# Proposal by the ICCT on family building for WLTP-GTR 15

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## Background

In spring 2017, ICCT analysed the definitions of families in the GTR and related regulations. The goal was to understand better the intention of the families and which vehicles can be grouped into them. During this exercise it became apparent that:

- The intention of the families in the GTR are to date not explicitly defined. Instead, parameters which need to have a certain similarity between the family members are defined. Thereby the family functionality is only contained implicitly in the list of parameters, which is not considered transparent.
- To ensure that only appropriate vehicles are members of the family, this approach requires a detailed list of unambiguously defined parameters. A comparison with parameters used in other family definitions (e.g. EU-WLTP) reveal that the descriptions of the parameters is strongly influenced by the state of the technology at the time the family was defined.
- Therefore, the family definition based on parameters will likely not be able to consider future, yet unknown technologies which might have the consequence that either vehicles cannot be grouped into families even though they fulfil the family functionality or that vehicles become members of a family without fulfilling its functionality.

The observed issues and an initial proposal for improvement was presented during the 'Annex 4 – New Issues Task Force' meeting on the 6th of September 2017. It was decided to request a mandate from IWG during the meeting in Seoul in September to proceed on this issue. The topic was then briefly presented during the IWG meeting with no objections to proceed.

During the 3rd 'Annex 4 – New Issues Task Force' meeting on the 4th of December 2017, ICCT proposed to work on a GTR text proposal. Japan raised some concerns and it was agreed that ICCT and Japan would discuss the proposal in more detail in a separate bilateral meeting. This informal meeting was held parallel to the IWG meeting in Geneva where Japan agreed that ICCT should continue to develop a text proposal.

The family definitions are included in part II, section 5. Changes and additions to the current text are marked below by Track Changes. The basis of this GTR text proposal is the clean version of document ECE/TRANS/WP.29/GRPE/2018/2, which includes the modifications of Amendment 4.

## Approach

The chosen approach to improve the family building process in this proposal contains the following elements:

1. A qualitative statement (i.e. a functional requirement) to express the intention of the family building, which clearly sets the purpose of the vehicle group and makes this the responsibility of the manufacturer.
2. Adding an explicit possibility for the responsible authority to challenge the family building for individual vehicles.
3. A quantitative criterion to demonstrate whether an individual vehicle should have been grouped into the family or not. Note that in principle the qualitative statement is more stringent than the quantitative criterion, i.e. a vehicle not fulfilling the qualitative criterion cannot be part of the family, independent of the quantitative criterion.
4. A list of characteristics which should at least be identical for all vehicles in the family, meaning that the list is not exhaustive and might have to be complemented.
5. Making the family building future proof by stating that any characteristic or technology having a non-negligible influence should be added to this list.

## Notes

- Cross-references to the paragraph numbers that are changed by this proposal need to be checked, this will be done after the this proposal has been discussed, modified and adopted.
- The terms used to describe the family characteristics have not been reviewed, they will be harmonised -and where necessary defined- in a second stage.

## GTR text proposal

**Family building in section 5 of Part II:**

5.6. Interpolation family

5.6.1. Interpolation family for ICE vehicles

5.6.1.1. Vehicles shall only be grouped into one interpolation family when their type approval $CO_2$ mass emissions can be accurately determined by a cycle energy based linear interpolation between two reference vehicles, i.e. vehicle L and vehicle H as defined in paragraph 2.3.1 of Annex 6 and if they do not exceed the applicable criteria emission limits according to paragraph 1.2. of Annex 6.

The responsible authority may require the manufacturer to demonstrate the linearity for an individual vehicle in the family if there is ground for concern on the accuracy of the interpolation. If the measured $CO_2$ mass emission of the tested vehicle over the applicable WLTC (output of step 8 of Table A7/1 of Annex 7) minus the $CO_2$ mass emission derived by interpolation is higher than 3 g/km or 3% of the interpolated value, whichever value is smaller, the individual vehicle shall not be grouped into the interpolation family. For vehicles with an interpolated $CO_2$ mass emission below 33 g/km the 3% criterion shall be replaced by 1 g/km.

5.6.1.2. Vehicles may be part of the same interpolation family in any of the following cases including combinations of these cases:

(a) They belong to different vehicle classes as described in paragraph 2. of Annex 1;

(b) They have different levels of downscaling as described in paragraph 8. of Annex 1;

(c) They have different capped speeds as described in paragraph 9. of Annex 1.

