Hybrid GRPE workshop on the global harmonization of Heavy Duty fuel economy, energy consumption and range determination

Session 2 : First elements to be considered for global harmonization

- Component testing as part of HDV FE regulatory frameworks -

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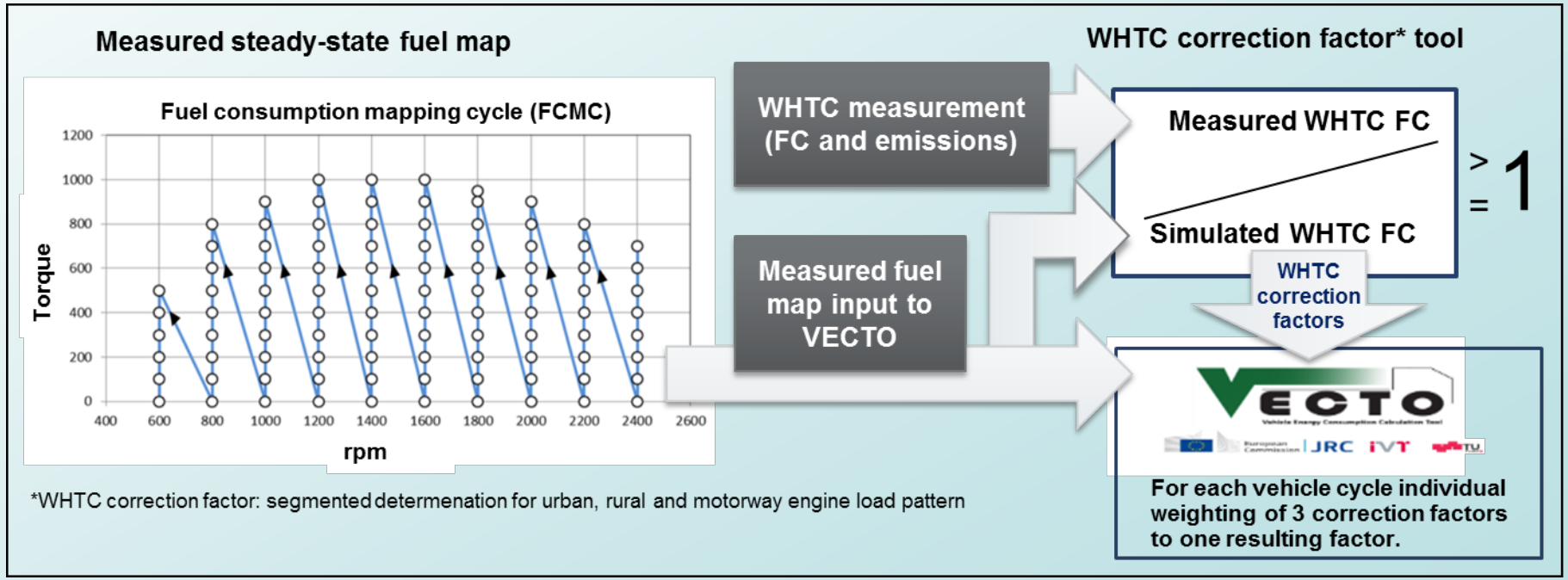
ITEMS

1. Engine measurement
2. Aero drag measurement
3. Tire rolling resistance measurement
4. Others (Gear, AT parts)

Measurement : Engine

Steady state engine map

- A steady-state fuel map covers the whole engine load/speed range which is needed to provide realistic CO2 simulation results. Approximately 100 test points are needed. A defined fuel consumption mapping cycle (FCMC) should be added to the emission certification test cycles.
- For representative consideration of transient engine behavior in the VECTO simulation and to secure consistency with criteria emissions a correction procedure is proposed. This procedure is based on the transient emission test cycle WHTC.
- Number of points, measuring order, and measuring process like sweep time and measuring time, etc.



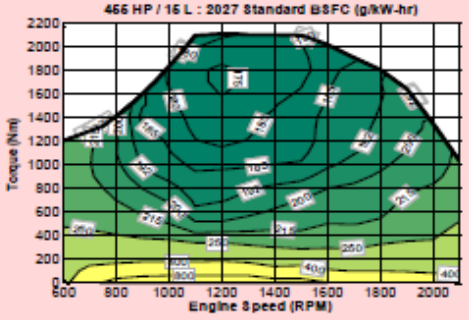
Cycle Average Method

Cycle Average Method is based on the map from transient mode experiment result with engine and T/M or HV parts.

