/46/EC.

4.3.1 Trucks > 7,5t

A defined standard payload for each vehicle class shall be used as specified in Table 4-2. If the legal weight limit or OEM-released weight limit will be reached, the legal limit and/or OEM-limit shall be used. For each vehicle class and application within a class one standard payload value is defined.

	Identification vehicle configuration			Class	Cycle allocation Vehicle configuration /weight/axle loads				
	Axle Configuration	Chasis configuration	Weight	Vehicle Class	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
2 axles	4x2	Rigid +(Tractor)	7.5t- 10t	1	**Approach: Payload vs: GVW**				
		Rigid +(Tractor)	>10t- 12t	2					
		Rigid +(Tractor)	>12t- 16t	3					
		Rigid	>16t	4	R+T/C+ 14t	R/C + 4.4 t		R/C + 4.4 t	
		Tractor	>16t	5	T/C + 19.3 t	T/C + 12.9 t			
	4x4	Rigid	7.5t- 16t	(6)	excluded				
		Rigid	>16t	7					R/C +4.3 t
		Tractor	>16t	(8)	ecluded				
3 axles	6x2/2-4	Rigid	all	9	R+T/C+ 17.9 t	R/C + 7.1 t		R/C + 7.1t	
		Tractor	all	10	T/C + 19 t	T/C + 12.7 t			
	6x4	Rigid	all	11					R/C + 7.6 t
		Tractor	all	12					T/C + 12.1 t
	6x6	Rigid	all	(13)	excluded				
		Tractor	all	(14)					
4 axles	8x2	Rigid	all	(15)	excluded				
	8x4	Rigid	all	16					R/C +11.6 t
	8x6/8x8	Rigi	all	(17)	excluded				

T=Tractor+Semitrailer, R+T=Rigid+Body+Trailer, T+T=Tractor+Semitrailer+Trailer
R=Rigid+Body, D=2-axle "Dolly" for semitrailer
C= Curbweigh: OEMs truck+standard curbweightbodytrailer

Table 4-2: Vehicle class specific payloads (trucks > 7.5 t)

For vehicle classes 1-3 a calculated payload $PL_{1\text{-}3}$ shall be used. The exact payload depending on the actual gross vehicle weight GVW_X and the vehicle application shall be obtained from the following formula.

$$PL_{1-3} = \frac{PL_B - PL_A}{GVW_2 - GVW_1} * (GVW_X - GVW_2) + PL_B$$

where:

GVW_X = The actual gross vehicle weight for vehicle of class 1-3. (In the range of 7.5-16 tons) [t]

GVW_1 = Lower limit of the GVW for vehicle classes 1-3: 7.5 tons [t]

GVW_2 = Upper limit of the GVW for vehicle classes 1-3: 16 tons [t]

PL_{1-3}	=	Calculated Payload for vehicle classes 1-3, depending on GVW and vehicle application [t]
PL_A	=	Payload value depending on vehicle application specified in Table 4-3
PL_B	=	Payload value depending on vehicle application specified in Table 4-3

	Application A For regional delivery, urban delivery, municipal utility and construction application	Application B For long-haul application
GVW_1 [t]	7.5	
GVW_2 [t]	16	
PL_A [t]	1.25	1.9
PL_B [t]	4.6	6.9

Table 4-3: Payload for truck classes 1-3

The payload is automatically defined in the simulation tool based on the vehicle specific input provided by the applicant.

4.3.2 Buses and coaches

t.b.d.

5 CONSTITUENTS TESTING

For the verification of the CO_2 emissions specific data related to the following constituents shall to be provided by the applicant:

i. Driving resistances

ii. Engine

iii. Transmission

iv. Axle

v. Auxiliaries

5.1 DRIVING RESISTANCES

The driving resistance force that applies for a vehicle in a certain driving situation consists of the main components rolling resistance, air drag, acceleration resistance and gradient resistance.

$$F_{res} = F_{roll} + F_{air} + F_{acc} + F_{grd}$$

where:

F_{res}	=	total driving resistance [N]
F_{roll}	=	rolling resistance [N]
F_{air}	=	air drag [N]
F_{acc}	=	acceleration resistance [N]
F_{grd}	=	gradient resistance [N]

The rolling resistance and the air drag shall be determined as defined in 5.1.1.

5.1.1 Rolling resistance

The rolling resistance shall be calculated using a speed-independent rolling resistance coefficient RRC:

$$F_{roll} = RRC * m * g * \cos{(\alpha_S)}$$

where:

F_{roll}	=	rolling resistance [N]
RRC	=	rolling resistance coefficient [-]
m	=	total vehicle mass [kg]
g	=	gravitational acceleration = 9.81 [m/s²]
α_S	=	slope [rad]

The RRC shall be calculated as specified below. The index *i* refers to each single vehicle axle (truck and if applicable trailer).

$$RRC = \sum_{i=1}^{n} s_{(i)} * RRC_{ISO(i)} * \left(\frac{s_{(i)} * m * g}{w_{(i)} * F_{zISO(i)}}\right)^{\gamma-1}$$

where:

$s_{(i)}$	=	relative axle load [-]
$RRC_{ISO(i)}$	=	tyre RRC according to ISO 28580 [-]
m	=	vehicle mass plus loading [kg]
g	=	gravitational acceleration = 9.81 [m/s²]
$w_{(i)}$	=	number of tyres (4 if twin tyres, else 2) [-]
$FzISO_{(i)}$	=	tyre test load acc. to ISO 28580 (85% of max. load) [N]
γ	=	constant parameter = 0.9 [-]

5.1.1.1 For the calculation of the rolling resistance, the applicable tyre rolling resistance coefficient (RRC_{ISO}) for each one of the tyres installed on the vehicle and the related tyre test load F_ZISO shall be declared by the applicant. The declared RRC shall be measured in accordance with ISO 28580 and aligned in accordance with EC 1235/2011.

Remark: For CoP reasons the declared RRC has an additional allowance of +0.3 kg/ton. This needs to be discussed and incorporated in the CoP parts of the future directive.

5.1.1.2 The relative axle loads s(i) are specified in Table 5-1.

	Long-haul cycle				Other Cycles			
Vehicle Class	Relative axle load-axle 1	Relative axle load-axle 2	Relative axle load-axle 3	Relative axle load-axle 4	Relative axle load-axle 1	Relative axle load-axle 2	Relative axle load-axle 3	Relative axle load-axle 4
1	----	----	----	----	45%	55%	----	----
2	40%	60%	----	----	45%	55%	----	----
3	----	----	----	----	40%	60%	----	----
4	20%	30%	50% (TR)	----	45%	55%	----	----
5	20%	25%	55% (ST)	----	25%	25%	50% (ST)	----
(6)	----	----	----	----	----	----	----	----
7		----	----	----	50%	50%	----	----
(8)	----	----	----	----	----	----	----	----
9	20%	30%	15%	35% (TR)	35%	40%	25%	----
10	15%	10%	20%	55% (ST)	20%	10%	20%	50% (ST)
11	----	----	----	----	35%	35%	30%	----
12	----	----	----	----	20%	15%	15%	50% (ST)
(13)	----	----	----	----	----	----	----	----
(14)	----	----	----	----	----	----	----	----
(15)	----	----	----	----	----	----	----	----
16	----	----	----	----	25%	25%	25%	25%
(17)	----	----	----	----	----	----	----	----
	TR=Trailer, ST=Semitrailer							

Table 5-1: Axle load distribution

These values shall be used in the calculations according to 5.1.1

5.1.2 Aerodynamic drag / Constant speed test

The air drag resistance force shall be calculated by

$$F_{air} = C_d * A_{cr} * \rho_{air,ref} * \frac{{v_{veh}}^2}{2}$$

where:

F_{air} = air drag [N]

C_d = air drag coefficient [-]

A_{cr} = cross sectional area of the vehicle [m²]

$\rho_{air, ref}$ = air density at reference conditions[1] 1.188 [kg/m³]

v_{veh} = vehicle velocity [m/s]

The air drag coefficient C_d shall be determined by

$$C_d = C_{d(0)} * f_{cd}(v_{veh})$$

where:

$C_{d(0)}$ = drag coefficient in windless conditions (yaw angle β=0) [-]

$f_{cd}\,(v_{veh})$ = vehicle speed dependent correction factor for cross-wind conditions [-]

The correction factor for cross-wind conditions shall be calculated by

$$f_{cd}(v_{veh}) = \frac{1}{2\pi * {v_{veh}}^2} \int_0^{2\pi} \Delta c_{d(\beta)} * v^2_{air(v_{veh},\alpha)}\, d\alpha$$

where:

$C_{d(0)}$ = drag coefficient in windless conditions (yaw angle β=0) [-]

$f_{cd}\,(v_{veh})$ = vehicle speed dependent correction factor for cross-wind conditions [-]

and:

$$v_{air} = \sqrt{(v_{wind} * \cos\alpha + v_{veh})^2 + (v_{wind} * \sin\alpha)^2}$$

$$\beta = \arctan\left(\frac{v_{wind} * \sin(\alpha)}{v_{veh} + v_{wind} * \cos(\alpha)}\right)$$

where:

v_{wind} = average wind velocity for European conditions = 3 [m/s]

β = yaw angle, between air flow direction and driving direction [rad]

[1] Reference conditions are defined with 20°C, 1000mbar and 50% humidity

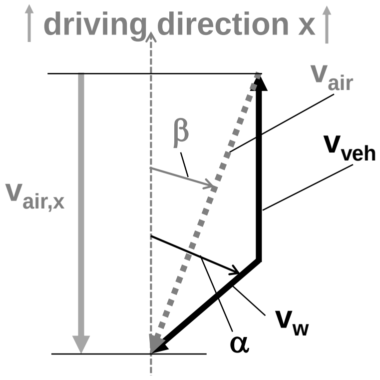

Fig. 5-1: Geometrics of air flow and vehicle speed

The product of air drag coefficient for zero yaw angle $C_d(0)$ by cross sectional area A_{cr} shall be determined by constant speed tests with direct torque measurement as described in 5.1.2.1. The measurement data of these tests shall be entered into the VECTO CSE-Tool which determines this value as input for VECTO.

5.1.2.1 Constant speed test

During the constant speed test the driving torque, vehicle speed, air flow velocity and yaw angle shall be measured at two different constant vehicle speeds (low and high speed) under defined conditions on a test track.

The execution of the constant speed testing shall meet the following requirements:

5.1.2.2 General requirements

5.1.2.2.1 Test track

i. Shape / Geometry of test track:
The test track shall be either a

a. Circuit track (drivable in one direction*):
with two measurement areas on each straight part, approximately parallel to each other (max. deviation: 20 degrees);
*at least for the misalignment correction of the mobile anemometer the test track has to be driven in both directions (>=5 laps)

or

b. Circuit track (drivable in both directions):
with one measurement area (or two with the above named max. deviation);

or

c. Straight line track (drivable in both directions):
with one measurement area;

Measurement influences due to the tire conditions on different test tracks are limited by general thresholds for tire temperature and pressure.

ii. Track surface

The test track surface shall be flat, clean, dry and free of obstacles or wind barriers that might impede the measurement of the running resistance (see viii). Its texture and composition shall be representative of current urban and highway road surfaces.

iii. Length of measurement area

The measurement area(s) consists of at least one measurement section and a stabilization section. Each measurement section shall have a length of 250 m. The first measurement section of a measurement area is preceded by a stabilization section (>100 m, length depending on the geometry of the track at the specific section) to stabilize the constant speed & constant torque (see thresholds for speed and torque variations). As the data evaluation considers separate data blocks for each measurement of 250 m length, useable measurement area lengths are multiples of 250 m added to the stabilization section length.

iv. Shape of the measurement section

The measurement section and the stabilization section have to be a straight line which can be passed without correctional steering.

v. Slope of the measurement section

Slope variations on the measurement section shall not lead to velocity and torque variations above the thresholds specified in 5.1.2.2.2.

vi. Side inclination of the measurement section

The side inclination shall not exceed 2 degrees.

vii. Selected standstill area

There shall be a selected standstill area on the test track where the vehicle can be stopped to perform the drift checks of the torque measurement system (torque sensors and or other relevant equipment e.g. amplifiers). This area shall have a maximum slope of t.b.d. percent and a maximum side inclination of 2 degrees. The location of the standstill section shall enable a coast down of the vehicle to a complete stop.

viii. Distance to roadside obstacles and vertical clearance

There shall be no obstacles within 5 m distance to both sides of the vehicle. Safety barriers up to a height of 1 m with more than 2.5 m distance to the vehicle are permitted. Any bridges or similar constructions over the measurement sections are not allowed. The test track shall have enough vertical clearance to allow the anemometer installation on the vehicle as specified in 5.1.2.4 vii.

5.1.2.2.2 Thresholds for variation of torque and vehicle speed

High speed test

Speed variation threshold [km/h]:

$$(v_{hms,avrg} - 0.3km/h) \leq v_{hm,avrg} \leq (v_{hms,avrg} + 0.3km/h)$$

where:

$v_{hms,avrg}$	=	average of vehicle speed per 10 s measurement section [km/h]
$v_{hm,avrg}$	=	1 s moving average of vehicle speed [km/h]

Torque variation threshold [Nm]:

$$(T_{hms,avrg} * 0.9) \leq T_{hm,avrg} \leq (T_{hms,avrg} * 1.1)$$

where:

$T_{hms,avrg}$	=	average of T_{sum} per 10 s measurement section [Nm]
T_{sum}	=	T_L+T_R; sum of corrected torque values left and right wheel [Nm]
$T_{hm,avrg}$	=	1 s moving average of T_{sum} [Nm]

Low speed test

Speed variation threshold [km/h]:

$$(v_{lms,avrg} - 0.15km/h) \leq v_{lm,avrg} \leq (v_{lms,avrg} + 0.15km/h)$$

where:

$v_{lms,avrg}$ = average of vehicle speed per X_{ms} seconds measurement section [km/h]

$v_{lm,avrg}$ = moving average of vehicle speed with X_{ms} seconds time base [km/h]

X_{ms} = time needed to drive 25 meter distance with low speed [s]

Torque variation threshold [Nm]:

$$(T_{lms,avrg} * 0.9) \leq T_{lm,avrg} \leq (T_{lms,avrg} * 1.1)$$

where:

$T_{lms,avrg}$ = average of T_{sum} per X_{ms} seconds [Nm]

T_{sum} = T_L+T_R; sum of corrected torque values left and right wheel [Nm]

5.1.2.2.3 Ambient conditions

The ambient conditions shall be measured with the equipment specified in 5.1.2.4.

i. The ambient temperature shall be below 25°C.

In case of ambient temperature exceeding 25 °C, measurements are permitted with the prior approval of the Type Approval Authority. In this case the tarmac conditions shall be documented in the Testing Logbook.
The temperature measurement shall be performed in the centre of one of the measurement sections (representative choice for all measurement sections) at begin and end of each low and high speed test section.

The tarmac temperature shall not exceed 50 °C. Measurement procedure to be defined.

[Example ECE-R.117: "Test surface temperature
The temperature sensor is to be positioned in a location where the temperature measured is representative of the temperature in the wheel tracks, without interfering with the sound measurement.

If an instrument with a contact temperature sensor is used, heat-conductive paste shall be applied between the surface and the sensor to ensure adequate thermal contact.
If a radiation thermometer (pyrometer) is used, the height should be chosen to ensure that a measuring spot with a diameter of ≥ 0,1 m is covered. […] Measurements shall not be made if the air temperature is below 5 °C or above 40 °C or the test surface temperature is below 5 °C or above 50 °C. "]

ii. Weather condition

The road surface during actual test & calibration shall be dry to provide comparable tyre temperatures and thereby rolling resistance coefficients.

iii. Wind

The wind conditions shall be within the following range:

Average wind speed: ≤ 5 m/s (Bft. 3) (average over the full measurement section)

Gust wind speed: ≤ 8 m/s (Bft. 4) (1 second moving average)

Average yaw angle (β) (average over full measurement section; after application of boundary layer correction):

≤ 3 degrees for high speed tests

≤ 5 degrees during anemometer calibration

Measurement data collected under conditions exceeding the above named limits will be excluded from the calculation.

5.1.2.3 Installation

i. The front height and slope of the truck and standard trailer / box shall be corresponding to a standard laden vehicle.

ii. The trailer setup shall be as defined in Annex 8.1.

iii. The minimal distance between cabin and semi-trailer / box shall be in accordance with manufacturer requirements.

iv. The vehicle payload is vehicle class specific defined in chapter 4.3.

v. The tyre inflation pressure shall be set to the maximum values within the manufacturer specification.

vi. The vehicle shall be equipped with tyres meeting the following demands:

- Minimum thread depth: 80 % of new tyre (or range of X - X mm)
- Lowest rolling resistance available for the application; (A-label ,alternatively B-label tyres)
- Maximum age: 3 years; DOT range for all tyres within 4 weeks
- Run-in: 1000 km with $v \geq 60$ km/h on test track or drum

  t.b.d. after pilot phase / RRC study

vii. The axle alignment shall be within the manufacturer specifications.

viii. Free rotation of wheels shall be given. Check disk brakes for inadvertent contact friction after instrumentation of the vehicle.

