Behavioural and Societal Sciences
Van Mourik Broekmanweg 6
2628 XE Delft
P.O. Box 49
2600 AA Delft
The Netherlands

www.tno.nl

T +31 88 866 30 00
F +31 88 866 30 10
infodesk@tno.nl

TNO report

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Development of a method for the measurement and monitoring of CO_2 emissions for N1 multi-stage vehicles Final report

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Author(s)	Robin Vermeulen (TNO) Pim van Mensch (TNO) Willar Vonk (TNO) Giorgos Mellios (Emisia) Petros Katsis (Emisia)
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Summary

This is the final report for work performed under FRAMEWORK CONTRACT ENTR/F1/2009/030.1, lot no 4 “Eco-Innovation Techniques in the Field of the Automotive Sector”, Specific contract SI2.594774: **"Development of a method for the measurement and monitoring of CO_2 emissions for N1 multi-stage vehicles"**.

The goal of the project is to assess options and to develop a method to measure and monitor the CO_2 emissions of N1 multi-stage vehicles (MSV).

In earlier discussion with the stakeholders, two concepts of methods were developed for measuring and monitoring the CO_2 emissions of MSV. These two methods were suggested in the Service Request as subject of the assessment. This project’s goal is to determine which of the methods provides the most representative emission values, and it ultimately aims to develop two robust methods for the measurement and monitoring of the specific CO_2 values from MSV. These two methods are:

1. the dynamometer settings method
2. the default added mass method

Both methods proved to have issues with general criteria like feasibility, reliability/robustness and fairness. This means that if one method is chosen it may be the better method with regard to some of the criteria, while it may be the worse one for others. Some of the points can be improved, however.

Method 1 is the most accurate with respect to the representativeness of the specific CO_2 value for individual vehicles. However, this method requires a robust process to ensure that the right CO_2 value is selected and made available in the EU monitoring system. This is especially true for vehicles approved individually. Furthermore, the technical procedure is currently designed in such a way that not all weight classes can be covered in a representative manner. To improve representativeness and fairness of method 1, this shortfall should be addressed.

Method 2 appears simpler to implement. This method, a default approach, benefits from the fact that the specific CO_2 value is known by the manufacturer at the moment of production. However, method 2 as proposed in [510/2011/EC] faces problems with N1 class boundaries and the lack of a good correlation between added mass for bodywork and reference mass of the base vehicle. These are important barriers for the selection of a representative default mass. Therefore, an alternative approach for the selection of default added mass is proposed which solves the issue with boundaries and may enable the selection of a more representative default mass for a given Base Vehicle type. Even if the Contractor would determine a very accurate default mass value and a more representative approach, method 2 would provide a fictitious CO_2 value which is still not very accurate for individual vehicles. The large inaccuracy is mainly caused by the large variation in bodywork and mass of this bodywork. This leads to individual vehicles on the road falling under CO_2 legislation while they should not and the other way around.

By means of a thorough exercise, combining data from several sources, a dataset was established which contains added mass per vehicle so that this parameter can be evaluated for use in method 2.

A simulation exercise was performed to calculate the effect of adding mass on the CO_2 emission of typical multi-stage vehicles. From this exercise it can be observed that within the current technical procedure for measuring the CO_2 emission, adding mass to a Base Vehicle does not result in a proportional increase of the CO_2 emission. In fact, the CO_2 emission of the vehicles with added mass will move downwards relative to the indicative CO_2 target for N1 vehicles. This is caused by two factors:

- The current procedure has a technical shortfall in assigning a representative load to a vehicle. For higher masses the error introduced by this shortfall becomes worse. It is recommended that the procedure is amended to include more representative loads.
- Without added mass the vehicles are tested in a relatively inefficient setting, meaning that the CO_2 emission improves in a relative sense as a function of mass (the efficiency of the engine's operation increases due to adding mass to the vehicle)

This latter effect impacts the different base vehicle manufacturers in an uneven way because the manufacturers have a different sales portfolio, where average mass is one of the different parameters. This means that, if other criteria were to be ignored, a manufacturer of heavier vehicles may benefit from method 1 while manufacturers of lighter vehicles may benefit from method 2.

Summary of the main conclusions reached regarding the two methods

More in detail, with regard to **method 1** (the dynamometer settings method), the following issues were noted:

- In principle, the advantage of this method is clear from the start: provided that the right processes are in place it enables the monitoring of the CO_2 emissions accurately on an individual vehicle level. However, the measuring procedure still has a technical shortfall affecting the representativeness in the higher inertia weight classes. The shortfall can be addressed by adding representative loads and inertia settings to the procedure.
- A time delay of months up to more than a year exists between production of a completed vehicle and release of the database with registration of that completed vehicle with its final mass and CO_2 value according to the bodywork added. The Base Vehicle manufacturers who are responsible for the CO_2 emission demand a short time delay to be able to plan their sales. A pan European live, real time database is being developed which can be upgraded with specific information of MSV so that OEMs can follow the developments of the MSV fleet in real time.
- A vehicle may in principle end up out of the scope of the N1 legislation if its reference mass is increased above 2610kg or 2840kg due to the body work. Next to a very small group of very special heavy MSV, a significant group of chassis cabs with refrigeration and an insulated box will fall in this zone, as well as for instance vehicles with lifting platforms. These vehicles can only be identified to have fallen 'out of the scope' once they are registered, although it seems hard to identify if an approval has been extended from 2610 to 2840kg.

With regard to **method 2** (the average mass method) the following issues were noted:

- The mass of the vehicle and its corresponding CO_2 value will be a fictitious value which will be added to the Member State (MS) registrations. This fictitious mass value may be confusing and lead to misinterpretation and wrong or false registrations.
- Vehicles will enter the market which should fall under N1 CO_2 legislation but won't (the mass of the real completed vehicle is lower than 2610kg but with default added mass are heavier than 2610kg) and vehicles will enter the market which fall under CO_2 legislation while they shouldn't (the mass of the real completed vehicle is higher than 2610kg but with default added mass lower than 2610kg).
- For the fleet of MSV it became apparent that the average added mass increases with average Base Vehicle mass. However, this relation is rather weak. The original average mass method may also introduce boundary effects at the N1 sub-class borders, for instance when used with discontinuous steps of mass to be added which increase with Base Vehicle mass per N1 sub-class. A continuous function may solve this, but still, a poor relation between Base Vehicle mass and added mass will cause individual vehicles to be assigned a very unrepresentative mass. This inaccuracy and low representativeness for individual vehicles can be somewhat improved by taking parameters from the vehicle which are better predictors for the mass that could be added to a base vehicle. An alternative function is evaluated which uses the maximum technically permissible laden mass and the reference mass of the base vehicle.

With regard to **both methods** some general issues were noted:

- For both method 1 and 2 and vehicles approved under individual approval (IVA), a robust and reliable process for data transfer is needed so that the right mass and the right corresponding CO_2 value arrive in the EU monitoring system. It was found during interviews and questionnaires from several stakeholders that at the moment most MSV are approved according to IVA (estimated at around 80%), following national rules and processes. This means that those vehicles are checked at local TS (Technical Services) against national criteria. The base vehicle manufacturer has no information regarding what happens with these base vehicles. For vehicles falling under IVA there are currently no processes in place which guarantee that the correct CO_2 value will be transferred to the Member State registration authority. It is advised to integrate a system for correct data transfer at the level of the member states registration and at (local) approval. For method 1 the mass and corresponding CO_2 as determined by the Final Stage Manufacturer should be checked.
- For WVTA (Whole Vehicle Type Approval) the situation is different. WVTA is typically done for larger series of vehicles all sharing more or less the same vehicle characteristics. There is a contract between the manufacturer of the base vehicle and the second stage manufacturer and both know what will be built onto the base vehicle. In this dialogue, the right information could easily be transferred for instance via the corresponding Certificate of Conformity (CoC) requested by the Final Stage manufacturer from the Base Vehicle manufacturer. In such cases, the Base Vehicle Manufacturer already knows the final CO_2 value.
- At the present time, based on the member states registration databases, it is very difficult to evaluate the fleet of MSV with regard to its CO_2 emissions and

its mass. To enable monitoring CO_2 emissions and mass of bodywork of MSV, it is recommended that an identifier is introduced which allows distinguishing MSV in a dataset. A swift introduction of this identifier and requirements for registration of mass of bodywork and CO_2 would be needed to be able to reliably monitor the status and developments of mass and CO_2 of MSV.

- Amongst the possibilities to increase the reliability of data transfer is the application of a Pan European live database, which is a preferred option for the OEMs. Also the general use of a unique identifier for individual vehicles may be considered. These options should be investigated further.

This report contains the detailed insights necessary to integrate MSV's in the EU CO_2 legislation.

Contents

Appendices

1 Introduction

This document is the result of the work performed under FRAMEWORK CONTRACT ENTR/F1/2009/030.1, lot no 4 “Eco-Innovation Techniques in the Field of the Automotive Sector”, SERVICE REQUEST number 448343: **"Development of a method for the measurement and monitoring of CO_2 emissions for N1 multi-stage vehicles"**.

1.1 Background

In [510/2011/EC] emission performance standards and targets are defined for light duty vehicles. The CO_2 emission target covers N1 vehicles up to the reference mass of 2610 kg with the exception of special purpose vehicles. Multi-stage vehicles (MSVs), i.e. vehicles built in stages by different manufacturers and approved under the multi-stage type approval, are covered by the scope of this proposal. The type-approval directive [2007/46/EC] sets an obligation to measure CO_2 emissions only for the basic structure (chassis-cabin), and the following stages of the type-approval cover only the parts of the vehicle added to this structure by other manufacturers. If further to the completion of the vehicle the main characteristics do not change, the vehicle does not require another test on the roller bench meaning that the CO_2 value stated on the certificate of conformity is for the chassis-cabin structure only.
The CO_2 emission target regulation requires the Commission to come up with a test procedure providing the CO_2 emission value more representative of the expected final emissions from multi-stage vehicles and sets several other criteria for this new procedure. Annex II to the proposal, sets out in its paragraph B.7, that the manufacturer of the base vehicle is the entity responsible for the overall CO_2 emissions of the completed vehicle. It also sets out that:

"…*in order to ensure that the values of CO_2 emissions, fuel efficiency and mass of completed vehicles are representative, without placing an excessive burden on the manufacturer of the base vehicle, the Commission shall come forward with a specific monitoring procedure and shall review and make the necessary amendments to the relevant type-approval legislation by 31 December 2011 at the latest. When defining such a procedure, the Commission shall, if appropriate, determine how the mass and CO_2 values are monitored, based on a table of CO_2 values corresponding to different final inertia weight classes or based on only one CO_2 value derived from the base vehicle mass plus a default added mass differentiated by N1 class. In the latter case, this mass would also be taken for part C*…".

Moreover, the Commission is required to:

"…*ensure that the manufacturer of the base vehicle has timely access to the mass and to the specific emissions of CO_2 of the completed vehicle*…".

The latter point means that the chosen method would have to ensure that the OEM is able to receive the data on CO_2 from completed vehicles which use the OEM’s base structure. This would preferably have to be done on a regular basis so that manufacturers are able to monitor their average compliance in the course of the year. This raises questions linked to the responsibility for supplying this data to the OEM and its accuracy, and therefore needs to be one of the criterions for choice of the most appropriate method.

The CO_2 emission target proposal, in consequence, lies down two possible methods for the monitoring of mass and CO_2 emissions from multi-stage vehicles:

1. **The "dynamometer settings method"**, further referred to as **"method 1"**, would consist of testing the base vehicle several times, each time setting the chassis dynamometer at a different equivalent inertia value, corresponding to a range of masses.

2. **The "default added mass method"**, further referred to as **"method 2"**, would consist of testing only one time the base vehicle while setting the inertia of the dynamometer at a value corresponding to the sum of the mass of the vehicle plus an estimated default average mass, which would be function of the class of the vehicle.

1.2 Objective of the project

Both methods, as described above, are developed as rough proposals and need to be detailed further. Each method could have advantages and drawbacks, regarding the representativeness and accuracy of its results, and its consequences with respect to the monitoring mandate established in the CO_2 emission target proposal. The project under this Service Request should help the Commission to choose and develop the method to apply by giving insight into the balance between technical and procedural aspects of the two proposed methods.

The work essentially focuses on the development of solutions for the essential shortcomings of each method: options for dataflow in the case of method 1, and the estimation of an average mass value for method 2. This is followed by an assessment of the feasibility of the two methods for the monitoring of mass and CO_2 emissions from multi-stage vehicles, taking into account:
- the accuracy and uncertainties of the methods and the possible influence of inaccuracies and uncertainties on the specific CO_2 emission:
- the feasibility and costs of the methods:
- the possibilities to organise the data transfer between the involved stakeholders (OEMs, second stage manufacturers, type approval and registration authorities and the Commission) and the feasibility and costs of these options:
- the need to close loop-holes and
- possible future implications taking into account the developments in for instance the WLTP working group.

1.3 Working method

To determine options for data transfer to the monitoring system, to derive the average added mass and to be able to assess the options a clear insight is needed in the market, construction, certification and registration of MSV.

The first stage of the project was therefore focused on deriving information from the stakeholders. These are typically:

1. Base Vehicle Manufacturers
2. Bodybuilders (upfitters, 2nd stage manufacturers, final stage manufacturers)
3. Type Approval Authorities
4. Member States Registration Authorities
5. The European Commission

Questionnaires and interviews have been arranged with the stakeholders and available databases have been analysed to retrieve information regarding MSV (Data mining). The most important part of this process is to look for data to establish an average mass value for the three different classes of N1 vehicles (I, II, III) for method 2 and to investigate the situation regarding the dialogue or data transfer between stakeholders.

The outcome of the first phase of the project should be an overview of the available information and a summary of key issues for both methods, so that based on this decisions can be made on to how to proceed in the second phase with the development and assessment of both methods.

In the second stage of the project, both methods are assessed with regard to the criteria mentioned under 1.2 and both methods are developed further in detail through the definition of step-by-step procedures. During the entire project the working group discussions (mainly WLTP) that clearly overlap with the MSV issue are followed closely so that at the final stage of the project an overview can be given on the possible future implications of both methods.

1.4 This report

In the chapter 2 the legislative context is discussed. It gives a summary of the directives and legislation in place and describes the two methods as developed earlier with the stakeholders. More alternatives to both methods and their assessment are presented as well. Furthermore, the implications of both methods for future developments of for instance the WLTP (World Light Duty Test Procedure) will be discussed.

In chapter 3 the fleet of MSV is characterized. This chapter includes the exercise to determine the default added mass for MSV, which is required for method 2.

In chapter 4 the options for the data transfer into the EU monitoring system are discussed.

In chapter 5 both options are assessed with regard to accuracy, robustness, feasibility, workability, costs and fairness. Furthermore, a few alternatives to both methods are assessed.

In chapter 6 the conclusions and recommendations are discussed.

2 Procedure for the measurement of the specific CO_2 emission of multi-stage vehicles

2.1 Legislative context

To clarify the legislative context of the monitoring of the CO_2 emission of N1 vehicles and for better understanding of the scope of the study, a summary is made of the European Directives and ECE Regulations that relate to CO_2 emissions and N1 vehicles. A good understanding of this legislation is needed since it defines the conditions for integration of a procedure for measuring and monitoring the CO_2 emissions of N1 vehicles.

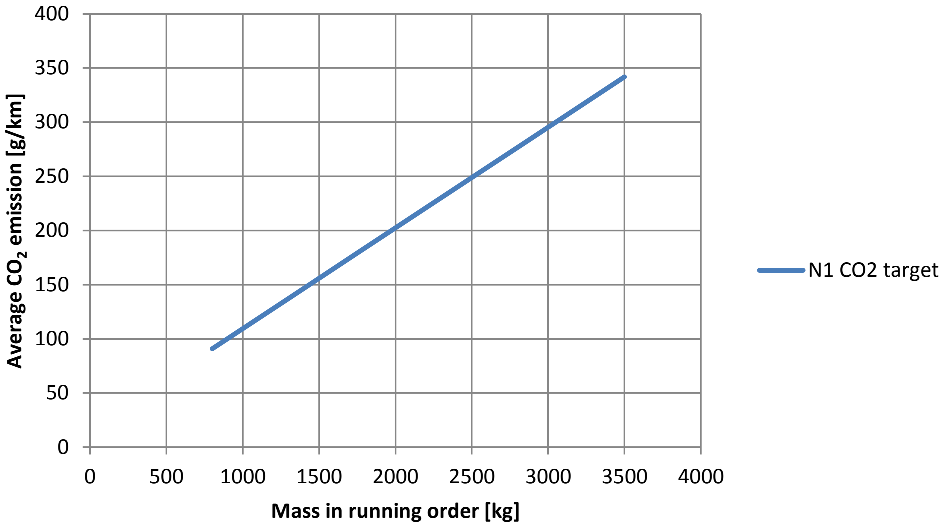
"…As part of its strategy to cut CO_2 emissions from light-duty vehicles, in May 2011 the EU adopted legislation to reduce emissions from vans ('light commercial vehicles'), similar to that passed in 2009 for passenger cars. The Vans Regulation will cut emissions from vans to an average of 175 gram of CO_2 per kilometre by 2017 – with the reduction phased in from 2014 - and to 147g CO_2/km by 2020. These cuts represent reductions of 14% and 28% respectively compared with the 2007 average of 203 g/km…."

In EU regulation [510/2011/EC] emission performance standards and targets are defined for light duty vehicles. The CO_2 emission target covers N1 vehicles up to the reference mass of 2610 kg, with a possible extension to 2840kg and with the exception of special purpose vehicles. An indicative emission target is defined for the average of the registered vehicles of an manufacturer or a pool of manufacturers for 2017:

$CO_2 = 175 + a \times (M - M_0)$ where:

a = 0,093
M= Mass of the vehicle in kilogram
M_0 = 1706

Figure 1: indicative specific CO_2 emission target of N1 vehicles from 2014 to 2017.



In the framework directive [2007/46/EC] a type approval process is defined for vehicles that can be build and certified in more than one stage:

The EU (type) approval of motor vehicles, trailers, components and separate technical units is arranged in framework directive 2007/46/EC. MSV fall under this directive. This directive sets out the requirements for approval and the different types of approval and for instance gives the model for the Certificate of Conformity (COC) in Annex IX (part I for complete or completed vehicles of N1, part II for incomplete vehicles). Annex I gives the complete list of information for the purpose of EC type approval of vehicles.

"…multi-stage type-approval' means the procedure whereby one or more Member States certify that, depending on the state of completion, an incomplete or completed type of vehicle satisfies the relevant administrative provisions and technical requirements of this Directive…"

These vehicles falling under multi-stage type-approval (Multi-stage vehicles or MSV) can thus receive certificates after subsequent stages of completion of a vehicle. The certificates cover the specific requirements for the vehicle for the given specific stage of completion.

In practise, however, these vehicles can also be approved individually, which means that in further stages to completion for certification currently only national rules or processes apply.

This will change when the framework directive [2007/46/EC] will come into force for N1 vehicles: for new types of N1 completed vehicles this is 29 October 2011, for existing types of N1 completed vehicles this is 29 April 2013. In an amendment to [2007/46/EC], namely[183/2011/EC], the Individual Approval is arranged and this regulation gives a model for an approval certificate. The scope of this amendment, however, is limited and **for the moment incomplete and completed vehicles are not included**. It is recommended to include these vehicles in the scope of individual approval.

Multistage vehicles' physical characteristics change due to addition of the bodywork: hence in practise the specific CO_2 emission is affected. This change of specific CO_2 emission should be reflected in the EU CO_2 monitoring system and the OEM, the manufacturer of the Base Vehicle, is the entity responsible for the CO_2 emission of the completed vehicle [510/2011/EC, act 22].

To take the effect of changes of the bodywork into account in the determination of the specific CO_2 emission two methods were developed. These methods are in principle suitable to be integrated into the current system of the measurement and monitoring of the specific CO_2 emission. In the EU regulation [692/2008/EC] regulates the measurement of the CO_2 emission (and fuel consumption) in its ANNEX XII. However, this regulation refers to [UN-ECE R101] and describes exceptions to R101. In its turn R101 refers to [UN-ECE R83] for the actual procedure to measure the CO_2 emission of M1 and N1 vehicles in ANNEX IV (The type I test).

In article 8 of [510/2010/EC] the monitoring and reporting of CO_2 emissions of new LCV is arranged. In ANNEX II the obligations are specified and under point B7 of this ANNEX further specifications are made with regard to the monitoring of the CO_2 emission from completed vehicles which in fact determines the need for this investigation:

"…In the case of multi-stage vehicles, the specific emissions of CO_2 of completed vehicles shall be allocated to the manufacturer of the base vehicle.

In order to ensure that the values of CO_2 emissions, fuel efficiency and mass of completed vehicles are representative, without placing an excessive burden on the manufacturer of the base vehicle, the Commission shall come forward with a specific monitoring procedure and shall review and make the necessary amendments to the relevant type-approval legislation by 31 December 2011 at the latest.

When defining such a procedure, the Commission shall, if appropriate, determine how the mass and CO_2 values are monitored, based on a table of CO_2 values corresponding to different final inertia weight classes or based on only one CO_2 value derived from the base vehicle mass plus a default added mass differentiated by N1 class. In the latter case, this mass would also be taken for Part C of this Annex.

The Commission shall also ensure that the manufacturer of the base vehicle has timely access to the mass and to the specific emissions of CO_2 of the completed vehicle…"

Registration of vehicles within the EU is arranged in a Directive 1999/37/EC. This directive lists the obligatory records required for registration.

2.2 Current situation regarding Approval of MSV and monitoring of CO_2

Multi stage approval in principle is a Whole Vehicle Type Approval. However, in practice MSV are approved mainly under individual approval (IVA). The following (Type)-approval systems are commonly used:

- Individual Approval IVA (+/-80%).
- Whole Vehicle Type Approval, WVTA (EU) (+/-20%)
- National Small Series (a few %, which can be higher for individual Member States)

At the moment the CO_2 of a MSV is most of the times only tested for a given base vehicle family without bodywork or under a certain 'worst case' condition like a high reference mass to cover for a range of bodywork. The family definition is based on identical and similar parameters (of the base vehicle) defined in 592/2008/EC. From Annex XII 3.6.1:

"…N vehicles may be grouped together into a family for the purposes of measurement of fuel consumption and CO_2 emissions if the following parameters are identical or within the specified limits:

3.6.1.1. Identical parameters shall be the following:

— manufacturer and type as defined in section I of Appendix 4,

— engine capacity,

— emission control system type,

— fuel system type as defined in point 1.10.2 of Appendix 4.,

3.6.1.2. The following parameters shall be within the following limits:
— transmission overall ratios (no more than 8 % higher than the lowest) as defined in point 1.13.3 of Appendix 4,
— reference mass (no more than 220 kg lighter than the heaviest),
— frontal area (no more than 15 % smaller than the largest),
— engine power (no more than 10 % less than the highest value).
…"

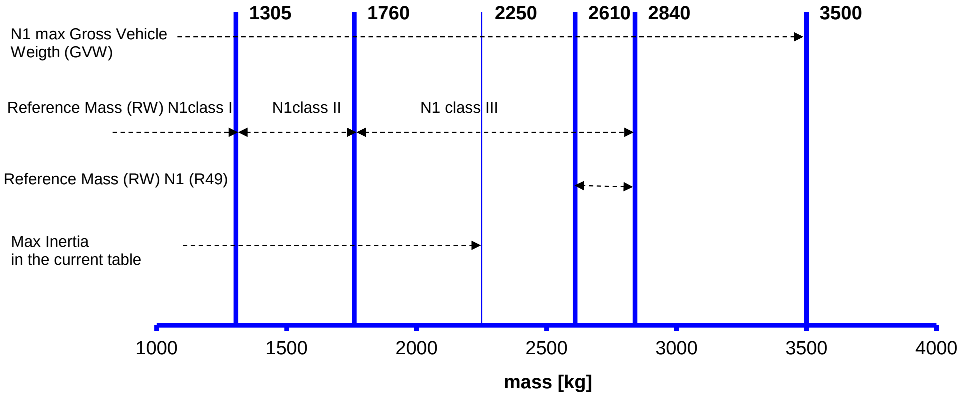
Furthermore, Type Approval can be extended to vehicles of the same type or vehicles of a different type differing in reference mass and transmission ratio within certain boundaries.

The figure below depicts the situation with regard to different masses and limits used within current EU legislation to define N1 Class I, II and III vehicles.
The picture shows that MSV may fall in the N1 heavy duty category (ECE-R49) if the reference mass exceeds 2610kg or 2840kg. The category between 2610 and 2840kg is only included in the scope of the N1 CO_2 legislation if type approval has been extended.

The opposite may also occur. This means that Base Vehicles with a reference mass lower than 2610kg may fall under N1 (R49) if the manufacturer can be demonstrate that the reference mass of 2610kg will be exceeded with all expected bodywork combinations:

From R49:
"…At the request of the manufacturer, the type approval of a completed vehicle given under this Regulation shall be extended to its incomplete vehicle with a reference mass below 2,610 kg. Type approvals shall be extended if the manufacturer can demonstrate that all bodywork combinations expected to be built onto the incomplete vehicle increase the reference mass of the vehicle to above 2,610 kg. The following do not need to be approved according to this Regulation: engines mounted in vehicles of up to 2,840 kg reference mass to which an approval to Regulation No. 83 has been granted as an extension…".

Figure 2: current situation with regard to definitions of scope and classes.



The CO_2 monitoring target applies to 'mass' and CO_2 measured over the type I test (NEDC). According 510/2011/EC 'mass' means the mass of the vehicle with bodywork in running order as stated in the certificate of conformity and defined in Section 2.6 of Annex I to Directive 2007/46/EC.