Alternate Method - Certification

GEM Input Data

- **EPA Default Fuel Map (default data not ultimately used, only needed for GEM to run)**
- Engine torque curve



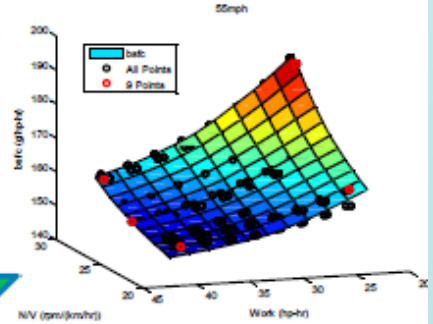
- CdA
- Crr
- Axle Ratio
- Tire radius
- Transmission gear ratios
- …

Run GEM

N/V and Work

Interpolate or curve fitted cycle average fuel Map

Fuel (g/hp-hr)

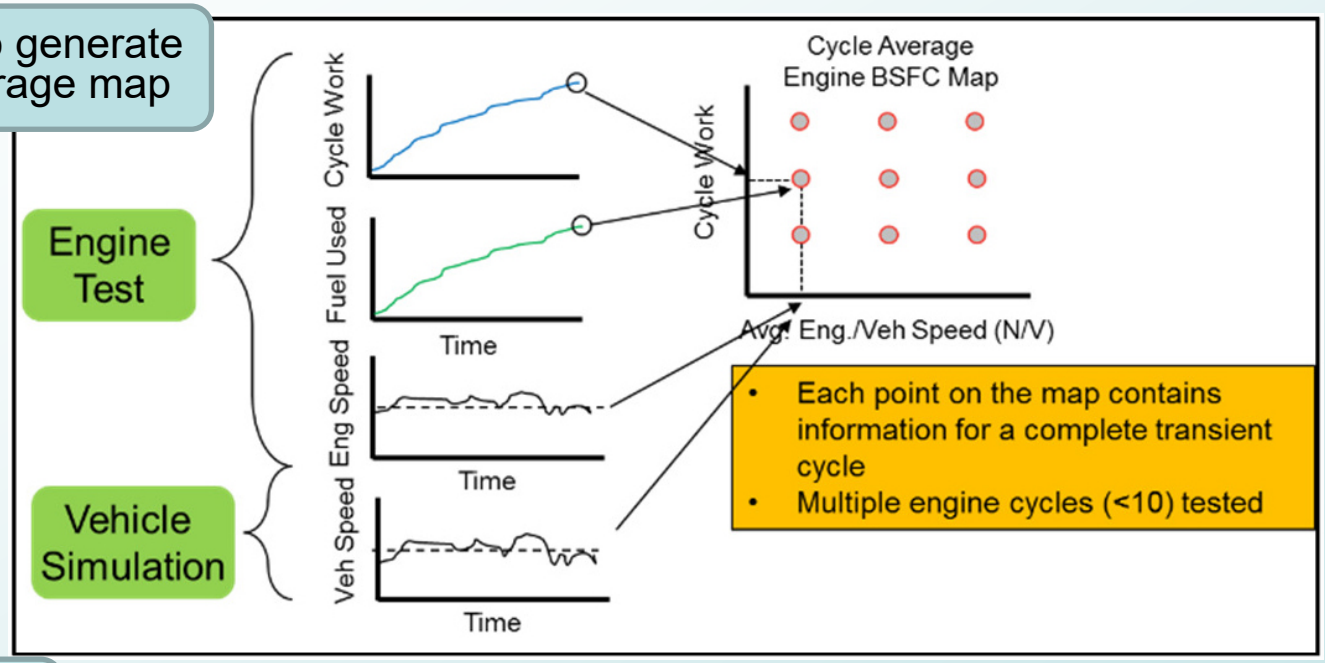


(Work (hp-hr)/ton-mile) x fuel (g/hp-hr) x CO2 (g)/fuel (g) = CO2 g/ton-mile)