5.1.2.4 Measurement equipment

The calibration of all measuring instruments and systems shall be traceable to national (international) standards. The measuring instruments and systems shall comply with the linearity requirements given in Table 7 of Annex 4 to UN/ECE Regulation No 49.06. The linearity verification shall be done as required by internal audit procedures, by the instrument manufacturer or in accordance with ISO 9000 requirements. If not specified differently below, the accuracy of the measurement equipment shall be such that the above named linearity requirements are not exceeded.

i. Torque

The direct torque at all driven axles shall be measured with one of the following measurement systems:

a. Hub torque meter
b. Rim torque meter
c. Half shaft torque meter

Required accuracy: t.b.d.

ii. Vehicle speed

The vehicle speed shall be determined via the speed signal (CAN-bus front axle signal) which shall be calibrated based on a reference speed calculated by a delta-time from two fixed opto-electronic barriers (see iii) and GPS data (see iv). and the known length of the measurement section. The data used for calibration shall be recorded during the calibration test for the anemometer calibration (see vii). Alternatively the ground speed signal of a differential GPS (DGPS) system or more accurate measurement system is permitted for calibration of CAN vehicle speed.

Required accuracy: ± 0.2 km/h

iii. Opto-electronic barriers

The signal of the barriers is used for triggering begin and end of the measurement section and the check of the vehicle speed signal (see ii).

iv. GPS system

a. for vehicle speed and position measurements:

Required accuracy:	Speed:	< 0.18 km/h RMS
	Position:	< 10 cm CEP (Circle of Error Probable)
	Update rate:	100 Hz

b. optional for vehicle speed determination and calibration:

Differential GPS system (DGPS)

Required accuracy:	Position:	t.b.d.
	Update rate:	100 Hz

v. Stationary weather station

The system shall be a calibrated weather station with registration of ambient conditions (temperature, pressure, humidity).

Average measurement values shall be recorded at least once every 5 minutes.

Required accuracy:	Temperature:	± 1° C
	Humidity:	± 5 %RH
	Pressure:	± 1 mbar

Installation position:

The meteorological instrumentation should be positioned adjacent to one of the measurement areas.

vi. Temperature transducer for ambient temperature on vehicle

Required accuracy: Temperature: ± 1° C

Installation position:

Install the thermocouple on the pole of the mobile anemometer. The sensor shall be shielded by a tube (synthetic material, e.g. water pipe; diameter approx. 50 mm; length approx. 80mm), the tube middle axis parallel to the vehicle longitudinal axis. The installation height shall be 20 to 30 mm below the mobile anemometer.

vii. Mobile anemometer

System to measure air flow conditions (air flow velocity and yaw angle between total air flow and vehicle longitudinal axis).

Required accuracy: for air speeds in the range of 20 – 33 m/s and yaw angles in the range of 0 ±7 degrees

Air speed: ± 2 % of actual reading

Yaw angle: ± 1 degree

The mobile anemometer shall be installed on the vehicle in the prescribed position:

- X position: front face of the semi-trailer or box-body;
  bus/coach: 40 to 50 % vehicle length from front face
- Y position: plane of symmetry
- Z position: installment height above the vehicle shall be one third of total vehicle height

The alignment of the instrument shall be done as exact as possible using geometrical/optical aids. After installation the misalignment of the instrument shall be determined to enable the error correction during the data processing.

Misalignment determination:

A possible misalignment of the anemometer shall be determined by calibration tests on the proving ground. These tests shall be included in the warm-up phase. The test vehicle shall pass one measurement section for at least 5 times in both driving directions. The ambient conditions shall meet the specified requirements for the testing. The thus recorded anemometer data will be used by the VECTO-CSE tool to calculate the misalignment error.

Blowertest:
t.b.d., if pilot phase shows a need for this test;
"*the instrument error (angle and speed) shall be determined by blower testing"*

Zero air speed check:
Once installed on the vehicle and after the completion of the tests the anemometer's signal should be checked over zero air speed conditions preferably by isolating the anemometer from external environment. The average air speed recorded over zero air speed conditions shall not exceed 0.t.b.d. m/sec.

The anemometer shall be calibrated in a specified facility in accordance with the zero air speed and wind tunnel test procedures described in ISO 16622. A focus shall be put on the air speed range of 20 to 33 m/s and a small β-range of ±7 °.

The correction factors for the individual instrument error determined in the calibration process will be applied to the measured data by the VECTO-CSE tool according to the method as described in 5.1.2.8.

viii. *For pilot phase only:* Temperature transducer for tyre temperatures

Required accuracy: Temperature: ± 1 °C

Monitor the tyre shoulder temperature of tractor and semi-trailer tyres with external pyrometers.

Sensor installation position: The pyrometer shall be mounted as specified by the instrument manufacturer, measuring the temperatures of the inner tyre shoulder on each axle.

ix. Pressure transducer for tyre pressure

Required accuracy: Pressure: ± 0.1 bar

Use internal tyre pressure sensors.

x. CAN-bus signal recorder

The device shall be capable to read and record the vehicle CAN-bus signals.

xi. *For pilot phase only*: Mobile fuel meter to measure fuel consumption

Measurement of the instantaneous fuel flow shall be done by systems that preferably measure mass directly such as the following:

a. mass flow sensor;

b. fuel weighting;

c. Coriolis meter;

The fuel flow measurement system shall have the following:

- an accuracy of ± 2 % of the reading or ± 0.3 % of full scale whichever is better;
- a precision of ± 1 % of full scale or better;
- a rise time that does not exceed 5 s;

The fuel flow measurement system shall meet the linearity requirements of Section 9.2 and Table 7 of Annex 4 to UN/ECE Regulation No 49.06.

Precautions shall be taken to avoid measurement errors. Such precautions shall at least include the following:

- the careful installation of the device according to the instrument manufacturers' recommendations and to good engineering practice;
- flow conditioning as needed to prevent wakes, eddies, circulating flows, or flow pulsations that affect accuracy or precision of the fuel flow system;
- account for any fuel that bypasses the engine or returns from the engine to the fuel storage tank.

5.1.2.5 Measurement signals and data recording

The following table shows the requirements for the measurement data recording and the preparatory data processing for the input into the VECTO-CSE tool. A detailed description of the requested data formats, the input files and the evaluation principles can be found in the technical documentation of the VECTO-CSEtool. The data processing shall be applied as specified in 5.1.2.8.

Signal	Column identifier	Unit	Measurement rate	Remarks	Input CSE-tool
Vehicle class code	-	[-]	-	01 - 16	**Vehicle data file**
Vehicle configuration		[-]		0 = rigid; 1 = truck/tractor&trailer	
Vehicle test mass		[kg]		Actual mass during measurements	
Wheels inertia		[kg m^2]		Rotational inertia of all wheels	
Axle ratio		[-]		Axle transmission ratio	
Gear ratio high speed		[-]		Transmission ratio of gear engaged during high speed test	
Gear ratio low speed		[-]		Transmission ratio of gear engaged during low speed test	
Anemometer height		[m]		Height above ground of the measurement point of installed anemometer	
Vehicle height		[m]		Maximum vehicle height	
Vehicle width		[m]		Vehicle width (without side mirrors)	
Time	<t>	[s] since daystart	-	-	**Ambient conditions**
Ambient temperature	<t_amb_stat>	[°C]	higher than 1 averaged value per 5 minutes	Stationary weather station	
Ambient pressure	<p_amb_stat>	[mbar]		Stationary weather station	
Relative air humidity	<rh_stat>	[%]		Stationary weather station	
Trigger signal used	-	[-]	-	1 = trigger signal used; 0 = no trigger signal used	**Measurement section configuration**
Measurement section ID		[-]		user defined ID number	
Driving direction ID		[-]		user defined ID number	
Heading		[°]		Heading of the driving direction	
Length of the measurement section		[m]		-	
Latitude start point of section		[mm.mm]		standard GPS: minimum 4 digits after decimal separator; DGPS: minimum 5 digits after decimal separator	
Longitude start point of section					
Latitude end point of section					
Longitude end point of section					

continued

Signal	Column identifier	Unit	Measurement rate	Remarks	Input CSE-tool
Time	<t>	[s] since day start	100 Hz	rate fixed to 100Hz; time signal used for correlation with weather data and for check of frequency	**Measurement data file (fixed data input rate: 100 Hz)**
(D)GPS latitude	<lat>	[mm.mm]	≥ 20 Hz	standard GPS: minimum 4 digits after decimal separator; DGPS: minimum 5 digits after decimal separator	
(D)GPS longitude	<long>	[mm.mm]	≥ 20 Hz		
(D)GPS heading	<hdg>	[°]	≥ 20 Hz		
(D)GPS velocity	<v_veh_GPS>	[km/h]	≥ 20 Hz	not used in analysis if opto-electronic barriers are used	
Vehicle velocity	<v_veh_CAN>	[km/h]	≥ 20 Hz	raw CAN bus front axle signal	
Air speed	<v_air>	[m/s]	4 Hz	raw data (instrument reading)	
Inflow angle (beta)	<beta>	[°]	4 Hz	raw data (instrument reading)	
Engine speed	<n_eng>	[rpm]	≥ 20 Hz	-	
Torque meter (left wheel)	<tq_l>	[Nm]	≥ 20 Hz	primary torque calibration (y=kx+d) to be done in data capturing system (i.e. before import into VECTO CSE)	
Torque meter (right wheel)	<tq_r>	[Nm]	≥ 20 Hz		
Ambient temperature on vehicle	<t_amb_veh>	[°C]	10 Hz		
Trigger signal	<trigger>	[-]	100 Hz	optional signal; required if measurement sections are identified by opto electronic barriers (option "trigger_used=1")	
Tyre temperature	<t_tire>	[°C]	≥ 1/3min	average value	
Tyre pressure	<p_tire>	[bar]	≥ 1/3min	average value; optional signal	
Fuel mass flow	<fc>	[kg/h]	≥ 20 Hz	optional signal	
Validity	<valid>	[-]	-	optional signal (1=valid; 0=invalid);	
-	-	-	-	optional file	**Altitude file**
-	-	-		altitude profile of the measurement sections	

Table 5-1: Measurement data

5.1.2.6 Test procedure

The constant vehicle speed test shall be conducted with a maximum velocity span between the measurement of mechanical resistance (low speed) and total running resistance (high speed).

The target speed of the low speed testing shall be a constant velocity of 10 - 15 km/h.

The target speed of the high speed testing shall be a constant velocity of:

Truck:	85 - 90 km/h
Citybus:	85 km/h
Coach:	90 km/h
Construction vehicles:	85 - 90 km/h or speed 5 km/h below maximum possible speed (if maximum speed is below 85 km/h)

The average vehicle speed recorded in each dataset[2] shall not deviate more than XXX km/h from the relevant target speed.

The vehicle speed shall meet the speed variation thresholds (see 5.1.2.2.2) to be considered as constant.

The testing shall be performed according to the following sequence:

i. Install the torque meters on the driven axles of the test vehicle and check the installment and signal data according to the manufacturer specification.

ii. Check the drive-wheels for proper rotation with installed torque meters and half shafts (wheels off the ground; manually rotating the wheel; without heavy points).

iii. Documentation of relevant general vehicle data for the Testing Logbook (see 5.1.2.7).

iv. For the calculation of an acceleration correction (by the VECTO-CSE tool), the actual vehicle weight shall be noted. Therefore, measure the total mass of the vehicle or if applicable compute the mass with the values of the previous measurement and the fuel consumption. The actual vehicle weight can be calculated based on the last weighing by

- reducing the mass by 0.25 kg per meanwhile driven kilometer
- adding 100 kg per additional vehicle occupant
- adding 0.83 kg per each additionally tanked liter of fuel

[2] A „dataset" refers to the data recorded during a single measurement section.

Document the actual vehicle mass in the Testing Logbook (see 5.1.2.7).

v. Check tyres for the maximum allowable inflation pressure.

vi. Prepare the opto-electronic barriers at the measurement section(s) (if applicable).

vii. Mount the mobile anemometer on the vehicle and control the installment, position and orientation. A calibration test has to be performed during the warm-up phase. (see 5.1.2.4 vii)

viii. Check the data registration of all relevant measurement signals.

ix. Start engine to pre-condition the vehicle (idling without parking brake).

x. Check the vehicle setup regarding the height and geometry. Adjust the height of the semi-trailer to the target value if necessary.

xi. With rim torque meters:

Lift the instrumented axle and perform the drift-zeroing of the torque meters. Document the time of zeroing in the Testing Logbook.

xii. Warm-up phase

Drive 90 minutes at the high speed to assure that the tyres reach a constant pressure and temperature level and the powertrain reaches a constant coolant and oil temperature level.

During warm-up phase: Drive at least 5 times through one of the measurement sections in each direction for the determination of the misalignment and position error of the mobile anemometer. (see 5.1.2.4 vii)

xiii. With hub or shaft torque meters:

Bring the vehicle to a standstill on the selected standstill area (see 5.1.2.2.1 vii) of the test track. The vehicle shall be slowed down carefully and rolled out for the last meters, with free clutch / neutral gear and engine switched off. Perform the zeroing of the amplifier reading of the torque meters.

The standstill phase shall not exceed 1 minute. Drive another warm-up phase for at least 2 km after the standstill phase.

xiv. First low speed test

Perform the first measurement at the low speed directly before the high speed test. It shall be ensured that:

a. the driving speed is constant at least for the measurement section and the preceding stabilization section;

b. the vehicle is driven through the measurement section along a straight line without steering;

c. the amount of recorded measurement sections (of 250 m length each) leads to at least 1 valid dataset for each combination of measurement section and driving direction as driven in the high speed test for the data processing;

d. the begin and end of the measurement section is clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system;

The average RRC values determined before and after the high speed test shall not differ more than ± 0.3 kg/ton. Otherwise the complete test shall be repeated.

xv. High speed test

Perform the measurement at the high speed directly after the first low speed test and minimum 2 minutes driving at high speed. It shall be ensured that:

a. the driving speed is constant at least for the measurement section and the preceding stabilization section;

b. the vehicle is driven through the measurement section along a straight line without steering;

c. an equal amount of measurement sections is driven in both headings; e.g.: either enough laps on an one-way circuit track with two measurement areas or an equal amount of measurements driven in each direction on a circuit track or straight line track with one measurement area;

d. the amount of recorded measurement sections (of 250 m length each) leads to at least 2 valid datasets for defined combination of measurement section and driving direction for the data processing;

e. the begin and end of the measurement sections is clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system;

xvi. Low speed test

Perform the second measurement at the low speed directly after the high speed test. It shall be ensured that:

a. the driving speed is constant at least for the measurement section and the preceding stabilization section;

b. the vehicle is driven through the measurement section along a straight line without steering;

c. the amount of recorded measurement sections (of 250 m length each) leads to at least 1 valid dataset for each combination of measurement section and driving direction as driven during the high speed test for the data processing;

d. the begin and end of the measurement sections is clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system;

xvii. Drift check of torque meters

For the drift check of the torque meters, one of the following procedures shall be applied:

a. Coast down:

Bring the vehicle to a standstill on the selected standstill area of the test track. The vehicle shall be slowed down carefully and coasted down for the last meters, with free clutch / neutral gear and engine switched off.

b. Axle lift:

Lift the instrumented axle(s) off the ground.

Record the signals of all torque meters for a minimum sequence of 30 seconds. The drift of each torque meter shall be less than t.b.d. Nm. Exceeding this limit leads to invalid measurement sequences.

xviii. General checks

- Check the axle/wheel bearings for overheating. Measurement shall be done with e.g. a hand-held infrared thermometer at the start of each measurement campaign and after exchanging the test vehicle/trailer.

- Re-check the vehicle configuration. Note any differences in height of the box/semi-trailer, etc. in the Testing Logbook.