According Section 2.6 of Annex I to Directive 2007/46/EC mass is defined as follows:

"…2.6. Mass of the vehicle with bodywork and, in the case of a towing vehicle of category other than M1, with coupling device, if fitted by the manufacturer, in running order**, or mass of the chassis or chassis with cab, without bodywork and/or coupling device if the manufacturer does not fit the bodywork and/or coupling device** (including liquids, tools, spare wheel, if fitted, and driver and, for buses and coaches, a crew member if there is a crew seat in the vehicle) (o) (maximum and minimum for each variant)…"

This means that currently in principle for MSV the mass ***without*** *bodywork will be used for monitoring.*

The CO_2 value stems from the type I test, which is performed with a certain adjustment of 'road load' in the chassis dynamometer. Either a road load from a **coast down test** is used or a load and inertia setting is taken from a **table** (table 3a ECE-R83, Annex 4a). In principle for MSV the table is used. The table consists of inertia weight ranges called Inertia Weight Class (IWC) and provides an equivalent inertia value, two load coefficients, a fixed load value and a load correction factor for adjusting the chassis dynamometer for the type I test. The equivalent inertia and corresponding settings are selected from the table based on the reference mass (RW in the table).

From R83:
4.1.3. Testing mass
The testing mass shall be the reference mass of the vehicle with the highest inertia range.

2.2. "Reference mass" means the "unladen mass" of the vehicle increased by a uniform figure of 100 kg for test according to Annexes 4a (Type I test) and 8 (Type IV test):

2.2.1. "Unladen mass" means the mass of the vehicle in running order without the uniform mass of the driver of 75 kg, passengers or load, but with the fuel tank 90 per cent full and the usual set of tools and spare wheel on board, where applicable:

2.2.2. "Running order mass" means the mass described in Paragraph 2.6. of Annex 1 to this Regulation and for vehicles designed and constructed for the carriage of more than 9 persons (in addition to the driver), the mass of a crew member (75 kg), if there is a crew seat amongst the nine or more seats.
The definition of running order mass in ECE-R83 in Annex 1 paragraph 2.6 is the same as in paragraph 2.6 of Annex I of 2007/46/EC.

Reference mass = mass in running order + 100kg -75kg

The reference mass as used for selecting the equivalent inertia (which is used for the Type I NEDC test) is thus 25kg higher than the monitored mass.

2.3 Definition of the two methods and alternatives

Two options came forward from earlier discussions between the EC and the automotive industry in order to enable the inclusion of additional mass into the measurement procedure and the process enabling the monitoring of CO_2 emission. The two options are adopted as options for further refinement of the procedures in Annex II B7 of 510/2010/EC and are described as follows:

1. The "dynamometer settings method"
Further referred to as **method 1**, would consist of testing the base vehicle several times, each time setting in the chassis dynamometer a different equivalent inertia value, corresponding to a range of masses. For the determination of the equivalent inertia values, the table 3 included in point 5.1 of Annex IV to UNECE Regulation 83 could be used. The entity responsible for carrying out the tests would be the OEM. As a result of this procedure, there would be one CO_2 measurement per inertia weight class (see the example in Appendix C) within which the second stage manufacturer would have to choose a single value, according to the mass of the added bodywork. The weight ranges are currently being reviewed in the WLTP group, in the framework of the UNECE.

Figure 3: table (ECE-R83, Annex 4a, table 3) with inertia and load settings as most often used for testing N1 vehicles.

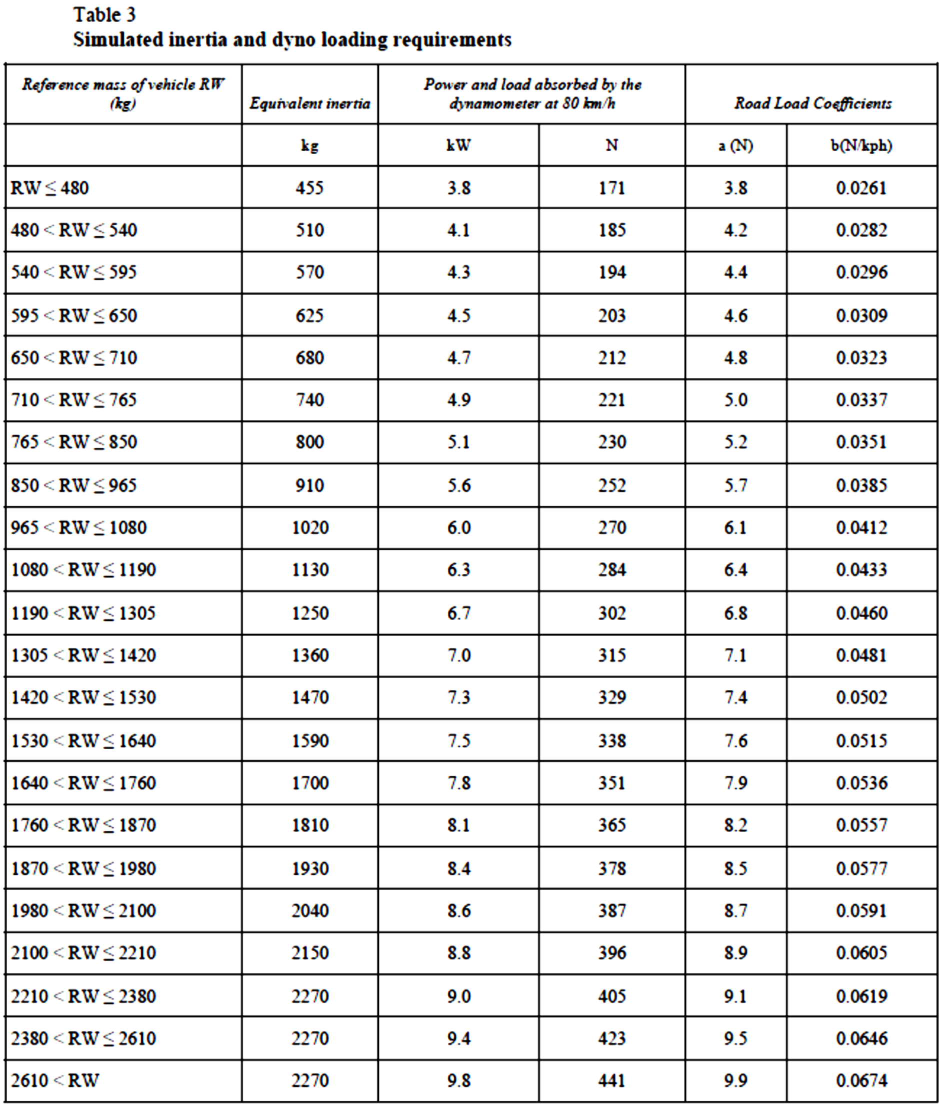


Table 3

Simulated inertia and dyno loading requirements

Reference mass of vehicle RW (kg)	*Equivalent inertia*	*Power and load absorbed by the dynamometer at 80 km/h*		*Road Load Coefficients*	
	kg	kW	N	a (N)	b(N/kph)
RW ≤ 480	455	3.8	171	3.8	0.0261
480 < RW ≤ 540	510	4.1	185	4.2	0.0282
540 < RW ≤ 595	570	4.3	194	4.4	0.0296
595 < RW ≤ 650	625	4.5	203	4.6	0.0309
650 < RW ≤ 710	680	4.7	212	4.8	0.0323
710 < RW ≤ 765	740	4.9	221	5.0	0.0337
765 < RW ≤ 850	800	5.1	230	5.2	0.0351
850 < RW ≤ 965	910	5.6	252	5.7	0.0385
965 < RW ≤ 1080	1020	6.0	270	6.1	0.0412
1080 < RW ≤ 1190	1130	6.3	284	6.4	0.0433
1190 < RW ≤ 1305	1250	6.7	302	6.8	0.0460
1305 < RW ≤ 1420	1360	7.0	315	7.1	0.0481
1420 < RW ≤ 1530	1470	7.3	329	7.4	0.0502
1530 < RW ≤ 1640	1590	7.5	338	7.6	0.0515
1640 < RW ≤ 1760	1700	7.8	351	7.9	0.0536
1760 < RW ≤ 1870	1810	8.1	365	8.2	0.0557
1870 < RW ≤ 1980	1930	8.4	378	8.5	0.0577
1980 < RW ≤ 2100	2040	8.6	387	8.7	0.0591
2100 < RW ≤ 2210	2150	8.8	396	8.9	0.0605
2210 < RW ≤ 2380	2270	9.0	405	9.1	0.0619
2380 < RW ≤ 2610	2270	9.4	423	9.5	0.0646
2610 < RW	2270	9.8	441	9.9	0.0674

Example of method 1

For method 1 a sequence of tests would have to be performed according to table 3 of ECE-R83, Annex 4a, each test performed at a higher class of reference mass (RW). For a medium chassis cab Base Vehicle with a reference mass of 1750 kg for instance tests would have to be performed at 1700 kg and at the 7 higher classes totalling 8 tests for this vehicle. The resulting CO_2 values should be collected in a table and included in the TA documents and the CoC of the Base Vehicle.

Table 1: example of a table with results from tests to be performed for a Base Vehicle with a reference mass of 1700 kg.

Reference mass (RW) [kg]	CO_2 [g/km]
1640<RW<=1760	208,0
1760<RW<=1870	210,6
1870<RW<=1980	212,9
1980<RW<=2100	215,3
2100<RW<=2210	217,6
2210<RW<=2380	220,2
2380<RW<=2610	221,5
2610<RW	222,8

Alternative 1 to method 1

An alternative to this first option is to determine the corresponding CO_2 values from a limited amount of tests. This would decrease the amount of tests that shall be performed by the manufacturer of the base vehicle and thus would decrease the financial and administrative burden. From these tests the CO_2 emission from the inertia classes in between the tests can be interpolated. The results of the interpolation can be used to generate a table of CO_2 values for use with the registration of individual completed vehicles. As an alternative to interpolation a linear regression function can be used which in principle is as accurate as interpolation.

The method using interpolation or regression can probably be relatively accurate compared to a method where all tests need to be performed because the relation between mass and fuel consumption (CO_2 emission) is almost linear (Reference [Elst, 2004] and Reference [Allen 2009]). In the table below an example is given of an exercise in which CO_2 values have been interpolated linearly, using three tests. Alternatively, two points can be used as well. The benefit and inaccuracy from this interpolation method are presented in paragraph 5.4

General function for linear interpolation between two points:

$$y = f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1} \cdot (x - x_1)$$

Table 2: example of linear interpolation of test results based on three tests on a medium chassis cab (1750 kg) to arrive at a full list of CO_2 results for the complete range and sequence of inertia ranges, the test performed at the inertia corresponding the ranges of reference mass (inertia weight classes). The results for the higher inertia remain the same because the test mass does not change anymore.

Real test or interpolation	Equivalent Inertia	Interpolated results
	[kg]	[g/km]
Test	1700	208,0
Interpolation	1810	210,3
Interpolation	1930	212,9
Test	2040	215,3
Interpolation	2150	218,9
Interpolation	2270	222,8
Interpolation	2270	222,8
Test	2270	222,8

Alternative 2 to method 1

To limit the amount of tests the maximum technically laden mass and the boundary of the N1 scope can be used as a maximum mass chosen for the tests: The tests shall be done up to the maximum inertia weight class unless the maximum technically permissible laden mass falls in a lower inertia weight class. In that case the lower inertia weight class shall be used as the maximum.

2. The "default added mass (DAM) method"

Further referred to as **method 2**, would consist of testing only one time the base vehicle while setting the inertia of the dynamometer at a value corresponding to the sum of the mass of the base vehicle plus an estimated default added mass (DAM), which would be function of the class of the vehicle. The classes are laid out, for N1 vehicles, in tables 1 and 2 of Annex I to Regulation 715/2007 and depend on the reference mass (RW) of the base vehicle.

The main uncertainty from this option would be, in principle, the value of the average or default added mass (DAM) to be added to the reference mass (RW) of the base vehicle and the consequences of using this average value for different manufacturers.

It should be remarked that base vehicles with a total mass (base vehicle mass + DAM) of higher than 2840 will fall out of the scope of CO_2 legislation even if it’s GVM is lower than 3500kg (N1 ECE-R49). For instance, if DAM for class III would be 800kg, a base vehicle heavier than 2040 would completely fall outside the scope of the CO_2 legislation. Currently, these are about 4% of the base vehicles (EU 2010 big 5 database). Base vehicles heavier than 1810kg will get a mass higher than 2610kg and these vehicles may fall out of the scope of the CO_2 legislation, depending on whether the type approval has been extended or not. These are 40% of the vehicles.

The estimation of the DAM will be discussed in 3.3.

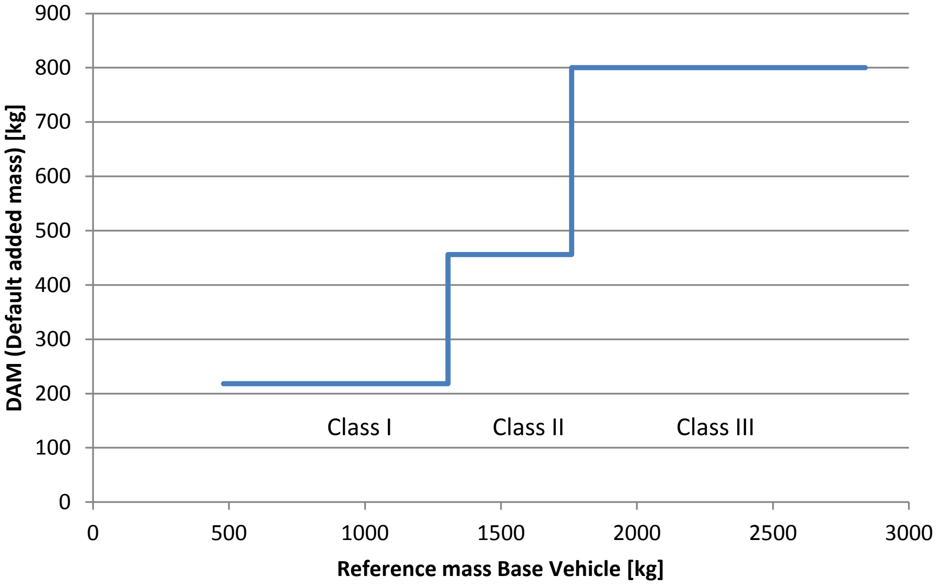
Example of N1 Class III mass definition:

$RW_{DefaultCompletedVehicle} = RW_{BaseVehicle} + DAM_{III}$ where $RW_{BaseVehicle} > 1706$ and $RW_{BaseVehicle} < 2610$ or $RW_{BaseVehicle} < 2810$

DAM_{I}= x kg
DAM_{II}= y kg
DAM_{III}= z kg

With x, y and z to be determined as average mass from the bodywork and fixed constructions added to the three classes of Base Vehicles classified as MSV .

Figure 4: example of method 2 using a fixed default added mass per N1 sub class.



Alternative 1 to method 2
Method 2 can be developed for use of a continuous function instead of a discontinuous function. This prevents certain boundary effects. In Figure 4 an example is given of method 2 and it shows that vehicles around a class boundary can become quite different values for DAM. A base vehicle near the class boundary can then be manipulated to fall in the most preferable class with regard to the DAM.

To define a function for DAM, a sample is required of base vehicle mass and DAM.

Alternative 2 to method 2
An alternative or further refinement to this second method would be to derive the DAM from specific characteristics of a vehicle instead of using a fixed default value per class. Characteristics that could serve as parameters on which to base the determination of DAM could for instance be the difference between technically permissible maximum laden mass (TPMLM) of the vehicle and the minimum mass of the vehicle. These two parameters in principle determine the minimum and maximum amount of mass which can be added to a base vehicle as bodywork and equipment. A percentage of this difference could represent the DAM. The minimum mass is required in the CoC.

The accuracy of method 2 and alternative options for the determination of DAM is assessed in paragraph 5.1.2.

Example of the alternative:

$DAM = a\% \times (TPMLM - RW_{BaseVehicle})$
And $RW_{DefaultCompletedVehicle} = RW_{BaseVehicle} + DAM$

2.4 Future implications

In the framework of the Worldwide harmonized Light vehicles Test Procedure (WLTP) group, a number of issues are currently being discussed that may be relevant for multi-stage N1 vehicles. The most important in terms of calculating and monitoring CO_2 emissions are those related to:

- the definition of test mass and inertia classes, as well as
- the development of a new driving cycle.

These issues are discussed in more detail in the following.

Changing the current inertia class approach is proposed in order to prevent manufacturers from changing the weight of their vehicles for the sole purpose of achieving a more favourable test weight. The current procedure based on discrete inertia classes results in a higher number of vehicle registrations just below an inertia class step compared to the number of registrations just above an inertia class step or in between inertia class steps[1]. The upper limit set for inertia mass provides an additional advantage for manufacturers offering heavier vehicles (above 2270 kg). These shortfalls are to a very large extent due to limitations of the chassis dynamometers (flywheels typically available in 60 kg steps), which however have nowadays been eliminated with modern electronic dynamometers.

Two alternative options have been proposed to tackle the above issues:
1. Continue with an inertia class based system but reduce the size of the discrete steps and
2. Move away from an inertia class based system and introduce a step-less approach.

For the first option a proposal was made to reduce the size of the inertia steps to 28,35 kg, reducing thus the incentive for manufacturers to optimize their vehicles to achieve a more favourable test weight. Steps of this size are expected to be a reasonable compromise between accurate test values and a limited testing burden for manufacturers. Also, there is no upper limit for inertia mass, which increases continuously in increments of 28,35 kg. Although this option does not entirely

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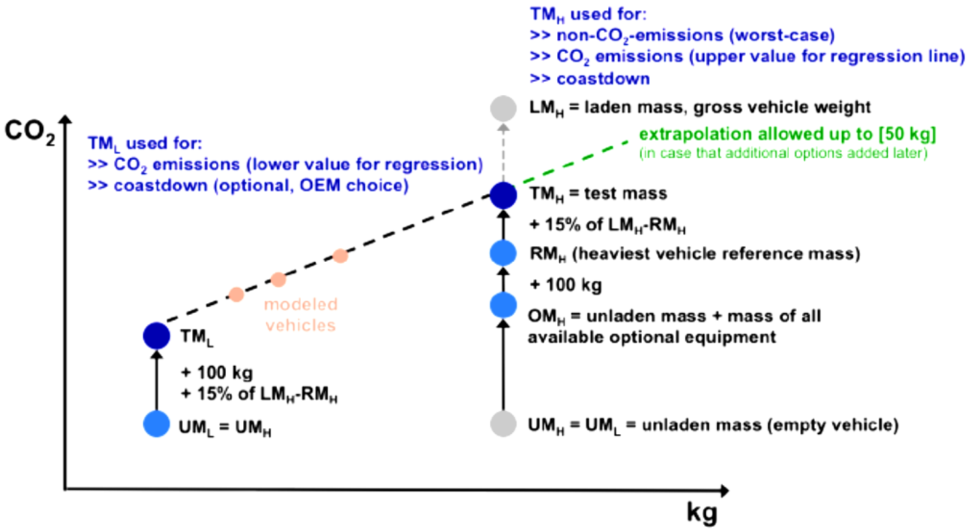
[1] Based on findings presented in the working paper 2011-5 of the International Council on Clean transportation (ICCT) about 28% of all vehicle registrations are associated with a reference mass that is just below an inertia class step (0-10% below a step). In contrast, less than 5% of all registrations are associated with a mass just above an inertia class step. The likelihood of a vehicle having a mass slightly below an inertia class step is more than five times higher than having a mass slightly above an inertia class step.

eliminate the shortfalls described above, it reduces the disadvantages of a step based approach.

With regard to the second option, the idea is to use the actual weight of the vehicle, instead of introducing discrete inertia steps. To enable this step-less approach, an improved definition of vehicle test mass has been proposed. For determining the latter, optional equipment and other load (driver, passengers, luggage, etc.) is taken into account. The suggested approach, including the various definitions of mass is shown in Figure 5. The CO_2 value is determined by a linear regression line over the test mass of the lightest and the heaviest vehicle.

Figure 5: an example of a step-less inertia approach, using two test points and interpolation to derive the CO_2 emissions of intermediate masses. This method is discussed in the WLTP working group. A manufacturer is able to calculate the CO_2 emission of a vehicle with a mass between the two tests with different masses (dark blue dots) by means of linear interpolation of the test results or by determination of a linear regression line.



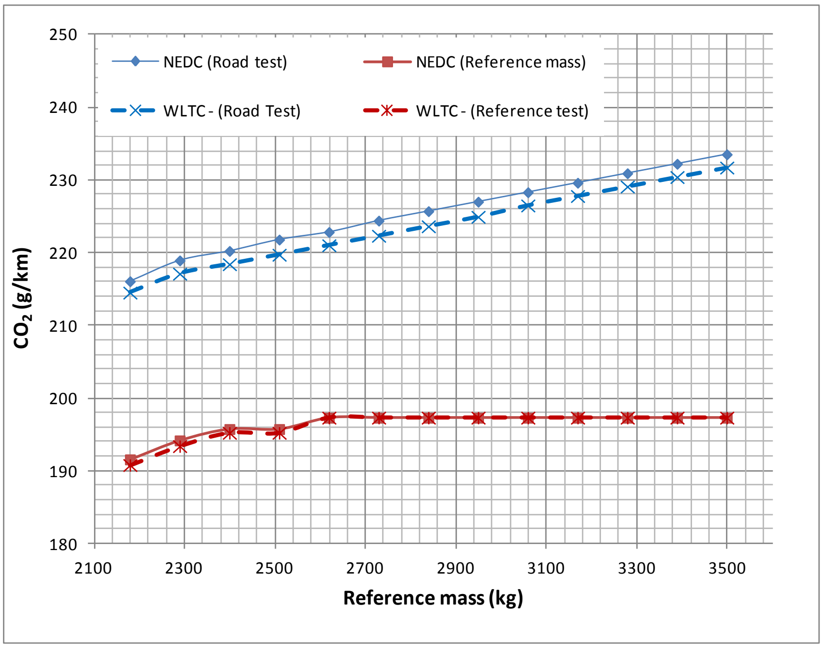
As already mentioned above and demonstrated by the simulations in section 5.3 vehicles with higher reference mass have a relative advantage, increasing with higher vehicle reference mass. Both proposals will eliminate these advantages by putting a representative load to the tested vehicle.

In addition to the above issues of test mass and inertia classes, a new test driving cycle is currently being developed. In order to assess possible future implications from the introduction of a new type approval cycle, a number of parametric simulations were conducted for one vehicle (the Iveco Daily) over the suggested WLTC cycle (version 2.0 of 09/08/2011). The results of these simulations are summarised in Table 3 and are also compared to the respective NEDC values. It should be noted that the suggested changes in inertia weight classes presented above have not been taken into account for the subsequent simulations.

Table 3: Simulation results for the Iveco Daily – comparison of NEDC – WLTC. Road test CO_2 emissions are simulated using an estimate of the real road load while reference mass CO_2 emissions are simulated using table 3 [ECE-R83, Annex 4a] with default inertia and load settings.

Equivalent inertia (kg)	Reference mass (kg)	NEDC - Road test CO_2 emissions [g/km]	NEDC - Reference mass CO_2 emissions [g/km]	WLTC - Road test CO_2 emissions [g/km]	WLTC - Reference mass CO_2 emissions [g/km]	CO_2 target [g/km]
2150	2180	216.1	190.5	214.5	190.8	219.1
2270	2290	219.2	193.1	217.1	193.4	229.3
2270	2400	220.5	194.7	218.4	195.2	239.5
2270	2510	221.8	194.7	219.7	195.2	249.8
2270	2620	223.1	196.5	221.0	197.3	260.0
2270	2730	224.7	196.5	222.3	197.3	270.2
2270	2840	226.0	196.5	223.6	197.3	280.5
2270	2950	227.3	196.5	224.9	197.3	290.7
2270	3060	228.6	196.5	226.5	197.3	300.9
2270	3170	230.1	196.5	227.8	197.3	311.2
2270	3280	231.4	196.5	229.1	197.3	321.4
2270	3390	232.7	196.5	230.4	197.3	331.6
2270	3500	234.0	196.5	231.7	197.3	341.8

Figure 6: CO_2 emissions vs. reference mass for the Iveco Daily over the NEDC and WLTC. Road test CO_2 emissions are simulated using an estimate of the real road load while reference mass CO_2 emissions are simulated using table 3 of ECE-R83, Annex 4a with default inertia and load settings.



As can be seen from the results of the comparison presented in Figure 6, CO_2 emissions over the WLTC are somewhat lower compared to NEDC values. The observed differences are due to the combined effect of the following:

- The idling time of the WLTC is lower both in absolute (234 sec vs. 290 sec) and in relative terms (13% vs. 24.6% of the overall cycle duration), which has a positive effect on tested CO_2 emissions.
- The cold-start extra emissions are also lower in relative terms (5.7% vs. 10.1% of the overall emissions) as a result of the longer duration (1800 sec vs. 1180 sec) of WLTC over NEDC.
- The gearshift strategy of the WLTC is more “aggressive” than in the NEDC, i.e. there is more driving in higher engine RPM. The additional fuel consumption, and hence also CO_2 emissions, somewhat counterbalances the benefits from the above two.

It should be noted that since the WLTC driving cycle is still under development, the above results should be seen as indicative only. However, some useful observations can be made based on these:

- The existing inertia weight classes and the road load *a* and *b* coefficients would result in even lower CO_2 emissions particularly in the event of a final WLTC cycle with a more “mild” gearshift strategy.
- Possible changes in the road load *a* and *b* coefficients and/or equivalent inertia could result in higher type approval CO_2 emissions. Since heavier vehicles equipped with larger engines operate at relatively lower RPM and have a higher efficiency over the complete engine map, it would be advantageous for manufacturers to produce heavier vehicles, enabling them to reach their CO_2 targets.
- Any advantage of producing heavier vehicles will be, however, eliminated if the suggested step-less inertia approach described above is eventually endorsed.