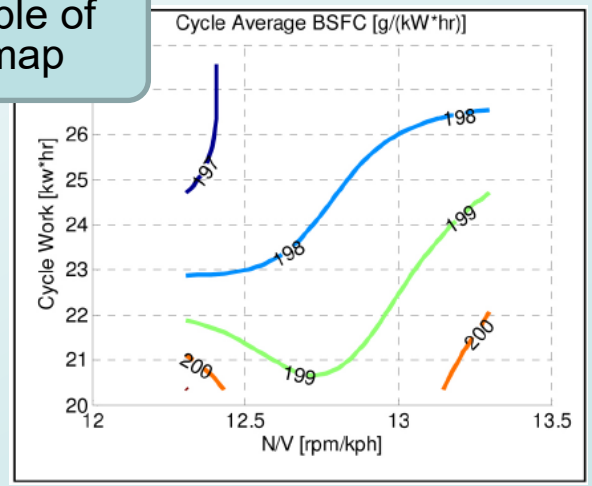
Certification data: CO2 g/ton-mile

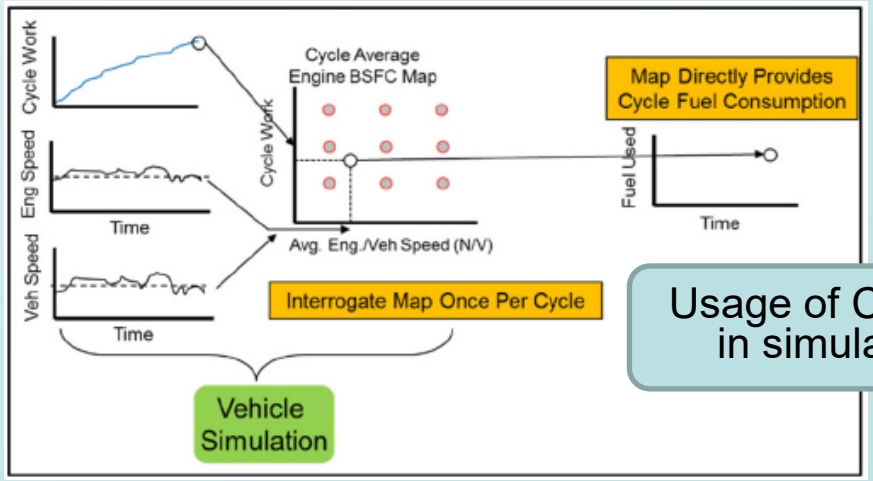
Cycle Average Generation and Usage

Process to generate cycle average map



Example of CA map





Usage of CA map in simulation

Cycle Average Map Input Data

Defined Class 2b through Class 7 vocational vehicle configurations for GEM engine duty cycle generation, engine testing and GEM interpolation

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7	TEST 8
Mass (kg)	7,257	11,408	7,257	11,408	7,257	11,408	7,257	11,408
C_dA	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Tire C_{rr} (kg/ton)	6.7	6.9	6.7	6.9	6.7	6.9	6.7	6.9
Tire Radius (m)	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426
Rotating Inertia (kg)	454	454	454	454	454	454	454	454
Axle Gear Efficiency (%)	95.5	95.5	95.5	95.5	95.5	95.5	95.5	95.5
Accessory Power (W)	1300	1300	1300	1300	1300	1300	1300	1300
Axle ratio at engine speed	A	A	B	B	C	C	Max. engine speed	Max. engine speed

Map and Mode Combination in Phase 2

Vehicle type	55, 65 mph	ARB	Comment
Conventional vehicle w/MT	Steady state fuel map (70 points)	Cycle average map	
	Cycle average		
Conventional vehicle w/AT, AMT	Steady state fuel map (70 points)	Cycle average map	Default AT and AMT logic in GEM is applied
	Cycle average map	Cycle average map	Unique AT and AMT logic is available but Power train test is required
Hybrid vehicle	Cycle average map	Cycle average map	

Measurement : Engine

- Only steady state engine map is used in FE simulation. In the test of engine map, it is necessary to select at least 81 data points to measure the fuel consumption in the range of the normal speed of the engine, from 10% to 100% of the maximum torque.
- The motored torque of engine is needed in the simulation of FE
- The resistance information in FE simulation comes from coast down testing.

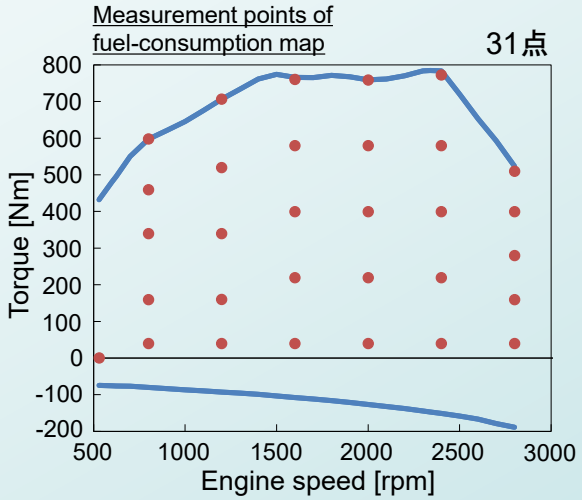
Measurement : Engine

1) Steady state engine map

- Number of points, measuring order, and measuring process like sweep time and measuring time, etc.