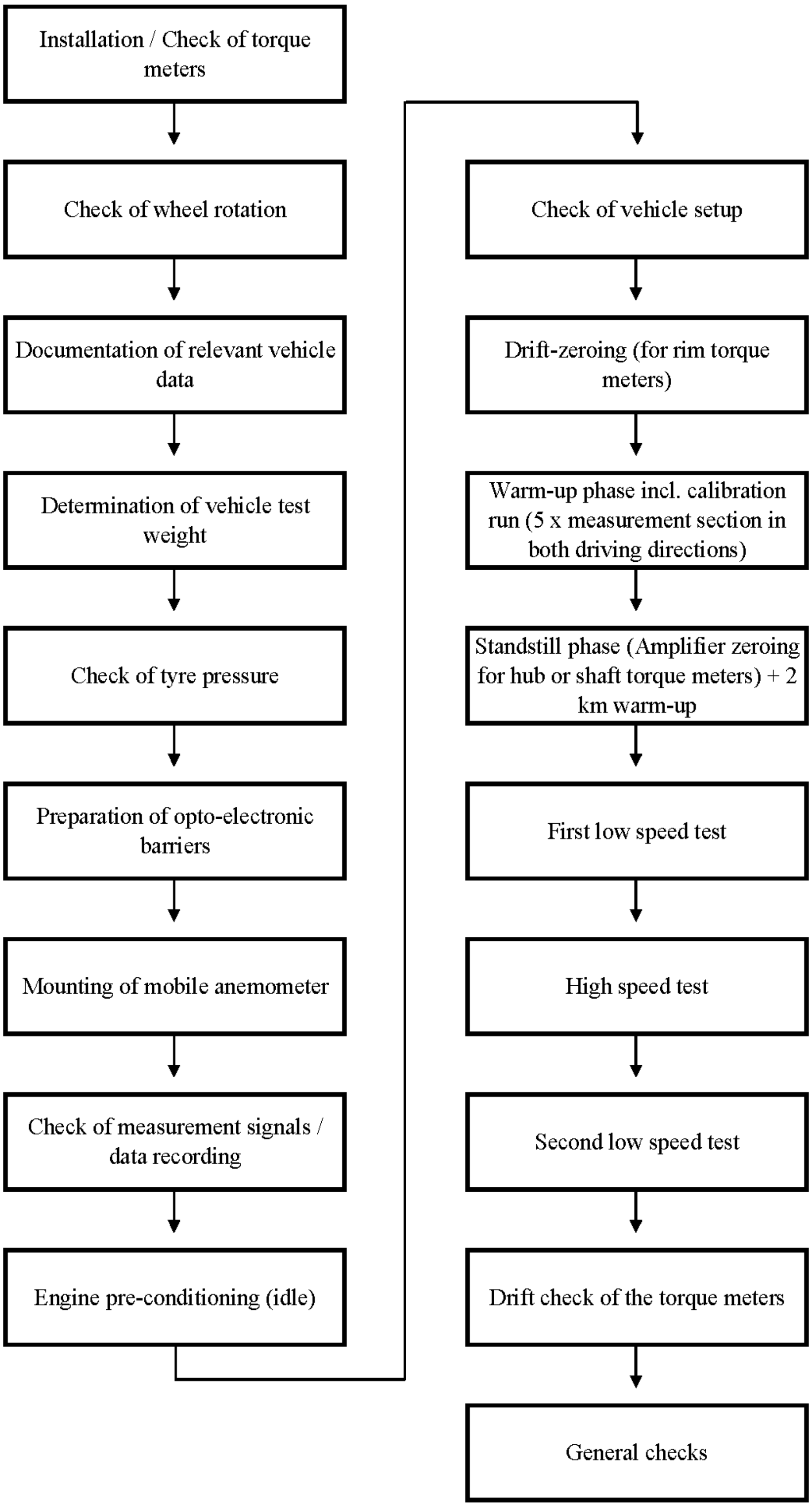

Fig. 5-1: Constant speed test

5.1.2.7 Testing Logbook

In addition to the recording of the modal measurement data, the testing shall be documented in a logbook which contains at least the following data:

a. General vehicle description

b. Pictures of the tested vehicle

c. Actual maximum vehicle height and width and potential deviations during the testing

d. km reading (at each step of the testing sequence)

e. Start time of the warm-up phase, the high speed test, the low-speed test

f. Fuel level and amount of additionally tanked fuel (combined with time and km reading)

g. Number of vehicle occupants (if applicable: time and detail of changes)

h. Actual vehicle mass (combined with km reading, occupants and fuel level)

i. Time of zeroing the drift of the torque meters

j. Name of the first measurement section for each testing sequence

k. Driving direction

l. Filename of measurement data

m. Tarmac temperatures (if applicable according to 5.1.2.2.2)

n. Documentation of extraordinary events (with time and number of measurement sections), e.g.

- close passing of another vehicle
- driving errors
- technical errors
- measurement errors

o. Engaged gear of the transmission for the low speed test and high speed test

5.1.2.8 Data processing

All recorded data shall be checked for any errors. Measurement data shall be excluded from further consideration in the following cases:

- data sets became invalid due to events during the measurement (see 5.1.2.7 n)
- Instrument saturation during measurement (e.g. high wind gusts which might have led to anemometer signal saturation)
- measurements in which the permitted limits for the analyzer drift were exceeded

Recorded datasets will be automatically excluded by the VECTO CSE-Tool in case of:

- invalid wind speed conditions (calibration test, low speed test, high speed test)
- invalid yaw angle conditions (calibration test, high speed test)
- stability criteria for vehicle speed not met (low speed test, high speed test)
- stability criteria for vehicle torque not met (low speed test, high speed test)
- t.b.d.: left and right torque signals have no random variation (e.g. because the wind speed and angle increased continuously during the measurement)
- unequal number of datasets per vehicle heading direction (high speed test)
- unequal number of datasets for a particular combination of measurement section and driving direction for the first and the second low speed test

For the pilot phase VECTO-CSE executes the evaluations but gives warnings in case of:

- valid range of ambient conditions exceeded
- maximum deviation of average tire pressure in low speed and high speed exceeded (±5 °C)
- maximum deviation of RRC between first and second low speed test exceeded

VECTO-CSE aborts evaluations in case of

- test track requirements not met (max. 20° direction deviations (from +/-180°) between measurement sections)
- not sufficient number of datasets available (calibration test, low speed test, high speed test)

To ensure optimal calculation results a similar amount of recorded measurements for each driving directions shall be used, e.g. full laps on a circuit track (started and stopped outside of the measurement sections).

The recorded data shall be synchronised and aligned to 100Hz temporal resolution, either by arithmetical average or linear interpolation.

Data processing: Most corrections will be included into VECTO CSE-Tool.

t.b.d. after latest VECTO CSE update.

i. Vehicle speed

The CAN vehicle speed signal shall be converted into [km/h] if being recorded in a different unit.
The vehicle speed used in the evaluations shall be calculated by

$$v_{veh} = v_{veh,CAN} * f_{v,veh}$$

where:

v_{veh}	=	calibrated vehicle speed [km/h]
$v_{veh,CAN}$	=	vehicle speed from CAN front axle signal [km/h]
$f_{v,veh}$	=	calibration factor for vehicle speed [-]

and:

$$f_{v,veh} = \frac{v_{ref,avrg}}{\bar{v}_{veh,CAN,avrg}}$$

where:

$\bar{v}_{ref,avrg}$	=	average reference speed for all datasets of the calibration test (see 5.1.2.4 ii)
$\bar{v}_{veh,CAN,avrg}$	=	average CAN vehicle speed for all datasets of the calibration test

ii. Local air speed

The air speed signal of the mobile anemometer shall be corrected in three steps for the instrument error, the position error and the boundary layer as follows:

Step 1 - Instrument error correction:
The anemometer speed reading shall be corrected with the calibration factors determined in the instrument calibration (5.1.2.4 vii).

$$v_{air,ic} = f_{vie} * v_{air,ar} + d_{vie}$$

where:

$v_{air,ic}$	=	instrument corrected air speed signal [m/s]
$v_{air,ar}$	=	air speed anemometer reading [m/s]

f_{vie}	=	proportional calibration factor from instrument calibration [-]
d_{vie}	=	constant calibration factor from instrument calibration [m/s]

Step 2 - Position error correction:
A correction factor f_{vpe} shall be obtained with the calibration test data during the warm-up phase. The data shall contain at least 5 measurements per driving direction on one measurement section. The correction factor shall be calculated with the average values for direction 1 and 2.

$$f_{vpe} = \frac{v_{veh,avrg}}{1/2 * (v_{air,ic,1} + v_{air,ic,2})}$$

where:

f_{vpe}	=	speed position error correction factor [-]
$v_{veh,avrg}$	=	average vehicle speed during calibration test [m/s]
$v_{air,ic,1}$	=	average air flow speed after instrument correction during calibration test, measured in driving direction 1 [m/s]
$v_{air,ic,2}$	=	average air flow speed after instrument correction during calibration test, measured in driving direction 2 [m/s]

The position error correction factor shall be applied to the data to receive the air speed in undisturbed flow conditions:

$$v_{UF} = v_{air,ic} * f_{vpe}$$

where:

v_{UF}	=	air speed in undisturbed flow conditions [m/s]
f_{vpe}	=	speed position error correction factor [-]
$v_{air,ic}$	=	instrument corrected air speed signal [m/s]

Step 3 - Boundary layer correction:
See step 4 of point iii. Yaw angle (β) correction.

iii. Yaw angle (β)

The air angle signal of the mobile anemometer shall be corrected in four steps for the instrument error, misalignment error, position error and the boundary layer as follows:

Step 1 - Instrument error correction:
The anemometer angle reading shall be corrected with the calibration factors determined in the instrument calibration (5.1.2.4 vii).

$$\beta_{ic} = f_{aie} * \beta_{ar} + d_{aie}$$

where:

β_{ic}	=	instrument corrected yaw angle signal [°]
β_{ar}	=	yaw angle anemometer reading [m/s]
f_{aie}	=	proportional calibration factor from instrument calibration [-]
d_{aie}	=	constant calibration factor from instrument calibration [°]

Step 2 - Misalignment error correction:
The anemometer misalignment error β_{ame} shall be obtained with the calibration test data during the warm-up phase. The data shall contain at least 5 measurements per driving direction on one measurement section. The correction factor shall be calculated with the average β values after instrument correction for direction 1 and 2.

$$\beta_{ame} = \frac{(\beta_{ic,1} + \beta_{ic,2})}{2}$$

where

β_{ame}	=	angle misalignment error [°]
$\beta_{ic,1}$	=	average yaw angle for driving direction 1 [°]
$\beta_{ic,2}$	=	average yaw angle for driving direction 2 [°]

Step 3 - Position error correction:
The correction factor f_{ape} for the angle position error is a generic value based on the specified installation position of the mobile anemometer, depending on the vehicle type.

Tractor + semi-trailer	:	$f_{ape} = 1.0$
Rigid truck	:	$f_{ape} = 1.0$
Citybus	:	$f_{ape} = 0.XX$
Coach	:	$f_{ape} = 0.XX$

The misalignment error β_{ame} and the correction factor f_{ape} for the angle position error shall be applied to the anemometer angle data to determine the yaw angle at undisturbed flow conditions as specified below:

$$\beta_{UF} = (\beta_{ic} - \beta_{ame}) * f_{ape}$$

where:

β_{UF}	=	yaw angle at undisturbed flow conditions [°]
β_{ic}	=	instrument corrected yaw angle signal [°]
β_{ame}	=	angle misalignment error [°]
f_{ape}	=	angle position error correction factor [-]

Step 4 - Boundary layer correction:
The boundary layer correction shall be applied to correct air speed, yaw angle and wind speed as determined for undisturbed flow conditions to average flow conditions as acting on the vehicle.

Wind speed at undisturbed flow location at height of anemometer

$$v_{wind}(ha) = [(v_{windx}(ha))^2 + (v_{windy}(ha))^2]^{0.5}$$

$$v_{windx}(ha) = v_{UF} * cos(\beta_{UF}) - v_{veh}$$

$$v_{windy}(ha) = v_{UF} * sin(\beta_{UF})$$

Wind speed variation with height
Assumption for wind profile using the power law boundary layer and δ=0.2

$$v_{windx}(h) = v_{windx}(ha) * \left(\frac{h}{ha}\right)^{\delta}$$

$$v_{windy}(h) = v_{windy}(ha) * \left(\frac{h}{ha}\right)^{\delta}$$

Air speed and β variation with height

$$v_{air}(h) = [(v_{windx}(h) + v_{veh})^2 + (v_{windy}(h))^2]^{0.5}$$

$$\beta(h) = atan\ [\frac{v_{windy}(h)}{(v_{windx}(h) + v_{veh})}]$$

Height-averaged air speed and β

$$v_{air} = \left(\frac{1}{hv}\right) * \int_0^{hv} v_{air}(h)dh$$

$$\beta = \left(\frac{1}{hv}\right) * \int_0^{hv} \beta(h)dh$$

where:

hv	=	vehicle height [m]
ha	=	installation height of anemometer above ground [m]
h	=	height above ground [m]
δ	=	atmospheric stability coefficient [-]
v_{windx}	=	wind speed in x-direction [km/h]
v_{windy}	=	wind speed in y-direction [km/h]
v_{air}	=	air speed [km/h]

iv. Torque

The collected torque data shall be corrected for the instrument error determined by the supplier.

$$T_{\mathrm{L}} = T_{\mathrm{Lr}} * f_{TLie} + f_{TLd}$$

$$T_R = T_{Rr} * f_{TRie} + f_{TRd}$$

where:

T_L	=	corrected torque left wheel [Nm]
T_R	=	corrected torque right wheel [Nm]
T_{Lr}	=	torque meter reading left wheel [Nm]
T_{Rr}	=	torque meter reading right wheel [Nm]
f_{TLie}	=	torque meter left - instrument error correction factor [-]
f_{TRie}	=	torque meter right - instrument error correction factor [-]
f_{TLd}	=	drift correction factor left torque meter [Nm]
f_{TRd}	=	drift correction factor right torque meter [Nm]

The corrected torque shall be provided as input for VECTO-CSE. If the torque meter drift exceeds the limit of t.b.d. Nm, the entire test shall be regarded invalid.

v. Rotational speed of the driven axle:

The rotational speed of the driven axle is determined via engine speed signal and the transmissions ratios of engaged gear and axle.

vi. Calculation of traction force:

The traction force shall be calculated as specified below:

$$F_{trac} = \frac{(T_L + T_R) * \dfrac{n_{eng} * \pi}{30 * i_{gear} * i_{axle}}}{v_{veh}}$$

where:

F_{trac}	=	traction force [N]
T_L, T_R	=	corrected torque for left and right wheel [Nm]
n_{eng}	=	engine speed [rpm]

i_{gear}	=	transmission ratio of engaged gear [-]
i_{axle}	=	axle transmission ratio [-]
v_{veh}	=	vehicle speed [m/s]

vii. Determination of the $C_d{\cdot}A_{cr}$ value:

The $C_d{\cdot}A_{cr}$ value for zero cross-wind conditions shall be determined based on the recorded data on traction force, air speed and yaw angle for all valid datasets. This evaluation shall comprise the following steps:

- Normalisation of traction forces to reference air density

$$F_{trac,ref} = F_{trac,ref} * \frac{\rho_{air,ref}}{\rho_{air}}$$

where:

$F_{trac,ref}$	=	traction force at reference air density [N]
F_{trac}	=	traction force at measurement conditions [N]
$\rho_{air,ref}$	=	air density at reference conditions 1.188 [kg/m³]
ρ_{air}	=	air density at measurement conditions [kg/m³]

ρ_{air} shall be calculated from the air temperature measured on the vehicle and the air pressure and relative humidity as measured at the stationary weather station based on the following equations:

$$p_{v,H2O} = 611 \cdot \frac{RH_{stat}}{100} \cdot 10^{\frac{7.5 \cdot t_{amb,stat}}{(237 + t_{amb,stat})}}$$

$$\rho_{air} = \frac{p_{amb,stat} - p_{v,H2O}}{287.1 \cdot (t_{amb,veh} + 273.15)} + \frac{p_{v,H2O}}{461.9 \cdot (t_{amb,veh} + 273.15)}$$

where:

$p_{v,H2O}$	=	H_2O vapour pressure [Pa]
RH_{stat}	=	relative humidity measured by stationary weather station [%]
$t_{amb,stat}$	=	ambient temperature measured by stationary weather station [°C]
$t_{amb,stat}$	=	ambient temperature measured on the vehicle [°C]
$p_{amb,stat}$	=	ambient pressure measured by stationary weather station [Pa]

- For all applicable combinations of measurement sections and driving directions the following analysis shall be performed:
    - Setup of a linear regression for all valid datasets from the high speed tests and the two low speed tests for $F_{trac,ref}$ as a function of squared air speed (v_{air}^2) achieving an regression coefficient F_2 and a constant term F_0. In the regression weighting factors shall be applied so that the cumulative weighting of all high speed datasets is 50%.
    - The average absolute yaw angle β_{avrg} shall be calculated from all high speed tests
    - The value for $C_d(\beta_{avrg})*A_{cr}$ [m²] shall be calculated from

$$C_d\left(\beta_{avrg}\right) * A_{cr} = 2 * {}^{F_2}/_{\rho_{air,ref}}$$

- The result for overall "$C_d(\beta_{avrg})*A_{cr}$" and overall "β_{avrg}" shall be calculated from the results for all applicable combinations of measurement sections and driving directions by arithmetical averaging
- The final result for $C_d * A_{cr}$ [m²] for zero cross-wind conditions is then achieved performing the yaw angle correction as specified below:

$$C_d * A_{cr} = C_d\left(\beta_{avrg}\right) * A_{cr} - \Delta C_d * A_{cr}(\beta_{avrg})$$

where:

$C_d\left(\beta_{avrg}\right) * A_{cr}$ = average result for product of air drag coefficient and cross sectional area from constant speed tests comprising an average absolute yaw angle of β_{avrg}

$\Delta C_d * A_{cr}\left(\beta_{avrg}\right)$ = yaw angle correction applying the generic curve for $\Delta C_d * A_{cr}$ as a function yaw angle for the value of β_{avrg}. In this correction the applicable generic curve for the particular vehicle class and vehicle configuration (rigid or with trailer) shall be used.

During the pilot phase also an alternative method for yaw angle correction will be calculated by VECTO-CSE (yaw angle correction performed for each combination of measurement section and driving direction before averaging of final result).

5.1.2.9 Default values

t.b.d:

generic values e.g. for dependencies of Cd-value on yaw angle for the HDV classes

5.2 ENGINE

To determine the specific fuel consumption of the engine a steady state fuel map shall be measured. To overcome inconsistencies of regulated emissions and fuel consumption between the WHTC (hot part) test and the steady state fuel map as well as considering effects of transient engine behaviour a “WHTC correction factor” is calculated on basis of a WHTC measurement.

The WHTC shall be performed in accordance with regulation UN/ECE R.49.06 on type approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles.

5.2.1 Engine families

t.b.d

5.2.2 General requirements

For each engine system type a separate fuel map has to be measured.

The measurement of the steady state map and the determination of the WHTC correction factor based on the hot WHTC fuel consumption shall be conducted on the same engine system.

The WHTC shall be prepared, conducted and validated as described in Annex 4, sections 7.2.1. and 7.3. to 7.6. of UN/ECE R.49.06.

The steady state map shall comply with the following specifications in order to meet the input data requirements of the HDV CO_2 simulator.