3 Characterization of multi-stage vehicles

For method 2, the ‘default added mass method’, it is important to develop a representative value for the average mass of the ‘body work’ added to a base vehicle. This mass should be as accurate as possible. For each of the three N1 sub-classes a dedicated additional average or default mass value should be determined. To determine such a value, different routes were investigated and an extensive data mining exercise was performed. In this chapter the data mining process and the process of approximation of average added mass are described. Additionally, the uncertainty of the approximated value for average added mass is estimated. To establish an average mass it is important to understand the market of MSVs and to investigate the typical appearance of these vehicles.

Multi-stage N1 vehicles are mainly custom built vehicles. For most commercial users standard solutions exist which already fit the clients’ purpose without heavy adaptation of a vehicle. However, some users need specially built vehicles, suited for their specific needs. Also, some manufacturers choose to not build their vehicles to completion themselves but leave the fitting of additional standard or special body work to dealers or dedicated upfitting companies. In all of such cases the vehicles are built in more than one stage and hence, the vehicles are certified in more than one stage.

The boundaries for the group of N1 vehicles are given in the ‘scope’ of ECE-R83: “…This Regulation shall apply to vehicles of categories M_1, M_2, N_1 and N_2 with a reference mass not exceeding 2,610 kg. At the manufacturer's request, type approval granted under this Regulation may be extended from vehicles mentioned above to M_1, M_2, N_1 and N_2 vehicles with a reference mass not exceeding 2,840 kg and which meet the conditions laid down in this Regulation...”

A further definition influencing the exact scope can be found in ECE-R49, see also paragraph 2.1:

“…At the request of the manufacturer, the type approval of a completed vehicle given under this Regulation shall be extended to its incomplete vehicle with a reference mass below 2,610 kg. Type approvals shall be extended if the manufacturer can demonstrate that all bodywork combinations expected to be built onto the incomplete vehicle increase the reference mass of the vehicle to above 2,610 kg. The following do not need to be approved according to this Regulation: engines mounted in vehicles of up to 2,840 kg reference mass to which an approval to Regulation No. 83 has been granted as an extension…”.

..and 2007/46/EC: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes.

Special purpose vehicles are excluded from this regulation (most fall under M1 and N3), as well as agricultural, forestry vehicles, quadricycles, tracked vehicles, armoured vehicles. TA is optional for some other categories (article 2.3), like airport facility vehicles, armed services and some special public services.

3.1 Data mining

To establish a default added mass value and to define options for data transfer of the right CO_2 value into the EU monitoring system, information is required from different stakeholders and data sources. Therefore, a data mining exercise was executed to obtain as much data and information as possible on these two topics.

It was acknowledged beforehand that it would be difficult to derive the added mass from the existing databases, simply because there is no key that identifies an N1 vehicle as multi-stage and because the base vehicle's mass is not registered.

Another problem is the actual registered mass of MSVs, because different Member States have potentially different requirements with regard to thresholds and obligations as to when to measure and register the mass of a vehicle. One other problem is that many MSV are approved according to the IVA (Individual Vehicle Approval) scheme. In such cases only the first stage CoC is available at certification and often at registration the CO_2 is not transferred from the CoC to the national registration, hence completed vehicle mass is determined according to national rules.

Investigated data sources can be grouped in a few categories: *databases, questionnaires, interviews and internet websites*. The data stems from different stakeholders: Base vehicle manufacturers, bodybuilders, Member State Registration Authorities or Member States, Type Approval Authorities and the European Commission.

Databases
The following data-bases were explored:

1. EU Big 5 database (2010) (D, F, UK, I and S)
2. Member State Registration databases containing a sample of the monitoring mechanism data of 2010 (UK, S, NL, LT, LV, SK, I, D and B)

EU big 5 countries database (2010)
A database was purchased in the framework of another EU project. This database contains 2010 sales of N1 vehicles of the five largest EU Member States (Germany (D), France (F), United Kingdom (UK), Italy (I) and Sweden (S)). An important record in this database is the chassis cab identifier (y/n) and the kerb mass (banded in 50kg bins). These records allow the definition of sales share of chassis-cabs, the weight distribution and the N1 sub class distribution.

Member State Databases
These databases contain a variety of data. However the main records, the ones required for CO_2 monitoring, are the same for each MS database. Databases were received from the following Member States: (United Kingdom (UK), Sweden (S), The Netherlands (NL), Lithuania (LT), Latvia (LV), Slovakia (SK), Italy (I), Germany (D) and Belgium (B)).

A scan of the data showed the usefulness for this investigation. In Annex B the records and completeness of each record are summarized. The following was observed for the Member State databases.

- There is no direct identifier for MSV.
- There is also no indirect identifier for MSV: for instance an identical Type Variant Version (T-V-V) code with different completed vehicle masses could indicate added bodywork, however T-V-V are missing, incomplete or other important parameters are missing as well, like mass.
- An attempt was made to link VIN to vehicle mass for the same VIN registered at the manufacturers to see if mass has changed (due to bodywork added). T-V-V turned out to be a not so good identifier. This exercise turned out not to be feasible for this project due to the low number of VIN numbers (by brand) of MSV in the available Member State databases.

Internet: websites of chassis cab sales portfolio and suppliers of individual components

This source provides detailed vehicle specifications for plain chassis cabs and platform chassis and chassis cabs with standard body work. Often this standard body work is an open drop-side. From these data, the typical mass of the Base Vehicles could be deducted. Some websites from manufacturers of bodywork specify weight of their products, for instance for types of boxes, cranes or tail lifts.

Questionnaires and interviews

Questionnaires were sent to the Base Vehicle Manufacturers. 8 Manufacturers responded. They responded individually to questions 1 to 3. See Appendix E for the questionnaire and the summarized responses.

- Interviews were held with a number of Base Vehicle Manufacturers:
  - ACEA: Ford, Iveco, Fiat, Renault, PSA, Toyota Motor Europe, Mercedes-Benz and Volkswagen
  - JAMA: Isuzu and Nissan

- Interviews were held with a number of bodybuilder representatives:
  - FOCWA maintains a database with sales over different vehicle construction (body) types from Netherlands, Germany, Belgium and France. For France information is only available for HD vehicles (trailers, semi-trailers, rigid, etc)
  - ANFIA: represents the Italian Automotive Industry
  - CCFA: Comité des Constructeurs Français d'Automobiles, French Association of Automotive Manufacturers
  - FFC: French Bodybuilders
  - CLCCP/Agoria (B)
  - SMMT: Society of Motor Manufacturers and Traders in the UK
  - Carserco: Chambre Syndicale National des Carrossiers et Constructeurs de Semi-Remorques et Conteneurs (CARSERCO) (FFC Constructeurs)

Interviews were held with a number of bodybuilders and a supplier. Some large bodybuilders did not manage to provide answers to the questionnaire:

  - Karhof Nieuw-Vennep B.V.
  - Carhar
  - Hartog-Est

- Interviews were held with a number of Member State Registration Authorities/Type Approval Authorities:
  - VCA/VOSA/dFt (UK)
  - KBA (Germany Bundesländern)
  - CNRV (Centre National de Réception des Véhicules, France)
  - RDW (Netherlands)

3.2 Fleet characterisation

From the Member State databases, the questionnaires from the OEMs and from 2nd stage manufacturers, internet sources and from a road side investigation, information was obtained to characterize the fleet of MSV.

The largest share of MSV are completed chassis cabs, see also the questionnaires [Annex E]. For the inquired OEMs, base vehicles are 5 to 65% of their N1 sales [Annex E].

The incomplete chassis cab registration are approximately 7% in 2010 in the total N1 sales in the EU 5 biggest counties for all OEMs.

When this share of 7% is applied to the total number of registrations of the 2010 sales of N1 vehicles in EU27 [ACEA, 2011] the total amount of registered chassis cabs in 2010 would be approximately 99.578 units.

From the Questionnaires [Annex E] the following distribution of base vehicles over N1 subclasses was derived:

Class I	(RW<1305)	7%
Class II	(1305<RW<=1760)	27%
Class III	(1760<RW)	66%

From [EU Big 5 countries (2010 registrations)] the distribution of chassis-cabs over N1 sub-classes is the following:

Class I	1%
Class II	33%
Class III	66%

The data of EU big 5 and [ACEA, 2011] is summarized in the table below:

Table 4: the total amount of registrations of N1 vehicles and chassis cabs in 2010 combined from the sources EU Big 5 countries and [ACEA, 2011].

2010	**N1 Registrations**	**Chassis cab registrations**
Class I	304.713 (20%)	739 (0,05%)
Class II	507.266 (34%)	33.573 (2,3%)
Class III	676.869 (45%)	65.266 (4,4%)
EU27	1.488.848 (100%)	99.578 (6.7% of N1)

A small difference between the questionnaires and 'EU big 5 countries' can be noted. The share of class I MSV is a bit uncertain, but in both cases small however. For individual manufacturers the share of class I MSV may be higher than 1%.

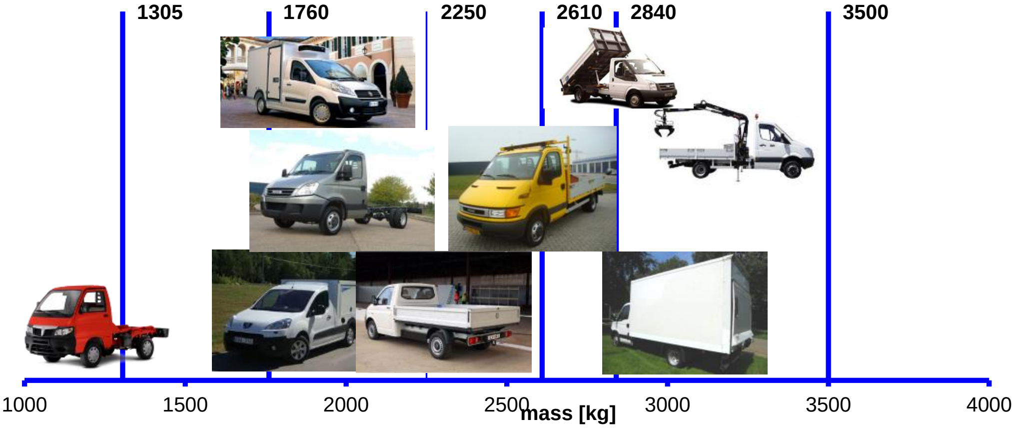
Different sources (Questionnaires, FOCWA, SMMT, Italian registrations, Slovakian registrations) report the typical appearance of MSV. The largest share of the fleet is composed of chassis cabs added with a box, drop side, tipper or box with refrigerator and isolation. Another common type, usually of minor importance in statistics, is the tractor meant for pulling a semi-trailer and the car transporter. See Annex G for examples of MSV.

In general Completed MSV vary widely in appearance and physical characteristics. The largest share of Completed MSV are commercial vehicles with chassis (ladder frame) and closed cabin apart, often called chassis cabs. To a lesser extent there are chassis cab with an open cab which will be integrated with the bodywork to be added. This type is often called integrated body chassis or platform chassis. The latter should not be confused with complete vans (complete integration of cabin, chassis and cargo area). In the beginning of the project TNO indicated vans also as MSV. Study has shown that vans are indeed converted regularly (often to refrigerated- or service vans, glass/window transport, or equipped with a tail lift), however further approval is not needed, hence the modified vans are not MSV.

MSV have all kinds of constructions added or changes made to make them a custom fit product. Each type also exists across a range of empty masses. For each type common construction variants can be distinguished which form the largest share of sales and registrations of each type.

Various other types exist next to the rather common types: various other B+E constructions (e.g. Clixstar), constructions with cranes, shovels, towing construction, containers for garbage collection, street cleaning and many more. All these variants are far less common than the (isothermal) box, tipper and drop side.

Figure 7: some types of MSV over the N1 mass range.



<u>Chassis cabs</u>

Chassis cabs can have various constructions added. Chassis cabs typically weigh 1450 to 2250 kg, however, considerable lighter chassis cabs also exist (e.g. Fiat Doblo platform chassis, 1170kg). The common construction types for chassis cabs are boxes, drop-side and tippers. The advantage of box type chassis cabs is that they offer a large transport volume (20m^3). However, they also offer a relatively low net payload. In many EU countries, if not all, these vehicles come with the advantage that the maximum speed is higher than for the light N2 vehicles and these vehicles can be driven with a regular B drivers license. The high construction weight of chassis cab + bodywork limits the payload. Typical payload of a box type with a tail lift (meant to load goods up to about 500-750 kg for instance) is around 200-700kg depending on what exactly is added to the construction. The cooled type boxes often have a very low net payload (300-500kg) due to the installation of a refrigerator and isolation.

Figure 8: the kerb mass of chassis cab registrations in 2010 ranges from 1450 to 2250kg with a peak around 1700kg [EU 2010 Big 5 countries].

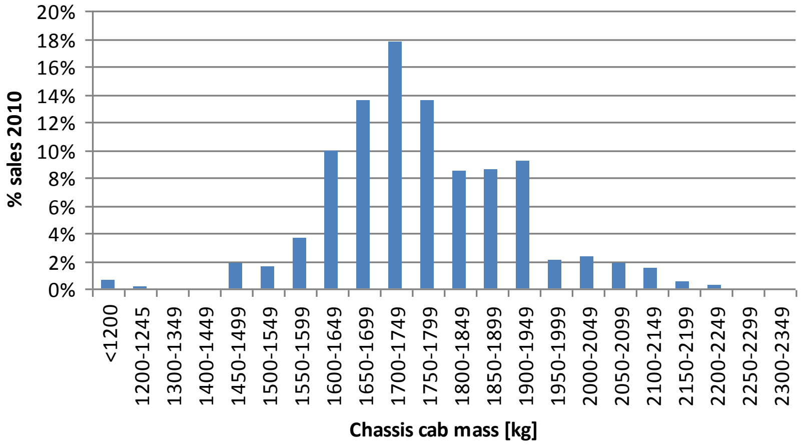
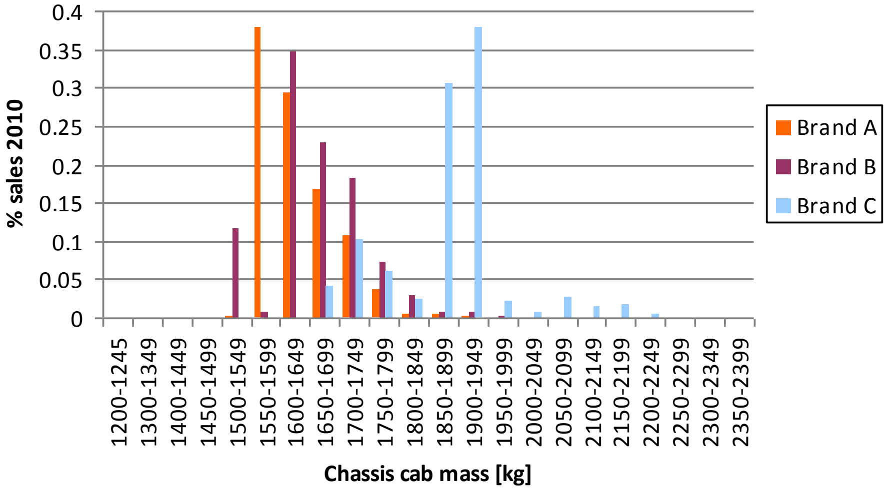


Figure 9: kerb mass of chassis cab registrations in 2010 for three different brands showing that brands may focus on a typical share of the market. [EU 2010 big 5 countries]



Typical physical appearance of MSV

For the chassis cabs a few typical bodywork constructions can be given which represent the largest share in sales from that type, see the next table.

Table 5: overview of identified common bodyworks and optionally added components.

2007/46/EC type definition	Main type of bodywork	Possible added components
Chassis cabin, Lorry (BA)	Standard box body Integral box body Curtain slider	Tail lift
		Side door
		Roof spoiler
	Insulated box	Same options as above
		Cooling unit
		Stationary cooling
		Dividing wall
	Drop side Drop side strengthened	Side fenders
		Cabin protection
		Ladder carrier rear
		Tail lift (slider)
	Tipper Tipper strengthened	Cabin protection
		Ladder carrier rear
	Others*	Others

* Tractor (as used for all kinds of ‘B+E’ combinations) and other special vehicles: cranes, shovel, plough, glass/window transport, food-bar, cradle elevator, container, flat beds, car transporters, etc...

3.3 Determination of the default added mass of the current fleet of MSV

For the determination of the default value for average added mass (DAM) two different approached were investigated: a direct approach and an indirect approach.

In principle the added mass originates from items added to complete the vehicle. Generally, this contains bodywork and a sub-frame for chassis cabs. Furthermore, all kinds of additional constructions and components may be added.

Direct approach

The direct approach relies on the availability of data which makes it possible to directly retrieve or calculate the average added mass. For this approach ideally the mass of a base vehicle and the mass of the same vehicle in completed form should be available for all MSV vehicles registered over a certain recent time period.

Added mass = mass completed vehicle – mass base vehicle

The registration databases of Member States and other data sources did not allow the direct retrieval of the added mass, simply because the mass of the base vehicle is not registered. However, if for a given range of vehicles identifiers are available which the OEM can link to a base vehicle and its specifications, it might become possible to compare the registered mass of the completed vehicle to the mass registered at the manufacturer for the base vehicle.

Individual manufacturers were approached to ask if they can provide such information. It turned out not to be feasible due to the low number of VIN numbers (by brand) of MSV in Member State databases.

Indirect approach

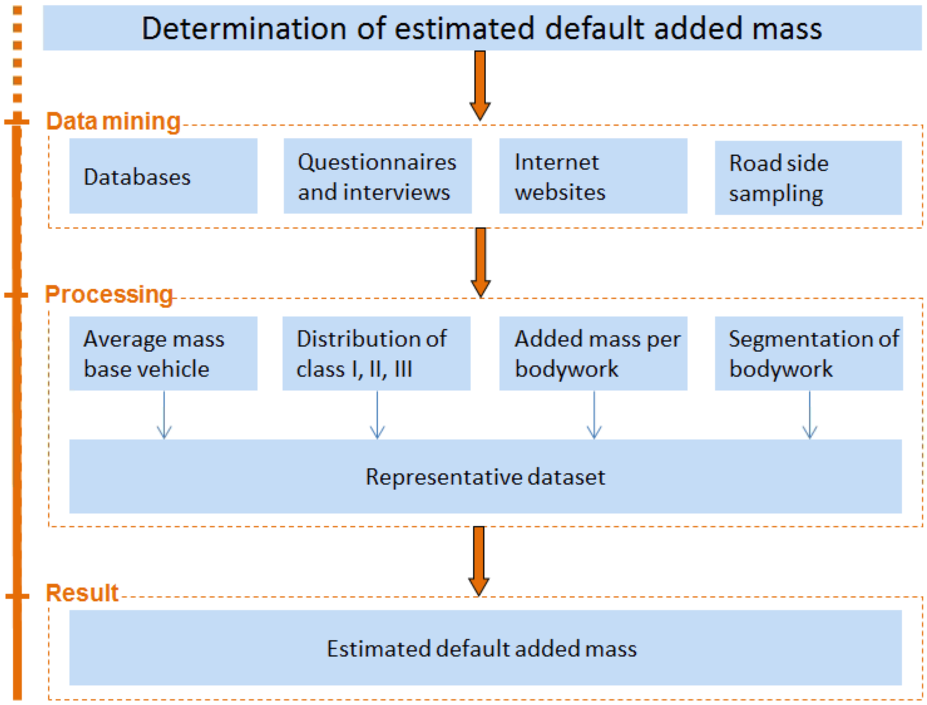
The base for this approach is the idea that the largest share of the fleet of MSV can be classified in a range of ‘common types’. The indirect approach can be used if the fleet can be clearly segregated in common types and if the common types are expected to have the highest contribution to the average mass.

The method combines data from different sources and relies on:

- the availability and accuracy of statistics (distribution) over types of MSV and
- the availability and accuracy of mass of body work and mass of the base vehicles per type

Figure 10 shows the exercise of determination of the estimated default added mass in a scheme. The exercise is explained in detail below the figure.

Figure 10: Exercise of determination of the estimated default added mass in short.



The exercise to determine the estimated default added mass combines data from:

- Questionnaires/interviews
- EU big 5 database (2010)
- Internet websites
- Road side sample (base for the representative dataset) consisting of 161 observations.

The mentioned sources above are used for determination of:

Average mass of the base vehicle and distribution over N1 subclasses
The default added mass depends to a certain extend on the base vehicle mass. The average base vehicle mass is determined using the EU big 5 database which distinguishes between the N1 subclasses I, II and III. The database is also used to specify the distribution over the N1 subclasses. The N1 sub class distribution is combined with information from the questionnaires.

Common body types
Internet and the questionnaires/interviews with manufacturers, bodybuilders and umbrella organisations were used to determine:

Segmentation of most common body types
The body types “Box”, “Box refrigerated”, “Drop-side” and “Tipper” are identified as most common, together these represent about 80% of the sales. The mentioned body types are often available in different variants (Table 5). For determination of the segmentation a weighted average is used for the information of base vehicle manufacturers based on sales numbers.

Depending on the applied bodywork additional components can be added (Table 5). An estimation is made, based on the information gathered during the interviews with bodybuilders, how often a component is added to the relevant bodywork. The same applies for the possible variants per particular bodywork, the estimations are based on input from the interviews.

Added mass per bodywork

Much data is gathered concerning the mass of the most commonly applied types of bodywork, including related components. The determined average mass per common type of bodywork is based on independently investigated masses for the bodywork and its components from the questionnaires and the interviews. In some cases the entire mass of the bodywork (including components) was specified, this corresponds well with the masses.

The rest of the bodywork is also examined (this group comprises about 20% of the sales). This “rest” varies strongly in both configuration and its mass. Since the “rest” consists of average, light (e.g. tractor) and heavy (e.g. crane) configurations and all kinds of heavily customized constructions it is hard to estimate the mass of this group. Because the group at least contains both light and heavy constructions and the market share is limited to about 20% it is assumed that this group cannot influence the average mass of the common body types very much. To evaluate the influence of uncertainty of mass an exercise was performed to estimate the impact on the CO_2 emission. This is further elaborated in chapter 5.

Default added mass for common body types

By combining the segmentation of bodywork and the added mass per bodywork, the default added mass for common body types can be determined. The goal of this exercise is to verify the mass of typical MSV bodywork obtained not only from datasets but from real data and experience from bodybuilders and manufacturers. It should be noted that the focus of this exercise has been on N1 class III and on class II (most of the MSV are within these classes). Appendix D shows the complete table, including bodywork variants and added components.

Table 6: Summary of the exercise to determine the mass of the most common types of body work for MSV. This value is an estimate based on information directly retrieved from manufacturers and bodybuilders. It gives an indication of the mass of bodywork, however it is not a representative value as it does not cover the complete fleet. The focus was on most common types of bodywork and therefore the value is representative mainly for a mix of class II and III vehicles. The value of 721 kg is closely comparable to the average mass of bodywork for class II and III vehicles (692 kg) as obtained from the road side sample, see the next page.

Bodywork	Share [%]	Mass [kg]
Box	25%	821
Box refrigerated	22%	1.125
Drop-side	24%	355
Tipper	29%	631
Average mass of common types of bodywork	100%	721

Road side sample
To improve the indirect approach, the data mentioned above was combined with data of an investigation performed along the road side to identify and trace down individual MSV and their characteristics such as kerb mass, bodywork, payload, technically permissible maximum laden mass.

The data of the observed vehicles stems from the publically accessible database of RDW who offers a service where one can enter a license plate number to retrieve vehicle characteristics. The base vehicle mass could be estimated for individual vehicles because the vehicle types were noted and data about the plain chassis cab mass is available on for instance the websites (sales portfolio of chassis cabs and platform chassis) of the manufacturers.

Out of the road side samples a dataset of MSV is established. The dataset was thereafter fitted using the following parameters:

- Average mass base vehicles per N1 subclass (EU big 5, 2010)
- Distribution of N1 subclasses (EU big 5, 2010)
- Segmentation of bodywork (databases, interviews and questionnaires)

After fitting, the dataset approximates the European fleet. Based on this representative dataset the estimated default added mass is determined for each N1 subclass, see Table 7. If taken into account the note that the default added mass of common body types primarily focused on N1 subclass III the overall default added mass corresponds well.

It should be noted that N1 subclass I has only few entries in the data set. This is as expected as the share was already predicted to be low. Due to the low number of entries the estimate for this class is more uncertain than for class II and III.
In Table 7 the result is given of the exercise to estimate the DAM per N1 sub class.