5.6.1.3. Only vehicles that are identical with respect to at least the following vehicle/power-train/transmission characteristics may be part of the same interpolation family:

(a) Type of internal combustion engine: fuel type, combustion type, engine displacement, full-load characteristics, engine technology, and charging system, and also other engine subsystems or characteristics that have a non-negligible influence on $CO_2$ mass emission under WLTP conditions;

(b) Operation strategy of all $CO_2$ mass emission influencing components within the powertrain;

(c) Transmission type (e.g. manual, automatic, CVT) and transmission model (e.g. torque rating, number of gears, number of clutches, etc.);

(d) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to n/v ratios of the most commonly installed transmission type is within 8 per cent;

**Commented [IR1]:** Note: In some cases there can also be a vehicle M, but that is only used to confirm the linearity. The CO2 value of vehicle M is not used for calculation.

**Commented [IR2]:** In par. 4.5.1. of Annex 8, the linearity of the interpolation family for NOVC-HEV and OVC-HEV is confirmed when vehicle M fulfils a maximum difference of 3% or 3 g/km, whichever is the lower, with a minimum allowance of 1 g/km. The same criterion is therefore applied here for the interpolation family.

**Commented [IR3]:** Check with the Heinz Steven if these requirements do not harm the linear interpolation principle.

**Commented [IR4]:** These terms will be reviewed. For now they remain unchanged.

**Commented [IR5]:** This subsentence might be deleted, as it is obsolete to the new text below (e). Note that the text here only concerns the engine subsystems and characteristics, so other driveline characteristics having an effect on CO2 would be missed.

(e) Number of powered axles.

Any other characteristic or technology that has a non-negligible influence on the $CO_2$ mass emission in the applicable Type 1 test and hence might compromise the linearity of the interpolation shall be added to this list.

5.6.1.4. If an alternative parameter such as a higher $n_{min\_drive}$, as specified in paragraph 2.(k) of Annex 2, or ASM, as defined in paragraph 3.4. of Annex 2 is used, this parameter shall be the same within an interpolation family.

5.6.2. Interpolation family for NOVC-HEVs and OVC-HEVs

In addition to the requirements of paragraph 5.6.1. of this UN GTR, only OVC-HEVs and NOVC-HEVs that are identical with respect to at least the following characteristics may be part of the same interpolation family:

(a) Type and number of electric machines: construction type (asynchronous/ synchronous, etc.), type of coolant (air, liquid) and any other characteristics having a non-negligible influence on $CO_2$ mass emission and electric energy consumption under WLTP conditions;

(b) Type of traction REESS (model, capacity, nominal voltage, nominal power, type of coolant (air, liquid)~~)~~;

(c) Type of electric energy converter between the electric machine and traction REESS, between the traction REESS and low voltage power supply and between the recharge-plug-in and traction REESS, and any other characteristics having a non-negligible influence on $CO_2$ mass emission and electric energy consumption under WLTP conditions;

(d) The difference between the number of charge-depleting cycles from the beginning of the test up to and including the transition cycle shall not be more than one.

The linearity requirements specified in paragraph 5.6.1.1. apply to both the charge depleting and the charge sustaining $CO_2$ mass emissions individually for OVC-HEVs.

5.6.3. Interpolation family for PEVs

5.6.3.1. Vehicles shall only be grouped into one interpolation family when the electric energy consumption can be accurately determined by a cycle energy based linear interpolation between two reference vehicles, i.e. vehicle L and vehicle H as defined in paragraph 2.3.1 of Annex 6.

The responsible authority may require the manufacturer to demonstrate the linearity for an individual vehicle in the family if there is ground for concern on the accuracy of the interpolation. If the measured electric energy consumption of the tested vehicle over the applicable WLTC (output of step 7 of Table A8/10 or step 6 of Table A8/11 of Annex 8) minus the calculated electric energy consumption derived by interpolation is higher than [X MJ] or [3%] or of the interpolated value, whichever is the lower value, the individual vehicle shall not be grouped into the interpolation family.

5.6.3.2. Only PEVs that are identical with respect to the at least following electric powertrain/transmission characteristics may be part of the same interpolation family:

**Commented [IR6]:** This implicitly means that the description of vehicle L and H in par. 2.3.1. of Annex 6 is applicable for NOVC-HEVs and OVC-HEVs. Check with the EV Subgroup if that is appropriate.