- The engine fuel map shall be measured on the engine dynamometer in a series of steady state engine operation points.
- The metrics of this map are the fuel consumption [g/s] depending on engine speed [rpm] and engine net torque [Nm].

The power consumption of the main engine auxiliaries and equipment like oil pump, coolant pump, fuel delivery pump, fuel high pressure pump and alternator to overcome the electricity demand of the engine itself are already covered in the fuel map.

The grid width for the measurement of the steady state fuel map shall be defined as indicated in Fig. 5-2 by:

Engine speed:

Minimum 10 engine speeds shall be measured. The four base speeds shall be:

- n_{idle}
- n_{pref} - n_{pref} *0.04
- n_{pref} + n_{pref} *0.04
- n_{95h}

as defined in UN/ECE R.49.06, section 7.4.6. The remaining minimum 6 engine speeds are determined by splitting each of the two ranges between n_{idle} to n_{pref} -4 % and n_{pref} +4 % to n_{95h} into a minimum of four equidistant sections.

Engine torque:

The step width of the torque levels is defined by clustering the range from zero to maximum torque into 10 equidistant sections. This step width applies to all applicable speeds to fill up the range below the mapping curve. In cases where the next step would exceed the mapping curve the full load torque becomes applicable. The starting point is defined at highest speed and highest torque. Afterwards the torque is stepwise reduced at constant speed until zero torque is reached. The speed then is reduced to the next speed step, first measurement point of the new speed step is max. torque.

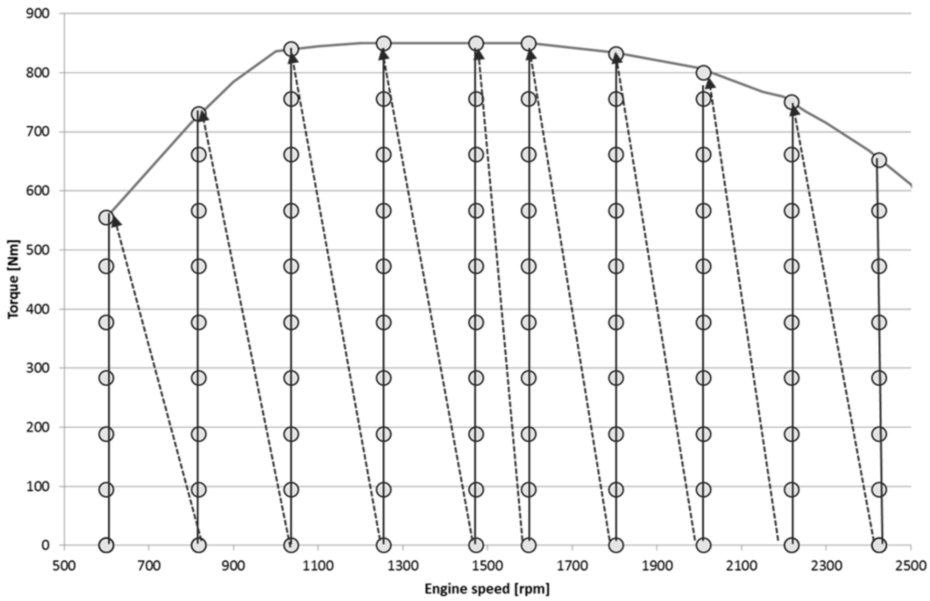

Fig. 5-2: Measurement points for fuel map

5.2.3 Installation

The test engine shall be installed on an engine test bench under the test conditions in accordance with UN/ECE R.49.06, Annex 4, section 6. The engine shall be tested with the auxiliaries / equipment listed in Annex 6 of the above mentioned regulation.

The fuel used for the test shall be reference fuel as specified in regulation (EC) 582/2011, Annex IX.

5.2.4 Measurement equipment

to be developed:
Further investigations are necessary regarding the accuracy of measurement equipment. Based on the accuracies for torque, speed and fuel flow defined in ECE R49, an total error of +/-5% for the fuel flow can occur (specified in the sensitivity analysis of TUG). Due to complex specifications of the accuracies demanded in the EURO VI regulation further consultations and discussions with the ACEA engine group are planned to come up with suitable accuracy definitions for the fuel flow tests in the HDV-CO2 test procedure.

5.2.5 Measurement signals and data recording

5.2.5.1 WHTC

The WHTC data shall be recorded as specified in UN/ECE Regulation No 49.06, Annex 4, section 7. The fuel flow shall be recorded at minimum 5 Hz sample frequency.

5.2.5.2 Steady state map

The data for engine torque and fuel consumption from the steady state map shall be obtained under stable operating conditions and measured with 1 Hz or higher. The stabilization time per set point is 60 sec followed by a 30 sec measurement phase. For the fuel map one averaged value out of the 30 sec measurement is used.

The following measurement data shall be recorded:

- fuel consumption [g/h]
- engine speed [rpm]
- engine net torque [Nm]

Additionally the following information and data shall be supplied:

- basic engine data [make, model, type, n_{idle}, n_{pref}, n_{95h}, rated power and torque]
- engine full load curve
- engine drag curve
- carbon content [%C] for deriving the CO_2 map based on complete oxidation of C to CO_2
- net heating value Hu [kJ/kg]

All data shall be exported in order to be compatible to the HD CO_2 simulator (see VECTO manual, final file formats open yet).

5.2.6 Test procedure

5.2.6.1 WHTC

The WHTC shall be conducted as specified in UN/ECE Regulation No 49.06, Annex 4, section 7 in warm start conditions. The WHTC is not valid if the emission limits in accordance with regulation (EC) No 595/2009 are exceeded.

The data obtained from WHTC tests are valid if the requirements of the regression line tolerances of UN/ECE R.49.06, Annex 4, section 7.8.7., Table 2 are complied. The engine shall comply with the applicable emission limits of Regulation (EC) 595/2009.

5.2.6.2 Steady state map

The steady state map shall be pre-conditioned after engine hot start at 55 % of normalized engine speed and 50 % of normalized engine torque for 10 min. (mode 9 of WHSC), directly followed by the first measurement point of the test sequence.

The sequence of the testing points shall follow the order as indicated in Fig. 5-2, starting with n_{95h} speed and full load. Each set point shall be held for 90 sec (60 sec stabilization + 30 sec measuring). The ramp time to the next torque level at the same speed shall be set to 20 sec and to the next engine speed to 45 sec.

The tolerances for the steady state map are +/- 1.5 % with respect to the speed set point and +/- 2 % with respect to the torque set point.

5.2.7 WHTC correction factor

To overcome inconsistencies of regulated emissions and fuel consumption between the WHTC (hot part) test and the steady state fuel map as well as considering effects of transient engine behaviour a “WHTC correction factor” is used.

Based on the target engine operation points of the particular engine in WHTC the fuel consumption is interpolated from the steady state fuel map (“backward calculation”) in each of the three parts of the WHTC separately. The measured specific fuel consumption per WHTC part in [g/kWh] is then divided by the interpolated specific fuel consumption to obtain the “WHTC correction factors”For the interpolation the same method as for interpolation in VECTO has to be applied (Delauney triangulation).

For the interpolation the motoring curve and the motoring curve of the engine have to be provided. For the 10 engine speeds of the fuel map the fuel flow on the motoring curve has to be set to zero.

The specific fuel consumption from the interpolation shall be computed from the interpolated fuel flow values as follows:

$$BsFc_{intpol\text{-}Urban}\ [g/kWh] = (\Sigma\ Fc_{i\ WHTC\text{-}Urban}) / (W_{ref\ WHTC\text{-}Urban})$$

$$BsFc_{intpol\text{-}Road}\ [g/kWh] = (\Sigma\ Fc_{i\ WHTC\text{-}Road}) / (W_{ref\ WHTC\text{-}Road})$$

$$BsFc_{intpol\text{-}MW}\ [g/kWh] = (\Sigma\ Fc_{i\ WHTC\text{-}MW}) / (W_{ref\ WHTC\text{-}MW})$$

where:

BsFc	=	Brake specific fuel consumption [g/kWh positive engine work]
FCi	=	Sum of fuel interpolated for a WHTC-sub-cycle [g]
Wref x	=	Average positive reference power in WHTC sub-cycle x sub-cycle duration [kWh]

The specific fuel consumption from the measurement shall be computed from the WHTC test as follows:

$$BsFc_{meas\text{-}Urban}\ [g/kWh] = (\Sigma\ Fc_{m\ WHTC\text{-}Urban}) / W_{posWHTC\text{-}Urban})$$

$$BsFc_{meas\text{-}Road}\ [g/kWh] = (\Sigma\ Fc_{m\ WHTC\text{-}Road}) / (W_{pos\ WHTC\text{-}Road})$$

$$BsFc_{meas\text{-}MW}\ [g/kWh] = (\Sigma\ Fc_{m\ WHTC\text{-}MW}) / (W_{pos\ WHTC\text{-}MW})$$

where:

BsFc	=	Brake specific fuel consumption [g/kWh positive engine work]
Σ FCmi	=	Sum of fuel measured in a WHTC-sub-cycle [g]
Wposx	=	Average positive power measured in WHTC sub-cycle x sub-cycle duration [kWh]

The correction factor for each part of the WHTC is calculated by dividing the measured fuel consumption in the WHTC sub-cycle “$BsFc_{meas}$“ in [g/kWh] by the fuel consumption interpolated for the same period, “$BsFc_{intpol}$“ [g/kWh].

The three WHTC correction factors are calculated by:

$$CF_{Urb} = BsFc_{meas\text{-}Urban} / BsFc_{intpol\text{-}Urban}$$

$$CF_{Road} = BsFc_{meas\text{-}Road} / BsFc_{intpol\text{-}Road}$$

$$CF_{MW} = BsFc_{meas\text{-}MW} / BsFc_{intpol\text{-}MW}$$

The total correction factor ($CF_{Tot\text{-}i}$) depends on the mission profile "*i*" and is produced in VECTO by mission profile specific weighting factors (WF_i), Table 5-2.

$$CF_{Tot\text{-}i} = CF_{Urb}\ x\ WF_{Urb\text{-}i} + CF_{Rur}\ x\ WF_{Rur\text{-}i} + CF_{MW}\ x\ WF_{MW\text{-}i}$$

where:

i = mission profile according to Table 5-2. For each vehicle class the corresponding mission profile is defined as default value. For some HDV classes more than one mission profile is allocated (see LOT 2 report and ACEA white book), thus more than one $CF_{Tot\text{-}i}$ is computed

Index	Mission profile	WF_{MW}	WF_{Road}	WF_{Urb}
1	Long haul	88%	6%	6%
2	Regional delivery	62%	13%	26%
3	Urban delivery	11%	12%	77%
4	Municipial utility	0%	0%	100%
5	Construction	1%	38%	61%
6	Citybus	0%	0%	100%
7	Interurban bus	17%	13%	70%
8	Coach	71%	20%	9%

Table 5-2: Weighting factors for the WHTC road category correction factors

All calculations related to the WHTC correction factor are fully implemented in VECTO.

5.3 DRIVETRAIN

The drivetrain is characterised by the power losses of the transmission including retarder or torque converter and the axle.

5.3.1 Transmission

For assessing the losses of the transmission, one of the three different methods can be applied, also for different gears within one transmission:

i. Option 1: Fall back values based on the maximum rated torque of the transmission

ii. Option 2: Measured torque independent losses, calculated torque dependent losses. Electric machine and torque sensor before transmission (output shaft free-rotating)

iii. Option 3: Measurement of total torque loss. Electric machines and torque sensors in front and behind transmission

5.3.1.1 Family definition

t.b.d. first proposal made by ACEA. to be further discussed. Depending on the later implementation (2007/46 or other), this definition has to be revised

5.3.1.2 Option 1: Default values based on transmission maximum rated torque

The torque loss $T_{l,in}$ on the input shaft of the transmission is calculated by

$$T_{l,in} = T_{d0} + T_{d1000} * \frac{n_{in}}{1000rpm} + f_T * T_{in}$$

where:

$T_{l,in}$	=	Torque loss at the input shaft in Nm
T_{dx}	=	Drag torque at x rpm in Nm
N_{in}	=	Speed at the input shaft in rpm
f_T	=	1-η; η = efficiency
	=	f_T=0.01 for direct gear
	=	f_T=0.04 for indirect gears
T_{in}	=	Torque at the input shaft in Nm

For transmissions with tooth shift clutches (Synchronised Manual Transmission (SMT), Automated Manual Transmission or Automatic Mechanically engaged Transmission (AMT) and Dual Clutch Transmissions (DCT)) the drag torque T_{dx} is calculated by

$$T_{d0} = T_{d1000} = 10Nm * \frac{T_{\max in}}{2000Nm}$$

where:

T_{maxin}	=	Maximum allowed input torque in any gear of transmission in Nm (= max($T_{maxin,gear}$), where $T_{maxin,gear}$ is the maximum allowed input torque in *gear*, where *gear* = 1, 2, 3,…*top_gear*)

For transmissions with friction shift clutches (> 2 friction clutches) the drag torque T_{dx} is calculated by

$$T_{d0} = T_{d1000} = 15Nm * \frac{T_{\max in}}{1000Nm}$$

Here, “friction clutch” is used in the context of a clutch or brake that operates with friction, and is required for sustained torque transfer in at least one gear.

5.3.1.3 Option 2: Measured torque independent losses, calculated torque dependent losses. Electric machine and torque sensor in front of transmission (output shaft free-rotating)

The torque loss $T_{l,in}$ on the input shaft of the transmission is calculated by

$$\begin{aligned} T_{l,in}(n_{in}, T_{in}, gear) &= T_{idle}(n_{in}, gear) + f_T(gear) * T_{in} \\ &= T_{idle}(n_{in}, gear) + (1 - \eta_T(gear)) * T_{in} \end{aligned}$$

$T_{l,in}$	=	Torque loss on input shaft in Nm
T_{idle}	=	Drag torque from testing without load in Nm
n_{in}	=	Speed at the input shaft in rpm
f_T	=	1-η_T; η_T = efficiency (to be calculated)
	=	0.005 (η_T=0.995) for direct gear
T_{in}	=	Torque at the input shaft in Nm

The torque dependent efficiency η_T shall be calculated for each gear separately.

For the direct gear a constant efficiency of η_T = 0.995 is assumed.

For indirect gears the efficiency is calculated according to

$$\eta_T = \eta_{m,splitter} * \eta_{m,main} * \eta_{range} * \eta_{bearings}$$

where:

η_T	=	Gear dependent efficiency [-]
$\eta_{m,splitter}$	=	Efficiency of the active splitter gear mesh = const. = 0.99 [-]
$\eta_{m,main}$	=	Efficiency of the active main section gear mesh = const. = 0.99 [-]
η_{range}	=	Efficiency of the range section [-]
	=	const. = 0.998 for high range (direct)
	=	$\eta_{lowrange}$ for low range (see below)
$\eta_{bearings}$	=	Efficiency of the bearings = const. = 0.998 [-]

For the case of a planetary-type range section, the efficiency is calculated by

$$\eta_{lowrange} = \frac{1 + \eta_{m,ring} * \eta_{m,sun} * \frac{z_{ring}}{z_{sun}}}{1 + \frac{z_{ring}}{z_{sun}}}$$

where:

$\eta_{m,ring}$	=	Efficiency of the ring meshes of the range section = const. = 0.995 [-]
$\eta_{m,sun}$	=	Efficiency of the sun meshes of the range section = const. = 0.99 [-]
z_{sun}	=	Number of teeth of the sun gearwheel of the range section [-]
z_{ring}	=	Number of the ring of the range section [-]

The torque independent losses are measured in accordance to the procedure described in the following.

5.3.1.3.1 General requirements

The transmission used for the measurements shall be out of serial production and in accordance to the drawing specifications for series production transmissions.

RUN-IN

The transmission used for the measurements shall be completely new. A run-in can be done. This procedure shall not exceed 100 hours at maximum 100% of maximum input torque for each gear, evenly distributed over all gears, excluding reverse and crawler gears.

TEMPERATURES

The ambient temperature during the test shall be in a range of 25°C ± 10°C. The ambient temperature shall be measured 1 m laterally from the transmission.

Except for oil, no external heating is allowed.

For SMT/AMT/DCT the drain plug oil temperature shall be in a range of 80°C ± 2°C without retarder and 80°C +7/-2°C with retarder.

For torque converter planetary transmissions and for transmissions having more than two friction clutches the drain plug oil temperature shall be in a range of 90°C ± 2°C without and 90°C +7/-2 °C with retarder.

During the run-in, temperature peaks up to 110°C are allowed but shall not exceed more than 10% of total run-in time.

To make use of the increased temperature tolerance for testing with retarder, the retarder shall be integrated in the transmission or have an integrated cooling or oil system with the transmission.

OIL QUALITY, LEVEL AND CONDITIONING

New, recommended factory fill oil for the European market shall to be used in the test. If multiple oils are recommended for factory fill, they are considered to be equal if, at the same temperature (within the specified tolerance band, for KV100), the oils have a kinematic viscosity within 10% of each other. If not, the factory fill oil with the highest viscosity (within 10%) shall be tested. More oils can be tested if wanted. An oil with lower viscosity is always considered to give lower losses for the tests performed within this option. It is therefore not required to do a new measurement if a change to lower viscosity oil is performed.

The oil level shall meet the specifications for the transmission.