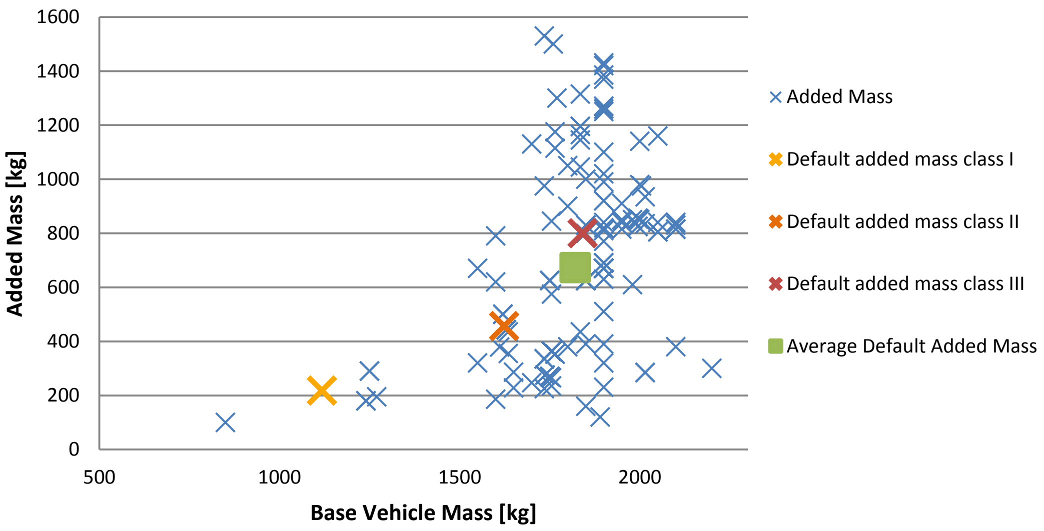
Table 7: Average added mass per N1 sub class as derived from the representative dataset (population mean) and as proposed for use in the original method 2. Values could optionally be rounded.

N1 Class	Est. Market share 2010 [%]	Average base vehicle mass [kg]	DAM (Default added mass) [kg]	95% confidence*
Class I	4%	1.118	**218**	+/- 78
Class II	30%	1.623	**456**	+/- 72
Class III	66%	1.841	**800**	+/- 56
Overall	100%	1.820	673	+/- 51

*student T-test for Class I (given the small sample size) and normal distribution for Class II and III.

The representative dataset in the picture below shows the added mass against base vehicle mass. A large spread can be noted, especially for heavier base vehicles. The added mass of the light base vehicles is more uncertain due to the low number of entries in the representative dataset.

Figure 11: The representative dataset (n=161) with default added masses plotted for the three N1 sub classes.



4 Process for data transfer into the EU CO_2 monitoring system via approval and registration

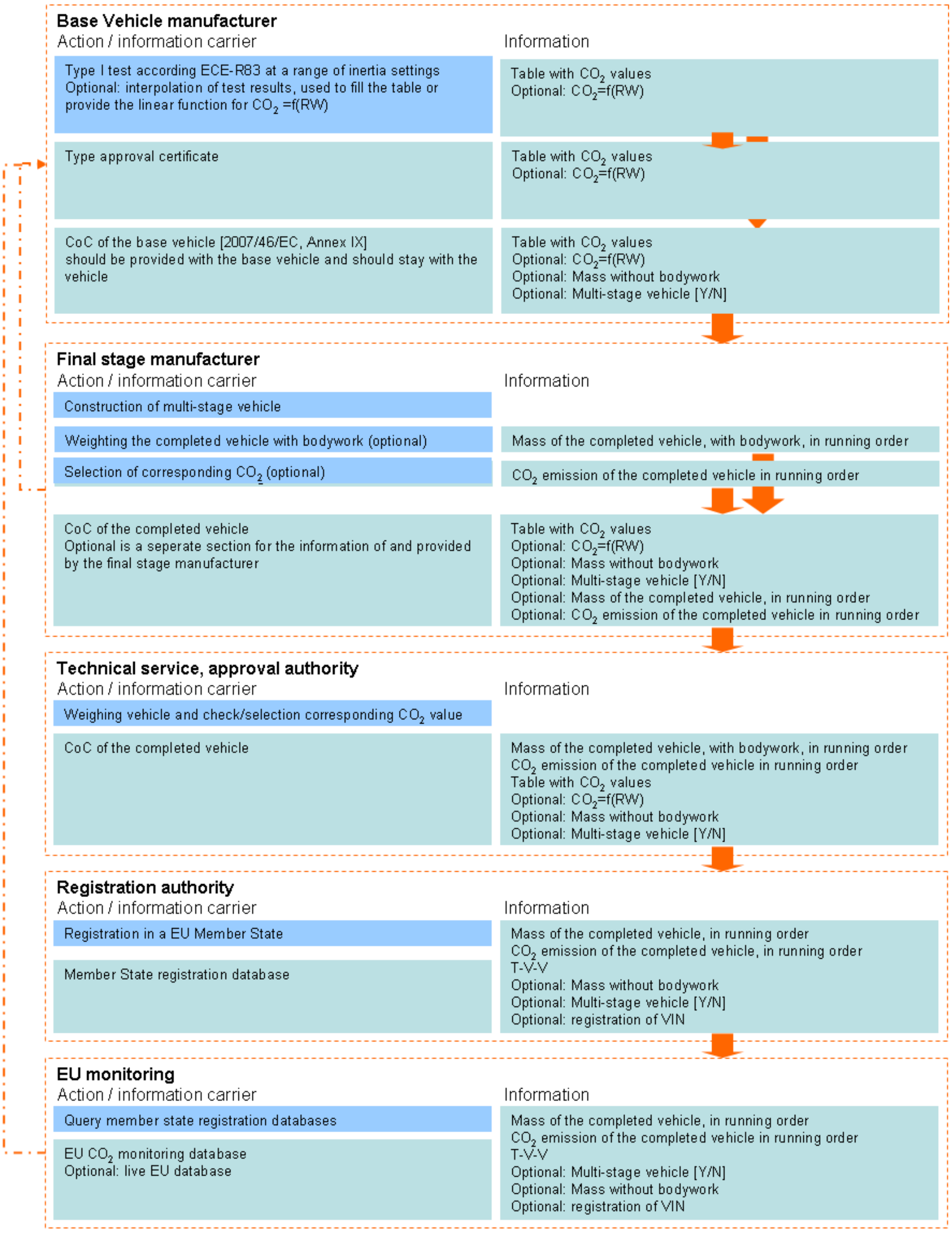
A detailed step by step procedure, for the transfer of the mass and corresponding CO_2 value into the EU CO_2 monitoring system, is presented hereafter. This is done for EC Whole Vehicle Type Approval. For Individual Approval additional notes are made and discussed in a separate paragraph. Given the difference between method 1 and 2 with regard to the required data and the transfer of data, the process for data transfer for each method will be presented separately.

4.1 Options for transfer of the monitoring parameters for EC Whole Vehicle Type Approval (WVTA)

4.1.1 Chassis dynamometer settings method (1)

First a scheme is given, showing the transfer of information between the involved entities. The scheme contains blocks for the different entities involved in the process. Within the blocks on the left the required actions and the information carrier (e.g. document, certificate, database) is given. On the right in the blocks the information required to be transferred via the information carrier is given. The information blocks do not contain the records which are already required for CO_2 monitoring, like the name of the manufacturer. After the scheme the process is explained in more detail, also giving options for different routes which could be followed.

Figure 12: options for information transfer for method 1.



Description of the process required for method 1, with options:

i) The OEM sells the incomplete vehicle with CoC (Annex IX of 2007/46/EC) of the Base Vehicle and publishes the relevant type approval documentation. The documentation contains information about the CO_2 figure applicable to the mass of the incomplete vehicle concerned. Additionally, a table of CO_2 values for different inertia mass settings is provided with the documents / information folder or CoC. The range of the mass in the table corresponds to the range of the mass the completed vehicle can become (from the base vehicles reference mass to the technically permissible maximum laden mass or the GVM, whichever is lower).

Information transfer: OEM to CoC Base Vehicle
Mass: ‘mass’ means the mass of the vehicle with bodywork in running order as stated in the certificate of conformity and defined in Section 2.6 of Annex I to Directive 2007/46/EC. (At present this is for a Base vehicles the mass of the vehicle without bodywork).

→CO_2 table. Optional is a function CO_2=f(RW).

RW [kg]	CO_2 [g/km]
…	…
1760<RW<=1870	208
1870<RW<=1980	218
…	…

Optional:
→Mass of the vehicle with bodywork in running order: … kg
→Mass of the vehicle without bodywork: … kg
This is required if one desires to monitor ‘added mass’ by calculating it from mass with and without bodywork.
→base vehicle/multistage vehicle: yes or no
This is required if one likes to uniquely identify MSV.

ii) The Final stage manufacturer (FSM) weighs the vehicle and includes the correct corresponding CO_2-value according to the information from the CoC or information folder obtained from the base vehicle manufacturer and includes mass with bodywork in the final CoC. He has to deduct 25 kg from the mass to select the corresponding CO_2 mass from the table.

Information transfer: Data from CoC of the base vehicle to the CoC of the Completed Vehicle or completion of the part of the CoC reserved for the FSM
Mass without bodywork according is already in CoC
→Mass of the vehicle with bodywork in running order: … kg
→Mass of the vehicle without bodywork: … kg
→CO_2 emission of the vehicle with bodywork (Corresponding CO_2 from the table)
→Completed vehicle/multistage vehicle: Yes or no

Optional: Depending on contract and process between OEM and FSM, FSM reports information on final mass and CO_2 back to OEM. (short loop). CO_2 responsible OEM is mentioned in the first CoC.

Optional: the FSM does not take care of the weighing and selection of CO_2 but the approval authority or technical service does.

Information transfer: CoC of the Completed Vehicle from FSM to OEM
Optional: instead of ii the FSM informs OEM with mass and CO_2 and provides the correct CoC with the CO_2 value corresponding to the mass of the bodywork he added (or plans to add).

iii) The final customer, but mostly the FSM registers the vehicle at the national registration authority. The registration authority needs to pull information from the CoC from the Base Vehicle and the Completed vehicle (if not already combined) provided by the FSM with the vehicle since e.g. name of CO_2-responsible OEM is stated in first stage CoC and appropriate mass and CO_2 are in the last stage CoC. (Or in a part in the CoC meant for MSV). Registration Authority checks the mass (weighing) and CO_2 (table) from the CoC and the values noted in the last CoC (Or in the part in the CoC meant for MSV). Appropriate mass and representative CO_2 arrive in the national registrations database.

Information transfer: Data from CoC of the Completed Vehicle to the Member State registration authority
→Mass of the vehicle with bodywork in running order: … kg
→Mass of the vehicle without bodywork: … kg
→CO_2 emission of the vehicle with bodywork (Corresponding CO_2 from the table)
→Completed vehicle/multistage vehicle: Yes or no
→VIN: in the case VIN is not yet available, it is advisable that the manufacturer separately distinguishes base vehicles within it's T-V-V system, In this case still vehicles with the same T-V-V will have a different mass and CO_2.

iiia) appropriate mass and representative CO_2 and T-V-V are inserted in a live EU-database. This EU-database is accessible by OEMs to allow sales planning for compliance (short loop). OEMs may need to be able to check the registered CO_2 values and weights.

Information transfer: from the Member State registration authority to the live EU database
→Mass of the vehicle with bodywork in running order: … kg
→Mass of the vehicle without bodywork: … kg
→CO_2 emission of the vehicle with bodywork (Corresponding CO_2 from the table)
→Completed vehicle/multistage vehicle: Yes or no
→VIN: in the case VIN is not yet available, it is advisable that the manufacturer separately distinguishes base vehicles within it's T-V-V system, In this case still vehicles with the same T-V-V will have a different mass and CO_2.

iiib) appropriate mass and representative CO_2 and T-V-V are regularly (monthly, annually, bi-annually, etc) pulled from the national databases (long loop) and published.

Information transfer: from the Member State registration authority to the EU database

→Mass of the vehicle with bodywork in running order: … kg
→Mass of the vehicle without bodywork: … kg
→CO_2 emission of the vehicle with bodywork (Corresponding CO_2 from the table)
→Completed vehicle/multistage vehicle: Yes or no
→VIN, T-V-V

4.1.2 *Default added mass method (2)*

Scheme of the process required for method 2 with information to monitor the right mass and CO_2 emission. Obvious fields/records, like name of the base vehicle manufacturer, etc aren't included:

Figure 13: options for information transfer for method 2.

Base Vehicle manufacturer

Action / information carrier	Information
Type I test according ECE-R83 with the corresponding default added mass. Manufacturer knows CO_2 and mass	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass RW Default added mass for bodywork
Type approval certificate	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass RW Default added mass for bodywork
CoC of the base vehicle [2007/46/EC, Annex IX] should be provided with the base vehicle and should stay with the vehicle	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass Default added mass for bodywork Optional: multistage vehicle [Y/N]

Final stage manufacturer

Action / information carrier	Information
Construction of multi-stage vehicle	
CoC of the completed vehicle	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass Optional: multistage vehcile [Y/N]

Technical service, approval authority

Action / information carrier	Information
Weighing vehicle and check/selection corresponding CO_2 value	
CoC of the completed vehicle	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass Optional: multi-stage vehicle [Y/N]

Registration authority

Action / information carrier	Information
Registration in a EU Member State Member State registration database	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass T-V-V Optional: multi-stage vehicle [Y/N] Optional: registration of VIN

EU monitoring

Action / information carrier	Information
Query member state registration databases EU CO_2 monitoring database Optional: live EU database	CO_2 emission of the vehicle with default vehicle mass Default vehicle mass T-V-V Optional: multi-stage vehicle [Y/N] Optional: registration of VIN

Description of the process required for method 2, with options:

i) The OEM sells the incomplete vehicle with a first stage CoC and publishes the relevant type approval documentation. The documentation or CoC contains information about the specific CO_2 emission, applicable to the mass of the incomplete vehicle concerned, added with the default average mass. The OEM already knows the mass and specific CO_2 for his vehicle.

Information transfer from OEM to CoC:
→Default added mass for bodywork, the selection of this mass is based on one of the options to determine default added mass.
→Default vehicle mass (mass without bodywork + default added mass for bodywork)
→CO_2 (corresponding to the default vehicle mass)
→Optional: Completed vehicle/multistage vehicle: Yes or no

ii) The Final stage manufacturer (FSM) takes care of the type approval for the completed vehicle. The Final customer or FSM registers the vehicle at the national registration authority. The registration authority needs to pull information from the CoC (if not already combined) since e.g. name of CO_2-responsible OEM, appropriate mass and CO_2 is stated in the CoC. The appropriate default vehicle mass (mass of the incomplete vehicle+ default added mass) and the representative CO_2 value arrive in the national registrations database.

Information transfer from CoC to the Member State registration authority:
→Default vehicle mass = Mass with bodywork (mass without bodywork + default added mass for bodywork)
→CO_2 corresponding to the vehicle without bodywork + default added mass for bodywork
→Optional: Completed vehicle/multistage vehicle: Yes or no

4.2 Options for transfer of the monitoring parameters for Individual vehicle approval (IVA)

Currently, for IVA the completed vehicle will be approved according to national rules and only the base vehicle needs to have a CoC for the given state of construction and in that state comply with EU regulation. When 2007/46/EC enters into force this will change and the vehicle will need to comply with the relevant Directives.

There are Member States which exclusively use the CoC for registration. However, some Member States use Type Approval documents.

For approval/certification of the completed vehicle with added bodywork, often a range of checks are performed at the Technical Service. Today, there will be no CoC for the completed vehicle, however. In some cases not the FSM but the customer organizes the approval. For IVA and registration the vehicle is often weighted to determine the new mass of the completed vehicle because it is needed for registration. At a national level, different rules may exist for weighting and a stringent and equal procedure is not in place for all Member States. For instance, in the UK individually approved vehicles are not weighted at all. The mass value provided by the FSM or owner is entered in the registration system without checking it. Today, often the specific CO_2 value is not taken from the CoC. This results in empty records in national registration for the CO_2 emission of vehicles approved under the IVA scheme.

There is a directive [1999/37/EC] which specifies the EU vehicle registration and defines records to be stored at registration. This includes:
- VIN
- T-V-V
- technical maximum permissible laden mass
- mass of the vehicle in service with bodywork
- date of registration

4.3 Issues for both IVA and WVTA

To enable registration of a CO_2 value or a correct mass it would be required, not only for MSVs but for any vehicle approved under the IVA scheme, that a transfer of the CO_2 value from the CoC of the base vehicle to the national registration should be made mandatory. Also an obligatory and strictly defined process should come in place for the determination or checking of the mass of the completed vehicle. This means that the Technical Services/Approval Authorities performing IVA nationally should be required to implement this in their process. Then the local Approval Authority or Technical Service would be the entity to select or check the right CO_2 value and determine or check the mass of a completed vehicles. It is advised to consult the TAAM, the collective of Type Approval Authorities, to discuss the options to secure this process.

<u>For method 1</u> the final stage manufacturer should provide the CoC with the table of CO_2 values at registration, provided by or requested from the manufacturer. The right mass needs to be transferred to the national registration. Based on this mass a corresponding CO_2 value should be chosen from the table. The determination of mass and the selection of CO_2 from a table or the checking of this values if the FSM selects them, should be a standardized EU procedure performed by an Authorized entity.

For MSVs approved under IVA the base vehicle manufacturer is not directly involved in the process – although it is the responsible entity for the CO_2 emission of the completed vehicle – so the base vehicle Manufacturer may need access to information from the FSM or monitoring database to check the mass and the selected CO_2 value. The first can probably not be arranged for all FSM as there is no communication with all FSM. At least it would be hard to establish this communication with all FSM because of the large amount of FSM who build bodywork. The release of the monitoring data would be the first moment for the OEM to check the data. Alternatively, registration authorities may on a regular basis provide the OEM with data of the national registrations of MSV. This requires an identifier for completed vehicles.

<u>For method 2</u> the correct representative CO_2 value is in the CoC of the base vehicle and this value needs to be transferred to the national registration. The Final Stage manufacturer should provide the CoC of the base vehicle to the registration authority and the Registration Authority needs to transfer the right values to the

national registration. This process needs to be formally secured at the level of the Member State registration process.

4.4 General issues

Unique identifier
The Vehicle Identification Number (VIN) is a unique identifier for a vehicle. With VIN an individual vehicle can be traced and checked easily in both the Member State and the base vehicle manufacturers database. A unique additional identifier is desirable at least for method 1 as for this method T-V-V with different masses may arrive in the monitoring system.

Real-time database
A live or real-time Pan European registration database is favoured by the OEMs because this allows strategic planning more accurately, taking account of their CO_2 target. Also this database would ease the checking of the data and could be more reliable. An example of such a database would be a list of VINs and corresponding CO_2 values provided by the OEMs. For every registration a VIN (unique vehicle) can be marked as ‘registered in an EU MS’ and its CO_2 value can then be attributed to an OEM’s CO_2 balance. For MSV also the new CO_2 value and mass must be entered in the case of method 1.

The development of a real time database is already on-going. The database comprises an interconnection between sources within the EU and it’s main goal is to centralize registration of technical data of vehicles with regard to safety and safety requirements. This database can be upgraded with information to register CO_2 for the EU CO_2 monitoring process. The development of this database takes some time, however. It is expected that the database will not be ready within the next years.

National procedures
In a lot of EU countries there are different procedures for the Approval of Individual Vehicles and procedures for Approval of the change of a construction. The latter is often used after a change of the body work. It is not clear how these procedures work and if for instance for such procedures mass is changed in the registration. It is advised to consult the TAAM, the collective of Type Approval Authorities, to discuss the practices in the Member States.

5 Assessment of the methods for measuring and monitoring CO_2 of N1 MSV vehicles

In this chapter both methods are assessed with respect to feasibility, reliability, accuracy and costs. Furthermore, some alternatives for both methods are assessed. More in detail the following is discussed:

- Feasibility of both methods with respect to implementation into the EU N1 CO_2 legislation and monitoring.
- The possible sources of inaccuracy of both methods are identified.
- Parametric simulations have been performed to quantify the inaccuracy.
- The accuracy of the option to simplify method 1 by demanding less tests is assessed.
- The accuracy of method 2 is assessed.
- An exercise was performed to look for an improvement of the accuracy of method 2.
- The implications of the introduction of a procedure for measuring and monitoring the CO_2 emission of MSV are calculated in relation to the CO_2 target.
- The costs are assessed.

In the tables hereafter the most important advantages and drawbacks are summarized for each method. An additional table is given with general issues for both methods.

Table 8: Summary of most important advantages and drawbacks of method 1

Method 1 Advantages	Notes
› Accurate and representative mass and CO_2 values for the fleet and for individual vehicles	› Current road load procedure has shortfall: accuracy and representativeness **can only be obtained if** this shortfall is addressed. The short fall also accounts for method 2.
Drawbacks	
› Amount of tests and relating costs increase › Increased complexity of information transfer (selection of corresponding CO_2 and mass and correct registration of these values) and identification of individual vehicles falling in or out of scope. › Final CO_2 and mass are not known until publication of the monitoring database	› Amount of tests and related costs can be reduced substantially until same level of method 2 by simplification of method 1 › A robust process for information transfer is required › A live database can advance the publication of monitoring data somewhat

Table 9: Summary of most important advantages and drawbacks of method 2

Method 2 Advantages	Notes
› A default approach: easier to implement › CO_2 and mass are immediately known by OEMs at production › Least amount of tests and somewhat lower costs	› Delay until final registration remains
Drawbacks	
› Inaccurate for individual vehicles › Inaccurate for OEM fleets (uneven impact on mass and CO_2 compared to CO_2 target) › Inaccurate due to boundary issues between N1 sub classes › No reproducible, measureable parameter available to select DAM › Introduction of a fictitious value for mass and CO_2 which may be interpreted wrongly › Of no use for labelling and national incentive programs (incorrect mass and CO_2 data for individual vehicles) › Scope issue. Individual vehicles may be wrongly appointed to fall in or out of the scope of CO_2 legislation	› Inaccuracy for fleets may be improved by alternatives for the method using DAM per sub class, like functions using vehicles parameters.

Table 10: Summary of general issues for both methods

General Issues	Notes
› Most MSV are approved according IVA and are checked by local Technical Service (TS) › Short fall of the technical procedure. The mass in the table for road load settings does not increase above 2380 kg, while a major share of MSV will fall around and above this mass.	› Requires clear and strict procedures and obligations (including weighing and selection of corresponding CO_2) for the TS, approval authorities and registration authorities for transfer of the right monitoring information from CoC to registration › The use of VIN would improve the identification and checking of data › A live and central database can possibly improve the quality of the monitoring data

5.1 Assessment of the feasibility and reliability of both methods with respect to practical issues for implementation

For either of both methods, issues exist which must be solved or taken into consideration before making a choice for one of both methods. A list of the points is given below:

5.1.1 *Method 1, Chassis dynamometer settings*

- Especially for IVA, transfer of the right CO_2 value and mass to the registration today is very unclear and probably not arranged at all at the moment. A reliable process is required with obligations and responsibilities for national Technical Services and registration authorities.
- A vehicle may fall in N1 ECE-R49 (RW>2610 or RW >2840 kg) after upfitting while its GVM remains lower than 3500kg. An exercise with the dataset of road side observations showed that after adding bodywork approximately 45% will fall outside the scope of 2610kg and 31% will fall outside the scope of 2840kg. It is not known beforehand if a vehicle will fall in or outside the scope of CO_2 legislation and it is also not clear from available monitoring data if the extension of the scope (to a maximum RW of 2840kg) is applicable for a given completed vehicle or not. A solution is needed. For instance for monitoring, vehicles need to be identified and marked either in the scope or outside the scope based on the available monitoring data. Mass in running order could be used, this value minus 25kg is the reference mass and the reference mass can used to decide whether the vehicle is in or out the scope of a maximum of 2840kg. However, with the reference mass the possible applicability of an extension cannot be identified because this information is not available. Optionally, a record can be added to the monitoring system which identifies vehicles with an extension to 2840kg. Or a choice needs to be made to chose either all vehicles with a reference mas below 2610kg or all vehicles with a reference mass below 2840kg to fall in the scope of CO_2 monitoring of N1 vehicles.
- The table of inertia weight and a and b coefficient to be used for testing over the Type I test ends at 2610kg and the maximum inertia for testing is 2270kg for the inertia weight class of 2210 until 2380kg, while MSV can be heavier. From the representative dataset is could be found that approximately 61% of the MSV are heaver than 2380kg.
- A filled table with CO_2 values to be used for selecting CO_2, based on tests performed with the table 3 from annex 4a of ECE-R83 can therefore never result in representative CO_2 values for higher masses. In practise vehicles may fall in the extension of N1 (between 2610 and 2840kg) and as mentioned above vehicles may even fall outside the scope.
- There will be a time delay between production of a completed vehicle and release of the database with registration of the completed vehicle with it’s final mass and CO_2 value according to the bodywork added . An OEM knows only at the time release of the database the CO_2 value of the vehicle. For the vehicle types which are approved according WVTA the OEM is able to know the type of bodywork added and is able to know the final mass and CO_2. At this moment this share is about 20% of the total amount of produced base vehicles. For the remaining 80% the OEM does not know the exact mass added, hence he does not know the specific CO_2 value. However, a large share of the market (around

80%) is dominated by common types of bodywork for which the OEM may be able to estimate the added mass for the time being. An inclusion of the mass and CO_2 in the CoC and a mandatory registration of this data for completed vehicles allows to evaluate the real mass and CO_2 of these vehicles and should be arranged as soon as possible so that manufacturers are able to estimate the typical CO_2 values for years coming. A pan European real time database is being developed which can be upgraded with specific information of MSV so that OEMs can follow the development of mass and CO_2 of the MSV fleet live.

- For vehicles of the same T-V-V (Type Version Variant), different values for mass will be established for individual vehicles, leading to possible problems with registration. These vehicles may need an additional unique identifier.