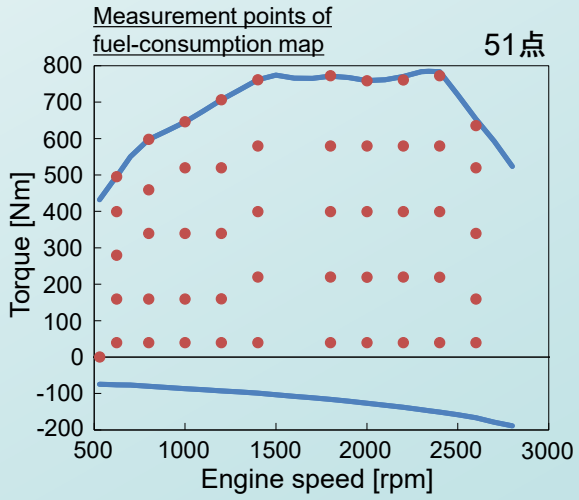
Current FES

Engine speed 6 ×Torque 5 + Idling = 31points



Next FES

Engine speed 10 ×Torque 5 + Idling = 51points



Summary: Engine Measurement

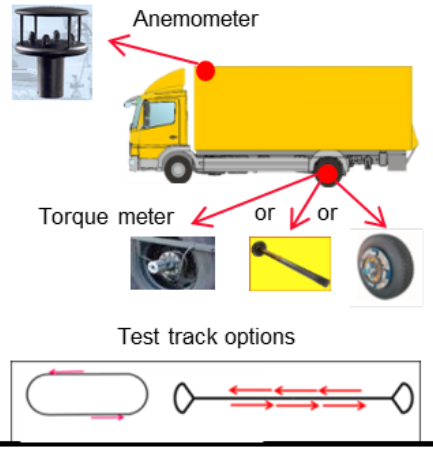
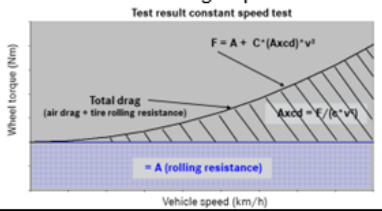
- Steady state fuel map is used in EU, Japan, China and part of US.
- Number of points, measuring order, transitional condition are different but seems available to be harmonized as it will be determined by technical reason.
- Cycle averaged map is based on transient mode operation and totally different policy. This may be a option for each government.
- Transient co-efficient for the steady state map is introduced in EU and Japan.
- Steady state map and cycle average map has quite different concept and may remain as option.

ITEMS

1. Engine measurement
2. Aero drag measurement
3. Tire rolling resistance measurement
4. Others(Gear, AT parts)

Measurement : Aero drag

- The **constant speed vehicle test** was decided to be used for trucks and coaches. As the air drag is a full vehicle characteristic, a full vehicle test incl. body/trailer is needed.
- Likely used for Variants with low sales volume and/or missions with little air drag contribution to CO2 emissions (e.g. city-bus)

Option 1	Table values for CdxA	Table values implemented in simulation tool and can be used as option or mandatory. Likely used for Variants with low sales volume and/or missions with little air drag contribution to CO2 emissions (e.g. city-bus)
Option 2	Measure CdxA with a constant full speed vehicle test and use standard trailer/body.	 Measure torque of driven wheels, vehicle velocity, actual air velocity and direction at two constant vehicle velocities (low speed and maximum vehicle speed). Assume constant rolling resistance force F_{roll} and air drag force F_{aero} to be quadratic to the velocity. Extract F_{aero} mathematically from the total drag forces measured at low and high speed.  Values may be copied from a measured parent vehicle. Multiple family concept rules have to be obeyed for copying, e.g. similarity of body-in-white & copying only from worse to a better variant (“worst-case principle”).

Measurement : Aero drag

- Coast down is major measurement method for aero drag.
- Simulation and wind tunnel are available.
- Bin is adopted for Cd value.

Table III-32 Phase 2 Aerodynamic Input Definitions to GEM for High Roof Tractors

	Class 7	Class 8	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Test Results (C_dA_{wad} in m^2)			
Bin I	≥7.2	≥7.2	≥6.9
Bin II	6.6-7.1	6.6-7.1	6.3-6.8
Bin III	6.0-6.5	6.0-6.5	5.7-6.2
Bin IV	5.5-5.9	5.5-5.9	5.2-5.6
Bin V	5.0-5.4	5.0-5.4	4.7-5.1
Bin VI	4.5-4.9	4.5-4.9	4.2-4.6
Bin VII	≤4.4	≤4.4	≤4.1
Aerodynamic Input to GEM (C_dA_{wad} in m^2)			
Bin I	7.45	7.45	7.15
Bin II	6.85	6.85	6.55
Bin III	6.25	6.25	5.95
Bin IV	5.70	5.70	5.40
Bin V	5.20	5.20	4.90
Bin VI	4.70	4.70	4.40
Bin VII	4.20	4.20	3.90

Measurement : Aero drag

- Provided by manufacture with reasonable report, otherwise use the recommended CD value as following.
- It is available for manufacture to use coast down or wind tunnel for aero drag measuremet.