If an external oil conditioning system is used, this must be completely filled. The amount of oil inside the transmission shall be kept to the specified volume. To guarantee that the external oil conditioning system is not influencing the test, one test point shall be measured with the conditioning system both on and off. The deviation between the two measurements shall be less than 7%. The test point is specified as follows:

i. highest indirect gear,

ii. input speed = 1400 rpm,

iii. input torque = free rotating output shaft

For transmissions with hydraulic control it is allowed to perform the measurement of torque independent losses at minimum system pressure of the transmission when the gear is engaged. If necessary, higher system pressures are allowed.

5.3.1.3.2 Installation

The electric machine and the torque sensor are mounted at the input shaft of the transmission. The output shaft rotates freely.

The installation of the transmission shall be done with an angle of inclination as for installation in the vehicle according to the homologation drawing or at 0°.

The internal oil pump shall be included in the test transmission.

Optional oil coolers shall not be included.

Power-takeoffs (incl. provisions therefore) shall not be included in test transmission.

If not already included in a separate retarder test, retarder provisions shall be included in the test transmission, refer to 5.3.2.

5.3.1.3.3 Measurement equipment

The calibration of all measuring instruments and systems shall be traceable to national (international) standards. The measuring instruments and systems shall comply with the linearity requirements given in Section 9.2 and Table 7 of Annex 4 to UN/ECE Regulation No 49.06. The linearity verification shall be done as required by internal audit procedures, by the instrument manufacturer or in accordance with ISO 9000 requirements.

Torque
The torque sensor measurement error shall be below 0.3 Nm. The use of torque sensors with higher measurement errors is allowed if the part of the error exceeding 0.3 Nm can be calculated and is added to the measured torque loss. The measurement error is calculated on basis of the total error of the sensor at 95% confidence level. The total error shall be calculated based on the following parameters:

i. Sensitivity tolerance

ii. Linearity and hysteresis

iii. Temperature effect

iv. Repeatability

v. Parasitic loads

vi. Calibration error

Detailed description of the error calculation t.b.described

Speed
The error of the speed sensors shall not exceed ± 1 rpm.

Temperature
The error of the temperature sensors for the measurement of the ambient temperature shall not exceed ± 1 ° C.

The error of the temperature sensors for the measurement of the oil temperature shall not exceed ± 0.5 ° C.

Pressure
The error of the pressure sensors shall not exceed 0,1% of full scale.

5.3.1.3.4 Test procedure

The drag torque shall be measured for the following speed steps (speed of the input shaft): 600, 800, 1000, 1200, 1400, 1700, 2000, 2400, 2800, 3200, […] rpm up to the maximum speed according to the specifications of the transmission or higher.

Torque losses for speeds below the above defined minimum speed shall be linear extrapolated.

The drag torque is defined as the torque measured at the input shaft with free-rotating output shaft and therewith equal to the torque loss.

The measurements shall be performed beginning with the lowest up to the highest speed. For each speed step a minimum of 10 seconds stabilization time within the temperature limits defined in 5.3.1.3.1 is required. If needed, the stabilization time can be extended. Oil and ambient temperatures shall be recorded.

After the stabilization time, torque and speed are recorded for the test point for 10 – 15 seconds with minimum 100 Hz sample rate. The average of torque and speed for the 10 seconds measurement shall be calculated.

The speed ramp between two speed steps shall not exceed 20 seconds.

The complete test shall be performed three times. The deviation between the averaged torque losses of the three measurement sets shall be below 5%. If the deviation is higher, the worst measurement value shall be taken or the test shall be repeated for the gear. The averaged speed deviation shall be below ± 5 rpm of the speed set point for each measured point for the complete torque loss series.

Total tested time per transmission individual may not exceed 2.5 times the actual testing time for 3x1 test series (allowing re-testing of transmission if needed due to measuring or rig error). New tests can be done up to 10 times with the same gearbox individual but only for other tests. It is not allowed to run the test multiple times to be able to choose reported test series with the lowest values.

5.3.1.4 Option 3: Measurement of total torque loss. Electric machines and torque sensors in front of and behind transmission.

5.3.1.4.1 General requirements

As specified for Option 2

RUN-IN

As specified for Option 2

TEMPERATURES

As specified for Option 2

OIL QUALITY, LEVEL AND CONDITIONING

New, factory fill oil for the European market shall be used in the test. If the factory fill oil is changed during the production of the transmission by the manufacturer, a new measurement shall be performed with the new factory fill oil.

Other requirements as specified in Option 2

5.3.1.4.2 Installation

Electric machines and torque sensors are installed at the input and at the output shaft of the transmission.

Other requirements as specified for Option 2

5.3.1.4.3 Measurement equipment

The torque sensor measurement error shall be below 5% of the measured torque loss. The use of torque sensors with higher measurement errors is allowed if the part of the error exceeding 5% can be calculated and is added to the measured torque loss. The measurement error is calculated as specified for Option 2.

Other measurement equipment as specified for Option 2

5.3.1.4.4 Test procedure

The torque loss shall be measured for the following speed steps (speed of the input shaft): 600, 800, 1000, 1200, 1400, 1700, 2000, 2400, 2800, 3200, […] rpm up to the maximum speed according to the specifications of the transmission (or higher). The speed ramp (time for the change between two speed steps) shall not extend 20 seconds.

For each speed step the torque loss shall be measured for the following input torques: 0 (free rotating output shaft)200, 400, 600, 800, 1000, 1200, 1400, 1700, 2000, 2400, 2800, 3200, 3600, 4000, […] Nm up to the maximum input torque according to the specifications of the transmission (or higher). The torque ramp (time for the change between two torque steps) shall not extend 15 seconds. If the maximum output torque exceeds 10000 Nm, the torque loss values for higher torques can be taken from one, and only one, of:

i. Option 1

ii. Option 2

iii. Option 3 in combination with a torque sensor for higher output torques

Torque losses for speeds below the above defined minimum speed shall be linear extrapolated.

The measurements shall be performed beginning with the lowest up to the highest speed. The input torque is varied according to the above defined torque steps from the lowest to the highest torque for each speed step. For each speed and torque step a minimum of 10 seconds stabilization time within the temperature limits defined in 5.3.1.3.1 is required. If needed, the stabilization time can be extended. Oil and ambient temperatures shall be recorded.

After the stabilization time, torque and speed shall be recorded for the test point for at least 10 seconds with a minimum sample rate of 100 Hz. The averages of torque and speed for the 10 seconds measurement shall be calculated.

The complete test shall be performed three times. After completing the speed run and before starting a new measurement set, the transmission shall idle at 800 rpm input shaft speed without load for 60 seconds.

The deviation between the averaged torque losses of the three measurement sets shall be below 5% or 1Nm. If the deviation is higher, the worst measurement value shall be taken or the test shall be repeated for the gear. The measured and averaged speed and torque at the input shaft shall be below ± 5 rpm and ± 5 Nm of the speed and torque set point for each measured operating point for the complete torque loss series.

Total tested time per transmission individual may not exceed 2.5 times the actual testing time for 3x1 test series (allowing re-testing of transmission if needed due to measuring or rig error).

5.3.2 Retarder

For the determination of the retarder losses two options can be applied:

i. Option 1: standard technology specific table value for drag torque losses

ii. Option 2: measurement of drag torque in deactivated mode

5.3.2.1 Option 1: Standard technology specific table value for drag torque losses

The torque loss $T_{l,Ret,input/prop}$ of the retarder referring to the transmission input or propeller shaft (dependent on installation of the retarder) shall be calculated by:

$$T_{l,Ret,input/prop} = 10 + 2 * \left(\frac{n_{input/prop}}{1000}\right)^2$$

where:

$T_{l,Ret,input/prop}$	=	Retarder torque loss referred to the transmission input or propeller shaft in Nm
$n_{input/prop}$	=	Speed of transmission input or propeller shaft in rpm

5.3.2.2 Option 2: Measurement of drag torque in deactivated mode

The measurement of the retarder losses can be performed in combination with the transmission testing. In this case, the transmission losses already include the retarder losses.

If the retarder model is used in multiple transmission models, its losses can be determined on basis of one test and be applied on other transmission models. Therefore, the torque independent losses of one transmission including and excluding retarder and provisions therefore are determined in accordance to 5.3.1.3 for one gear. The losses of the retarder are calculated by building the difference of the torque losses for the different speed steps.

5.3.2.2.1 General requirements

The retarder used for the measurements shall be out of serial production and in accordance to the drawing specifications for series production transmissions.

RUN-IN

The retarder used for the measurements shall be completely new and the run-in time shall not exceed 6 hours at maximum 100% of maximum brake torque.

TEMPERATURES

The ambient temperature during the test shall be in a range of 25°C ± 10°C. The ambient temperature shall be measured 1 m laterally from the retarder.

Except for oil, no external heating is allowed.

For SMT/AMT/DCT the oil/water temperature shall be in a range of 80°C +7/-2°C with retarder.

For torque converter planetary transmissions and for transmissions having more than two friction clutches the oil/water temperature shall be in a range of 90°C +7/-2 °C.

OIL AND WATER QUALITY, LEVEL AND CONDITIONING

New, recommended factory fill oil for the European market shall to be used in the test. If several oils are recommended for factory fill, they are considered to be equal if, at the same temperature (within the specified tolerance band, for KV100), the oils have a kinematic viscosity within 10% of each other. If not, the factory fill oil with the highest viscosity (within 10%) shall be tested. More oils can be tested if wanted. An oil with lower viscosity is always considered to give lower losses for the tests performed within this option. It is therefore not required to do a new measurement if a change to lower viscosity oil is performed.

The oil level shall meet the specifications for the retarder.

If an external oil conditioning system is used, this must be completely filled. The amount of oil inside the retarder shall be kept to the specified volume. To guarantee that the external oil conditioning system is not influencing the test, one test point shall be measured with the conditioning system both on and off. The deviation between the two measurements shall be less than 7%.

i. highest indirect gear,

ii. input speed = 1400 rpm,

iii. input torque = 0.5 x maximum input torque

For water retarders the water quality shall meet the specifications set out for the retarder. The water pressure shall be set to a fixed value close to vehicle condition.

5.3.2.2.2 Installation

The installation of the retarder shall be done with an angle of inclination as for installation in the vehicle according to the homologation drawing or at 0°.

The transmission shall be installed in accordance with 5.3.1.3.2

Torque and speed are measured at the retarder connection point, either:

i. At propeller shaft for the retarder connected after the gearbox

ii. At gearbox input shaft for the retarder connected before the gearbox

iii. At retarder input shaft, but then the retarder provision needs to be included in the transmission measurement procedure

5.3.2.2.3 Measurement equipment

As specified for transmission testing option 2 in 5.3.1.3.3

5.3.2.2.4 Test procedure

The measurement of the retarder losses are performed from 200 rpm up to the maximum speed for the retarder (at connection point) in speed steps of 200 rpm. For lower speeds either measurements or linear extrapolation can be performed.

Linear interpolation shall be applied to the recorded data points.

Further requirements, e.g. for oil specification and measurement accuracy, shall be in accordance with option 2 of transmission testing procedure.

5.3.3 Torque converter

to be further developed

5.3.4 Automatic transmissions

t.b.d. first proposal made by ACEA, not part of Lot 3

5.3.5 Axle

For assessing the losses of the axle, one of the two different methods can be applied:

i. Option 1: Torque loss table values (default values) based on a generic constant efficiency and torque loss of the axle

ii. Option 2: Test bench measurement of torque loss maps for each individual axle and ratio

The applicant is free to choose an option.

5.3.5.1 Family defintion

t.b.d. first proposal made by ACEA. to be further discussed. Depending on the later implementation (2007/46 or other), this definition has to be revised

5.3.5.2 Option 1: Torque loss table values (default values) based on generic constant efficiency and torque loss of the axle

The standard torque losses for axles shall be taken from the tables defined for the different axle types (Table 5-3).

Those standard table values consist of the sum of a generic constant efficiency value covering the load dependent losses and a generic basis drag torque loss to cover the drag losses at low loads. The generic values are defined for each axle type as specified below.

	Generic efficiency	Basis drag torque
Standard axle	0.97	40 Nm
Tandem axle / single portal axle	0.94	100 Nm
Standard hub reduction axle	0.97	60 Nm

Tandem hub reduction axle	0.94	150 Nm

Table 5-3: Generic efficiency and drag loss

The torque loss $T_{l,in}$ on the input shaft of the transmission is calculated by

$$T_{l,in} = T_{d0} + f_T * T_{in}$$

where:

$T_{l,in}$ = Torque loss at the input shaft in Nm

T_{d0} = Basis drag torque over the complete speed range [Nm]

f_T = 1-η; η = efficiency [-]

T_{in} = Torque at the input shaft in Nm

5.3.5.3 Option 2: Test bench measurement of torque loss maps for each individual axle and ratio

The torque loss of the axle can be calculated by

$$T_{loss} = T_{in} * i_{gear} - T_{out}$$

where:

T_{loss} = torque loss of the axle [Nm]

T_{in} = Inlet torque [Nm]

i_{gear} = axle gear ratio [-]

T_{out} = Outlet torque [Nm]

The determination of the inlet and outlet torques on the test bench shall be done according to the following procedure.

5.3.5.3.1 General requirements

The axle used for the measurements shall be out of the serial production and in accordance to the drawing specifications for series production axles. If axle variants with different gear ratios shall be tested, the usage of one unchanging axle housing including the bearings is permitted.

RUN-IN

The axle gears used for the measurements shall be completely new. A run-in can be done. This procedure shall not exceed 100 hours at a limited power of 300 kW (or less) with a maximum oil temperature of 100°C (these limitations are not valid for wheel end bearings).

The run-in and the test bench measurements shall be performed within 100 + 20 hours.

The speed and torque profile shall be specified by the OEM.

TEMPERATURES

The ambient temperature during the test shall be in a range of 25°C ± 10°C. The ambient temperature shall be measured 1 m laterally from the axle.

Except for oil, no external heating is allowed (requirements for oil conditioning below).

The oil temperature measured at the oil sump / hub reduction must not exceed 70°C during the testing.

OIL QUALITY, LEVEL AND CONDITIONING

Only factory fill oil is allowed to be used for measurement.

If different factory fill oils are available, at least the worst oil has to be used for the measurements. The results with worst case oil are valid for more efficient oils that not have been measured.

To find the worst case oil for each axle line all factory fill oils have to be tested with one axle variant. The effect of the different oils on CO_2 has to be compared by VECTO simulation with a reference vehicle configuration. The oil with the highest total vehicle CO_2 emissions is the worst case oil.

Optional measurements with additional factory fill oils possible (data has to be labeled accordingly)

In case of different available factory fill oils the measurement with highest axle ratio and worst oil would be valid for every variant of the axle submodel series, if no other tests will be done

Test results with better oils can only be applied for axles with lower ratio and equal or better oils from the same submodel series

If there are test results for an axle ratio with worst oil and for a higher ratio with better oils available, the manufacturer can choose what result is being used.

The oil shall be changed for run-in procedure and for each measurement of different gear ratio variants.

The oil level shall meet the specifications for the axle (factory fill oil level).

An external oil conditioning system is allowed but shall not influence the measurement.

5.3.5.3.2 Installation

The installation of the axle shall be done with an angle of inclination as for installation in the vehicle according to the homologation drawing or at 0°. In case of a tandem axle, each axle has to be measured separately.

The setup shall meet the following requirements:

i. for axles with a lockable differential:
test setup with two electric motors
- one on the input flange of the axle
- second on one of the wheel ends

ii. for axles without lockable differential:
test setup with three electric motors
- one on the input flange of the axle
- one on each wheel end

iii. for drive-through axles (for tandem axle setup):
the longitudinal and inter-wheel differentials have to be locked

iv. a speed and torque measurement flange / gauge bar installed between each motor and the axle

5.3.5.3.3 Measurement equipment

The calibration of all measuring instruments and systems shall be traceable to national (international) standards. The measuring instruments and systems shall comply with the linearity requirements given in Section 9.2 and Table 7 of Annex 4 to UN/ECE Regulation No 49.06. The linearity verification shall be done as required by internal audit procedures, by the instrument manufacturer or in accordance with ISO 9000 requirements.

Torque:
The inlet and outlet torque of the axle shall be measured with suitable torque gauges / flanges with temperature compensation.

Measurement ranges:	Inlet torque	0 – 5000 Nm
	Outlet torque	0 – 10000 Nm
Required accuracy:	± 0,05 % of maximum torque	

Rotational speed:
The rotational speeds shall be measured with suitable sensors (e.g. incremental encoders).
The error of the speed sensors shall not exceed ± 1 rpm.

Temperatures:
The temperatures shall be measured with PT100 or thermocouples Type K sensors.
The error of the temperature sensors for the measurement of the ambient temperature shall not exceed ± 1 °C.
The error of the temperature sensors for the measurement of the oil temperature shall not exceed ± 0.5 °C.

5.3.5.3.4 Measurement signals and data recording

At least the following signals shall be recorded during the measurement:

i. Inlet and outlet torques [Nm]
ii. Inlet and outlet rotational speeds [rpm]
iii. Ambient temperature [°C]
iv. Oil temperature [°C]

The measurement rate shall be 10 Hz or higher.

5.3.5.3.5 Test procedure

The measurements shall cover the torque and speed ranges within the limits specified below:

Output torque range: 500 to 10000 Nm
or
for axles with a maximum torque below 10 kNm limited by the 90 % line of coverage of fuel consumption

Input torque range: 0 to 5000 Nm
or
if lower, limited by the maximum possible engine power

Wheel speed range: 50 rpm to maximum wheel speed (occurring with smallest available tire @ 90 km/h for trucks, 110 km/h for coaches)

Output torque steps: T_{out} < 5000 Nm: 500 Nm steps
T_{out} > 5000 Nm: 1000 Nm steps

Wheel speed steps: 50 rpm steps

Measurement sequence:

The measurements shall be performed beginning with the highest speed down to the lowest (max. to 50 rpm). For each speed step the torque loss shall be measured for each output torque step, moving the torque from 500 Nm up to the maximum and back down. Let the torque stabilize at each grid point for minimum 10 seconds before starting the measurement for 30 seconds per point. The recorded values shall be averaged for each measurement point.