**Commented [IR7]:** This can be deleted, as it is obsolete to the new text below (d). Note that the text here only concerns the engine subsystems and characteristics, so other driveline characteristics having an effect on CO2 would be missed.

**Commented [IR8]:** The requirement in 5.6.1.3 below (e) have not been repeated here, because these requirements come in addition to 5.6.1, so this requirement already applies

**Commented [IR9]:** Is it sufficient to only address the CS and CD mass CO2 emissions for linearity, or should we add the EC and AER as well? I would expect that if CD and CS CO2 behave linearly, likely the EC and AER will have the same linear behavior. Maybe it is even sufficient to only address the CS CO2.
Check this with the EV Subgroup.

**Commented [IR10]:** There is no separate description for vehicle L and H of a PEV interpolation family. This implicitly means that the description of vehicle L and H in par. 2.3.1. of Annex 6 is applicable for PEVs. Discuss this with the EV Subgroup if the description of vehicle L and H in par. 2.3.1. is appropriate for PEVs.

**Commented [IR11]:** Also an absolute value should also be added, to avoid that 3% creates a too high tolerance. In contrast to the non-PEV vehicles, a minimum absolute value will not be needed, since the EC will not become extremely low (the low type approval CO2 values for hybrids are related to the combined use of ICE and electric drivetrains). An approach could be to determine what the electric energy consumption equivalent to 3g/km CO2 would be considering average powertrain effiency of both electric and ICE powered vehicles would be.

(a) Type and number of electric machines: construction type (asynchronous/ synchronous, etc.), type of coolant (air, liquid) and any other characteristics having a non-negligible influence on electric energy consumption and range under WLTP conditions;

(b) Type of traction REESS (model, capacity, nominal voltage, nominal power, type of coolant (air, liquid));

(c) Transmission type (e.g. manual, automatic, CVT) and transmission model (e.g. torque rating, number of gears, numbers of clutches, etc.);

(d) Number of powered axles;

(e) Type of electric energy converter between the electric machine and traction REESS, between the traction REESS and low voltage power supply and between the recharge-plug-in and traction REESS, and any other characteristics having a non-negligible influence on electric energy consumption and range under WLTP conditions;

(f) Operation strategy of all components influencing the electric energy consumption within the powertrain;

(g) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the n/v ratios of the most commonly installed transmission type and model is within 8 per cent.

Any other characteristic or technology that has a non-negligible influence on the energy consumption in the applicable Type 1 test and hence might compromise the linearity of the interpolation shall be added to this list.

5.7. Road load family

5.7.1. Vehicles shall only be grouped into one road load family when the type approval road load coefficients can be accurately calculated from the differences in road load relevant characteristics (i.e. mass, aerodynamic drag and tyre rolling resistance) between two reference vehicles, i.e. vehicle L and vehicle H as defined in paragraph 4.2.1.1.2. of Annex 4.

The responsible authority may require the manufacturer to demonstrate the road load for an individual vehicle in the family if there is ground for concern on the accuracy of the calculated road load from the differences in road load relevant characteristics. If the cycle energy based on the measured road load over the applicable WLTC minus the cycle energy based on the calculated road load over the applicable WLTC is higher than [3% or [X MJ]] of the calculated value, the individual vehicle shall not be grouped into the road load family.

5.7.2. Only vehicles that are identical with respect to at least the following characteristics may be part of the same road load family:

(a) Transmission type (e.g. manual, automatic, CVT) and transmission model (e.g. torque rating, number of gears, number of clutches, etc.). At the request of the manufacturer and with approval of the responsible authority, a transmission with lower power losses may be included in the family;

**Commented [IR12]:** This can be deleted, as it is obsolete to the new text below (d). Note that the text here only concerns the engine subsystems and characteristics, so other driveline characteristics having an effect on CO2 would be missed.

**Commented [IR13]:** V2.2: According to 3.3.9: "Energy converter" means a system where the form of energy output is different from the form of energy input.
This contradicts the energy converter that is referred to here, which has electrical energy both as input and output
V2.3: We might also refer to these as 'power convertors', which seems to be a common used term. It might need a separate definition.