5.1.2 *Method 2, Default added mass*

- The mass of the vehicle and its corresponding CO_2 value will be fictitious values which will be added to the Member State registrations. This fictitious mass and CO_2 values may be confusing and lead to misinterpretation and wrong or false registrations. Furthermore, the fictitious CO_2 value and mass will differ from the actual value in the case a vehicle is heavier or lighter than the average or default. For individual vehicles this mass and CO_2 may vary substantially from the average value, see next item below and paragraph 5.2. This may be undesirable for instance for use in a national CO_2 based tax scheme because a vehicle owner will be at a disadvantage if tax would be based on a fictive higher CO_2 value when the vehicle of the owner is lighter and emits less CO_2 than what would result from the default mass. Vehicles will enter the market which should fall under CO_2 legislation but they don’t because the real mass in running order of the completed vehicle is lower than 2610kg. Vehicles will also enter the market which will be recorded to fall in the scope of CO_2 legislation while they actually shouldn’t because the real mass in running order of the completed vehicle is higher than 2610kg.
- For the fleet of MSV it became apparent that the average added mass increases with average base vehicle mass. However, this relation is rather weak because individual vehicles may substantially differ from the default or average, see paragraph 5.2. The original average mass method (relating mass to N1 sub classes) may also come with boundary effects at the N1 sub-class borders, for instance when used with discontinuous steps of mass to be added which increase with base vehicle mass per N1 sub-class. A continuous function may solve this but still a poor relation between base vehicle mass and added mass will cause individual vehicles to get a very unrepresentative mass. This inaccuracy and unrepresentativeness for individual vehicles may be somewhat improved by taking parameters from the vehicle which are better predictors for the mass that could be added to a base vehicle. An alternative function is assessed in paragraph 5.6 which uses the maximum technically permissible laden mass and the reference mass of the base vehicle.
- The chassis cab mass distribution differs per manufacturer (for instance Iveco seems to have heavier chassis cabs than e.g. Renault or Ford, because their market is for somewhat heavier transport). Fixing a default mass influences the CO_2 emission in a relative sense and in a different way for manufacturers who differ concerning the mass of their vehicles

5.1.3 *Commercial reasons for certification as R83 and/or R49 and N1 and N2.*

Vehicles certified as R49 can be registered as N1 or not, stimulated by commercial or market driven reasons. A few of these reasons have been identified and are summarised hereafter:

- Incentives for maintaining R49: National Tax incentives for clean vehicles (e.g. EEV).
- Incentives for maintaining N1 are Driver license B (+E) for GVM <=3500kg, the maximum speed is higher for vehicles with a GVM<=3500kg.
- The CO_2 legislation and the premium for CO_2 emissions add a new commercial incentive. In the case a heavy vehicle emits a relatively high amount of CO_2 it can be taken from R83 to R49. It is doubtful whether this will happen given the advantage heavy vehicles have in relation to the CO_2 target. The opposite could also happen in theory: vehicles could be taken from R49 to R83 because they are relatively heavy and may perform relatively well compared to the CO_2 target.

5.2 Accuracy of both methods

For MSV inaccuracy can be found in the current technical procedure (ECE-R83) but also in the proposed methods. A summary is given below. Each inaccuracy is worked out in detail further in separate paragraphs.

1. The equivalent inertia (in R83, Annex 4a, table 3) for testing is maximal 2270 kg. Heavier vehicles than 2380 kg will also be tested with this value. From the representative dataset it could be found that approximately 61% of the MSV are heaver than 2380 kg.
2. The load settings (in R83, Annex 4a, table 3) for testing go up to 2610 kg, while type approval can be extended to 2840kg.
3. There is an additional factor of 1,3 to be applied to the load of table 3 for vehicles with a reference mass more than 1700 kg.
4. The inertia weight classes are 110 kg, meaning that a vehicles reference mass can vary within this range. This is the case for all Light Duty Vehicles.
5. For the default added mass approach, method 2, the real mass and CO_2 emission of an individual vehicle may substantially deviate from the mass of the base vehicle added with the default mass. A special function may improve the correlation. A first assessment of options was performed to explore if a better function can be found to define the relation between base vehicle mass and the default added mass.
6. In table 3 of R83 Annex 4a the load settings are default values fixed long time ago and probably not even for N1 vehicles: the representativeness of these values can be doubted. Individual MSV may have different drag and rolling resistance resulting in a different real road load. The accuracy of method 1 and 2 is therefore determined by the accuracy and representativeness of the inertia weight classes and the corresponding load settings: the adjusted inertia and dyno load requirements (Table 3 from Annex 4a of ECE-R83).
7. Mass alone does not fully represent an effect on real CO_2: for instance a box type construction and a tipper may weigh the same but have totally different air drag due to the large differences in shape (frontal area and drag coefficient). In table 3 with simulated inertia and dynamometer load requirements a default

load setting is used. This means that the road load from individual vehicles may deviate from this default. Possible effects have been calculated.

8. For method 1 a table [mass, CO_2] needs to be defined which is based on a range of tests at different Inertia Weight Classes. Alternatively, a simple approach with for instance only two or three tests may fix a function CO_2=f(mass), based on which a CO_2 value can be calculated / interpolated. Such an approach will be less accurate. The accuracy can be determined from the simulation exercise as performed for three typical MSV configurations.

5.3 Parametric simulations to determine the effect of the methods on CO_2 accuracy and representativeness

In order to assess the technical suitability of the two methods, three typical individual vehicles were simulated using the CRUISE model. Key technical specifications for the base vehicles (chassis cabs) are presented in the table below.

Table 11: technical specifications of the of the three typical MSV selected for the simulations.

Base vehicle model	Engine Capacity [cm^3]	Max Power [kW]	Max Torque [Nm/rpm]	Frontal Area [m^2]	Drag coefficient	Kerb weight [kg]	Road test CO_2 emissions [g/km]	Reference mass CO_2 emissions [g/km]
Fiat Fiorino	1248	55	190 /1750	2.65	0.31	1090	124.6	113.1
Ford Transit SWB300	2198	81	285/ 1750	3.94	0.4	1545	237.2	208.0
Iveco Daily	2300	85	270/ 1800	4.30	0.4	2080	216.1	190.5

CRUISE is AVL's vehicle and powertrain level simulation tool and it can simulate the vehicle operation over a driving pattern and can calculate emissions and fuel consumption, provided it can be fed with appropriate vehicle specifications and engine maps. As input to the CRUISE software, a number of key vehicle characteristics such as mass, drag coefficient, frontal area, engine map and other technical data are required. These are used by the model to calculate the engine operating points over a specified driving cycle and therefore efficiency and fuel consumption. For this study, the main parameters which were used as input for the model were fuel consumption maps, engine power, frontal area and aerodynamic drag, vehicle mass, rolling resistance coefficient(s), gear and final drive ratios, wheel diameter and dimensions and weight of various components.
As a first step, the above vehicles were set-up within the CRUISE model to calculate their type approval CO_2 emissions. To this aim, all input parameters collected above related to vehicle, engine, transmission and wheel were entered into the software. Once the vehicles were set-up, the legislated driving cycle (NEDC) was simulated. Thus, the road load forces acting on the vehicle when driving on the road are simulated. Alternatively, type approval CO_2 emissions may be also calculated by using the road load coefficients included in Table 3 of UN-

ECE Regulation 83. Both type approval values (road test and reference mass CO_2 emissions respectively) have been calculated and are provided in the table above.

In order to simulate the effect on CO_2 emissions of adding a superstructure to the above base vehicles, the vehicle reference mass has been varied (in 110kg steps) up to the Gross Vehicle Weight value defined by each manufacturer. The results of these simulations are summarised in table 12, table 13 and table 14 for the selected vehicles. CO_2 values for both road test and reference mass methods are shown in the tables.

EC Regulation No. 510/2011 sets specific emissions targets by means of a so-called limit value curve for each manufacturer based on the average vehicle mass sold by the particular manufacturer. The proposed targets set by this limit value curve are also included in the subsequent tables. It should be noted that this target is only indicative as it refers to the entire fleet of each manufacturer rather than to individual vehicle types.

Table 12: Simulation results for the Fiat Fiorino.

Equivalent inertia (kg)	Reference mass (kg)	Road load coefficient a (N)	Road load coefficient b (N/kph^2)	Road test CO_2 emissions [g/km]	Reference mass CO_2 emissions [g/km]	CO_2 target [g/km]
1130	1190	6.4	0.0433	124.6	113.1	127.0
1250	1300	6.8	0.0460	127.7	116.2	137.2
1360	1410	7.1	0.0481	130.8	118.6	147.5
1470	1520	7.4	0.0502	134.0	121.4	157.7
1590	1630	7.6	0.0515	137.3	123.8	167.9
1700	1740	10.27	0.0697	140.7	134.7	178.2

Table 13: Simulation results for the Ford Transit.

Equivalent inertia (kg)	Reference mass (kg)	Road load coefficient a (N)	Road load coefficient b (N/kph^2)	Road test CO_2 emissions [g/km]	Reference mass CO_2 emissions [g/km]	CO_2 target [g/km]
1700	1645	7.9	0.05360	237.2	208.0	169.3
1700	1755	10.27	0.06968	238.5	215.8	179.6
1810	1865	10.66	0.07241	241.6	218.7	189.8
1930	1975	11.05	0.07501	244.7	221.5	200.0
2040	2085	11.31	0.07683	247.8	224.1	210.2
2150	2195	11.57	0.07865	251.0	226.5	220.5
2270	2305	11.83	0.08047	254.4	229.3	230.7
2270	2415	12.35	0.08398	255.9	230.9	240.9
2270	2525	12.35	0.08398	257.2	230.9	251.2
2270	2635	12.87	0.08762	258.8	233.0	261.4
2270	2745	12.87	0.08762	260.4	233.0	271.6
2270	2855	12.87	0.08762	261.9	233.0	281.9
2270	2965	12.87	0.08762	263.5	233.0	292.1

Table 14: Simulation results for the Iveco Daily.

Equivalent inertia (kg)	Reference mass (kg)	Road load coefficient a (N)	Road load coefficient b (N/kph^2)	Road test CO_2 emissions [g/km]	Reference mass CO_2 emissions [g/km]	CO_2 target [g/km]
2150	2180	11.57	0.07865	216.1	190.5	219.1
2270	2290	11.83	0.08047	219.2	193.1	229.3
2270	2400	12.35	0.08398	220.5	194.7	239.5
2270	2510	12.35	0.08398	221.8	194.7	249.8
2270	2620	12.87	0.08762	223.1	196.5	260.0
2270	2730	12.87	0.08762	224.7	196.5	270.2
2270	2840	12.87	0.08762	226.0	196.5	280.5
2270	2950	12.87	0.08762	227.3	196.5	290.7
2270	3060	12.87	0.08762	228.6	196.5	300.9
2270	3170	12.87	0.08762	230.1	196.5	311.2
2270	3280	12.87	0.08762	231.4	196.5	321.4
2270	3390	12.87	0.08762	232.7	196.5	331.6
2270	3500	12.87	0.08762	234.0	196.5	341.8

Road test type approval CO_2 emissions are higher by 9% on average compared to reference mass emissions for the Fiat Fiorino, which is the lightest of the three vehicles simulated. This difference, however, increases for heavier vehicles, being 11% for the Ford Transit and 15% for the Iveco Daily. These differences may explain the manufacturers' preference of the load settings from the table over the load settings derived from the coast down method for type approving their vehicles.

The above simulation results are graphically shown in Figure 14, Figure 15 and Figure 16. Both road test and reference mass simulated CO_2 emissions are presented (blue and red lines respectively), as well as the CO_2 target as explained above (green line). As expected, CO_2 emissions increase with vehicle mass and this correlation is in principle linear (e.g. as in the case of emissions calculated with the road test method for the Fiat Fiorino, shown in Figure 14). However, certain slope changes are observed in these figures, which are due to the following reasons:

- The maximum equivalent inertia for testing is 2270kg and hence any heavier vehicles are tested with this value. As a result, there is a decrease in the slope of the blue line around the 2270kg value for the Ford Transit and the Iveco Daily.
- For reference mass values above 1700kg the road load coefficients a and b are multiplied by a factor of 1.3. This breakpoint around 1700kg is apparent in the case of the Fiat Fiorino and the Ford Transit (red lines).
- For reference mass values above 2610kg the road load coefficients a and b remain constant. As a result, the calculated CO_2 values remain also constant above the 2610kg threshold for the Ford Transit and the Iveco Daily (blue lines).

The CO_2 target line is steeper than the simulated CO_2 functions for all three vehicles. Two of the three vehicles (the Fiat Fiorino and the Iveco Daily) are below the CO_2 target for the entire range of reference mass values simulated. The difference between type approval and target is marginal for the base vehicles, whereas it increases considerably for heavier vehicles. The picture for the Ford Transit, which in terms of weight is in between the other two vehicles, is somewhat different. The simulated CO_2 emissions are above the target for reference mass values below 2300kg (for the reference mass type approval) or 2600kg (for the road test type approval).

Figure 14: CO_2 emissions vs. reference mass for the Fiat Fiorino. Road test CO_2 emissions are simulated using an estimate of the real road load while reference mass CO_2 emissions are simulated using table 3 of ECE-R83, Annex 4a with default inertia and load settings.

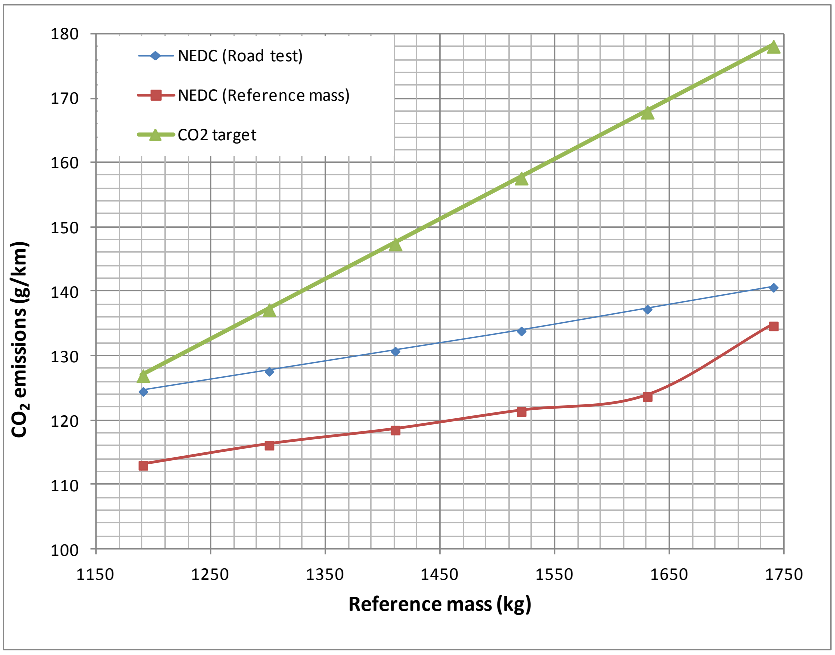


Figure 15: CO_2 emissions vs. reference mass for the Ford Transit. Road test CO_2 emissions are simulated using an estimate of the real road load while reference mass CO_2 emissions are simulated using table 3 of ECE-R83, Annex 4a with default inertia and load settings.

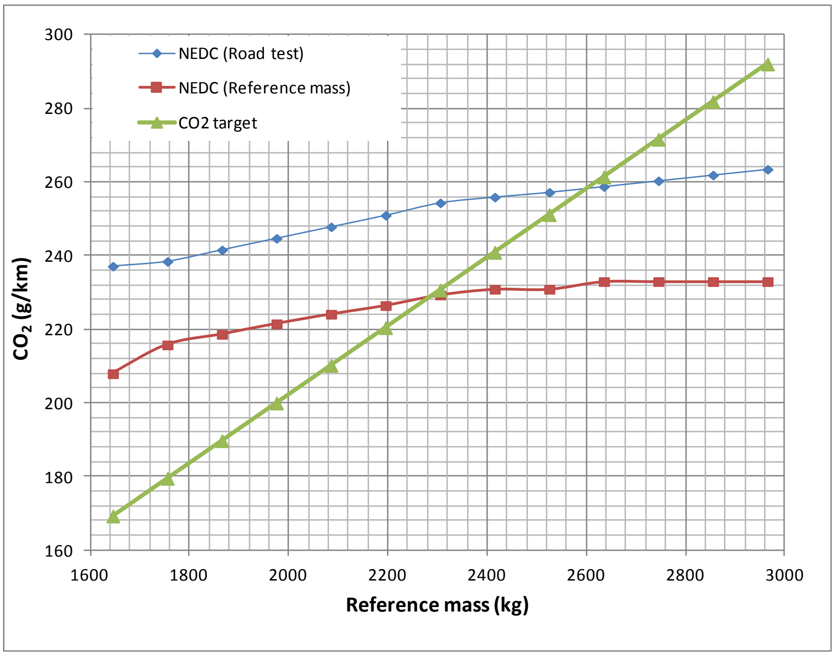
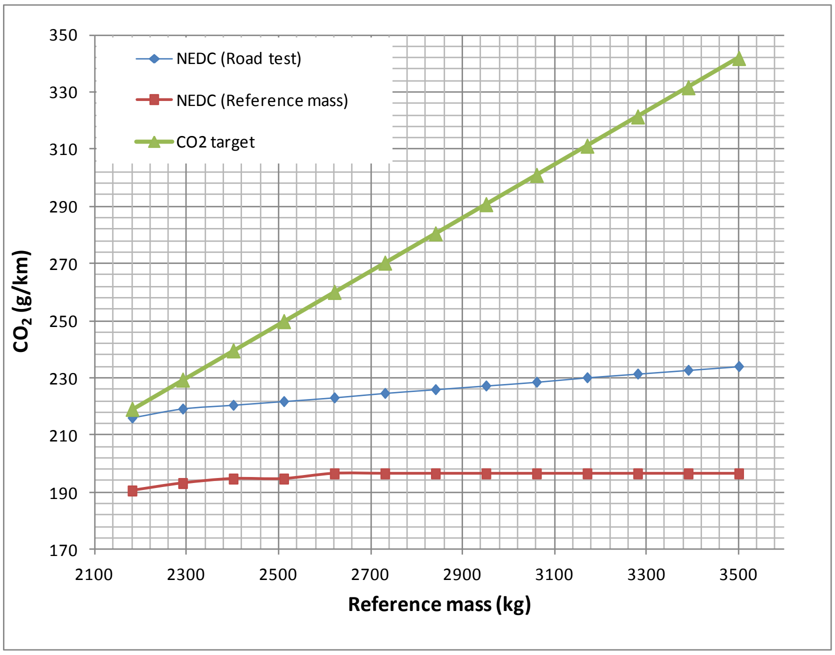


Figure 16: CO_2 emissions vs. reference mass for the Iveco Daily. Road test CO_2 emissions are simulated using an estimate of the real road load while reference mass CO_2 emissions are simulated using table 3 of ECE-R83, Annex 4a with default inertia and load settings.



A number of interesting observations can be made based on the above simulation results, which can be summarised as follows:

- The current type approval procedure clearly favours vehicles with higher reference mass as can be seen from the above graphs, with the relative advantage increasing with higher vehicle reference mass. This is due to the technical shortfall in putting a representative load to the vehicle, as a result of (a) restricting the maximum equivalent inertia for testing to 2270kg and (b) keeping the road load coefficients *a* and *b* constant for reference mass values above 2610kg.
- The observed increase in CO_2 emissions with mass is lowest for heavier vehicles and highest for lighter vehicles. Although this behaviour is not straightforward to explain, one reason could be engine efficiency variations as a function of size. Larger engines operate at relatively lower RPM and have a higher efficiency over the complete engine map. Thus operating a large engine at a different region would have a relatively smaller effect than for a small engine.
- Evidently, manufacturers producing heavier vehicles are expected to have a preference for method 1, as the CO_2 type approval value diverges from the CO_2 target of the Regulation No. 510/2011 with increasing weight. On the other hand method 2, although it could result in lower CO_2 type approval values due to a default mass possibly lower than the anticipated average added mass, it could result in reducing the gap to CO_2 target if below the target, or increasing the gap if above the target.

In addition to the above parametric study, a number of simulations have been performed for typical MSV vehicles based on the above selected chassis cab versions. These include upfitting with a standard box (with and without loading platform), as well as drop side versions of the Ford Transit and the Iveco Daily base vehicles.

Figure 17: examples of the simulated MSV.

The table below summarises the changes assumed for the simulations, which are mainly related to vehicle weight and frontal area. An additional weight of 250 and 300kg for the Ford Transit and the Iveco Daily respectively has been assumed for the drop side versions. Similarly, an additional weight of 800 and 900 kg respectively has been considered for the standard box and platform. An increase in the frontal area has been assumed for the MSV fitted with a box, whereas no change in aerodynamic drag has been assumed for the drop side versions.

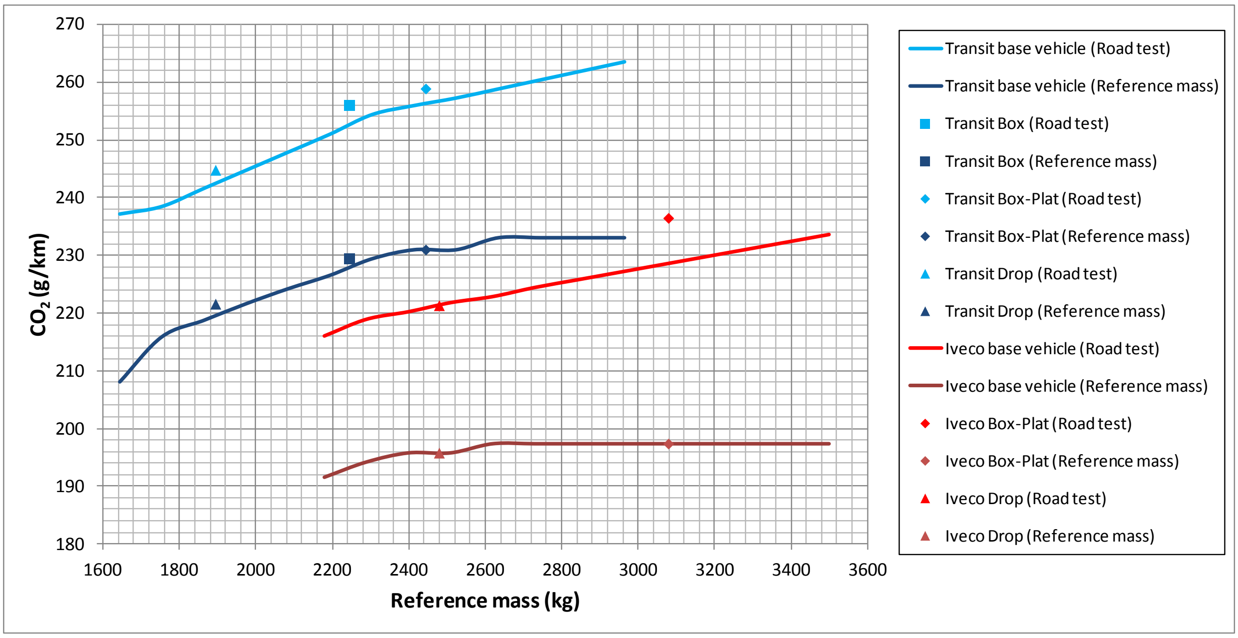
Table 15: Simulation results for the Iveco Daily and Ford Transit and both fitted with typical bodywork.

Base vehicle + typical bodywork	Frontal Area [m^2]	Equivalent inertia (kg)	Reference mass [kg]	CO_2 emissions using an estimate for the real road load [g/km]	CO_2 emissions using default road load from the table 3 [g/km]
Ford Transit Dropside	3.94	1930	1895	244.7	221.5
Ford Transit + Box	4.2	2270	2245	255.9	229.3
Ford Transit + Box + Platform	4.2	2270	2445	258.8	230.9
Iveco Daily Dropside	4.30	2270	2480	221.8	194.7
Iveco Daily + Box + Platform	5.30	2270	3080	237.2	196.5

The results of the above table confirm the findings of the parametric simulations presented above that the current procedure for testing N1 vehicles (ECE-R83), which uses a table with load settings, does not provide a representative load to individual vehicles. In addition to this, other parameters related to the addition of specific bodywork and influencing CO_2 emissions may contribute to the observed inaccuracies even further.

These effects are illustrated in Figure 18, in which the CO_2 values of the above vehicle configurations are plotted against the respective emission values of the base vehicles.

Figure 18: CO_2 emissions vs. reference mass for the base vehicles and the various bodyworks fitted on Iveco Daily and the Ford Transit.



As an example, the addition of a standard box and platform for the Iveco Daily (i.e. additional mass of 800 kg) would have no effect in estimating CO_2 emissions when using the fixed road load settings (brown coloured line and points in Figure 18). This is because the increased aerodynamic drag does not influence the *a* and *b* coefficients used for conducting the test on the chassis dynamometer. Hence, although the real resistances of the vehicle increase (as a result of the increased aerodynamic resistance) this has no effect on the type approval CO_2 emissions if the fixed road test settings are selected (which is the case for most N1 vehicles). However, the increased frontal area of the final vehicle (due to the standard box) will result in higher CO_2 emissions than the reference mass would suggest (red coloured point for the box and platform version is above the respective line of the base vehicle in Figure 18).

The same picture can also be observed for the Ford Transit in the case of adding a standard box and platform (dark blue dot on the respective line of the base vehicles, whereas light blue dot is above the respective line of the base vehicles, as shown in Figure 18). In this case, however, the inaccuracy in estimating the emissions is lower, due to the relatively lower (less than 7%) increase assumed in the frontal area of the vehicle.

However, the above observations do not hold true for bodyworks that do not change significantly the aerodynamic drag of the end vehicle, as shown in Table 15 and in Figure 18 for the dropside versions. This is also the case for other bodywork types, such as tippers, tractor units, etc.

As a concluding remark, it can be thus stated that the addition of a bodywork which may negatively affect the aerodynamic resistance of the completed vehicle, may provide an additional advantage to the manufacturers as the current procedure further underestimates the effect of this bodywork on CO_2 emissions.

5.4 Accuracy of interpolation of tests as alternative approach for use in method 1

For method 1 a table of [mass, CO_2] needs to be defined which is based on a range of tests at different Inertia Weight Classes. Alternatively, a simple approach with for instance only three or two tests may fix a function CO_2=f(mass), based on which a CO_2 value can be calculated / interpolated (see paragraph 2.3). Such an approach will be less accurate.