Category	C_D
Truck	0.8
Dumper	0.8
Bus	0.8
Coach	0.65
Tractor	0.65

Measurement : Aero drag

1. Aero drag measurement method
   - How to measure Cd coefficient like coast down, etc with correction using wind flow meter.

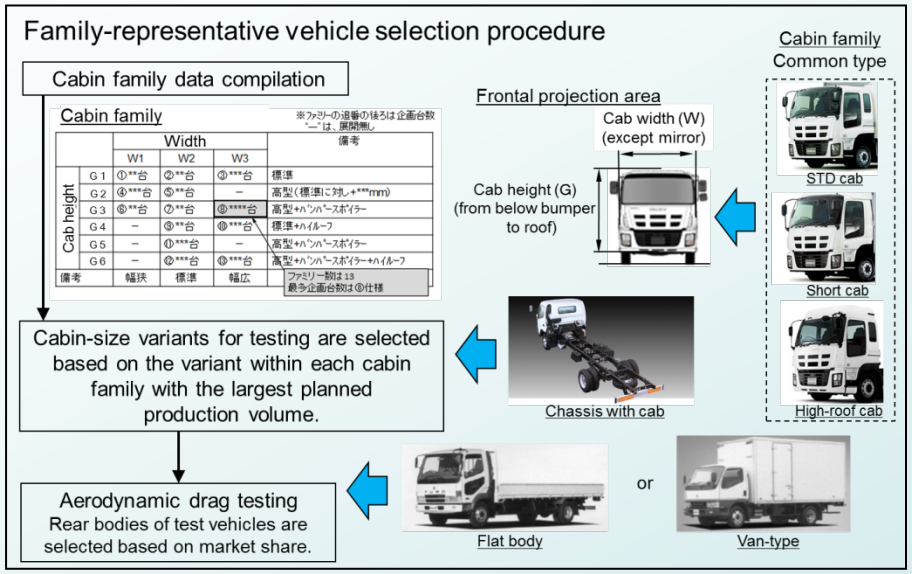
→ “Constant speed (with wheel torque meter)” and “Coast down “
“Anemometer” is Option

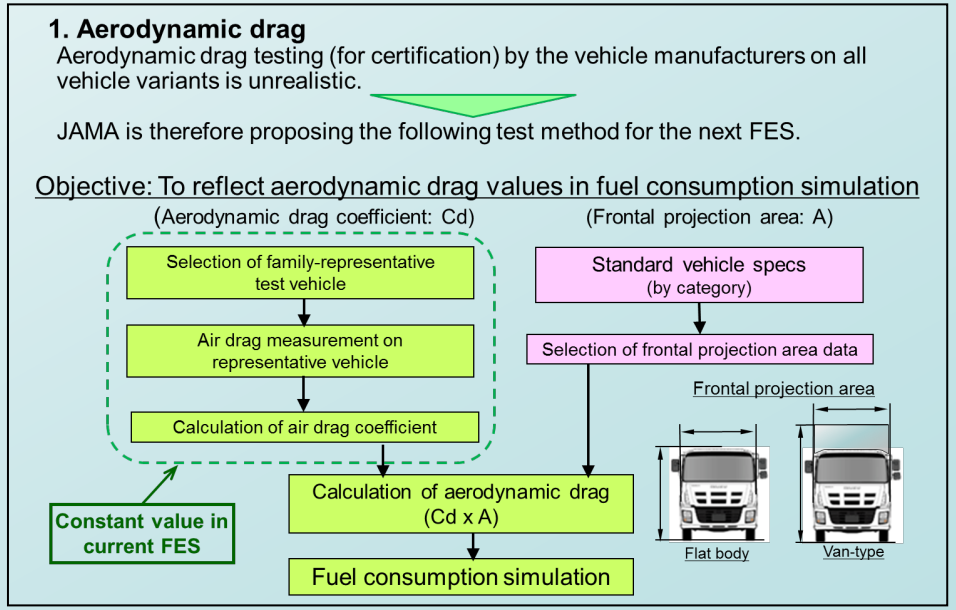
“Constant speed” & “Coast down” testing

- CFD and wind tunnel is also included. → N/A

Measurement : Aero drag

2. Select method of cab and vehicle
   - How to select or specify cabin and rear body should be included.





Summary of Aero Drag Measurement

- EU adopted torque meter method mainly and CFD simulation as option.
- Coast down, wind tunnel and CFD is adopted in US.
- Coast down and wind tunnel are adopted in China.
- Coast down and torque meter are adopted in Japan.
- It will be possible to harmonize the aero drag measurement as common method is used in each area.