The torque variation sequence shall be repeated once, hence gaining 4 measurements per grid point. These values shall be averaged to one result per grid point (see 5.3.5.3.6).

5.3.5.3.6 Data processing

All recorded data shall be checked for any errors.

The results of each measurement point (30 s averages) shall not deviate from the target values more than

± 1 Nm for the input torque
± 1 rpm for the output speed.

The range of the output torque values for the four results per grid point shall not exceed 3 Nm (min. to max.).

If exceeding the above named limits…

5.3.6 Transfer cases

To determine the torque loss of transfer cases the axle test procedure shall be applied, diverging in the following specifications:

5.3.6.1 Installation

The transfer case shall be installed on a test rig with two electric motors, one on the input flange (gearbox side) and one on the output flange to rear axle. The front axle flange shall rotate freely.

The differential shall be locked.

In case of a switchable front wheel drive, the front axle shall be engaged.

The oil sump shall be cooled. Additional air cooling of the transfer case is permitted. External oil cooling is permitted, oil temperatures shall meet the specifications as defined for the axle test procedure.

5.3.6.2 Test procedure

The transfer case shall be tested for each available gear (reduction gears).

The applicable speed range shall be limited upwards considering the maximum vehicle speed with highest axle ratio and smallest available wheel size.

5.3.6.3 Data processing

For vehicles with switchable front wheel drive, the losses of the front wheel drive shall be considered in special operating conditions only (heavy traction mode).

5.3.7 Auxiliaries (Trucks)

The power consumption of truck auxiliaries is considered within the CO_2 calculation by adding a constant power demand to the engine load. This power demand is defined in dependence of the auxiliary type and can be dependent on the vehicle segment, the mission profile and the specific technology. The power consumption of the following auxiliaries shall be considered:

1. fan
2. steering pump
3. electric system

4. pneumatic system
5. AC system

5.3.7.1 Fan

For the fan power the following default values are to be used depending on mission profile and technology:

Fan drive	Fan control	Fan power consumption [W]				
		Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
Crankshaft mounted	Electronically controlled visco clutch	618	671	516	566	1037
	Bimetallic controlled visco clutch	818	871	676	766	1277
	Discrete step clutch	668	721	616	616	1157
	On/off cluch	718	771	666	666	1237
Belt driven of driven via transmission	Electronically controlled visco clutch	889	944	733	833	1378
	Bimetallic controlled visco clutch	1089	1144	893	1033	1618
	Discrete step clutch	939	994	883	883	1498
	On/off cluch	989	1044	933	933	1578
Hydraulic driven	Variable displacement pump	738	955	632	717	1672
	Constant displacement pump	1000	1200	800	900	2100
Electrically	Electronically	700	800	600	600	1400

Table 5-4: Fan power consumption

5.3.7.2 Steering pump

For the steering pump power the following default values [W] are to be used depending on the application:

Identification of vehicle configuration					Steering power consumption [W]													
Number of axles	Axle configuration	Chassis configuration	Weight	Vehicle class	Long haul				Regional delivery				Urban delivery				Municipal utility	Construction
					U	F	B	S	U	F	B	S	U	F	B	S	?	?
2	4x2	Rigid + (Tractor)	> 7,5t - 10t	1					110	130	20	0	100	120	20	30		
		Rigid + (Tractor)	> 10t - 12t	2	150	190	30	0	130	160	30	0	120	140	20	30		
		Rigid + (Tractor)	>12t - 16t	3					140	170	30	0	130	150	30	40		
		Rigid	> 16t	4	230	280	100	0	220	270	40	0					?	
		Tractor	> 16t	5	270	330	120	0	250	290	90	0	?	?	?	?		
	4x4	Rigid	> 7,5 - 16t	6	excluded													
		Rigid	> 16t	7														?
		Tractor	> 16t	8	excluded													
3	6x2/2-4	Rigid	all	9	270	330	120	0	220	270	60	0					?	
		Tractor	all	10	200	250	120	0	200	240	90	0						
	6x4	Rigid	all	11														?
		Tractor	all	12														?
	6x6	Rigid	all	13	excluded													
		Tractor	all	14														
4	8x2	Rigid	all	15	excluded													
	8x4	Rigid	all	16														?
	8x6/8x8	Rigid	all	17	excluded													

Table 5-5: Steering power consumption

where:

U = Unloaded – pumping oil without steering pressure demand

F = Friction – friction in the pump

B = Banking – steer correction due to banking of the road or side wind

S = Steering – steer pump power demand due to cornering and manoeuvring

To consider the effect of different technologies, technology depending scaling factors shall be used:

Technology	CF_U (Unloaded)	CF_F (Friction)	CF_B (Banking)	CF_S (Steering)
Fixed displacement	1	1	1	1
Dual displacement	?	?	?	?
Variable displacement	0,6	0,6	0,6	0,6
Electrically supported hydraulic	0,7	1	0,9	0,9
Electric	?	?	?	?

Table 5-6: Scaling factors (Steering power)

The final power demand is calculated by:

$$P_{tot} = P_U * CF_U + P_F * CF_F + P_B * CF_B + P_S * CF_S$$

where:

P_{tot} = Total power demand [W]

P_U = Unloaded power demand [W]

P_F = Friction power demand [W]

P_B = Banking power demand [W]

P_S = Steering power demand [W]

CF_U = Correction factor unloaded [-]

CF_F = Correction factor friction [-]

CF_B = Correction factor banking [-]

CF_S = Correction factor steering [-]

5.3.7.3 Electric system

For the electric system power the following default values [W] are to be used depending on the application and technology:

Technologies influencing electric power consumption	Electric power consumption [W]				
	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
Standard technology electric power [W]	1240	1055	974	974	975
Electric power saving technology 1	-50	-50	-50	-50	-50
Electric power saving technology 2	0	0	0	0	0
Additional consumers	0	0	0	0	0
Total average electric load [W]	**1190**	**1005**	**924**	**924**	**925**

Table 5-7: Electric system power consumption

To derive the mechanical power, an alternator technology dependent efficiency shall be applied:

Alternator (power conversion) technologies Generic efficiency values for specific technologies	Efficiency η				
	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
Standard alternator	0,7	0,7	0,7	0,7	0,7
High efficiency alternator	0,75	0,75	0,8	0,8	0,8
Super high efficiency alternator	0,8	0,8	0,8	0,8	0,8

Table 5-8: Alternator efficiency

The final power demand is calculated by:

$$P_{tot} = \frac{P_{el}}{\eta_{alt}}$$

where:

P_{tot} = Total power demand [W]

P_{el} = Electrical power demand [W]

η_{alt} = Alternator efficiency [-]

5.3.7.4 Pneumatic system

t.b.d.

5.3.7.5 AC system

For the AC system power the following default values [W] are to be used depending on the application:

Identification of vehicle configuration					AC power consumption [W]				
Number of axles	Axle configuration	Chassis configuration	Weight	Vehicle class	Long haul	Regional delivery	Urban delivery	Municipal utility	Construction
2	4x2	Rigid + (Tractor)	> 7,5t - 10t	1		150	150		
		Rigid + (Tractor)	> 10t - 12t	2	200	200	150		
		Rigid + (Tractor)	>12t - 16t	3		200	150		
		Rigid	> 16t	4	350	200		300	
		Tractor	> 16t	5	350	200			
	4x4	Rigid	> 7,5 - 16t	6	excluded				
		Rigid	> 16t	7					200
		Tractor	> 16t	8	excluded				
3	6x2/2-4	Rigid	all	9	350	200		300	
		Tractor	all	10	350	200			
	6x4	Rigid	all	11					200
		Tractor	all	12					200
	6x6	Rigid	all	13	excluded				
		Tractor	all	14					
4	8x2	Rigid	all	15	excluded				
	8x4	Rigid	all	16					200
	8x6/8x8	Rigid	all	17	excluded				

Table 5-9: AC system power consumption

5.3.8 Driver assistance functions

Issues t.b.d.

- Final testing of system behaviour (OEM comparison with company data)
- Definition of criteria when such a feature can be claimed in the declaration (technical description, verification procedure, check if the feature can be deactivated by the driver etc.)
- Decision whether generic function parameters (e.g. over- and under-speed in the Eco-roll function) or OEM specific values shall be used (rather unlikely). Latter would require testing standards to determine these parameters

6 CONFORMITY OF PRODUCTION

to be developed

7 VALIDATION OF PROCESS / EX-POST VALIDATION

Comment Hausberger: in the “LOT 3 draft final report” the procedure is described as it is suggested for a “proof of concept phase” (validation of this specific test procedure). Details of the final procedure shall be discussed when results from the “proof of concept” phase are available. Tests should be performed in 2014 (participants and funding not decided with status 12.04.2014). The following text thus outlines just the description from the “LOT 3 draft final report”.

Outline of proposal for the proof of concept phase for the validation method.

The SiCo-test (simple constant speed test) is developed to allow a relatively simple check of the entire vehicle specific input data used for single vehicles for certification with VECTO without the demand to have access to the detailed component input data in VECTO. The principle idea is to calculate the fuel consumption in VECTO for a predefined simple constant speed test, which can be driven later on a test track to compare ex-post results from VECTO with the measured values.

7.1 Simulation of a simple constant speed test by VECTO

All input data for VECTO has to be the official data for the certification procedure[3].

Beside the standard CO_2 test cycles for each HDV class also the SiCo velocities are stored in the data base of VECTO for each HDV class. The SiCo velocities are defined by target speed over distance containing the main target speeds of the corresponding CO_2 test cycle (Table 7-1).

	0	30	50	60	85	100
Long haul	x	x		x	x	
Reg Del	x	x		x	x	
Urb Del	x	x		x	x	
Municipal	x	x		x	x	
Construction	x	x		x	x	
City Bus	x	x	x	x		
Coach	x		x		x	x

Table 7-1: Constant speed phases for the SiCo for the corresponding CO_2 test cycles

(0) In idling the auxiliaries have high impact on the measured fuel flow. Since auxiliaries are simulated based on generic data in VECTO, no reasonable accuracy can be expected in idling. The actual proposal still included idling since it may be an indicator on the [g/h] uncertainty added by auxiliaries to the result at higher velocities

[3] As described in 3.3 (where is the set of input data described).

VECTO simulates the SiCo as target speed cycles similarly to the CO_2 test cycles (as option in the proof of concept phase also accelerations and decelerations between the constant speeds are provided to achieve a continuous cycle).

Each constant speed phase is simulated for variations in wind conditions (yaw angle and velocity) and in road gradients (e.g. -0.5%, -0.25%, 0%, +0.25%, +0.5%) to provide table results from which later the real test conditions can be interpolated.

The results for the SiCo are provided by VECTO in a separate SiCo file in addition to the official fuel consumption for the vehicle. The SiCo file contains the vehicle description and the fuel consumption computed for the single phases of the SiCo and for the entire SiCo as shown in Table 7-2.

Comment: The data shown in Table 2 may be gained in a later certification procedure also in 2 steps (step 1 testing and comparing only the fuel flow in [g/h], in case of too high deviations against VECTO results also the torque measurement at wheel hubs can be applied to better allocate the source of the deviation).

	Gear	P-wheel	FC	FC	Time
		[kW]	[g/h]	[g/kWh]	[s]
Idling	0	0.0	1808.6		--
60 const	A	51.0	12413.6	243.4	--
85/0% const	B	101.5	22557.2	222.2	--
85/0.5% const	C	140.8	29802.2	211.7	--
accel 60-85 (1)	Start in A	250.7	--		28
accel 30-85 (1)	Start in z	251.2	--		53
Total (2)		41.8	15938.9	381.4	626

Table 7-2: Example table for the data to be provided by VECTO in the SiCo file for each certified HDV

(1) Accelerations only included if test track and test equipment is sufficient. If acceleration phases can be used in final certification is questionable but it is suggested to include them in the proof of concept phase where possible)

(2) Higher accuracy is expected for the single constant speed phases than for the entire cycle result. Nevertheless in the proof of concept phase also the uncertainties related to a complete cycle should be analysed

7.2 Measurement of the SiCo on a test track with the corresponding HDV

The measurements shall be performed on selected HDV under following conditions:

- The HDV has to be equipped with the vehicle components defined in the SiCo file (*Comment: which auxiliary engagement should be simulated by VECTO for the SiCo needs further discussion*)
- The HDV has to have a total mileage between *aa* and *bb*[4] km
- The tire makes and models have to be in line with the declared ones. The tire profile depth shall be not less than 80% of the new tire, otherwise tires shall be changed
- No additional equipment shall be installed which influences the aerodynamic resistance

The manufacturer shall tests xx[5] HDV per family to report to the type approval authority.

<u>Test set up:</u>

The measurements of the SiCo shall follow exactly the specifications defined in chapter 5.1.2 *(Cd x A test procedure)* with following extensions and open questions:

- Conditioning similar to the aerodynamic drag test procedure *(to be discussed, depends also on findings on influences of preconditioning on RRC which are expected in 2014 from separate test campaigns)*
- Fuel consumption shall be measured on board with the accuracy defined in the technical annex[6]
- If acceleration phases are included in the proof of concept testing, the driver shall perform full load acceleration to the next target speed level (in case of increasing speed) or he shall perform normal braking to reach the next (lower) target speed at the next mark.
- Wind speed and road gradients have to be recorded and calibration of anemometer and velocity signal shall be in line with the aerodynamic drag test (see chapter 5.1.2).
- During the SiCo test the torque and speed at the wheel hub as well as the velocity have to be recorded in accordance with the aerodynamic drag test (see chapter 5.1.2).

7.3 Evaluation of the SiCo test

The values in
Table 7-3 shall be evaluated from the test results as follows:

P-wheel [kW] from following calculations:

M_d [Nm] = average over minimum 10 and maximum 60 seconds of the measured torque, starting averaging later than 15 seconds after reaching each target speed (*Comment: in the proof of concept Phase also data from shorter test tracks with corresponding shorter stabilisation time will be highly welcome, minimum requirements for later certification procedure open yet*).

[4] The mileage values are just placeholders. It needs to be discussed in course of the proof of concept phase if the test procedure shall reflect “new” fuel consumption or fuel consumption after run-in phase.

[5] Placeholder: needs to be discussed if roll in is needed.

[6] Open yet. Fuel flow meters shall allow accuracies <1%, Carbon balance in case of PEMS equipment rather less accurate

Rotational speed [s^{-1}] = average in accordance with M_d.

P-wheel [kW] = Md x Rotational speed x 2 x Pi

FC in [g/h] from following calculations:

FC [g/s] = average in accordance with M_d.

FC [g/h] = FC [g/s] x 3600

FC in [g/kWh] from following calculations:

FC [g/kWh] = FC [g/h] / P-wheel [kW]

Time [s] from following calculations:

Time stamp when new target speed is reached the first time with less than 2% deviation minus time stamp when the former target speed is left the first time with more than 2% deviation *(reasonable thresholds to be defined after first experience with tests)*.

Each result shall be computed per direction first. Then the average over the both directions shall be calculated.

The measured values shall not exceed the limits defined in
Table 7-3.

	P-wheel	FC	FC	Time
	[kW]	[g/h]	[g/kWh]	[s]
Idling	-	-	-	--
60 const	7%	--	4%	--
85/0% const	7%	--	4%	--
85/0.5% const	7%	--	4%	--
accel 60-85	--	--	--	10%
accel 30-85	--	--	--	10%
Total	--	--	7%	--

Table 7-3: Tolerances allowed for the measured values against the ex-post results from VECTO *(all tolerances are just placeholders yet)*

If P-wheel is exceeded by more than the defined tolerances, a deviation in air resistance and/or rolling resistance against the VECTO data exists. The consequences are:

1) Re-check if same tires are mounted as defined in CO_2 certification
2) Check if wind conditions and road gradients are within the boundary conditions

3) Check if aerodynamic condition of the vehicle is as defined in CO_2 certification (body and trailer, additional accessories etc.).
4) If errors are found in 1) to 3), repeat the tests after elimination of the error source

If no error in the test is visible but still the tolerances are exceeded, the component tests for C_d x A and for the tire RRC values have to undergo a quality check.

If the FC in [g/kWh] exceeds the defined tolerances, a deviation in auxiliary power demand, in transmission efficiency or in engine efficiency against the VECTO data exists. The consequences are:

1) Check if correct gears have been used
2) Check auxiliary status, load battery and repeat the test

If exceeding of tolerances remains, the component tests for the gear box, for the axle and for the engine have to undergo a quality check by the type approval authority.

8 ANNEX

8.1 STANDARD BODIES AND TRAILERS

The standard body configurations for the CdxA test procedure depend on the HDV vehicle class (see Table 4-1). Table 8-1 below gives an overview on the standard bodies for each HDV-class.