The accuracy of this approach has been evaluated in a first simple exercise to demonstrate the potential. To evaluate this approach the simulated results from the parametric analyses were used.

Two options have been evaluated:

1. Using three tests to interpolate the results between those three.
2. Using two tests to interpolate the results between those two.

Option using three tests
From the applicable inertia range for the given three simulated base vehicle types the highest, lowest and middle result have been used as if these were real tests performed an a chassis dynamometer. For the middle value, if it is not exactly falling in the middle the lower value is used. All inertia ranges in between have been interpolated and where compared with the results from the parametric simulation. See Table 16, Table 17 and Table 18.

The following can be concluded:

- For the medium base vehicle 5 out of 8 tests could be saved.
- For the heavy base vehicle 2 out of 4 tests could be saved. Here a substantial reduction of 2 tests can only be achieved if only the highest and lowest inertia are tested.
- For the light base vehicle 3 out of 6 tests could be saved.
- For the inertia classes in the table where inertia still increases (until 2270kg) the accuracy is about 0,6%.
- For the inertia classes in the table where inertia does not increase anymore (2270kg and beyond) the inaccuracy increases up to 1,7%. This is caused by the fact that interpolation is based on the test inertia and the inertia does not increase anymore. As a result the interpolated value becomes the highest CO_2 value of the table as soon as the inertia doesn't change anymore. This can be improved by extending the table with more representative inertia and load settings above 2270kg.

Table 16: example of interpolation of test results based on three tests on a medium chassis cab (1750 kg) to arrive at a full list of CO_2 results for the complete range and sequence of inertia ranges. The largest difference between test result and interpolation result occurs for the classes where the inertia remains the same (2270 kg) and the load setting still increases. For this vehicle the interpolation method saves 5 tests.

Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	1700	208,0	208,0		
Interpolation	1810	210,6	210,3	-0,2	-0,1%
Interpolation	1930	212,9	212,9	0,0	0,0%
Test	2040	215,3	215,3		
Interpolation	2150	217,6	218,9	1,3	0,6%
Interpolation	2270	220,2	222,8	2,6	1,2%
Interpolation	2270	221,5	222,8	1,3	0,6%
Test	2270	222,8	222,8		

Table 17: example of interpolation of test results based on three tests on a light chassis cab (1175 kg) to arrive at a full list of CO_2 results for the complete range and sequence of inertia ranges. For this vehicle the interpolation method saves 3 tests. Here, already a maximum is set for the test range for inertia. Instead of the maximum of the table the maximum technically permissible laden mass (MPMLM) of the vehicle type of 1700kg is used.

Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	1130	113,1	113,1		
Interpolation	1250	116,2	116,0	-0,3	-0,2%
Test	1360	118,6	118,6		
Interpolation	1470	121,4	121,2	-0,3	-0,2%
Interpolation	1590	123,8	124,0	0,3	0,2%
Test	1700	126,7	126,7		

Table 18: example of interpolation of test results based on two tests on a heavy chassis cab (2180kg) to arrive at a full list of CO_2 results for the complete range and sequence of inertia ranges. For this vehicle the interpolation method saves 2 tests. The largest difference between test result and interpolation result occurs for the classes where the inertia remains the same (2270kg) and the load setting still increases.

Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	2150	190,5	190,5		
Interpolation	2270	193,1	196,5	3,4	1,7%
Interpolation	2270	194,7	196,5	1,8	0,9%
Test	2270	196,5	196,5		

Option using two tests

The same exercise as performed with three tests was repeated, now only using two tests.

The following can be concluded:

- For the two lightest of the three simulated vehicle types, one additional test can be saved, leading to 4 out of 6 saved tests for the light vehicle and 6 out of 8 tests saved for the medium vehicle.
- The accuracy of interpolation of a single result, using two points is within about 3 g/km and 1,0%. To give an indication of the magnitude of this error: the repeatability of a type I test is estimated at about 1%.

Table 19: example of interpolation of test results based on two tests on a medium chassis cab.

Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	1700	238,5	238,5		
Interpolation	2305	254,4	251,8	-2,6	-1,0%
Test	2635	259,1	259,1		

Table 20: example of interpolation of test results based on two tests on a heavy chassis cab.

Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	2150	216,1	216,1		
Interpolation	2620	223,1	222,3	-0,8	-0,3%
Test	3500	234,0	234,0		

Table 21: example of interpolation of test results based on two tests on a light chassis cab.

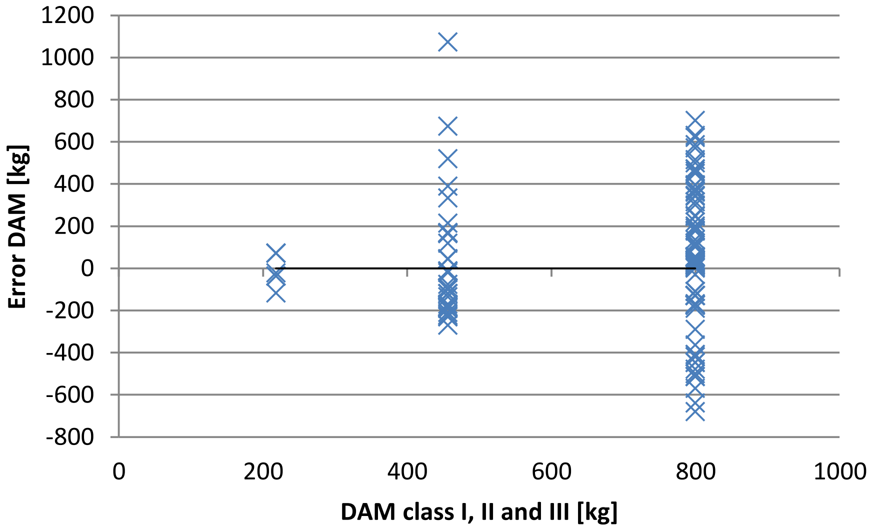
Real test or interpolation	Inertia weight	Test results (simulated)	Interpolated results	Difference	Difference
	[kg]	[g/km]	[g/km]	[g/km]	[%]
Test	1130	124,6	124,6		
Interpolation	1360	130,8	131,1	0,3	0,2%
Test	1700	140,7	140,7		

5.5 Accuracy of method 2

Method 2 is a ‘default approach’, meaning that as originally proposed a ‘default’ or average mass is added to the reference mass of the base vehicle (incomplete vehicle) which depends on the N1 class, see paragraph 2.3. This already implicates that the default added mass (DAM) is an average and thus may not be representative for individual vehicles. To determine the error for individual vehicles an exercise was performed in which the real mass of a completed vehicle is compared with the default mass of the completed vehicle. The default mass of the completed vehicle is the reference mass plus the default added mass (Class I: 218, Class II: 456 and Class III: 800kg). Note that the mass in running order as used for monitoring of CO_2 is 25 kg lower than the reference mass.

The difference between real mass versus default mass of the completed vehicle ranges from -700 to + 1050kg. On average the error for vehicles being too light or too heavy compared to the target is 206kg. The largest positive deviation stems from a vehicle with a lifting platform. Isothermal boxes form the largest typical group with positive deviation. The deviations in the negative direction stem from tractors, car transport and pick-up/drop-sides.

Figure 19: the error of the DAM between real DAM and a fixed DAM per N1 sub class.



5.6 Accuracy of alternative approaches for method 2

Method 2 as originally proposed uses a discontinuous function for the default added mass where each N1 sub-class has it’s own value. Alternatively, a continuous function can be used, which comes with the advantage that boundary effects between N1 classes are avoided.

A further option was proposed by ACEA. Here DAM is calculated from the difference between the ‘maximum’ mass of the vehicle and the ‘minimum’ mass of the vehicle, where factor ‘a’ represents the fraction of this difference for bodywork.

$$DAM = a \times (TPMLM - RW_{BaseVehicle})$$

DAM is the Default Added Mass and TPMLM is the Technically Permissible Maximum laden Mass or the Gross Vehicle Mass, whichever is the lowest.

Below, in Figure 20 the relation between DAM and base vehicle mass is plotted for a representative sample of MSV. In general, there is a large spread of the DAM, this is the highest for the heavier base vehicles. For the lighter base vehicles few data is available and makes the relation somewhat more uncertain in this area. However, the DAM tends to increase with base vehicle mass. Above 1600 kg the scatter of mass becomes very large. This is already explained in paragraph 5.5 and is typically caused by the large scatter in mass of bodywork added.

Function for DAM based on reference mass of the base vehicle mass

For method 2 the determination of DAM can be done using the plain relation between base vehicle mass and added mass. DAM=f(mass base vehicle). In the graph below an exponential function is plotted to show the correlation between the two parameters. A disadvantage is that heavy base vehicles may get an unrealistically high DAM and light base vehicles can get an unrealistically low DAM. This can be solved by putting a minimum and maximum cap. Optionally, the DAM from class I and III can be used (218 and 800kg respectively) as caps.

Figure 20: relation between added mass and base vehicle mass. An exponential function was added to show the increase of added mass towards higher base vehicle mass.

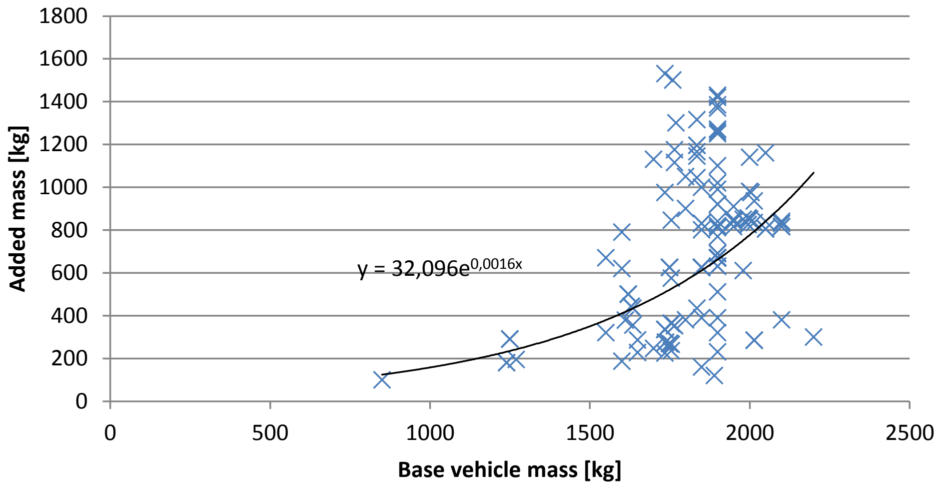
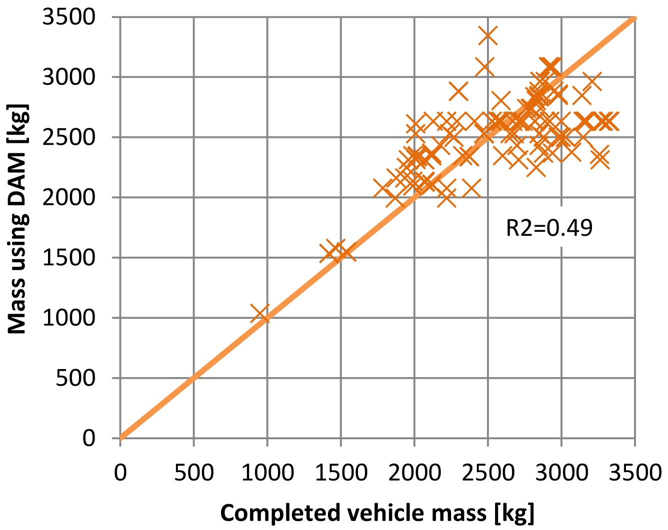


Figure 21: the correlation between the complete vehicle mass estimated using base vehicle mass and the DAM and the real completed vehicle mass. The DAM was estimated using an exponential fit to the base vehicle mass and observed added mass.

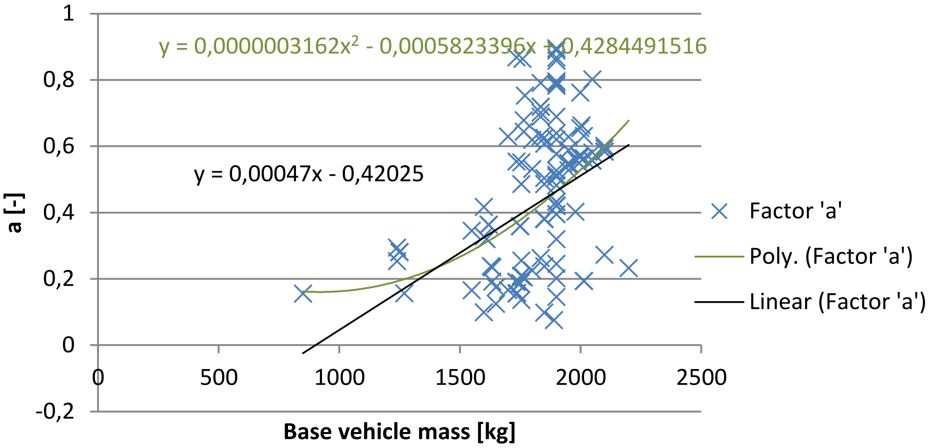


Functions for DAM based on the difference between TPMLM and base vehicle mass, using factor ‘a’ as the fraction of this difference for bodywork.

In the case of further alternatives to method 2 the factor ‘a’ typically represents the average fraction of the mass that can possibly be added to a base vehicle. As such this fraction would be related to the potential of the vehicle to add bodywork, equipment and payload. This potential is reflected in the difference between TPMLM and the Reference mass of the base vehicle. As an alternative to reference mass of the base vehicle, the minimum mass may be used.

Below the relation between the factor ‘a’ and the base vehicle mass is shown. Just like for the DAM the scatter of ‘a’ is large for base vehicles above 1600kg and somewhat uncertain below this mass. A steep rise of factor ‘a’ can be observed at a base vehicle mass of 1700kg.

Figure 22: relation between factor ‘a’ and base vehicle mass. Regression lines are shown for a linear function and a 2nd order polynomial.



Some options can be defined for the determination of ‘a’.

- *Fixed ‘a’*. Here ‘a’ represents an average value (arithmetic mean) for the whole fleet.
- *Split ‘a’*. Because ‘a’ and the mass of bodywork on average increase with the mass of a base vehicle, a bias may be required for heavier vehicles. Because in the suggested function the difference between maximum mass (TPMLM) and minimum mass determines the added mass and because heavier base vehicles tend to have heavier bodywork, the default added mass may be underestimated for heavy vehicles: The function using a fixed ‘a’ leads to a lower added mass for heavy base vehicles as the minimum mass is relatively high. To compensate for this effect heavier base vehicles may need a higher ‘a’. A split value for ‘a’ could be based on GVM. A suggested boundary is 3000kg because vehicles with a lower GVM are typically lighter base vehicles. The boundary is rather arbitrary however. The two values of ‘a’ represent the arithmetic mean of ‘a’ of each chosen mass range.
- *Function for ‘a’: polynomial*. Applying different kinds of regression to the dataset it proved that a polynomial showed the best fit. In principle, the function can be tuned to fulfil the need to estimate the DAM with an equal accuracy for light and heavy vehicles. This was not further investigated.
- *Function for ‘a’: linear*: Alternatively, different functions for ‘a’ can be used. A linear *function* seems a very simple and straightforward approach and therefore this options was included in the evaluation. As can be seen in Figure 22, factor ‘a’ becomes smaller than zero at a base vehicle mass lower than around 900kg. To deal with this effect a cap, a minimum value for ‘a’, is advisable.

The potential of the alternative functions to predict the DAM can be further analysed by comparing the predicted value with the actual DAM from the representative sample.

Fixed ‘a’

First the use of a fixed value of ‘a’ is evaluated. The graph below shows the error made for DAM when an average ‘a’ of 0,43 is used. The value for ‘a’ of 0,43 was obtained from the representative dataset (paragraph 3.3) and represents the arithmetic mean of ‘a’ of the sample . This fixed ‘a’ leads to an underestimation of DAM for heavier base vehicles, and an overestimation which is obvious given the increase of ‘a’ for heavier vehicles in relation to base vehicle mass.

Figure 23: the error of added mass when a fixed value is used for ‘a’.

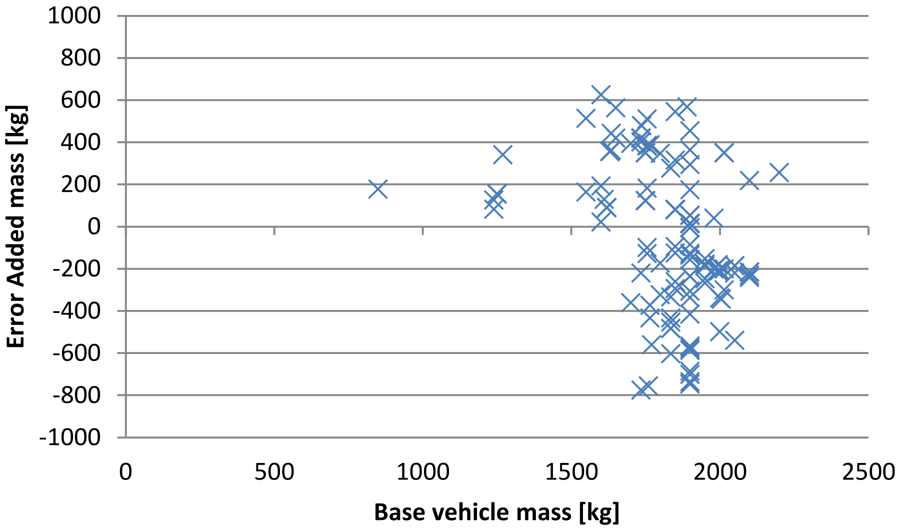
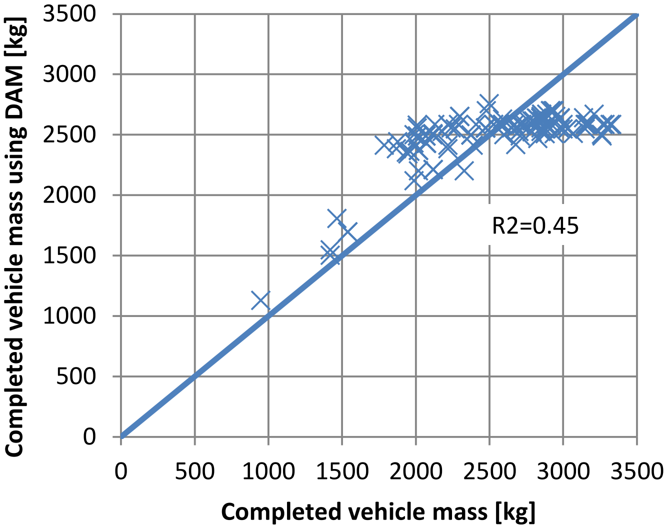


Figure 24: the correlation between the complete vehicle mass estimated using base vehicle mass and the DAM and the real completed vehicle mass. The DAM was estimated using a fixed coefficient for ‘a’ (0,43).

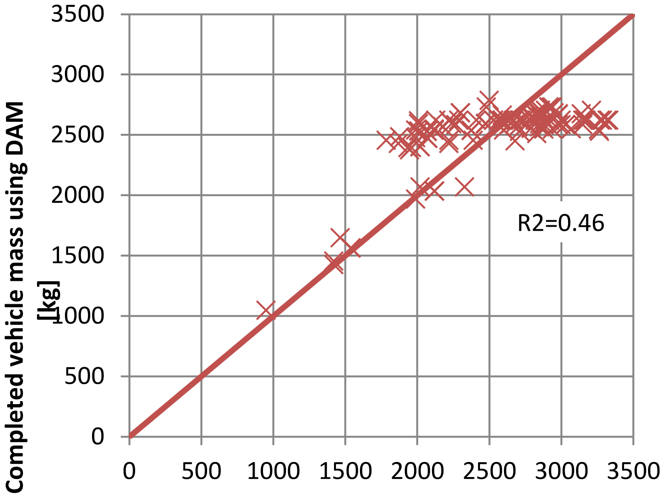


Alternatively, a correction could be used for ‘a’ to compensate for the lower ‘a’ of light base vehicles and the higher ‘a’ for heavy base vehicles. This correction is not done implicitly in the formula (a(TPMLM-RW). In the formula it is even the other way around. In the formula heavy base vehicles of a certain GVM get a lower added mass than lighter base vehicles of the same GVM.

Split ‘a’

An option to amplify factor ‘a’ for heavier base vehicles is to introduce a split approach with two bins for two GVM classes and to use a different factor ‘a’ for both GVM classes: one bin of GVM of 3000-3500 kg and one bin of GVM smaller than 3000 kg. The representative sample has a sample mean of ‘a’ of 0,3 for vehicles lighter than 3000kg and has a sample mean of ‘a’ of 0,45 for vehicles between 3000kg and 3500kg.

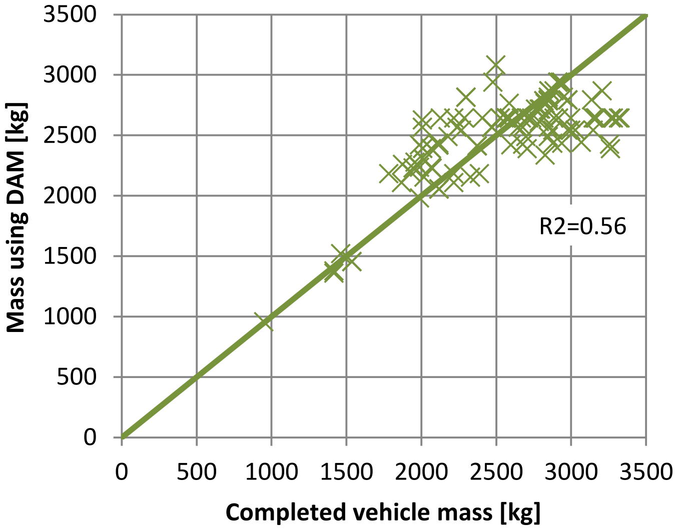
Figure 25: the correlation between the complete vehicle mass estimated using base vehicle mass and the DAM and the real completed vehicle mass. The DAM was estimated using a split approach for coefficient for ‘a’ (0,3 for vehicles <3000kg and 0,45 fir vehicles >=3000kg).



Function for ‘a’: polynomial

To assess if a further bias of the factor ‘a’ for heavier vehicles improves the accuracy of the estimation of DAM the polynomial of Figure 22 was used as well. It seems that the ‘a’ which is based on the polynomial on average improves the accuracy for both lighter vehicles and heavier vehicles.

Figure 26: the correlation between the complete vehicle mass estimated using base vehicle mass and the DAM and the real completed vehicle mass. The DAM was estimated using a polynomial for coefficient for ‘a’.



A 2^{nd} degree polynomial has a certain minimum (or maximum) which results from the function. For the given polynomial which is based on the representative dataset the minimum value for ‘a’ is 0,16. This value can be used as a minimum (cap).

In theory ‘a’ can never become higher than ‘1’ because bodywork can never add so much mass that the vehicle would weigh more than it’s GVM. For the given polynomial ‘a’ is getting the value ‘1’ for a base vehicles with a mass of 2550 kg. With an ‘a’ of ‘1’ the DAM is 950 kg for a vehicle with a GVM of 3500 kg (2550+950=3500kg). With a maximum for ‘a’ of ‘1’ any base vehicle heavier than 2550 kg would get a total mass of 3500 kg as well. If the mass boundary of the scope of the CO_2 legislation is taken as theoretic maximum (2610kg), then ‘a’ would never become higher than 0,45. In this case the base vehicles weighs 1880kg. For vehicles extended to a maximum of 2840kg ‘a’ would be 0,55, see the table below. The table below shows the different options for a maximum cap on ‘a’ for use with the polynomial function.

Table 22: examples of maximum values for factor ‘a’ and the resulting DAM and completed vehicle mass.

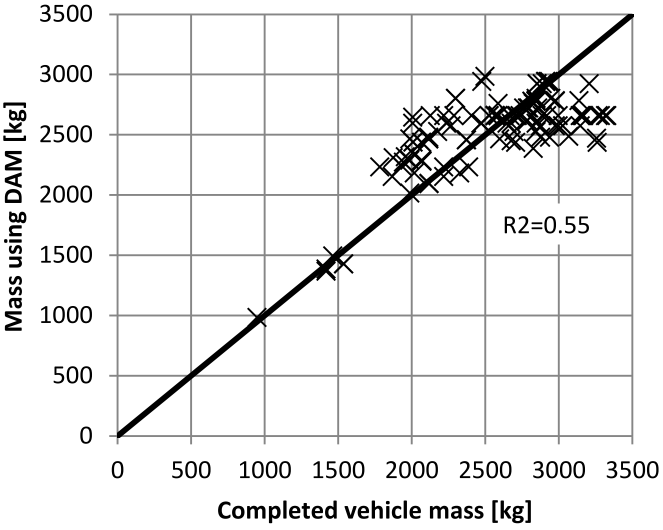
Base Vehicle mass	DAM estimated using a polynomial for ’a’	Completed vehicle mass using DAM	Factor ‘a’ calculated from the polynomial	GVM
[kg]	[kg]	[kg]	[-]	[kg]
1880	730	2610	0,45	3500
2032	808	2840	0,55	3500
2550	950	3500	1	3500

Function for ‘a’: linear

The linear regression line for the relation between factor ‘a’ and base vehicle mass was used.

When this option is considered a minimum value or minimum cap for ‘a’ should be used. A minimum for ‘a’ could be 0,16 which is also the minimum value of the polynomial. Alternatively, 0,24 could be used. This is the mean ‘a’ of all observed vehicles with a base vehicle mass lower than 1305kg. The maximum cap could be’1’, like for the polynomial. Due to the shape and steepness of the linear function a value ‘1’ would in theory never be reached as ‘1’ would result from base vehicles of 3020 kg which do not exist this heavy today.