ITEMS

1. Engine measurement
2. Aero drag measurement
3. Tire rolling resistance measurement
4. Others(Gear, AT parts)

Measurement: Tire rolling resistance

The rolling resistance values from the tire labeling regulation shall be taken directly as input for the simulation.

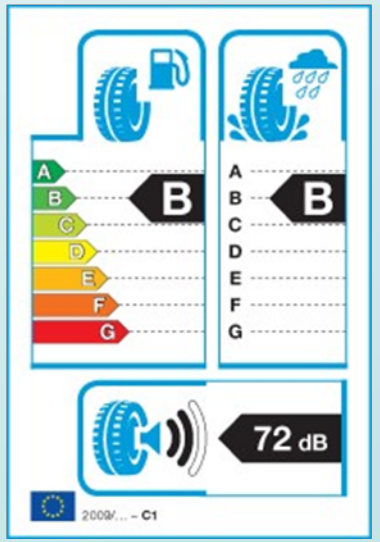
How to measure → (EC) 1222/2009 = ISO28580

Rolling resistance values

C1 tyres		C2 tyres		C3 tyres	
RRC in kg/t	Energy efficiency class	*RRC* in kg/t	Energy efficiency class	*RRC* in kg/t	Energy efficiency class
RRC≤6.5	A	*RRC*≤5.5	A	*RRC*≤4.0	A
6.6≤*RRC*≤7.7	B	5.6≤*RRC*≤6.7	B	4.1≤*RRC*≤5.0	B
7.8≤*RRC*					C
Empty					D
9.1≤*RRC*					E
10.6≤*RR*					F
RRC≥12.1	G	*RRC*≥10.6	G	Empty	G

Specific measured rolling resistance values to be used (e.g. 4.83 kg/t)

Tire labeling system



Wet grip index

External noise of the tire

Measurement : Tire rolling resistance

- Harmonized tire measurement method ISO28580 is adopted.
- Direct value of measurement is used for simulation.

Measurement : Tire rolling resistance

Tire rolling resistance is determined according to:

GCW/GVW<14000kg	bias tire	f=0.0076+0.000056V
	radial tire	
GCW/GVW≥14000kg	bias tire	f=0.0066+0.0000286V
	radial tire	f=0.0041+0.0000256V