Reference body	**Reference body type**
B1 B2 B3 B4	hard shell box
B5[7]	tipper for sand/cement
B6	hard shell box
B7[7]	tipper for sand/cement
B8[7]	Construction HDV
B9 [7]	tipper for sand/cement
ST1 *ST2*[7]	hard shell box tipper for sand/cement
T1 = T2	box body

Table 8-1: Standard bodies

[7] *It is suggested not to demand CdxA tests for construction trucks since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a generic Cd-value and a generic mass of body and payload to save test efforts.*

8.1.1 Specifications of Standard Bodies

8.1.1.1 B1

		External	Remarks
Length	mm	6,200	internal >= 6,050 for 15 pallets 5 x 1,200= 6,000
Width	mm	2,550	legal limit (96/53EU), internal >= 2,480
Height	mm	2,680	box: external height: 2,560 internal height; 2,400
Corner radius side & roof with front panel	mm	50 - 80	
Corner radius side with roof panel	mm	50 - 80	
Remaining corners	mm	broken with radius<=5	sharp edges
Mass	kg	1,600	w/o side door (s) w/o tail lift
Accessories			2 back doors

Table 8-2: Standard Body B1

8.1.1.2 B2

		External	Remarks
Length	mm	7,400	internal >= 7,250 for 18 pallets 6 x 1,200= 7,200
Width	mm	2,550	legal limit (96/53EU), internal >= 2,480
Height	mm	2,760	box: external height: 2,640 internal height; 2,480
Corner radius side & roof with front panel	mm	50 - 80	
Corner radius side with roof panel	mm	50 - 80	
Remaining corners	mm	broken with radius<=5	sharp edges
Mass	kg	1,900	w/o side door (s) w/o tail lift
Accessories			2 back doors

Table 8-3: Standard Body B2

8.1.1.3 B3

		External	Remarks
Length	mm	7,450	internal >= 7,250 for 18 pallets 6 x 1,200= 7,200
Width	mm	2,550	legal limit (96/53EU), internal >= 2,480
Height	mm	2,880	box: external height: 2,760 internal height; 2,600
Corner radius side & roof with front panel	mm	50 - 80	
Corner radius side with roof panel	mm	50 - 80	
Remaining corners	mm	broken with radius<=5	sharp edges
Mass	kg	2,000	w/o side door (s) w/o tail lift
Accessories			2 back doors

Table 8-4: Standard Body B3

8.1.1.4 B4

		External	Remarks
Length	mm	7,450	internal >= 7,250 for 18 pallets 6 x 1,200= 7,200
Width	mm	2,550	legal limit (96/53EU), internal >= 2,460
Height	mm	2,980	box: external height: 2,860 internal height; 2,700
Corner radius side & roof with front panel	mm	50 - 80	
Corner radius side with roof panel	mm	50 - 80	
Remaining corners	mm	broken with radius<=5	sharp edges
Mass	kg	2,100	w/o side door (s) w/o tail lift
Accessories			2 back doors

Table 8-5: Standard Body B4

8.1.1.5 B5

B5 is a tipper for sand/cement. It is suggested not to demand CdxA tests for construction trucks (vehicles which only run in the mission profile "construction" in the VECTO HDV-classes) since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their

Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a generic Cd-value and a generic mass of body and payload to save test efforts. Simulation of such Cd-values is ongoing and shall be available for the final LOT3 report.

8.1.1.6 B6

		External	Remarks
Length	mm	7,820	internal >= 7,700 for 19 pallets (3x5) +(2x2) pallets = 19 pallets
Width	mm	2,550	legal limit (96/53EU),
Height	mm	2,980	box: external height: 2,860 internal height; 2,700
Corner radius side & roof with front panel	mm	50 - 80	
Corner radius side with roof panel	mm	50 - 80	
Remaining corners	mm	broken with radius<=5	sharp edges
Mass	kg	2,200	w/o side door (s) w/o tail lift
Accessories			2 back doors

Table 8-6: Standard Body B6

8.1.1.7 B7

B7 is a tipper for sand/cement. It is suggested not to demand CdxA tests for construction trucks (vehicles which only run in the mission profile "construction" in the VECTO HDV-classes) since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a generic Cd-value and a generic mass of body and payload to save test efforts. Simulation of such Cd-values is ongoing and shall be available for the final LOT3 report.

8.1.1.8 B8

B8 is a body for construction trucks. It is suggested not to demand CdxA tests for construction trucks (vehicles which only run in the mission profile "construction" in the VECTO HDV-classes) since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a generic Cd-value and a generic mass of body and payload to save test efforts. Simulation of such Cd-values is ongoing and shall be available for the final LOT3 report.

8.1.1.9 B9

B9 is a tipper for sand/cement. It is suggested not to demand CdxA tests for construction trucks (vehicles which only run in the mission profile "construction" in the VECTO HDV-classes) since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a *generic Cd-value and a generic mass of body and payload to save test efforts. Simulation of such Cd-values is ongoing and shall be available for the final LOT3 report.*

8.1.2 Specifications of Standard Trailers and Semi-Trailers

8.1.2.1 T1

The standard trailer T1 shall meet the following specifications:

Type:

- 2-axle center axle trailer

Body:

- Hard shell body (dry-out box design) only with two rear doors (w/o side doors)

Chassis:

- End to end ladder frame
- Frame w/o underfloor cover
- Drawbar, short coupling
- 2 stripes at each side as underride protection, acc. ECE- R 73, Amendment 01 (2010)
- Rear underride protection (UPS)
- Rear lamp holder plate
- Two spare wheels after the 2rd axle
- One toolbox before first axle (left or rear side)
- Mud flaps before and behind axle assembly
- Air suspension
- Disc brakes

Dimensions and detailed specifications:

		External	Remarks
Total lenght	mm	10,310	
Body lenght	mm	7,820	internal ≥ 7,700 mm for 19 Euro pallets
Total width (Body width)	mm	2,550	legal limit (96/53EU), intern. ≥ 2,460mm
Body height	mm	2,730	ma. Full height: 4,000 (96/53EU)
Full height unloaded	mm	4,000	
Drawbar height, unloaded	mm	425	low coupled, mid of drawbar eye
Wheelbase	mm	6,600	tolerance of +/- 100 acceptable
Axle distance	mm	1,310	2-axle assembly, 18t (96/53EU)
Drawbar length	mm	2,490	
All corners	mm	broken with radius ≤ 5	sharp edges
Toolbox length	mm	445	
Toolbox cross section	mm²	655 x 493	cover plate surface
Cross vehicle weight	kg	18,000	legal CVWR: 18,000 (96/53EU)
Vehicle curb weight	kg	5,400	with two spare wheels with one tool box
Technical axle load	kg	18,000	2 x 9,000
Permitted drawbar load	kg	1,000	

Table 8-7: Standard Trailer T1

Tyre

- Size**:** 385/65 R 22.5
- Rolling resistance: Labeling range Class C (5.1 ≤ RRC ≤ 6.0)
- Rim size: 22.5x11.75
- Pressure: 9.0 bar (cold tyre)
- Same DOT range (≤ 4 weeks) of all tyres
- ≥ 80% of new threat depth
- Tyre age ≤ 3 years
- 1,000 km on test track or drum
- v ≥ 60 km/h

8.1.2.2 S1

The standard semi trailer S1 shall meet the following specifications:

Type:

- 3-axle semi-trailer w/o steering axle(s)

Body:

- Hard shell body (dry-out box design) only with two rear doors (w/o side doors)

Chassis:

- End to end ladder frame
- Frame w/o underfloor cover
- 2 stripes at each side as underride protection
- Rear underride protection (UPS)
- Rear lamp holder plate
- w/o pallet box
- Two spare wheels after the 3rd axle
- One toolbox at the end of the body before UPS (left or right side)
- Mud flaps before and behind axle assembly
- Air suspension
- Disc brakes

Dimensions and detailed specifications:

		External	Remarks
Total length	mm	13, 685	internal 13,620 for 34 Euro pallets
Total width (Body width)	mm	2,550	legal limit (96/53EU), intern. ≥ 2,470
Body height	mm	2,850	max. full height: 4,000 (96/53EU)
Full height, unloaded	mm	4,000	height over the complete length
Trailer coupling height, unloaded	mm	1,150	
Wheelbase	mm	7,700	tolerance of +/- 100 acceptable
Axle distance	mm	1,310	3-axle assembly, 24t (96/53EU)
Front overhang	mm	1,685	radius: 2,040 (legal limit, 96/53EU)
Front wall			flat wall with attachments for compressed air and electricity
Corner front/ side panel	mm	broken with strip under 45 and edge radii ≤ 5	within a radius of 2, 040 (origin: kinpin), (legal limit, 96/53EU)
Remaining corners	mm	broken with radius ≤ 5	sharp edges
Toolbox length	mm	445	
toolbox cross section	mm²	655 x 493	cover plate surface
Side underride protection length	mm	3,045	2 stripes at each side, acc.ECE- R 73, Amendment 01 (2010), +/- 100 depending on wheelbase
Stripe profile	mm²	100 x 30	ECE- R 73, Amendment 01 (2010)
Technical cross vehicle weight	kg	39,000	legal CVWR: 24,000 (96/53EU)
Vehicle curb weight	kg	7,500	with two spare wheels with one tool box
Allowable axle load	kg	24,000	legal limit (96/53EU)
Technical axle load	kg	27,000	3 x 9,000

Table 8-8: Standard Semi-Trailer S1

The tyres to be used during the testing shall meet the following specifications:

- Size: 385/65 R 22.5
- Rolling resistance: Labelling range Class C (5.1 ≤ RRC ≤ 6.0)
- Rim Size: 22.5x11.75
- Pressure: 9.0 bar (cold tyre)
- Same DOT range (≤ 4 weeks)
- ≥ 80% of new threat depth
- Tyre age ≤ 3 years
- 1,000 km on test track or drum
- v ≥ 60 km/h

8.1.2.3 S2

S2 is a tipper for sand/cement. It is suggested not to demand CdxA tests for construction trucks (vehicles which only run in the mission profile "construction" in the VECTO HDV-classes) since the bodies of such HDV vary a lot and are quite different to any "standard". In addition these vehicles hardly drive high velocities, thus their Cd value has only very limited influence on the resulting fuel consumption. Thus these vehicles shall get a generic Cd-value and a generic mass of body and payload to save test efforts. Simulation of such Cd-values is ongoing and shall be available for the final LOT3 report.

8.2 CYCLES

8.2.1 Trucks

For trucks ≥ 7,5t five specific cycles are defined:

8.2.1.1 Long haul

Cycle overview

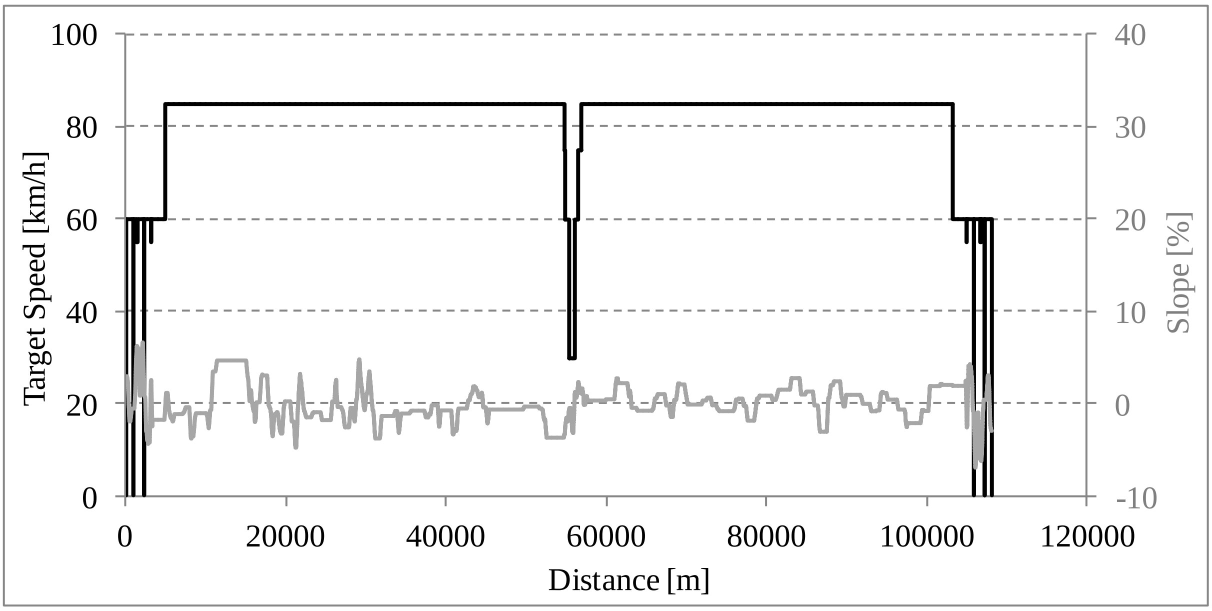

Table 8-9: Long-haul truck cycle

8.2.1.2 Regional delivery

Cycle overview

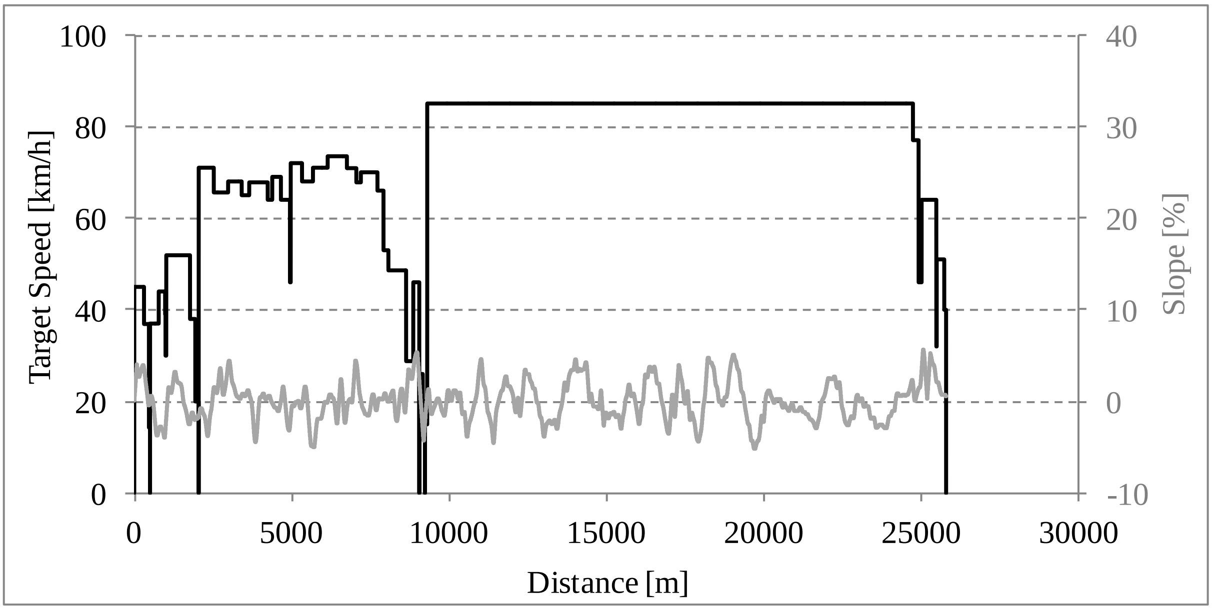

Table 8-10: Regional delivery truck cycle

8.2.1.3 Urban delivery

Cycle overview

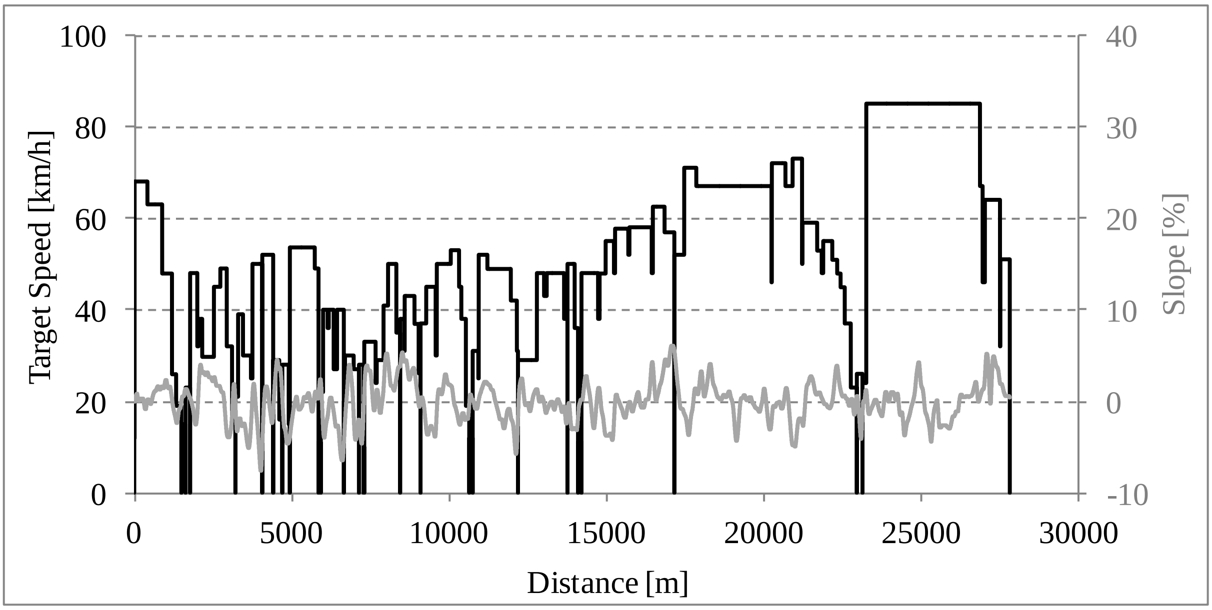

Table 8-11: Urban delivery truck cycle

8.2.1.4 Municipal utility

Cycle overview

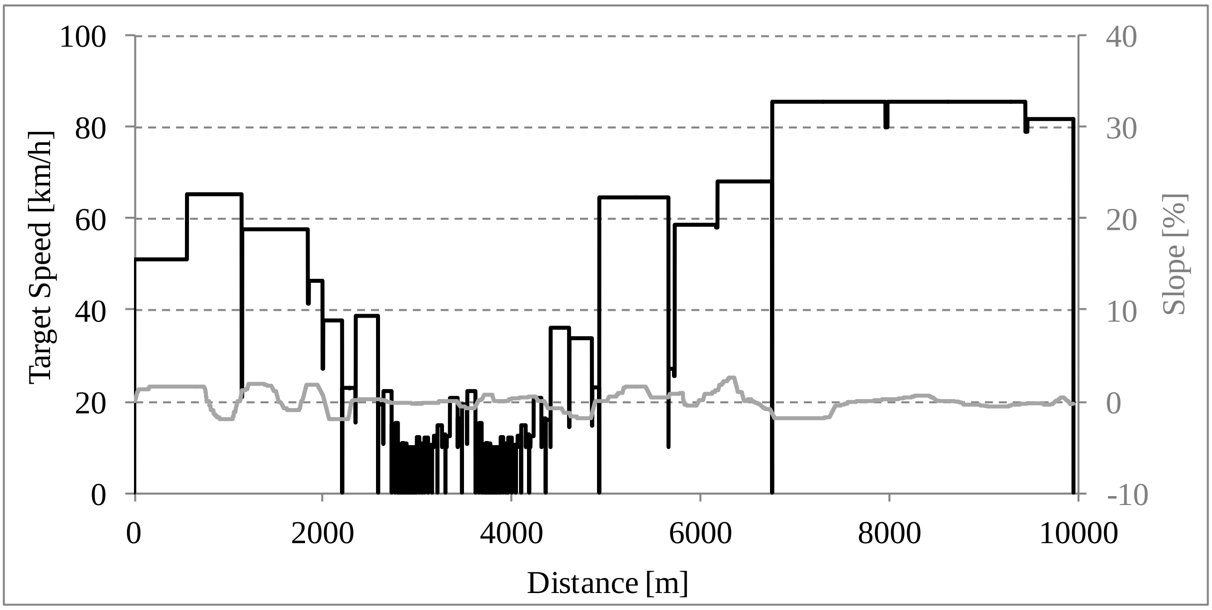

Table 8-12: Municipal utility truck cycle

8.2.1.5 Construction

Cycle overview

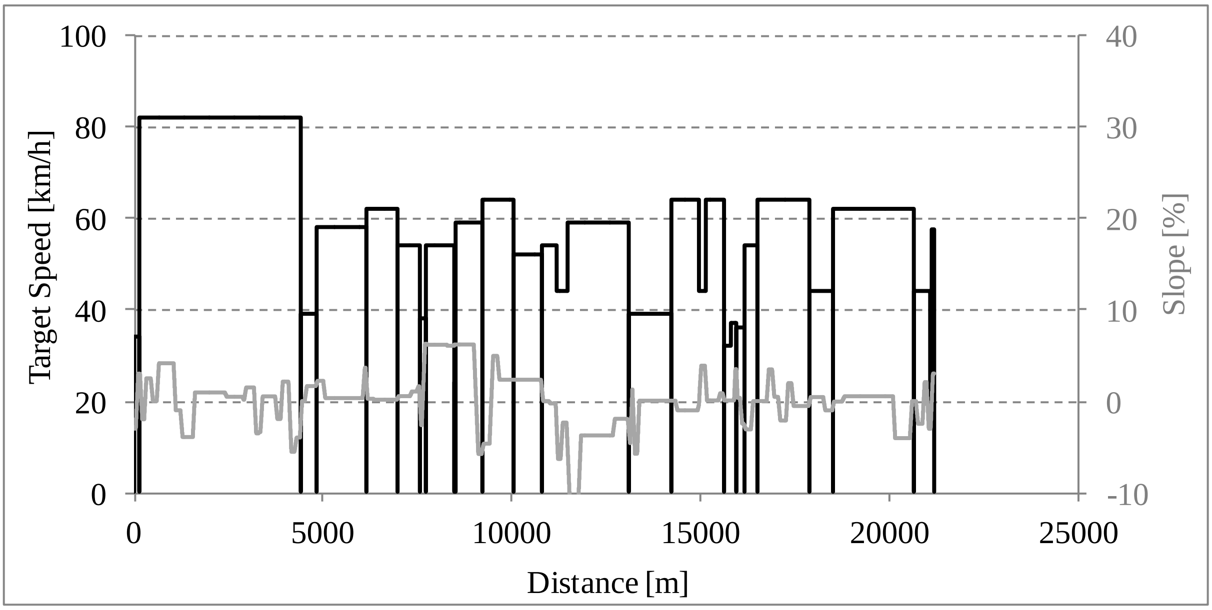

Table 8-13: Construction truck cycle

8.2.2 Buses and Coaches

For Buses and coaches five cycles are defined:

8.2.2.1 Three cycles for city class I (heavy urban, urban, sub-urban)

8.2.2.1.1 Heavy Urban

Cycle overview

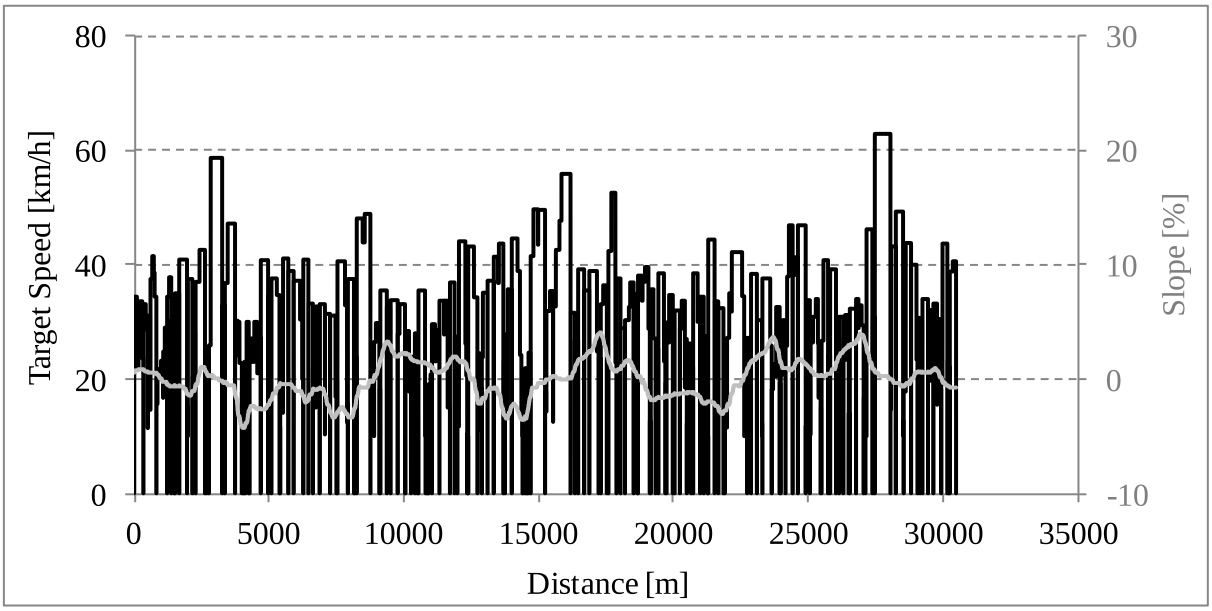

Table 8-14: Heavy Urban bus cycle

8.2.2.1.2 Urban

Cycle overview

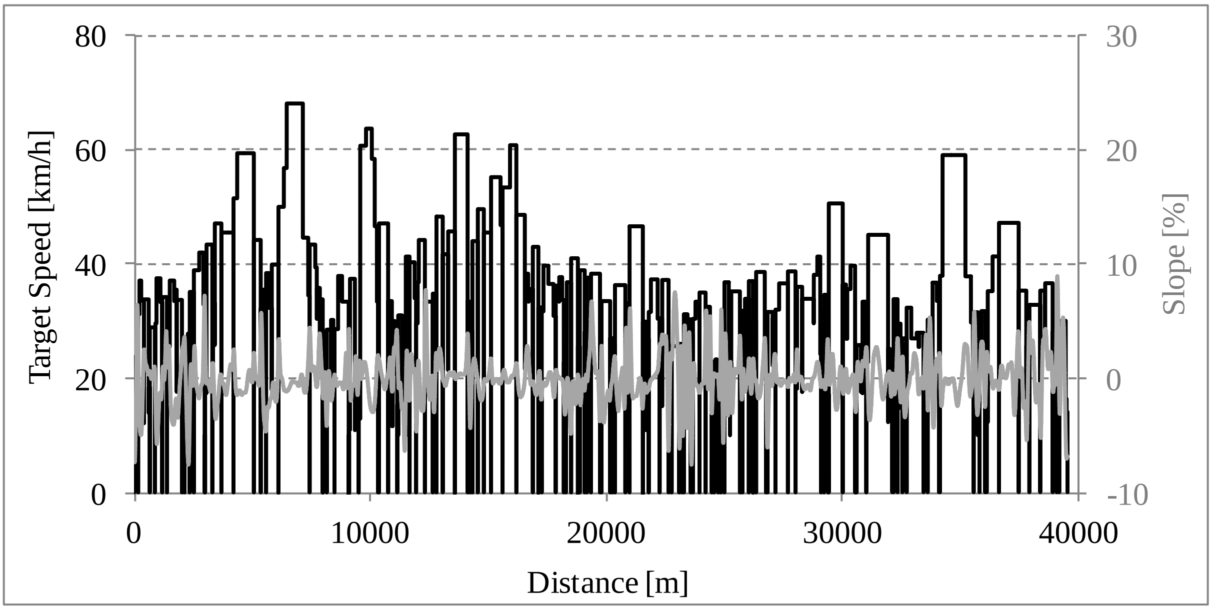

Table 8-15: Urban bus cycle

8.2.2.1.3 Sub-urban

Cycle overview

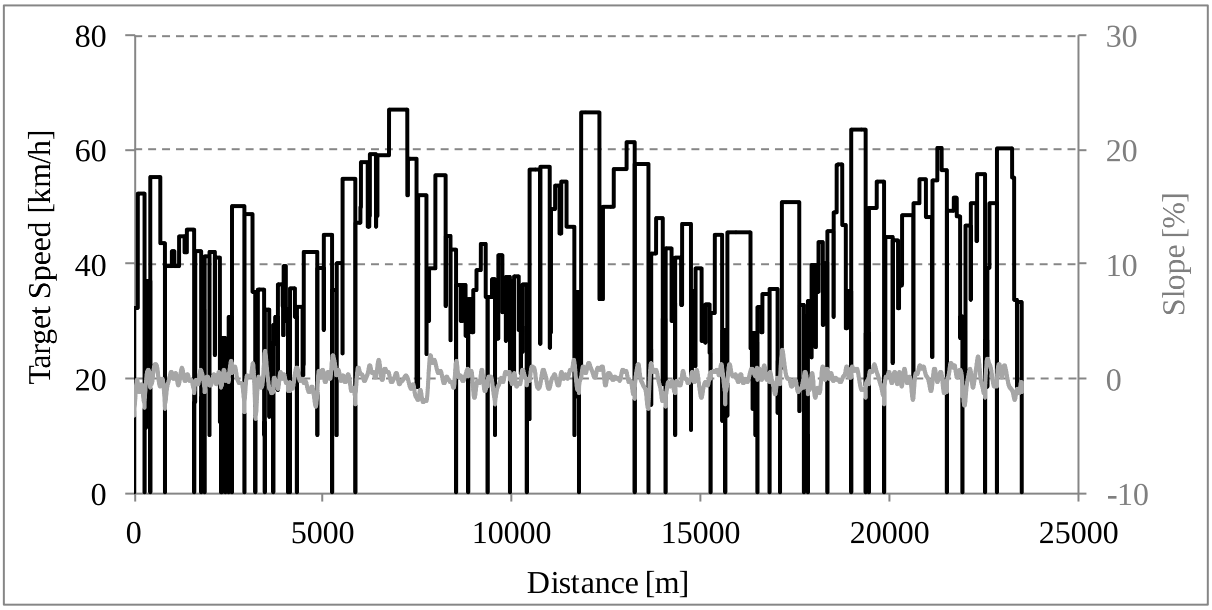

Table 8-16: Sub-urban bus cycle

8.2.2.2 One cycle for interurban class II

Cycle overview

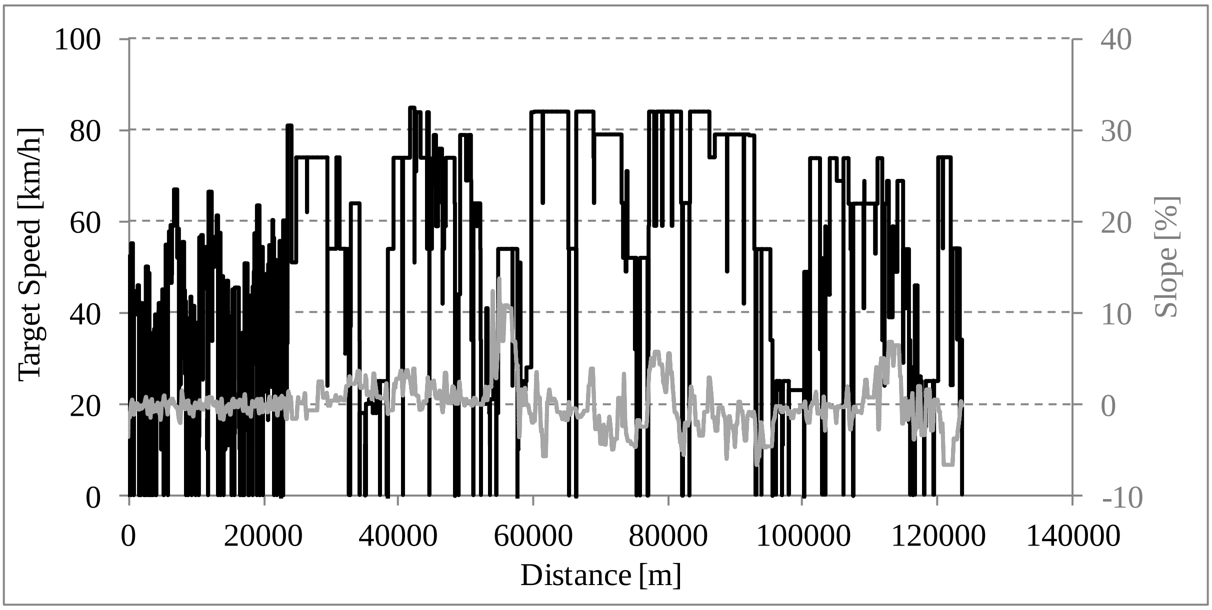

Table 8-17: Interurban class II bus cycle

8.2.2.3 One cycle for coach class III

Cycle overview

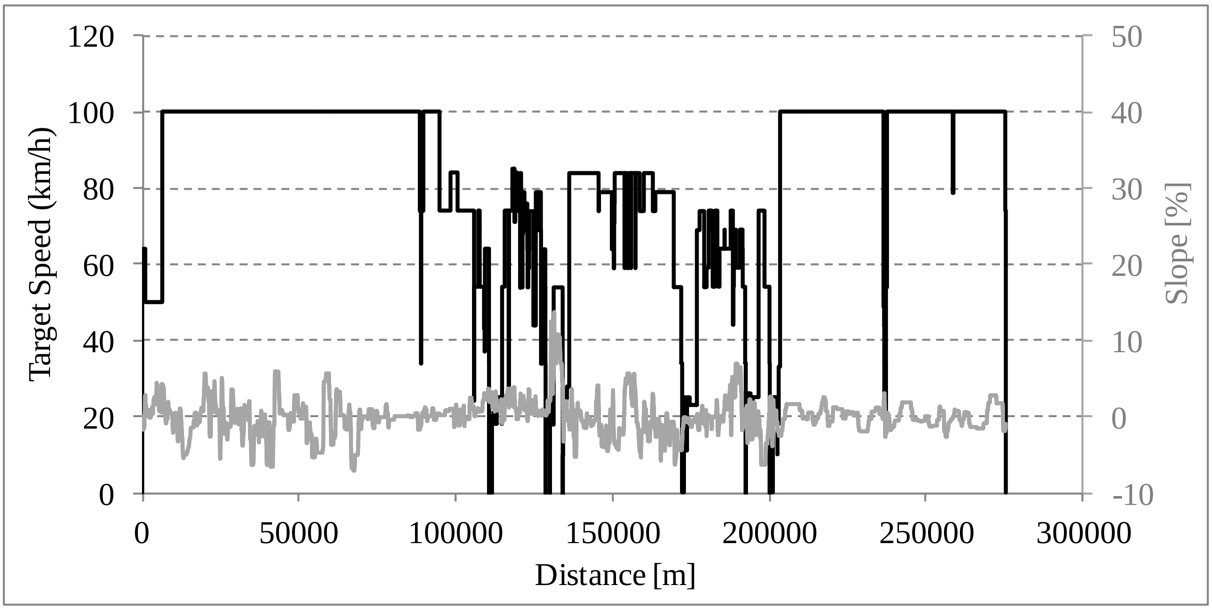

Table 8-18: Coach class III bus cycle