Figure 27: the correlation between the complete vehicle mass estimated using base vehicle mass and the DAM and the real (observed) completed vehicle mass. The DAM was estimated using a linear function for coefficient ‘a’.



A calculation exercise *roughly* shows the accuracy for every option. One has to take note of the generally large spread of the data and the fact that this analyses was not done on the real EU fleet but on a limited dataset of observations.

For a handful of base vehicle mass ranges the mean error was calculated. The factor ‘a’ which is based on the polynomial shows on average the best prediction of DAM over the range of base vehicle mass. The fixed ‘a’ and the split ‘a‘ overestimate the DAM for low base vehicle masses while they underestimate the DAM for high base vehicle masses. However, for all options the scatter remains large and for individual vehicles the errors may be much higher. This can be simply explained by the fact that a function can not predict what kind of bodywork is added exactly, although still a slight relation between base vehicle mass and added mass exists.

Figure 28: the mean error is shown of the prediction of DAM for the four different options for ‘a’ and as an example also for the relation DAM vs. base vehicle mass based on an exponential fit. The mean error was calculated for different ranges of base vehicle mass. For each option the prediction leads to mean errors over the smaller mass ranges.

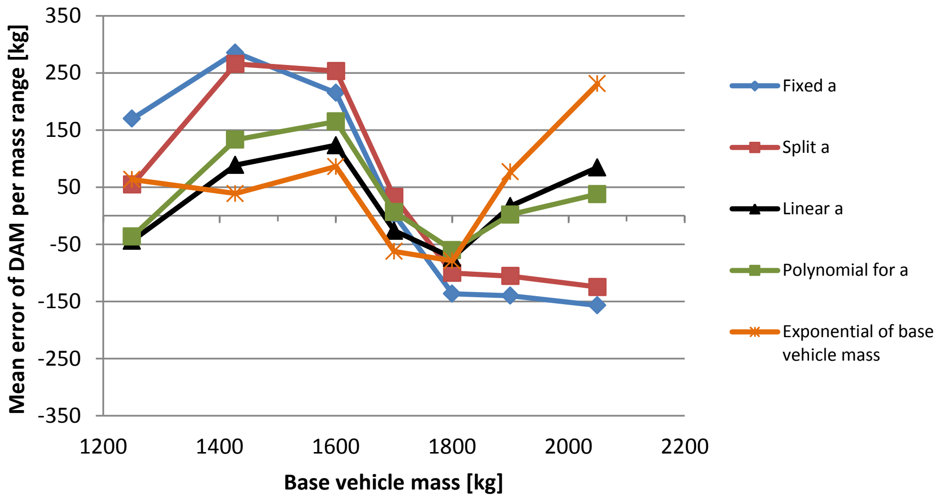
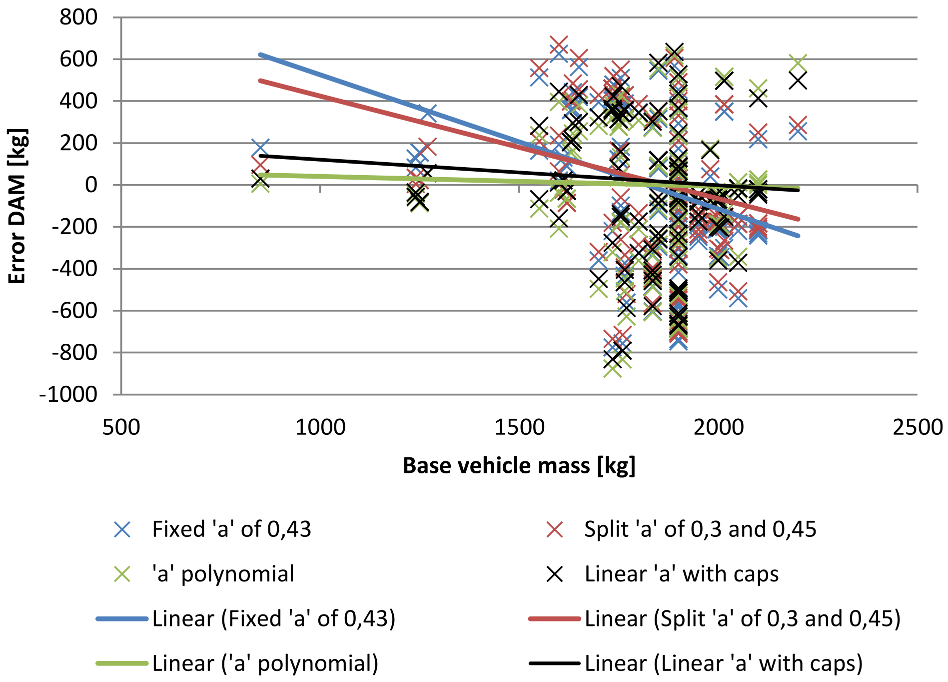


Figure 29: the error is shown of the prediction of DAM for the four different options for ‘a’ for the individual vehicles in the dataset. Linear regression lines show the goodness of fit of the options as weighted for the whole fleet. The scatter for individual vehicles remains large from minus800 to plus 600 kg.



The method under discussion in this paragraph relies on the use of the TPMLM and the reference mass. **The TPMLM is not a reproducible and verifiable value.** The TPMLM can not be quantified and verified by means of a objective measurement as it is a figure provided by a manufacturer for which he declares that this maximum may be used for e.g. bodywork and payload. It is more or less based on the strength of the construction.

For the mass to be taken as a basis to determine DAM in principle two candidates exist; the minimum mass as defined in the CoC and the reference mass of the base vehicle. The value given for minimum mass may only encompass the mass distribution over axles (2007/46/EC). If this mass is used for the method it should encompass the minimum mass of the vehicle. Instead of minimum mass, the reference mass of the base vehicle may be used. In principle this parameter could be used since reference mass is indirectly related to the mass in running order, meaning that a vehicle must be complete. However, section 2.6 of Annex I to Directive 2007/46/EC, in which mass in running order is defined, does not clearly explains that a vehicle must be complete, see paragraph 2.2.

As a final alternative for the methods that use factor ‘a’, so as to avoid the use of TPMLM, the simple relation between added mass and base vehicle mass could be used. This relation is shown in Figure 20. The best correlation was found using the shown exponential function which needed some additional tuning to better fit the whole fleet equally.

5.7 Implications for CO_2 and mass due to the introduced methods in relation to the CO_2 target

A calculation exercise is performed to demonstrate the effects of different scenarios on the CO_2 emissions of the N1 fleet and the position of the fleet against the N1 CO_2 target, taking account of the current situation and the introduction of a procedure to measure and monitor the CO_2 emissions of MSV. The exercise aims at the demonstration of relative effects and the direction of the effects in relation to the CO_2 target line, rather than the determination of accurate absolute effects.

The exercise calculates the **first order effect** on the fleet average CO_2 emission in relation to the CO_2 target line (N1 target line of 2017) in the case:

- no legislation is implemented and base vehicle manufacturers may choose to change the production process and produce single-stage vehicles as multi-stage vehicles. Consequently, the mass and thus the CO_2 emission of these vehicles decreases.
- legislation is implemented with a procedure to measure and monitor MSV with the mass of bodywork included in the procedure to measure the CO_2 emission. Consequently, the mass and thus the CO_2 emission of these vehicles increases.

Both cases have been assessed with and without a correction of the ‘M0’ [510/2011/EC] for the change in vehicle mass.

The following scenarios have been defined:

- ‘Business as usual’ (BAU): this scenario sets the baseline.
- ‘No Procedure’ (NP): no procedure is introduced to correct for the addition of body work. A base vehicle manufacturer may choose to produce single stage

vehicles as multistage vehicles. It is assumed that 10% of the SSV (single stage vehicles) become MSV and the mass of the MSV is 20% lower than the SSV.

- ‘No Procedure, with correction of M0’ (NP_M0): the decrease of the fleet average mass because more MSV are produced and registered is used to correct the M0 of the target line.
- ‘Procedure’ (P): Introduction of a method to measure the CO_2 emissions of MSV which corrects for the addition of bodywork.
- ‘Procedure, with correction of M0’ (P_M0): the increase of the fleet average mass due to the addition of bodywork is used to correct the M0 of the target line.

For the case where no procedure is implemented, the manufacturing of more MSV as replacement for single-stage vehicles initially leads to a CO_2 emission which moves away from the indicative 2017 target line, see table 22 . The distance above the target line increases from 11 to 13 g/km. Removing mass from the measuring and monitoring process would thus lead to a disadvantage for base vehicle manufacturers and thus in principle does not incentivise production of more MSV as replacement for single stage (normal N1) vehicles. A correction changing ‘M0’ for the change in mass would bring the CO_2 emission somewhat closer to the target.

The opposite situation (producing more complete vehicles, hence less MSV) would lead to opposite results.

Table 23: results of the scenarios without implementation of legislation to measure and monitor the CO_2 emission of MSV, with and without correction of ‘M0’ due to the change in vehicle mass: first order possible impact on fleet average mass, CO_2 emissions and distance to the indicative CO_2 target line.

	BAU	NP	NP_M0
		10% SSV become 20% lighter MSV without introduction of a new procedure	if M0 is corrected for decrease of mass
Average Mass N1 fleet [kg]	1654	1623	1623
Average CO_2 emission N1 fleet [g/km]	181,5	180,5	180,5
M0 [kg]	1706	1706	1675
CO_2 target [g/km]	170	167	170
Distance to target [g/km]	11	13	10

If a procedure would be implemented which takes into account the additional mass of bodywork, the average of the monitored mass of the fleet would increase. The CO_2 emission of the fleet would increase as well, see Table 24. Altogether, the distance to the target line would move 3 g/km, from 11 to 8 g/km above the line. A correction, changing ‘M0’ for the change in mass, would bring the CO_2 emission further away from the target (+12 g/km) then where it started in the BAU situation (+11 g/km).

Without correction, the introduction of a procedure for MSV, using method 1 or 2 would bring the CO_2 emissions of the fleet for a base vehicle manufacturer closer to the target line. The underlying causes are:

- The shortfall of the technical procedure to deliver representative CO_2 emissions at higher inertia values (vehicles masses).
- The relative inefficient testing of the CO_2 emissions of a vehicle if the unrepresentative and too low mass of the base vehicle would be used.

Table 24: results of the scenarios with implementation of legislation to measure and monitor the CO_2 emission of MSV, with and without correction of 'M0' due to the change in vehicle mass: first order possible impact on fleet average mass, CO_2 emissions and distance to the indicative CO_2 target line.

	BAU	P	P_M0
		Introduction of procedure (Mass added)	if M0 is corrected for increase of mass
Average Mass N1 fleet [kg]	1654	1701	1701
Average CO_2 emission N1 fleet [g/km]	181,5	182,3	182,3
M0 [kg]	1706	1706	1753
CO_2 target [g/km]	170	175	170
Distance to target [g/km]	11	8	12

5.8 Simple cost assessment

Technical and administrative burden

Introducing a method to measure and monitor the CO_2 emission of MSV by means of either of the two proposed methods will involve additional costs and effort. There are differences between the two proposed methods with regard to costs and effort which stem from differences in the amount of testing and differences between the administrative processes. A simple cost assessment was therefore elaborated which focussed on costs for:

1. Testing (manufacturer)
2. The administrative process for CO_2 monitoring

Information regarding the technical and administrative burden was collected with the questionnaire and during interviews with OEMS, bodybuilders and TAA.

5.8.1 Costs of testing for the base vehicle manufacturer

Two types of costs can be distinguished:

- costs for additional tests. Method 1 would lead to more testing. Method 2 would not lead to more testing, because the test with the base vehicles reference mass will be replaced with a test for the base vehicle with default added mass.
- costs for test equipment. If the range of inertia would be extended, a certain share of the chassis dynamometers might need an upgrade to fulfil the new requirement. Such an upgrade would include an additional set of flywheels or a stronger electric motor to cover for the wider range of inertia to be simulated. It is not known how many chassis dynamometers lack inertia up to 2840kg and it is not known how much such an upgrade would cost. Furthermore, in the WLTP working group this extension is also discussed for M1 vehicles. As such it would not be due to MSV that this would need to be implemented. It is assumed that the costs of these upgrades will be reflected in a small increase of the hourly rate of the test cell.

Cost for more tests to fill the table for method 1

For method 1 more tests are needed to fill the table which is needed for the selection of the right corresponding CO_2 value according to the mass of the base vehicle with bodywork. In principle the amount of tests is limited from the range of the Reference mass of the base vehicle to the highest possible mass this vehicle can become with bodywork added. This mass is either the GVM or the TPMLM also called ‘technically permissible maximum laden mass’ or ‘maximum mass’ in ECE-R83.

A single test is composed of preconditioning, soak and the Type I test. The preconditioning generally is done by driving three times the EUDC part of the NEDC prior to the soak period at prescribed conditions (often in a soak room that fulfils these conditions). The test starts with a so called cold engine and the NEDC (type I test) is driven and the CO_2 emission is measured. If more tests need to be performed the tests need to be performed in the same way, with exception of the preconditioning cycle, because the first NEDC may act as preconditioning cycle for the next test.

The costs of complete single NEDC test is about 1000 Euro. Often more than one test (duplicate, triplicate) are done to obtain a reliable average. As can be seen from the examples in paragraph 5.4 a range of tests is needed from 3 to 8 more chassis dynamometer settings, depending on the vehicle type.

Below the results of a simple exercise are given. It was assumed that on average 5 more test would be needed for method 1, and that fixed administrative TA costs are about 10.000 Euro per family.

It can be observed that the annual sales heavily influence the cost per vehicle. For an OEM who produces a small volume of 5000 units for the EU market (example A) costs may be as high as 25 Euro per vehicle. For every other OEM with higher sales this value will probably be much lower, which can be observed for example B.

Table 25: simple cost calculation for a manufacturer with a small and a large volume of sales of MSV in the EU, showing a rough estimate of the additional costs per unit.

Example	Additional # of tests	# tests per value	Cost /test [€ / Test]	# TA / year	Fixed cost per TA [€ / TA]	Annual sales	Additional costs / year (5 tests) [€ / year]	Additional costs for 5, 3 and 2 tests [€ / Vehicle]
OEM A (small volume)	5/3/2	3	€1000	5	€10000	5000	€125000	€25/19/16
OEM B (large volume)	5/3/2	3	€1000	10	€10000	60000	€250000	€4/3,2/2,7

5.8.2 *Administrative burden for the process of CO_2 monitoring*

Here method 1 and method 2 differ from each other because for method 1 the burden will be higher. For method 2 only the CO_2 value will be different and probably a few additional parameters (default mass, MSV yes/no) may need to be administered throughout the process of data transfer from OEM to national registration database.

It is found impossible to estimate the costs for adaptations of administrative processes of both methods. Especially for the registration process it is hard to give an estimate because each Member State, Type approval authority, OEM uses it’s own registration system and uses different kinds of methods for dealing with the data for administration.
Below an overview is given of the required adaptations for method 1.

For method 1 additional work and adaptation of the administrative process is required for:
- administration of the additional table of CO_2 values by the base vehicle manufacturers and possibly reorganisation of TA and T-V-V administration
- administration of the corresponding CO_2 value by the final stage manufacturer, communication with the OEM
- checking of the mass (weighing) and the CO_2 value by the Technical Service at approval/registration
- entering additional records in the registration database by the registration authority (the right mass, the corresponding CO_2 value, an MSV identifier, and optionally an unique identifier (e.g. VIN))
- an upgrade of the EU live database (DG-MOVE) with records for MSV, records as mentioned above and possible additional maintenance and operational costs of this database.
- entering registration data in the EU live database by the registration authority or querying of the registration databases by the EU live database

6 Conclusions and recommendations

The work for this study, the assessment of options to measure and monitor the CO_2 emissions of N1 vehicles approved in multiple stages (multi-stage vehicles, MSV), has lead to a diversity of detailed insights and conclusions regarding the two proposed methods to integrate MSV into the EU CO_2 legislation. The results of the work has been worked out in this report. Hereafter, a summary of the general conclusions and recommendations is given.

Both methods which were subject to the assessment proved to have issues with general criteria like feasibility, reliability/robustness and fairness. This means that if one method is chosen it may be a better option with regard to some of the criteria, while it may be a worse one for others. Some of the points can be improved, however.

The ‘chassis dynamometer method’ (method 1), is more accurate for individual vehicles as the actual mass of the completed vehicle is used for the determination of it’s corresponding CO_2 emission. There is, however, a technical shortfall in the general test procedure for Light Duty Vehicles which leads to unrepresentative CO_2 emissions with an increasing inaccuracy for heavier vehicles.
The burden for the base vehicle manufacturer and for type approval authorities is higher than for method 2, the ‘default added mass method’. This because of the additional costs for more tests which are needed and because more administration is required for method 1. Also the process of approval and registration needs to be adapted to make it robust: a check for the mass (weighing) and transfer of the right CO_2 value and mass from the table, derived from the range of tests performed at the chassis dynamometer, is required. It is important to arrange and secure this process at the level of the approval authorities, technical services and registration authorities. Furthermore, there is a time delay between production and release of the monitoring database of possibly more than a year and as such a base vehicle manufacturer does not know the real CO_2 emission of his fleet of MSV until release of this monitoring database.

The ‘default added mass method’ (method 2), is a default approach, meaning that the results will represent an average for a fleet or part of a fleet and will not accurately represent the CO_2 emission of individual vehicles, especially given the fact that MSV vary widely in appearance and mass. This leads to vehicles having fictitious values for CO_2 and mass which may differ substantially from the real mass of a vehicle. These values may be misinterpreted in the process of administration. Furthermore, it leads to vehicles falling under CO_2 legislation while they shouldn’t and the other way around.
This method is also a rather simple method, meaning that already early in the process of approval a mass value will be determined which will receive a corresponding CO_2 value for use in the monitoring system. These values remain unchanged throughout the process of administration.

Some of the critical issues regarding both methods can be solved or improved.

The administration of the right mass and CO_2 values of MSV can be improved and made more robust at the level of approval and registration, through the introduction of a requirement to check mass and CO_2 and by making the use of the CoC for registration mandatory.

At the present time, based on the member states registration databases, it is very difficult to evaluate the fleet of MSV with regard to its CO_2 emissions and its mass development. To be able to monitor CO_2 emissions and the impact of a possible procedure on the development of mass with added bodywork, it is recommended that an identifier is introduced to allow the identification of individual MSV in a dataset. A swift introduction of this identifier and requirements for registration of mass of the completed vehicle and CO_2 of this vehicle, would enable the Commission and manufacturers to estimate the final mass and CO_2 emission of these completed vehicles.

Identification of MSV, for instance using VIN and an identifier for MSV [completed vehicle y/n] is required to distinguish MSV in a registration database. A field with information about mass of the bodywork is additionally required to monitor the evolution of mass and to enable checking of the registered mass and CO_2 values of MSV. Part C of Annex II of Regulation 510/2011 and the CoC could be adapted to include a dedicated field for completed vehicles with the mass of bodywork or to include, next to the field of mass with bodywork a field with mass of the base vehicle without bodywork, so that mass of bodywork can be calculated from both values.

The technical shortfall of the test procedure and thus the representativeness of the CO_2 value resulting from the type I test (NEDC) can be improved by adding more representative load and inertia settings for the upper mass range of the table which provides the default load settings based on reference mass. This would mean that the table needs to be extended with new inertia steps up as of 2270kg to the maximum mass of a MSV, which can be as high as 3500kg. Additionally, a set of load settings (a and b coefficients) should be defined, for use with the new inertia steps. In general, the table with load settings seems to result in underestimated CO_2 values for commercial vehicles. To improve this, an overall revision of the table would be required.

The different problems which arise from boundaries of the scope could be solved. However, this requires a change of the scope of the N1 CO_2 legislation.

The definition of monitoring ‘mass’ is currently for vehicles without bodywork [2007/46/EC, Annex I, section 2.6] in the case the manufacturer of the base vehicle does not fit the bodywork. It is recommended to adapt the section so that definitions are clear.

Completed and incomplete vehicles do not fall under the scope of individual approval as arranged in [183/2011/EC]. It is recommended to extend the scope of individual approval to these vehicles.

The implementation of a live, real time database with vehicle registrations could make the monitoring process more robust in general. Furthermore, it shortens the time delay before an OEM knows the final CO_2 value in case of method 1 somewhat. The process of development of such a database is on-going. To finalise the database will take some years, however. In the meantime, base vehicle manufacturers could for instance use default values for the added mass to estimate the contribution of MSV to their fleet average CO_2 emissions.

The additional burden of costs for more testing for method 1 can be relieved somewhat by requesting only a limited number of additional tests and allowing interpolation of the remaining values, with minimal loss of accuracy.

The introduction of CO_2 legislation for N1 MSV may come with uneven effects for different manufacturers, regardless of which of the original methods is implemented. The uneven effects originate from the disproportionate increase of CO_2 emission with the increase of mass at the vehicle level and the technical shortfall for test load. A part of this effect can be addressed by improving the load settings. This would lead to a generally more fair procedure for methods 1 and 2. Another improvement can be made for method 2 if the default added mass would be related to vehicle parameters, with a correction for heavier base vehicles. This correction is only assessed in this study to a limited extend and needs to be worked out further in detail if this would be the preferable way to proceed. It is expected, however, that the accuracy of method 2, for individual vehicles can hardly be improved anymore.

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Regulations and directives

[2007/46/EC] DIRECTIVE 2007/46/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles

[692/2008/EC] COMMISSION REGULATION (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information

[183/2011/EC] COMMISSION REGULATION (EU) No 183/2011 of 22 February 2011 amending Annexes IV and VI to Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers and of systems, components and separate technical units intended for such vehicles (Framework Directive)

[510/2011/EC] REGULATION (EU) No 510/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO 2 emissions from light-duty vehicles

[ECE-R49] Regulation No. 49 Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles

[ECE-R83] Regulation No. 83 Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements

[ECE-R101] Regulation No. 101 UNIFORM PROVISIONS CONCERNING THE APPROVAL OF PASSENGER CARS POWERED BY AN INTERNAL COMBUSTION ENGINE ONLY, OR POWERED BY A HYBRID ELECTRIC POWER TRAIN WITH REGARD TO THE MEASUREMENT OF THE EMISSION OF CARBON DIOXIDE AND FUEL CONSUMPTION AND/OR THE MEASUREMENT OF ELECTRIC ENERGY CONSUMPTION AND ELECTRIC RANGE, AND OF CATEGORIES M1 AND N1 VEHICLES POWERED BY AN ELECTRIC POWER TRAIN ONLY WITH REGARD TO THE MEASUREMENT OF ELECTRIC ENERGY CONSUMPTION AND ELECTRIC RANGE

8 Signature

Delft, 7 February 2012

Willar Vonk
Project leader

A Definitions

Definitions from legislation relating to mass

"Reference mass"
means the "unladen mass" of the vehicle increased by a uniform figure of 100 kg for test according to Annexes 4a and 8:

"Unladen mass"
means the mass of the vehicle in running order without the uniform mass of the driver of 75 kg, passengers or load, but with the fuel tank 90 per cent full and the usual set of tools and spare wheel on board, where applicable:

"*Running order mass*"
means the mass described in Paragraph 2.6. of Annex 1 to this Regulation and for vehicles designed and constructed for the carriage of more than 9 persons (in addition to the driver), the mass of a crew member (75 kg), if there is a crew seat amongst the nine or more seats.

"Maximum mass"
means the technically permissible maximum mass declared by the vehicle manufacturer (this mass may be greater than the maximum mass authorised by the national administration):

Definitions from legislation relating to information transfer

"Information document"
means the document set out in Annex I or Annex III (of 2007/46/EC), or in the corresponding Annex to a separate directive, or regulation, that prescribes the information to be supplied by an applicant, it being permissible to supply the information document in the form of an electronic file:

"Certificate of conformity" (COC)
means the document set out in Annex IX (of 2007/46/EC), issued by the manufacturer and certifying that a vehicle belonging to the series of the type approved in accordance with this Directive complied with all regulatory acts at the time of its production:

Definitions from legislation relating to vehicle types

"Base vehicle"
means any vehicle which is used at the initial stage of a multi-stage type-approval process:

"Incomplete vehicle"
means any vehicle which must undergo at least one further stage of completion in order to meet the relevant technical requirements of this Directive:

"Completed vehicle"
means a vehicle, resulting from the process of multi-stage type-approval, which meets the relevant technical requirements of this Directive:

"Complete vehicle"
means any vehicle which need not be completed in order to meet the relevant technical requirements of this Directive:

Related to type approval processes

"EC type-approval" or EC Whole Vehicle Type Approval (WVTA)
means the procedure whereby a Member State certifies that a type of vehicle, system, component or separate technical unit satisfies the relevant administrative provisions and technical requirements of this Directive and of the regulatory acts listed in Annex IV or XI:

"Individual approval" (IVA)
means the procedure whereby a Member State certifies that a particular vehicle, whether unique or not, satisfies the relevant administrative provisions and technical requirements:

"Multi-stage type-approval"
means the procedure whereby one or more Member States certify that, depending on the state of completion, an incomplete or completed type of vehicle satisfies the relevant administrative provisions and technical requirements of this Directive:

Abbreviations

CoC	Certificate of Conformity (Annex IX of 2007/46/EC)
DAM	Default added mass
IVA	Individual Approval
GVM	Gross Vehicle Mass
LCV	Light Commercial Vehicle
MS	Member State
MSV	Multistage Vehicle, a vehicle which has been approved according to the procedure of Multi-stage type-approval
N1	Light Commercial Vehicle, GVM<=3500kg, RW<2610kg or <2840kg by extension
N2	Heavy Commercial Vehicle, 3500<GVM<12000kg, RW >2610 or >2840
OEM	Original Equipment Manufacturer
RW	Reference mass
TAA	Type Approval Authority
TS	Technical Service
T-V-V	Type-variant-version
WVTA	Whole Vehicle Type Approval

B Member State registration databases

The table summarizes the received databases with data of N1 vehicles. The table gives the coverage of some important fields for monitoring of the CO_2 emission of N1 vehicles.