**Commented [IR14]:** V2.2: This can be deleted, as it is obsolete to the new text below (d). Note that the text here only concerns the engine subsystems and characteristics, so other driveline characteristics having an effect on CO2 would be missed.

**Commented [IR15]:** Is it sufficient to only address the road load or should we also specifically mention the running resistances? Note: According to par. 8.2.4 of Annex 4, the running resistance is transposed into an equivalent road load (except for the road load matrix family, see below)
Check with road load experts

**Commented [IR16]:** The GTR is not consistent on this term. There are references to road load parameters, values and coefficients. Probably 'coefficients' is the best option, and this should be harmonized.
Check with DC

**Commented [IR17]:** An absolute tolerance may need to be included if the 3% for vehicles with low cycle energy leads to a tolerance equivalent to the test-to-test variation.

(b) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the transmission ratios of the most commonly installed transmission type is within 25 per cent;

(c) Number of powered axles;

Any other characteristic or technology that has a non-negligible influence on the road load in the applicable Type 1 test and hence might compromise the accuracy of the road load calculation shall be added to this list.

If at least one electric machine is coupled in the gearbox position neutral and the vehicle is not equipped with a coastdown mode (paragraph 4.2.1.8.5. of Annex 4) such that the electric machine has no influence on the road load, the criteria in paragraph 5.6.2. (a) of this UN GTR and paragraph 5.6.3.2. (a) of this UN GTR shall apply.

~~If there is a difference, apart from vehicle mass, rolling resistance and aerodynamics, that has a non-negligible influence on road load, that vehicle shall not be considered to be part of the family unless approved by the responsible authority.~~

5.8. Road load matrix family

5.8.1 Vehicles shall only be grouped into one road load matrix family when the type approval road load coefficients can be accurately calculated from the differences in road load relevant characteristics (i.e. mass, aerodynamic drag and tyre rolling resistance) between two reference vehicles, i.e. vehicle $L_M$ and vehicle $H_M$ as defined in paragraph 4.2.1.4. of Annex 4.

The responsible authority may require the manufacturer to demonstrate the road load for an individual vehicle in the family if there is ground for concern on the accuracy of the calculated road load from the differences in road load relevant characteristics. If the cycle energy based on the measured road load over the applicable WLTC minus the cycle energy based on the calculated road load over the applicable WLTC is higher than [3% or X MJ] of the calculated value, the individual vehicle shall not be grouped into the road load matrix family.

5.8.2 The road load matrix family may be applied for vehicles designed for a technically permissible maximum laden mass ≥ 3,000 kg.

Only vehicles which are identical with respect to at least the following characteristics may be part of the same road load matrix family:

(a) Transmission type (e.g. manual, automatic, CVT);

(b) Number of powered axles.

Any other characteristic or technology that has a non-negligible influence on the road load in the applicable Type 1 test and hence might compromise the accuracy of the road load calculation shall be added to this list.

**Commented [IR18]:** Both paragraphs have the exact same requirement, so wouldn't it be sufficient to only refer to one of them Check with road load experts

**Commented [IR19]:** This text was already expressing the functional requirement. It is therefore redundant and can be deleted.

**Commented [IR20]:** Is it sufficient to only address the road load or should we also specifically mention the running resistances?
Note: for vehicles in the road load matrix family there is no transformation of running resistance into road load coefficients

**Commented [IR21]:** Note: In some cases there can also be a vehicle M, but that is only used to confirm the linearity. The CO2 value of vehicle M is not used for calculation.

**Commented [IR22]:** Apply the same criteria as for the road load family.
Note: this tolerance is more relaxed than for the road load family, due to the fact that a safety margin is included for the RLMF. It would become too complex to include a variable tolerance which is reduced by the applicable safety margin.

5.9. Periodically regenerating systems ($K_i$) family

5.9.1. Vehicles shall only be grouped into one $K_i$ family when the regeneration characteristics of the respective periodically regenerating system are similar to those of the test vehicle selected for determining the $K_i$ of the vehicle family.

The responsible authority may require the manufacturer to demonstrate the $K_i$ for an individual vehicle if there is ground for concern on the validity of the $K_i$-value for all vehicles in $K_i$ family due to differences in the regeneration characteristics, e.g. the distance between two regeneration events, the regeneration duration, and the $CO_2$ and criteria emissions during the regeneration event.. If the $K_i$ factor of the tested vehicle over the applicable WLTC minus the family $K_i$ factor is higher than [0.01], respectively if the ratio of the $K_i$ offset for the tested vehicle over the applicable WLTC and the family $K_i$ offset is higher than [1.01], the individual vehicle shall not be grouped into the $K_i$ family.