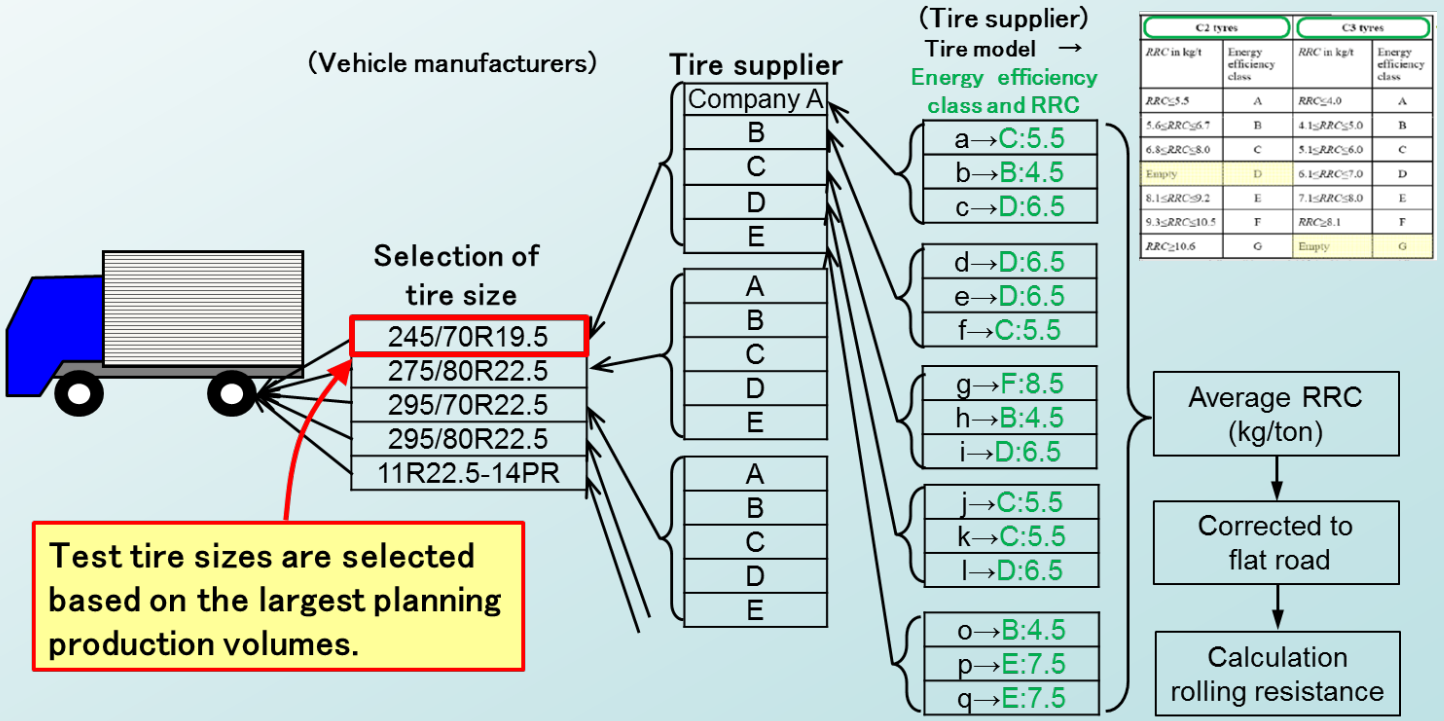
Where V is vehicle speed in km/h

Measurement : Tire rolling resistance

1. Tire rolling resistance
   - How to measure tire rolling resistance. → ISO28580
2. Resistance select method
   - How to select the rolling resistance.
   - Unique value of tire or value using ranking of tire.

Test tire selection method

Tires are selected based on market share, to simplify the selection process in view of the many tire suppliers, tire models and tire sizes in the market.



C2 tyres		C3 tyres	
RRC in kg/t	Energy efficiency class	RRC in kg/t	Energy efficiency class
RRC≦5.5	A	RRC≦4.0	A
5.6≦RRC≦6.7	B	4.1≦RRC≦5.0	B
6.8≦RRC≦8.0	C	5.1≦RRC≦6.0	C
Empty	D	6.1≦RRC≦7.0	D
8.1≦RRC≦9.2	E	7.1≦RRC≦8.0	E
9.3≦RRC≦10.5	F	RRC≧8.1	F
RRC≧10.6	G	Empty	G

Summary of Tire Rolling Resistance

- Tire rolling resistance measurement method is already harmonized and provided by tire maker.
- Remaining part to be harmonize is how to treat resistance value.
- Direct value or value base on ranking is the point of harmonization.

ITEMS

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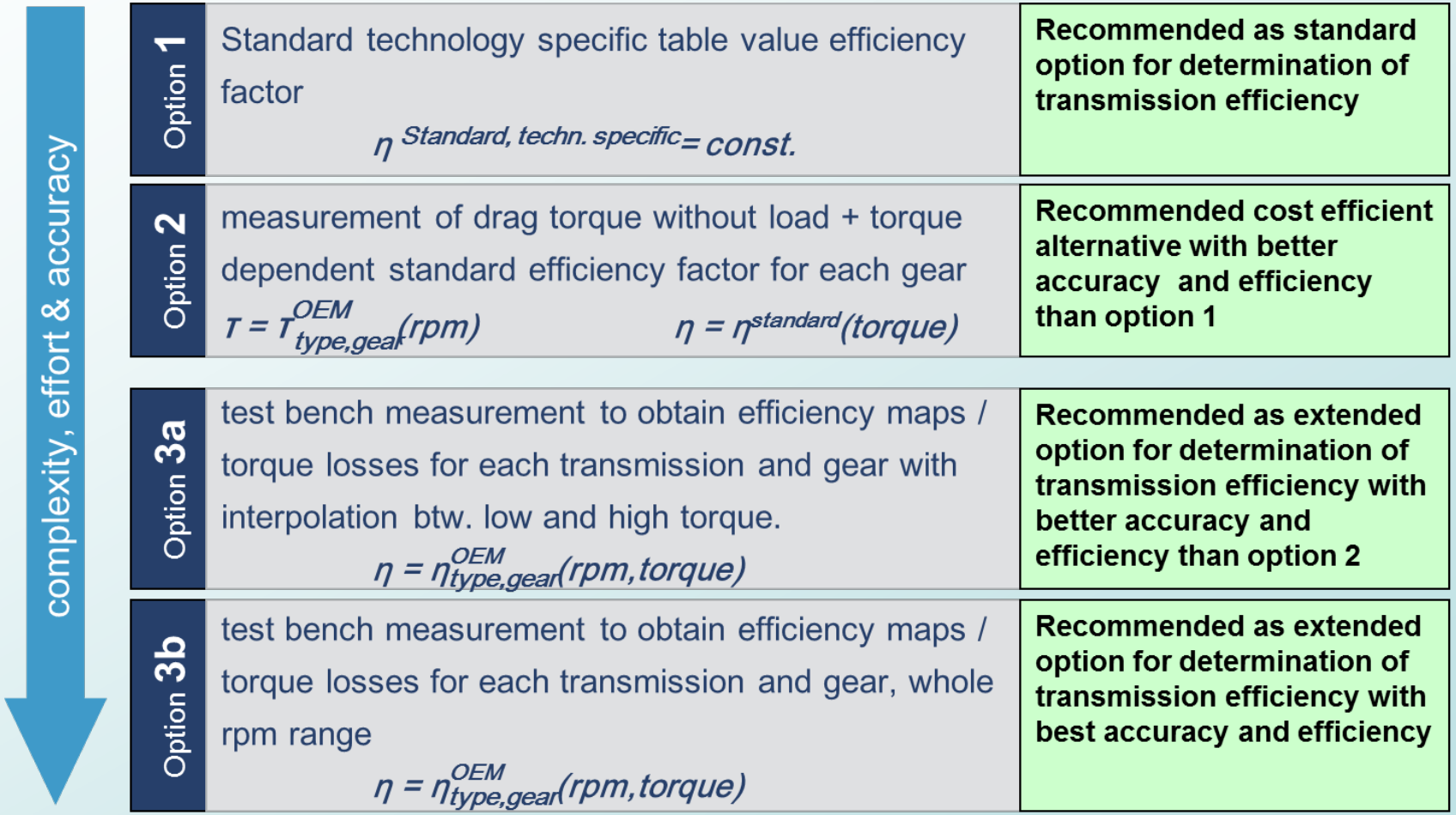
3. Tire rolling resistance measurement
4. Others(Gear, AT parts)