MS	Time span	# lines	# registrations	Manufac-turer	Type	Variant	Version	Total new registrations	Specific emissions of CO2 (g/km)	mass completed vehicle
D	01-2010 to 05-2011	31299	323317	100%	98%	84%	80%	100%	76%	94%
UK	01-2010 to 04-2011	4871	88114	100%	76%	73%	86%	100%	0%	82%
IT	01-2010 to 04-2011	37288	270984	100%	100%	15%	14%	63%	100%	100%
BE	01-01-2010 to 30-06-2010	10559	86353	100%	99%	52%	50%	100%	68%	93%
S	01-01-2010 to 27-06-2011	2286	46568	90%	97%	79%	76%	100%	100%	100%
NL	01-01-2010 to 31-12-2010	1058	7684	90%	100%	100%	100%	100%	80%	100%
SK	01-2010 to 04-2011	8609	8609	100%	100%	98%	89%	100%	98%	100%
LT	01-01-2010 to 31-03-2010	779	779	100%	99%	99%	94%	100%	98%	100%

C Method1: examples chassis dyno method

					Class I						Class II				Class III						
			Eq. inertia	...	740	800	910	1020	1130	1250	1360	1470	1590	1700	1810	1930	2040	2150	2270	2270	2270
			Reference mass of vehicle	...	765	850	965	1080	1190	**1305**	1420	1530	1640	**1760**	1870	1980	2100	2210	2380	2610	
			Load [N]		221	230	252	270	284	302	315	329	338	351	329	378	387	396	405	423	441
			a [N]		5,0	5,2	5,7	6,1	6,4	6,8	7,1	7,4	7,6	7,9	8,2	8,5	8,7	8,9	9,1	9,5	9,9
			b [N/km/h^2]		0,0337	0,0351	0,0385	0,0412	0,0433	0,046	0,0481	0,0502	0,0515	0,0536	0,0557	0,0577	0,0591	0,0605	0,0619	0,0646	0,0674
Examples of base vehicles	**Kerb base**	**GVW/MTPLM**	factor to be applied to load		1	1	1	1	1	1	1	1	1	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3
Piagio Porter	750	1700			x	x	x	x	x	x	x	x	x	x							
Peugeot Partner Pick up (platform)	1455	2240										x	x	x	x	x	x	x	x		
Renault Master (platform)	1570	3500											x	x	x	x	x	x	x	x	x
Ford Transit SWB300	1475	3000										x	x	x	x	x	x	x	x	x	x
Iveco Daily C35	2000	3500															x	x	x	x	x
Nissan Cabstar Y25	1737	3500												x	x	x	x	x	x	x	x
Examples of completed vehicles	**Est. Mass completed [kg]**																				
Piagio Porter Pick up	850						🟩 x														
Piagio Porter Box	950						🟩 x														
Peugeot Partner Pick up cooling	1900												🟩	🟩	🟩	🟩 x					
Peugeot Partner Pick up pick up	1600												🟩 x	🟩	🟩	🟩					
Ford Transit SWB300 dropside	1775														🟩 x	🟩	🟩	🟩	🟩		
Ford Transit SWB300 box	1975														🟩	🟩 x	🟩	🟩	🟩		
Ford Transit SWB300 box loading platform	2275														🟩	🟩	🟩	🟩	🟩 x		
Iveco Daily drop side	2300																		🟩 x	🟩	🟩
Iveco Daily box isotherm loading platform	2950																		🟩	🟩	🟩 x
Nissan Cabstar dropside	2012																🟩 x	🟩	🟩	🟩	🟩
Nissan Cabstar aerolifter	3400																🟩	🟩	🟩	🟩	🟩 x

D Common types of superstructures and result of the default mass exercise

Bodywork	Components	Mass [kg]	Share [%]	Mass share [kg]	Market-share [%]	Mass Share [kg]
Box	Box body	647	100%	647		
	Curtain slider	548	20%	110		
	Components					
	Tail lift	239	40%	96		
	Slider lift	300	10%	30		
	Side door	67	60%	40		
	Roof spoiler	35	80%	28		
	Total	**824**			**25%**	**205**
Box refrigerated	Insulated box	795	100%	795		
	Components					
	Cooling unit	150	80%	120		
	Tail lift	239	35%	84		
	Slider lift	300	15%	45		
	Side door	67	60%	40		
	Spoiler	35	80%	28		
	Stationary cooling	25	10%	3		
	Dividing wall	55	20%	11		
	Total	**1125**			**22%**	**249**
Drop-side	Drop-side	256	100%	256		
	Drop-side strengthened	425	20%	85		
	Components					
	Cabine protector	30	75%	23		
	Side fenders	20	100%	20		
	Ladder carrier rear	30	25%	8		
	Slider lift	300	5%	15		
	Total	**349**			**24%**	**83**
Tipper	Tipper	550	100%	550		
	Tipper strengthened	725	25%	181		
	Components					
	Cabine protector	30	100%	30		
	Ladder carrier rear	30	25%	8		
	Total	**623**			**29%**	**182**
Added Mass	**Total**				**100%**	**718**

E Questionnaire base vehicle manufacturers

Summary of the questionnaires received

1 Participating Base Vehicle Manufacturers

- Volkswagen
- Fiat
- Iveco
- Ford
- PSA
- Renault
- Toyota Motor Europe
- Nissan

2 Identification, characterization and categorization of Base Vehicles and MSV

For the MSV in the range of view of the manufacturer (e.g. for which the manufacturer arranges EU WVTA, or for Base Vehicles delivered to dealers of its own brand and up-fitted by these dealers or contracted up-fitters) it is important to get as much information as possible on the characteristics of the fleet of MSV (completed vehicles) sold. This is especially important since for method 2 an average mass could be established based on for instance a break down of sales of MSV over different types of MSV.

2.1 How many N1 vehicles (up to a reference mass of 2610 kg) are produced annually?

Average of approximately 170,000 with a range between 33.000 and 376.500.

Manufacturer	N1 Vehicles
A	146.667
B	60.000
C	152.000
D	376.500
E	308.000
F	33.000
G	116.471

2.2 How many Base Vehicles are produced annually?

Average of approximately 36.500 with a range between 2.600 and 92.400.
In percentage, this is an average of approximately 21% (with a range between 5 and 65%) of the produces N1 vehicles.

Manufacturer	# N1 Base Vehicles	% Base Vehicles of N1 Vehicles
A	29.333	20%
B	37.800	63%
C	11.300	7%
D	75.300	20%
E	92.400	30%
F	2.600	8%
G	5.431	5%
H	7.377	20%

2.3 Divide the produced Base vehicles over N1 classes I, II, III

Manufacturer	# Base Vehicles divided over N1 classes				Base Vehicles divided over N1 classes		
	Class I	Class II	Class III	Other	Class I	Class II	Class III
A		1.695	9.605		0%	15%	85%
B			37.800				100%
C	100	1.600	9.600		1%	14%	85%
D	37.650		37.650		50%		50%
E	4.985	74.749	95.545	132.721	4%	42%	54%
F			2.600				100%
G			5.431				100%
H			7.377				100%

Based on the table above, the following breakdown can be made roughly over N1 classes:

I 7%
II 27%
III 66%

2.4 What are the names of the vehicle series in the sales portfolio in the EU (e.g. Sprinter, Movano, Daily, …)

Not relevant for this report.

2.5 How much T-V-V (Type-Version-variants) of Base Vehicles are in the portfolio for TA and how are they categorized (engine, chassis length, cab type,…).

OEM	# T-V-V's N1 All vehicles	# T-V-V's N1 Base vehicles
A	unknown	356
B	±2.000	unknown
C	±2.000	Unknown
D	30*	21*
E	1.629*	268*
F	210	Unknown
G	>50.000	unknown
H		32

*T-V-V's of only one model

Type
- Type identification
- Gross vehicle weight

Variant
- Engine capacity
- Engine working principle/fuel type
- Gross vehicle weight
- Engine type

Version
- Type of body
- Engine power
- Fuel tank capacity
- Gearbox type
- Gear ratio
- Tech. permissible max. mass on front axle
- Distribution of tech. permissible max. mass on the axle
- Wheelbase
- Tyres
- Door configuration and number

2.6 Give a breakdown of different types of completed vehicles as they end up at the market/client (E.g. from EU WVTA process or from vehicles which arrive at the client via dealers of your own brand or from direct contact with the 2nd stage manufacturer/upfitters).

Please, classify types of MSV according to your knowledge (chassis cab + box, chassis cab + flat bed/side dropper, chassis cab + tipper, other types?) and give sales numbers or shares.

OEM	Drop side	Tipper	BOX	BOX refrigerated
A	57%	12%	3%	29%
B	17%	36%	21%	26%
C	23%	23%	25%	30%
D	15%	15%	14%	56%
E	20%	27%	28%	25%
SMMT (UK)	27,5%	37%	28,5%	7%
Weighted Average	**28%**	**21%**	**16%**	**35%**
Average	**24%**	**29%**	**25%**	**22%**

3 Characterization of processes of distribution, Type Approval and Registration

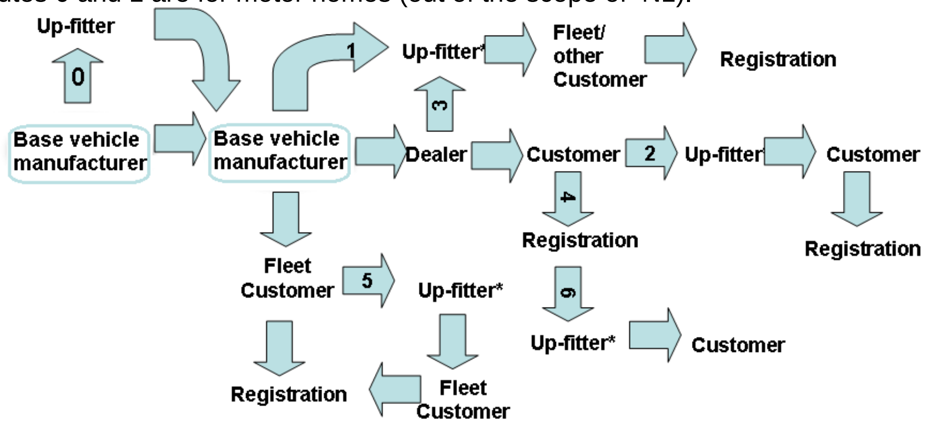
For **method 1** a feed back loop is required for information which enables the selection of the CO_2 emission that corresponds to the final mass of the vehicle. Therefore, it is important to understand who is involved in what way in the process of dealing with MSV from production to client and from production to registration and to look for opportunities or problems for a feed back loop of the relevant information (e.g. added mass, total mass, VIN). Therefore it is important to gain insight in:

1) The routes the Base Vehicles take to the market and to
2) Identify and describe the possible different processes of TA (EU WVTA, small series, national, single, etc).

3.1 Describe for your company the possible routes for a Base Vehicle to the market/client and give typical examples and numbers of vehicles following these routes.

Example:

Routes 0 and 1 are for motor homes (out of the scope of N1).



* If needed up-fitters organise the Individual Vehicle Approval (IVA) [around 80% of volume] or if there are big volumes of same changes an addition to the WVTA [around 20% of volume]

3.2 Provide a list of typical 2nd stage manufacturers/upfitters your company deals with.
Not relevant for this report

3.3 At what stage(s) for the possible routes does TA take place?

The base vehicle manufacturers perform the WVTA for larger series. Individual vehicle approval is done in most cases (relatively small volumes). Up-fitters only adding a WVTA Annex (requiring communication with base manufacturer) if they have big volumes. Cost for a WVTA are high, therefore it's only makes sense if there are high volumes of the same modification.

3.4 Do you see options to integrate within the current process a way to feedback relevant information, like total mass or added mass, to the manufacturer, registration office or to the Commission, or are such processes that might provide the information already in place?

Best way would be a EU harmonized, on-line, real-time database where base manufacturer, up-fitter and all EU registration offices have access and add/modify the data.
Otherwise only the registration offices know the final transformation based on the COC.

3.5 What TA processes are used and give shares (e.g. EU WVTA, national small series, single TA, …).

- Single TA (around 80%)
- National small series
- EU WVTA (together with the national small series around 20%, but the number is increasing)

3.6 Does your company use an administration system to store Type approval data and vehicle data. Can individual vehicles be traced and how?

In general, the vehicles can be followed using the VIN or COC, this is usually only for incomplete vehicles.

4 Suitability/workability/costs/robustness/fairness of the two methods

There are two options to include the effect of added mass in the monitoring of CO2 of MSV.

Option 1: Dynamometer method
Option 2: Average mass method

It is important to learn from individual manufacturers what their preference is, or what the critical issues are with one method or the other and why. The issues include for instance administrative burden /costs, fairness, robustness, but the individual manufacturer may also bring up suggestions for other issues that should be taken into account. Please, describe your issues hereafter:

4.1 What are the costs for different parts of **option 1** (e.g. more testing per TVV [Cost per additional test] x T-V-V, costs for administrative processes. If possible describe how and what parts of your company's process should be adapted if option 1 would be integrated and what the associated costs would be.

OEM A: Cost per additional test is approx. €1.000,- (3 tests per value needed, approx. 5 values), costs for administration are around €5.000,-.

OEM B: The CO2 certification test including all the administrative burden costs between €30.000 & €50.000.
The TVV administrative process is very difficult to assess. It might affect the IT tools/database and lead to cost step functions or specific investments. In addition to that, the TVV diversity is very high.

OEM C: €2000Euro per NEDC, 8 versions per MY = €16.000 with option 1 tests increase from 8 to 41 = €82.000. COP testing and pre homologation testing would increase costs by 410%.

4.2 What are the costs for different parts of **option 2** (e.g. costs for administrative processes). If possible describe how and what parts of your company's process should be adapted if option 2 would be integrated.

OEM A: Cost for one additional test is approx. €3.000, plus administration the total is around €10.000.

OEM B: The TVV administrative process is very complicated. Modification on IT tools/database lead to cost step functions or specific investments. In addition to that, the TVV diversity is already very high.

OEM C: Method does not represent additional costs as only one test needs to be performed.

4.3 Describe critical issues for **option 1,** if any

OEM A:

- Biggest issue is that option 1 undermines any CO_2 planning: base manufacturer cannot know what numbers will be picked by up-fitters when vehicles are produced. This option is only reasonable if there is an on-line, real-time system where status (CO_2, mass, registration date) is entered by the base up-fitter and registration offices + base manufacturer can immediately see the latest CO_2 performance.
- Unclear whether up-fitters will pick the right number, in particular if they cannot weight the completed vehicle. Also, errors can happen or SMEs may strategically pick lower mass to get to lower CO= and higher payload figures as a sales argument.

- The high number of up-fitters makes it extremely difficult for base manufacturers to have a robust communication with all.
- Too complicated for small up-fitters.
- What happens with complete vehicles sold by OEMs that will be up-fitted later?

OEM B:

- Given the current very high administrative diversity of TVV, OEM B can not support the burden of additional complexity on this parameter.
- It is impossible to have feedback from all 2nd stage manufacturers on the different products. Therefore, we recommend that the feedback on the conversion mass comes from an authority (to the 1st stage OEM) via an aggregated way and not from all the body-builders.
- OEM B avoid additional testing burden by using the max inertia weight class (2270+ max CO_2) regardless of the transformation. This practice should still be allowed and is transparent from a regulatory point of view because the target line is set via a 100% slope.
- IWC definition will change with the WLTP.

4.4 Describe critical issues for **option 2,** if any

OEM A:

- Representativeness and stability of default value (should be possible based on EU study of completed vehicles based on registration data).
- What happens with complete vehicles sold by OEMs that will be up-fitted later?

OEM B:

- This option should not lead to additional testing burden: for instance if the assigned masses do not correspond to already tested vehicles, there should be some flexibility for the OEM to use the closer test from the assigned mass proposed.

5 Suggestions

Does your company have a suggestion for a system or process in which the flow of relevant information (for instance added or total mass, VIN,…) can be handled in the case of option If so, what information should be handled how and by whom?

No suggestions.

6 Additional items of interest

Is there something else you wish to mention or discuss? Please, write it down here or save it for the interview.

- OEMs need to have a reliable picture of their positioning during the year, to be able to adopt all the measures to get the target, or to reduce the gap between the target and the measured CO_2 emissions. National authorities should guarantee the availability of reliable registration data to OEMs during the year, through a centralized EU data base. A timetable for deliveries has to be defined.
  It must be clear that if some MS will not be able to guarantee their compliance to the delivery schedule, this event will become a critical issue, in particular for OEMs with a high market share in that countries, with potential distortion of competition rules.

- Option 1 and Option 2 do not solve a fundamental issue: If the base vehicle

manufacturer doesn’t know the registration date and the category of completed vehicle, he cannot evaluate the performance in a reliable way. Both the following situations could happen:
a. Incomplete N1 vehicle in Class III to be used to assemble M1 special vehicle, out of the CO_2 legislation scope:
b. Incomplete vehicle and Multi-stage vehicle are delivered and registered in two calendar years. Reasons: incomplete vehicle delivered in Nov-Dec. – unpredictable delay in second stage manufacturer activities – etc..

- Additional test are required to manage both the options. To avoid costs increase, it is mandatory to develop a virtual testing systems that allows manufacturers to physically implement only a defined and limited number of CO_2 tests. This methodology is currently in use for UN ECE R66 roll over tests. Considering this approach, the whole set of CO_2 data should be calculated using as main source the results of the physical tests and an approved tool.

F Summary of the interviews with TAA

1. What kind of type approval is used most often (or rank) for MSV, and why?
    a. -National Small Series (NSS)
    b. -Individual Vehicle Approval
    c. -WVTA

Centre National de Réception des Véhicules (CNRV)
the choice of mode of approval is based on the strategic choices of the 2nd stage manufacturer : desire to remain a national market (NSS) or niche (IVA), or will to export (EU WVTA) but also based on the timetable for the enforcement of directive 2007/46 (obligatory WVTA for completed vehicles of N1 category on 29 April 2013)

VCA
Answer: All three options are possible although, because for most bodybuilders the range of subjects is quite simple (side guards, lamps etc) we expect most to go for full EU WVTA. Now approval/inspections are not obligatory.

RDW
Only IVA.
WVTA is difficult because of the necessary communication with the base vehicle manufacturer.

KBA
Mostly IVA, although WVTA may increase.

Summary:
A mixed response, all three options are mentioned, today according the OEMs IVA is most commonly applied, also NSS is used in some larger countries (which have a larger market), almost no WVTA is used yet. By exception there is no approval needed at all.

2. How do the different approval methods work?
    a. Proces (OEM → registration)
    b. Determination of mass
    c. Needed paperwork/certificates (what happens with the CoC for instance)

Centre National de Réception des Véhicules (CNRV)
Regarding national approvals in France, body builders may be approved by regulatory procedures by the approval authority, and thereafter may register completed vehicles using statutory certificates themselves.

Regarding European approval, European Community rules apply.

VCA
Dealers arrange the registrations, determination of mass is not required.
From 2013 the masses and dimensions will be covered within the IVA, National Small Series or EU WVTA processes. In the meantime, masses and dimensions are policed via UK 'in-use' legislation. Hence, the vehicle operator

is responsible for ensuring that the vehicle's GVM and max axle loads (as shown on the manufacturers plate) are not exceeded.

From 2013:
VOSA will conduct Individual Vehicle Approval inspections
VCA will conduct the National Small Series approval work
VCA or any other EU Authority chosen by the manufacturer, will conduct EU WVTA approval work

RDW

a. Bodybuilder received vehicle via customer (private or dealer) → construction → registration at TAA
b. Weighted at TAA, also dimensions and lighting of bodywork are be checked.
c. Base document vehicle and end user information

KBA

For MSV it is advised that OEMs and FSM should interact to transfer the right information. Method 1 is the preferred option to deal with measuring and monitoring of MSV.

Summary:

In most cases approval is or will be done by a TAA/TS, although in France the bodybuilder himself may be authorized. For now, there is no COC being used.

3. On what criteria is chosen for a particular method?

Centre National de Réception des Véhicules (CNRV)

Approvals regarding base vehicle emissions are not changed, if the bodybuilder do not intervene in the motor of the base vehicle. See also 1.

RDW

Always IVA, others are more complex and probably are more expensive.

Summary:

Complexity, Export, Costs.

4. Are there differences in stringency for different TA processes (national, EU), especially regarding mass and CO2

Centre National de Réception des Véhicules (CNRV)

Yes, national approvals apply the EU rules of directive 2007/46 on fuel consumption/CO2 emissions, but keeping the masses of the base vehicle and therefore the emission values

5. How is dealt with mass changes?

Centre National de Réception des Véhicules (CNRV)

Pending the outcome of EU discussions on these issues, we apply the following rules for national approvals :
Compliance with reference masses of the base vehicle used for emissions approval for the approval of the 2nd stage

RDW
After registration mass changes are not taken into account

6. Is CO2 corrected if mass changes ? Threshold ?

   Centre National de Réception des Véhicules (CNRV)
   No, we use for national approvals the results of the base vehicle regarding this question.

   RDW
   After registration mass changes are not taken into account, therefore CO2 is not corrected. Because most MSV have IVA CO2 is not registered.

7. Can mass be added at a later stage without TA ?

   Centre National de Réception des Véhicules (CNRV)
   Yes, if this mass is considered as payload (paymass) and not include in mass in running order

   RDW
   Yes. However, re-inspection is not required.

8. Is there a definition for a completed vehicle?

   Centre National de Réception des Véhicules (CNRV)
   In France, a completed vehicle is a vehicle ready to be registered (and therefore it is already modified with its bodywork)

   RDW
   Yes, a vehicle with bodywork ready for registration.

Additional items of interest

Centre National de Réception des Véhicules (CNRV)

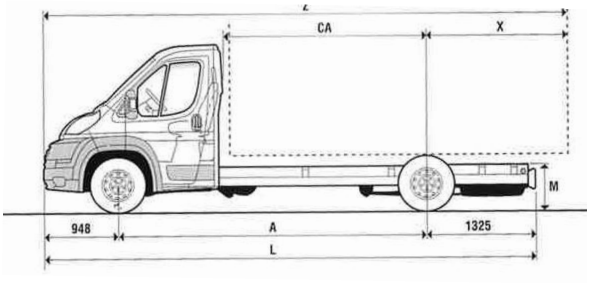
- Should be careful to ensure consistency between the method of measuring CO2 emissions of N1 category with future legislation being discussed in Brussels and Geneva, such as :
- Proposal to amend the scope of 715/2007 (over limit of reference mass) as part of the problem of "double testing" (Euro 5-6 and Euro V-VI)
- Discussion on the new test procedure in WLTP (with proposal of a reference mass sum for N1 : reference mass = unladen mass + 800 kg)

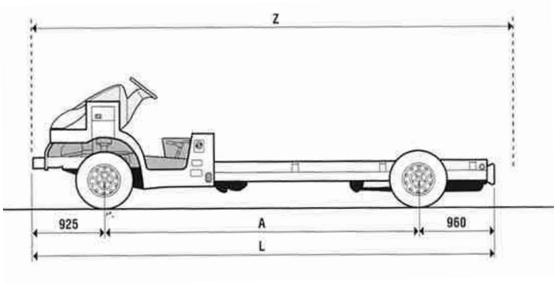
RDW

- MSV with bodywork are registered as N1 with own masses up to their max GVM (without driver).
- MSV drive always with maximum payload.
- Most bodybuilders seem to have no problem with WVTA if the TAA perform the CO2 registration. However the bodybuilders do not know much about WVTA.
- COC is not yet applicable.

G Examples of Multi-Stage Vehicles

Examples of typical chassis cabs are given below: on the top left a typical chassis cab with ladder frame, which has the largest share in the MSV market. On the top right a platform chassis cab. Below a chassis without complete cab to illustrate that an incomplete vehicle is rather undefined regarding its physical characteristics and appearance. The share of these vehicles is small.





Examples below: on the top left a typical chassis cab with standard box. On the top right a typical chassis cab with a tipper, further below a tractor unit.

Special vehicles (chassis cab)

An example below of what can be produced within N1. Top left: The yellow cabin and the first rear axle belong to the N1 vehicle. The drop-side pickup together with the most rear axle is in fact a kind of fixed trailer. This can be driven with B+E driver's license and >>3500 GCW (Gross Combination weight) because the mass of the trailer is not limited. The tractor itself should remain below 3500 GVW to be able to use B+E driver license (above 3500 GVW it becomes C+E). For the top right vehicle the payload is 3380 kg, empty it weighs 4430kg, GCW is 7400kg, however mass of the pulling vehicle or tractor is <3500 kg).

Examples below: on the left a smaller chassis cab. On the right a chassis cab with the typical double cabin and a crane. The vehicle with the crane weighs around 3200 kg and is in the upper mass range of N1.

Platform chassis cab
Examples of incomplete platform chassis cabs: these are most often used for motor homes (which do not fall in N1 but in M1) but with an increasing share these are also used for e.g. parcel/delivery service with integrated box body, for cooled transport with a small isolated box mounted or for pick ups.

Below an example of a normal panel van which can be upfitted with for instance interiors, loading platform (see further below), cooling and isolation. However, these vehicles are often not approved in multiple stages.

Example of a smaller platform van upfitted with a crane (not typical) and a refrigerated box (typical)and an example of a special type of MSV with electric propulsion