5.9.2. Only vehicles that are identical with respect to at least the following characteristics may be part of the same periodically regenerating systems family:

(a) Type of internal combustion engine: fuel type, combustion type,

(b) Periodically regenerating system (i.e. catalyst, particulate trap);

(i) Construction (i.e. type of enclosure, type of precious metal, type of substrate, cell density);

(ii) Type and working principle;

(iii) Volume ±10 per cent;

(iv) Location (temperature ±100 °C at second highest reference speed).

(c) The test mass of each vehicle in the family shall be less than or equal to the test mass of the vehicle used for the $K_i$ demonstration test plus 250 kg.

Any other characteristic or technology that has a non-negligible influence on the $K_i$ shall be added to this list. The vehicle selected for measuring the family $K_i$ should have the characteristics and/or technologies expected to result in the highest $K_i$ factor respectively $K_i$ offset.

**Commented [IR23]:** Note to the GTR drafting taskforce: there are no references in Appendix 2 of Annex 6 towards the possibility to create a $K_i$ family, nor any requirements towards selecting a vehicle for testing(!). For obvious reasons, the worst-case vehicle of the family should be selected

**Commented [IR24]:** This tolerance can be kept low. Since the worst-case vehicle should be selected for the $K_i$ determination, only the test-to-test variation is allowed as tolerance. Secondly, if the tested vehicle has a higher $K_i$ factor or offset, the manufacturer should declare the higher $K_i$ as the family $K_i$, which would then include all vehicles in the family

**REESS monitoring family building in Appendix 2 of Annex 6:**

2.2.2. The accuracy of the vehicle on-board REESS charging and discharging data shall be demonstrated by the manufacturer to the responsible authority.

2.2.3 REESS monitoring family

2.2.4 Vehicles shall only be grouped into one REESS monitoring family when they use the same methodology for on-board determination of REESS charging and discharging and if the on-board data are in agreement with the measurement results as determined by the test procedure specified in paragraph 2.1 of this Appendix.

The responsible authority may require the manufacturer to demonstrate the on-board REESS monitoring data for an individual vehicle in the family if there is ground for concern on the accuracy of these data. If the ratio of the measured charging energy over the applicable WLTC and the charging energy from the on-board data is higher than [1.01], or if the ratio of the measured discharging energy over the applicable WLTC and the discharging energy from the on-board data is lower than [0.99], the individual vehicle shall not be grouped into the road load matrix family.

~~The manufacturer may create a REESS monitoring vehicle family to prove that the vehicle on-board REESS charging and discharging data are correct.~~ The accuracy of the data shall be demonstrated on a representative vehicle.

Only vehicles that are at least identical with respect to the following characteristics may be part of the same REESS monitoring family: ~~The following family criteria shall be valid:~~

~~(a) Identical combustion processes (i.e. positive ignition, compression ignition, two-stroke, four-stroke);~~

(a) Same hardware specifications of systems used to determine the REESS data;

(b) Identical charge and/or recuperation strategy (software REESS data module);

(c) On-board data availability;

(d) Identical charging balance measured by REESS data module;

(e) Identical on-board charging balance simulation.

Any other characteristic or technology that has a non-negligible influence on the on-board REESS monitoring and hence might compromise the accuracy of the measured charging and discharging energy shall be added to this list.

2.2.5. All REESSs having no influence on $CO_2$ mass emissions shall be excluded from the on-board monitoring.

**Commented [IR25]:** Note to the GTR drafting taskforce: For reasons of consistency and clarity the REESS monitoring family building paragraph could alternatively be moved to par. 5.10 of Part II

**Commented [IR26]:** This demonstration should be accompanied by acceptance criteria, e.g. "This demonstration shall be accepted if the difference between the measured and on-board data for charging and discharging is less than [x]%".
Check with EV Subgroup

**Commented [IR27]:** Use the same text as for the other vehicle families.

**Commented [IR28]:** What is the idea of this family criterion? The family grouping is mainly dependent on the on-board monitoring hardware, not on the installed engine. This should probably be deleted, and replaced by a monitoring hardware requirement.
Check with EV Subgroup.