Measurement : Gear

1. Method to determine transmission losses

The vehicle manufacturer can choose from the following four options.



Measurement : Gear

2. Method to determine losses in driven axles

The vehicle manufacturer can choose from the following two options.

complexity, effort & accuracy

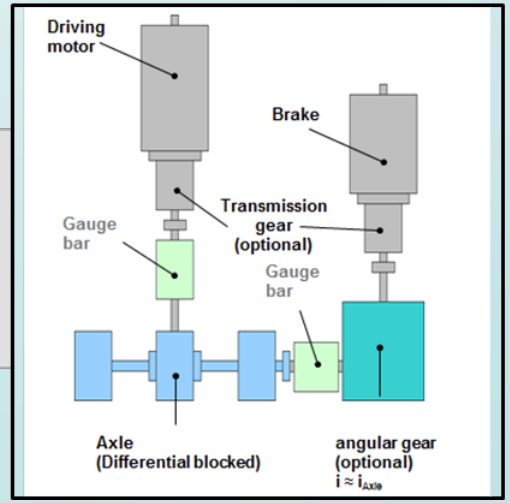
Option 1

Standard torque loss table values from generic const. efficiency and generic constant torque loss

	Generic efficiency η	Drag torque (wheel side) T_d
Standard single driven axle	0.98	T_0 = 70 Nm T_1 = 20 Nm
Tandem axle / single portal axle	0.96	T_0 = 80 Nm T_1 = 20 Nm
Standard hub reduction axle	0.97	T_0 = 70 Nm T_1 = 20 Nm
Tandem hub reduction axle	0.95	T_0 = 90 Nm T_1 = 20 Nm

Option 2

Test bench measurement to obtain speed and load dependent torque loss maps for each individual axle variant



Conclusions

What to focus on as a first step for global harmonization

The driving force for global harmonization is to minimize the resources needed for certifying vehicles, resources in terms of:

- Cost for performing tests.
- Cost for certification administration.
- Investments in test rigs.
- Knowledge and competence building for test personal.

As a first step in harmonization, we should focus on harmonizing the component testing and/or simulations used for certifying the component input data.

If so, when methodology is harmonized, we could (in order of preference):

1. Use one certificate, approved in one market, for all markets.
2. Measurement data derived during one certification test in one market could be used for all markets but the component certificate to be issued on respective market.
3. If test data is not able to use outside the market where the test has been certified, at least use the same testing procedure but redo measurement for each market.

Components testing procedures to be consider for harmonization:

- Engine efficiency
- Air drag performance
  - Physical testing procedure
  - CFD simulation
- Gear box efficiency and ratio
- Rear axle efficiency and ratio
- Tire RR
- Wheel bearing
- Auxiliaries
- ……

We also have component testing for ZEV vehicles that are subject for harmonization, such as:

- Electric drive systems power and efficiency
- Battery system capacity and efficiency
- Fuel cell systems
- …….

Possible next steps

- Bring the topic at GRPE proper session to take official decisions
- Verify the level of interest of GRPE Contracting Parties to create an Informal Working Group on FE Harmonization
- Identify a Contracting Party available to take the leadership of the harmonization activities
- Define the ToR of the IWG, decide the preferable solution for harmonization (UNR? GTR? Mutual Resolution? Other?)

Thank You for the attention!